Critical Explorations

Food Science and Nutrition

Breakthroughs in Research and Practice

Information Resources Management Association

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Food Science and Nutrition:

Breakthroughs in Research and Practice

Information Resources Management Association
USA

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Preface

The constantly changing landscape surrounding food science and nutrition makes it challenging for experts and practitioners to stay informed of the field's most up-to-date research. That is why IGI Global is pleased to offer this one-volume comprehensive reference collection that will empower students, researchers, and academicians with a strong understanding of these critical issues by providing both broad and detailed perspectives on cutting-edge theories and developments. This compilation is designed to act as a single reference source on conceptual, methodological, and technical aspects, as well as to provide insight into emerging trends and future opportunities within the discipline.

Food Science and Nutrition: Breakthroughs in Research and Practice is organized into four sections that provide comprehensive coverage of important topics. The sections are:

1. Consumption Behavior and Nutrition;
2. Economic Development and Sustainability;
3. Food Engineering and Packaging;
4. Medicinal and Therapeutic Uses.

The following paragraphs provide a summary of what to expect from this invaluable reference source:

Section 1, "Consumption Behavior and Nutrition," opens this extensive reference source by highlighting the latest trends in nutritional habits and human health models. Through perspectives on healthy food choices, eating disorders, and the food pyramid, this section demonstrates the importance of food and nutrition planning on human health. The presented research facilitates a better understanding of how proper nutrition strategies affect a person's quality of life.

Section 2, "Economic Development and Sustainability," includes chapters on food and nutrition security in developing countries. Including discussions on biotechnology, malnutrition, and herbalism, this section presents research on the need for those in developing countries to have physical, social, economic, and environmental access to a balanced diet. This inclusive information assists in advancing current practices in sustainable and industrial development for greater sustainable food security.

Section 3, "Food Engineering and Packaging," presents coverage on the use of eco-friendly technology and edible films and coatings in agriculture and food processing. Through innovative discussions on essential oils, nano-fertilizers, and antimicrobial packaging material, this section highlights the innovations in agriculture, processing, nutrition, and products through the use of nanotechnology. These inclusive perspectives contribute to the available knowledge on the study of agronomy and functional foods.

Section 4, "Medicinal and Therapeutic Uses," discusses coverage and research perspectives on the use of complementary and alternative medicines. Through analyses on epidemiology, macro- and micro-nutrients, and the health benefits of lentils, camel milk, and kimchi, this section contains pivotal information on the health benefits of herbal remedies and other alternative medicines. The presented research facilitates a comprehensive understanding of innovative medicinal practices in disease prevention and control.

Although the primary organization of the contents in this work is based on its four sections, offering a progression of coverage of the important concepts, methodologies, technologies, applications, social issues, and emerging trends, the reader can also identify specific contents by utilizing the extensive indexing system listed at the end.

As a comprehensive collection of research on the latest findings related to Food Science and Nutrition, this publication provides researchers, practitioners, and all audiences with a complete understanding of the development of applications and concepts surrounding these critical issues.

Section 1

Consumption Behavior and Nutrition

Chapter 1
Health Determinants:
Nutrition-Related Facts

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Bucharest University of Economic Studies, Romania

ABSTRACT

The starting point of this chapter is the Lalonde health model, which takes into account the influence of non-medical factors upon human health. As it turns out, health services contribute to good health to a lesser extent than human behavior and genetic background. Since lifestyle choices and behavior prove to affect human health significantly – both as improvement or deterioration – nutrition habits determine some of the most severe illnesses that health care systems must deal with, also augmenting the burden of disease. This chapter aims at emphasizing the impact of nutrition on individual and societal health using a varied range of indicators regarding food consumption habits among various populations of the EU Member States within the wider context of economic development (GDP/capita, Actual Individual Consumption, access to basic utilities – drinkable water and sewage systems, standards of living etc.).

INTRODUCTION

The health of a population should be perceived and examined in relation to its direct and indirect determinants. According to Marcu (2002), a health determinant is "a factor or any condition that has an effect upon health, or in measurable quantitative terms, has an effect upon the state of health".

The first example of substantiation of a health strategy based on a model that takes into consideration the major influence upon health of other factors besides medical services, dates from 1974 and can be found in the document known as *Lalonde Report*[1]. The conceptual model provided by this report was taken over by A. Dever in 1984 (Figure 1), remaining up to this date a reference model in health policy, due to categorizing health determinants into 4 groups: human biology, health care services, behavior and environment.

The four categories of factors represented a step forward in understanding the relationships that affect health and in grounding the basis of new types of intervention. Quantitative epidemiologic arguments, which assign to behavioral factors the highest potential influence to improving human health, followed

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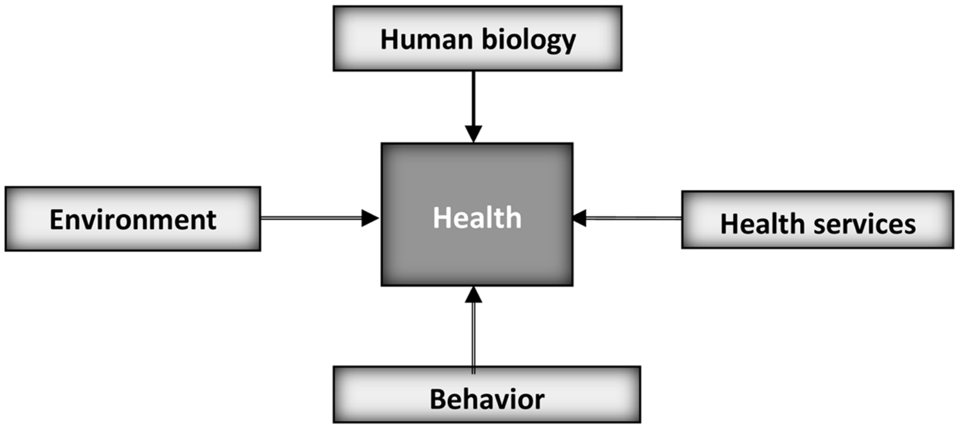
Figure 1. Determinants of health: The Dever epidemiological model
Source: Dever, 1984



by the biological ones, environmental ones and only afterwards to the medical ones, have motivated interventions that allowed slowdown in growth or even reduction of the frequency of diseases or their consequences. As Drăgoi (2010) points out, the successes recorded in the last three decades for cardiovascular diseases, some cancers or accidents in many developed countries can be explained to a lesser extent by the progress of medical interventions, the role of behavior modification being the most important.

The important factors that influence human health remain poverty, social factors, lifestyle, unemployment, unhealthy housing, environmental pollution, the level of education. These factors require a national approach accompanied by interventions at the community level, which should develop projects involving public and private resources in the community. For this it is of high importance that individuals take responsibility for maintaining or improving their health.

As interpreted by the models described in the available literature, health determinants can be distributed into four groups (Table 1), each group including both direct and indirect determinants.

The group of direct determinants with major impact on health includes: nutrition, smoking, alcohol, genetics, legal/illegal drug use, access to drinking water, housing, violence (especially in the family) and access to health care.

Within the group of indirect determinants, the following factors have a special significance for health: gross domestic product (GDP), distribution of income among regions, poverty, climatic developments, pollution, socio-demographic factors (social classes, changes in the population structure, migration), education, crisis situations (natural or man-made disasters, armed conflicts).

Table 1. Groups of health determinants

Determinants	**1. macroeconomic**
	2. environmental
	3. socio-demographic
	4. educational

Source: Author's synthesis based on literature review

Subsequently, a person's health depends on multiple social, economic and cultural factors. This is why persons belonging to the same communities and having more or less the same social status and age for example turn out to present different health conditions. Thus, as previously stated, access to health care services is not the most important factor in determining good health.

In fact, health determinants interact with each other, but what matters is the impact the results of these interactions has on health. Health is an important determinant of socio-economic development and the socio-economic status is an important determinant of health. Stratification is based on macro-economic determinants, such as GDP and GDP/capita, level of education, income, occupation and the rates of morbidity and mortality show higher values for groups with low socioeconomic level.

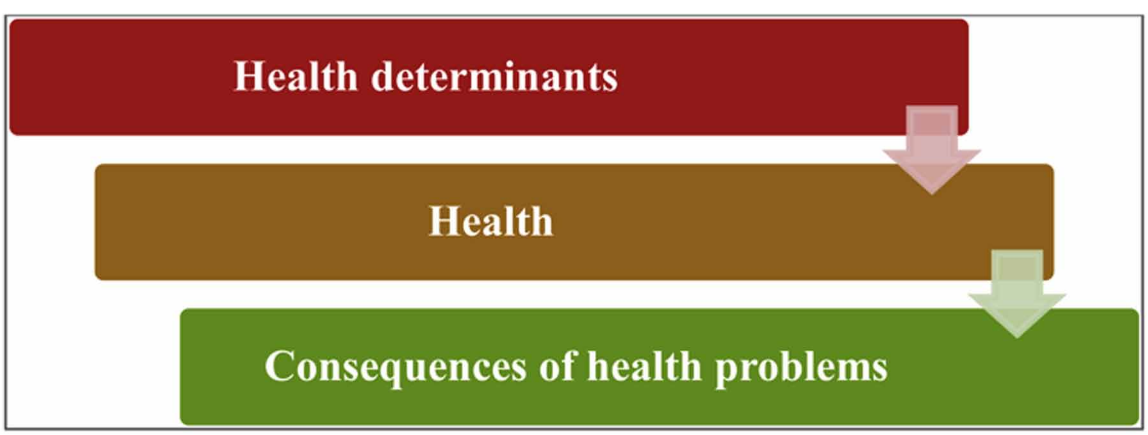
Therefore, in essence, the health model includes three levels (Drăgoi, 2010), as presented in Figure 2.

SYSTEM PERFORMANCE INDICATORS

In order to broader analyze nutrition facts and their determination of health status, a previous analysis on the standard of living is of high importance, since the financial resources of a country and their populations are extremely relevant to nutrition habits and food acquisitions. Therefore, a brief comparison among European Union Member States regarding their economic development and the average income of the population shows that life expectancy and Human Development Indices are higher in wealthier EU countries.

As Eurostat analysis points out, *to evaluate standards of living, it is more appropriate to use GDP per capita in purchasing power standards (PPS), in other words, adjusted for the size of an economy in terms of population and also for differences in price levels across countries*. Before the financial crisis spread out among EU countries in 2008, the average EU GDP per capita was PPS 25.9 thousand. For 2013, Eurostat data show that EU-28 GDP per capita reached PPS 26.6 thousand, so the crisis period has determined only a modest increase over the period of time 2008-2013. *The relative position of individual countries can be expressed through a comparison with this average, with the EU-28 value set to equal 100* (Eurostat, 2015).

Figure 2. Health model basics
Source: Author's synthesis based on literature review



Luxembourg recorded the highest value among the EU Member States, where GDP per capita in PPS was about 2.6 times the EU-28 average in 2013. A plausible explanation for this discrepant value compared to other countries is the importance of cross-border workers from Belgium, France and Germany. On the other hand, GDP per capita in PPS was less than half the EU-28 average in Bulgaria in 2013, followed by Romania, with a little over half EU-28 average.

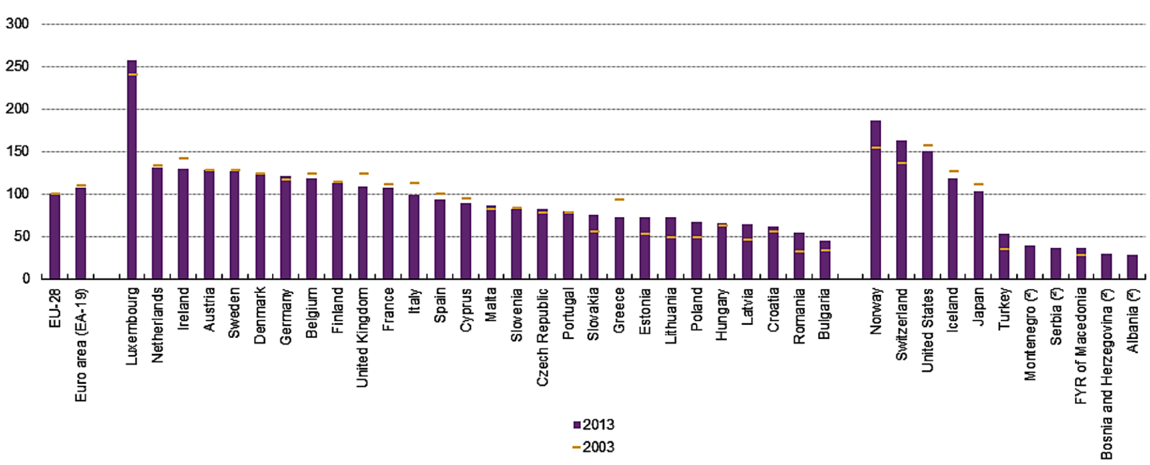
Although Eurostat argues that *PPS figures should, in principle, be used for cross-country comparisons in a single year rather than over time, the development of these figures during the past decade suggests that some convergence in living standards took place as most Member States that joined the EU in 2004, 2007 or 2013 moved closer to the EU average despite some setbacks during the financial and economic crisis*.

Figure 3 emphasizes that Luxembourg, Germany and Austria moved further ahead of the EU-28 average, comparing the situation in 2013 with the one in 2003, while several other EU-15 Member States, notably the United Kingdom, Ireland, France and Belgium, moved closer to the EU-28 average. Other important countries of EU-15, respectively Italy and Spain moved from above or level with the EU-28 average to a position below it. The greatest moves towards EU-28 average was recorded in Lithuania, Romania, Estonia, Slovakia, Latvia, Poland and Bulgaria, while Greece fell further below the EU-28 average, as did Cyprus and Slovenia to a much lesser extent (Eurostat, 2015).

While GDP is mainly an indicator of the level of economic activity, Actual Individual Consumption (AIC) is an alternative indicator better adapted to describe the material welfare of households. Table 2 reunites data concerning both GDP and AIC, showing that *levels of AIC per capita are more homogeneous than GDP but still there are substantial differences across the EU Member States*.

As was the case of GDP per capita, Luxembourg is the country with the highest level of AIC per capita in the EU, 40% above the average of the EU-28. However, the disparities in terms of AIC are not so high as for GDP, due to the fact that *cross-border workers contribute to GDP in Luxembourg while their consumption expenditure is recorded in the national accounts of the country of their residence*. The second highest AIC per capita is recorded in Germany at 23% above the average, followed by Austria

Figure 3. GDP per capita at current market prices, 2003 and 2013 (EU-28 = 100; based on PPS per inhabitant)
Source: Eurostat, 2015



and Denmark. The last places in terms of GDP are confirmed for AIC as well, with Bulgaria situated at 51% below the EU-28 average and Romania at 45% below.

Moreover, in terms of price level for AIC (including the exchange rates applied in the calculation of the price level indices), Table 3 shows *that Denmark has the highest price level among the Member States, 40% above the EU-28 average. Other countries which in 2014 exceeded the overall EU-28 level by more than 20% are Luxembourg, Sweden, Ireland, Finland and the United Kingdom* while the lower end of the figure confirms the same countries Romania and Bulgaria that show the lowest price levels among the Member States at less than half the EU average.

Nevertheless, Eurostat analysis argues that *several of the major price level changes observed between 2011 and 2014 can be at least partly explained by fluctuations of country's currencies against the Euro*. Therefore, the data comprised in Table 3 demonstrate that *the price dispersion is much less pronounced in the euro area than in the EU as a whole, which can be partially impacted by the volatility of exchange rates* (Eurostat, 2015).

Confirming the starting arguments, the economic development of a country determines higher life expectancy, as Table 4 shows, with Luxembourg, France and Italy ranking among first with life expectancy over 80 years. The lowest life expectancies can be found in Latvia and Lithuania, followed closely by Romania and Bulgaria, all with less than 74 years. The green cells emphasize the highest values of this indicator while the red ones the lowest – all shades in between show the position of a country within the time range 2000-2010 compared to the minimum and maximum levels.

Life expectancy at birth can be explained or determined by several living conditions, such as access to drinkable water or hygienic means of sewage disposal, which the World Health Organization (WHO) considers to be of high importance in preventing or spreading various diseases. Table 5 illustrates that these living indicators are also part of the EU strategy of reducing regional disparities and that improvements have been made since 1990 up to present.

In the case of access to water supply systems, there are several Member States which provided full access to their population ever since 1990, such as Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Italy, Luxembourg, Netherlands, Sweden and the United Kingdom. Others have made efforts to meet the 100% coverage by 2015, such as Czech Republic, Portugal and Slovakia. The most spectacular evolution by far (the only one starting from a red zone moving towards a green zone) was in the case of Romania, where in 1990 less than 74% of the population had access to a water supply system. By the year 2000, 85.3% of the Romanian population gained access, reaching a full coverage by the year 2013 (which is not visible in Table 5).

The right part of the table analyzes figures regarding availability of hygienic sewage systems in Member States. There are considerably fewer EU countries which grant national coverage, including Austria, Cyprus and Malta with 100% coverage, followed up closely by Spain with 99.9% of the population having access to sewing systems. While the average percentage for the countries which joined the European Union after 2004 is above 91, there is one Member State which struggles below the 80% threshold. Even though progress has been made since 1990 in this living sector also, Romania ranks last within EU-28, sewage systems being reported as missing even in large urban areas, not just the rural side of the country.

All the indicators previously presented influence the value of the Human Development Index, which maps the European Union' countries as presented in Figure 4. The highest values pointed put in dark red can be found in Norway, 0.955, while within the European Union, the best placed country is the Netherlands with a HDI value of 0.921. Close to this value is 0.92 for the case of Germany, followed by Ireland and Sweden which both share the same figure of 0.916. The EU-28 average stands at 0.877

Table 2. Volume indices per capita, 2011-2014 (EU-28=100)

	Gross Domestic Product				Actual Individual Consumption			
Country	**2011**	**2012**	**2013**	**2014**	**2011**	**2012**	**2013**	**2014**
LU	265	264	258	263	138	139	136	140
IE	130	130	130	132	97	94	95	93
NL	135	133	131	130	118	116	113	112
AT	128	129	128	128	120	120	120	121
DK	126	125	124	124	114	115	115	115
DE	122	123	122	124	121	122	122	123
SE	127	126	127	124	114	114	115	114
BE	120	120	119	119	111	112	111	114
FI	117	116	113	110	113	115	115	113
UK	106	107	109	108	114	115	115	114
FR	108	107	107	107	111	110	110	112
EA-19	**108**	**107**	**107**	**107**	**107**	**106**	**106**	**106**
IT	103	101	99	97	106	102	100	98
ES	95	94	94	93	91	90	90	90
CY	96	94	89	85	98	98	93	91
MT	84	85	86	85	81	80	80	78
CZ	83	82	82	84	73	73	74	75
SI	83	82	82	83	79	78	76	74
PT	78	76	78	78	83	80	84	83
SK	73	74	75	76	72	73	74	74
LT	65	69	73	74	70	73	78	80
EE	68	71	73	74	59	63	65	65
EL	77	74	73	72	89	84	83	83
HU	65	65	66	68	62	62	62	62
PL	64	66	67	68	70	73	75	74
LV	57	60	64	64	57	60	66	65
HR	60	61	61	59	59	60	61	59
RO	51	53	54	54	53	55	55	55
BG	44	45	45	45	47	50	49	49

Source: Eurostat, 2015

and the EU-13 average stands at 0.819. The last countries that adhered to the European Union are also occupying the last positions among Member States: Croatia – 0.805, Romania – 0.786 and Bulgaria 0.782, which comes as no surprise if we take into consideration the fact these countries ranked last for other development indicators as well.

Table 3. Exchange rates and price level indices for AIC, 2011-2014 (EU-28=100)

	Exchange Rates				Price Level Indices			
Country	**2011**	**2012**	**2013**	**2014**	**2011**	**2012**	**2013**	**2014**
DK	7.4506	7.4437	7.4579	7.4540	143	141	142	140
LU	1	1	1	1	135	134	137	134
SE	9.0298	8.7041	8.6515	9.0985	132	136	139	133
IE	1	1	1	1	123	122	123	124
FI	1	1	1	1	123	122	124	124
UK	0.8679	0.8109	0.8493	0.8061	110	116	114	122
NL	1	1	1	1	112	112	114	113
BE	1	1	1	1	114	113	114	111
AT	1	1	1	1	111	111	112	110
FR	1	1	1	1	111	110	111	107
IT	1	1	1	1	103	103	103	102
EA-19	**1**	**1**	**1**	**1**	**103**	**102**	**103**	**102**
DE	1	1	1	1	102	100	102	101
ES	1	1	1	1	97	94	93	92
CY	1	1	1	1	94	93	91	89
EL	1	1	1	1	92	89	86	83
MT	1	1	1	1	77	78	80	82
SI	1	1	1	1	85	83	82	82
PT	1	1	1	1	84	82	79	79
EE	1	1	1	1	84	82	79	79
LV	0.7063	0.6973	0.7015	1	67	67	66	68
SK	1	1	1	1	65	65	65	64
HR	7.4390	7.5217	7.5786	7.6344	68	65	63	63
CZ	24.590	25.149	25.980	27.536	69	67	65	60
LT	3.4528	3.4528	3.4528	3.4528	58	59	58	59
HU	279.37	289.25	296.87	308.71	56	56	55	53
PL	4.1206	4.1847	4.1975	4.1843	55	53	53	53
RO	4.2391	4.4593	4.4190	4.4437	49	47	48	49
BG	1.9558	1.9558	1.9558	1.9558	45	44	44	44
Coefficients of Variation of PLIs								
EA-19					22.1	22.1	23.0	22.2
EU-28					30.2	31.0	31.8	31.4

Source: Eurostat, 2015

Table 4. Life expectancy at birth (years)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
AT	78.47	78.95	79.01	78.90	79.44	79.67	80.19	80.46	80.72	80.57	80.88
BE	77.96	78.32	78.32	78.45	79.12	79.20	79.79	79.90	80.00	80.29	80.31
BG	71.71	71.91	72.17	72.39	72.60	72.60	72.77	73.07	73.41	73.77	73.82
HR	73.00	74.65	74.85	74.73	75.66	75.44	76.01	75.89	76.14	76.43	76.86
CY	77.89	79.35	77.30	79.66	79.71	79.20	80.64	80.45	81.16	81.57	82.19
CZ	75.21	75.43	75.51	75.40	75.96	76.19	76.82	77.10	77.42	77.50	77.81
DK	77.22	77.30	77.28	77.59	77.98	78.44	78.51	78.61	78.98	79.20	79.52
EE	70.95	70.71	71.24	71.78	72.29	72.89	73.14	73.21	74.34	75.31	76.03
FI	77.88	78.36	78.46	78.72	78.99	79.36	79.68	79.70	80.04	80.19	80.34
FR	79.35	79.43	79.55	79.44	80.50	80.49	81.16	81.47	81.56	81.76	81.98
DE	78.42	78.76	78.75	78.73	79.36	79.54	79.99	80.21	80.29	80.42	80.64
EL	78.23	78.62	78.80	78.93	79.04	79.32	79.79	79.56	80.13	80.34	80.69
HU	71.93	72.56	72.64	72.59	73.03	73.02	73.57	73.66	74.23	74.45	74.78
IE	76.61	77.24	77.75	78.28	78.70	79.21	79.85	79.77	79.98	79.98	80.80
IT	79.75	80.09	80.38	80.17			81.58	81.70	81.91	82.07	82.50
LV	70.51	69.95	70.25	70.72	70.97	70.71	70.59	70.83	72.12	72.80	73.15
LT	72.21	71.71	71.86	72.13	72.05	71.27	71.02	70.78	71.82	73.01	73.32
LU	79.07	78.84	78.96	78.47	80.04	80.26	80.09	80.30	81.54	81.55	81.49
MT	78.24	78.85	78.73	78.63	79.43	79.44	79.59	80.05	79.86	80.46	81.51
NL	78.29	78.49	78.56	78.80	79.42	79.67	80.07	80.54	80.67	81.00	81.15
PL	73.86	74.28	74.65	74.74	74.99	75.12	75.38	75.45	75.73	75.91	76.58
PT	76.85	77.19	77.41	77.55	78.44			79.30	79.55	79.77	80.13
RO	71.25	71.27	70.97	71.32	71.88	72.21	72.69	73.27	73.47	73.61	73.83
SK	73.45	73.82	73.91	73.91	74.38	74.30	74.54	74.66	75.05	75.42	75.66
SI	76.27	76.49	76.73	76.53	77.32	77.58	78.35	78.53	79.31	79.46	79.96
ES	79.49	79.80	79.88	79.78	80.46	80.44	81.22	81.19	81.52	81.91	82.32
SE	79.92	80.01	80.09	80.37	80.55	80.82	81.05	81.19	81.35	81.61	81.77
UK	78.06	78.27	78.38	78.45	79.03	79.29	79.66	79.86	79.97	80.55	80.78
EU	77.45	77.74	77.87	77.90	78.50	78.68	79.17	79.36	79.58	79.85	80.16
EU-15	78.75	79.02	79.13	79.12	79.77	79.97	80.47	80.65	80.82	81.09	81.37
EU-13[2]	72.98	73.30	73.44	73.58	73.98	74.08	74.45	74.66	75.04	75.29	75.72

Source: World Health Organization, 2015b

DETERMINANTS OF NUTRITION CHANGES

The basket of goods and services that determines the price level indices has changed significantly over the past decades. Changes have been determined by several factors, the most obvious one being the technological development. Audio cassettes have been removed from the basket, while DVDs replaced them; items regarding mobile communication devices have been added recently since they did not exist for the previous generations, and the list can continue.

Table 5. Population with homes connected to water supply system (%) and population with access to sewage system, septic tank or other hygienic means of sewage disposal (%)

	Water Supply System (%)					Sewage System (%)				
Country	**1990**	**2000**	**2005**	**2010**	**2015**	**1990**	**2000**	**2005**	**2010**	**2015**
AT	100	100	100	100	100	100	100	100	100	100
BE	100	100	100	100	100	99.5	99.5	99.5	99.5	99.5
BG	99.9	99.7	99.6	99.5	99.4	85.3	85.6	85.9	85.9	86
HR	98.2	98.3	98.7	99.2	99.6	97.3	97.3	97.2	97.1	97
CY	100	100	100	100	100	100	100	100	100	100
CZ	99.8	99.8	99.9	100	100	99.1	99.1	99.1	99.1	99.1
DK	100	100	100	100	100	99.6	99.6	99.6	99.6	99.6
EE	99	99	99.2	99.5	99.6	97	97	97.1	97.2	97.2
FI	100	100	100	100	100	97.1	97.4	97.5	97.6	97.6
FR	100	100	100	100	100	98.7	98.7	98.7	98.7	98.7
DE	100	100	100	100	100	99.2	99.2	99.2	99.2	99.2
EL	97.6	98.8	99.4	100	100	92.5	95.5	97.1	98.5	99
HU	96.1	98.2	99.2	100	100	98	98	98	98	98
IE	96.4	96.3	96.9	97.4	97.9	89.3	89.2	89.7	90.1	90.5
IT	100	100	100	100	100	99.5	99.5	99.5	99.5	99.5
LV	98.3	98.3	98.6	98.9	99.3		81.7	83.5	85.6	87.8
LT	87.2	91	93	95	96.6	82.8	86.6	88.5	90.5	92.4
LU	100	100	100	100	100	97.8	97.7	97.7	97.6	97.6
MT	99.8	100	100	100	100	100	100	100	100	100
NL	100	100	100	100	100	98.3	98.1	97.9	97.8	97.7
PL	94.3	95.9	96.8	97.6	98.3		87	90.6	94.3	97.2
PT	96.1	98	98.8	99.6	100	92.8	96.2	97.6	99	99.7
RO	73.9	85.3	91.1	96.9	100	70.4	73.8	75.6	77.5	79.1
SK	99.8	99.8	99.9	100	100	98.9	98.9	98.9	98.8	98.8
SI	99.6	99.6	99.6	99.5	99.5	99.1	99.1	99.1	99.1	99.1
ES	99.9	99.9	100	100	100	99.9	99.9	99.9	99.9	99.9
SE	100	100	100	100	100	99.3	99.3	99.3	99.3	99.3
UK	100	100	100	100	100	99.2	99.2	99.2	99.2	99.2
EU	97.88	98.75	99.2	99.6		95.94	96.38	96.94	97.44	
EU-15	99.78	99.86	99.92	99.96		98.75	98.91	98.99	99.07	
EU-13[3]	91.69	94.92	96.65	98.28		86.77	87.7	89.57	91.44	

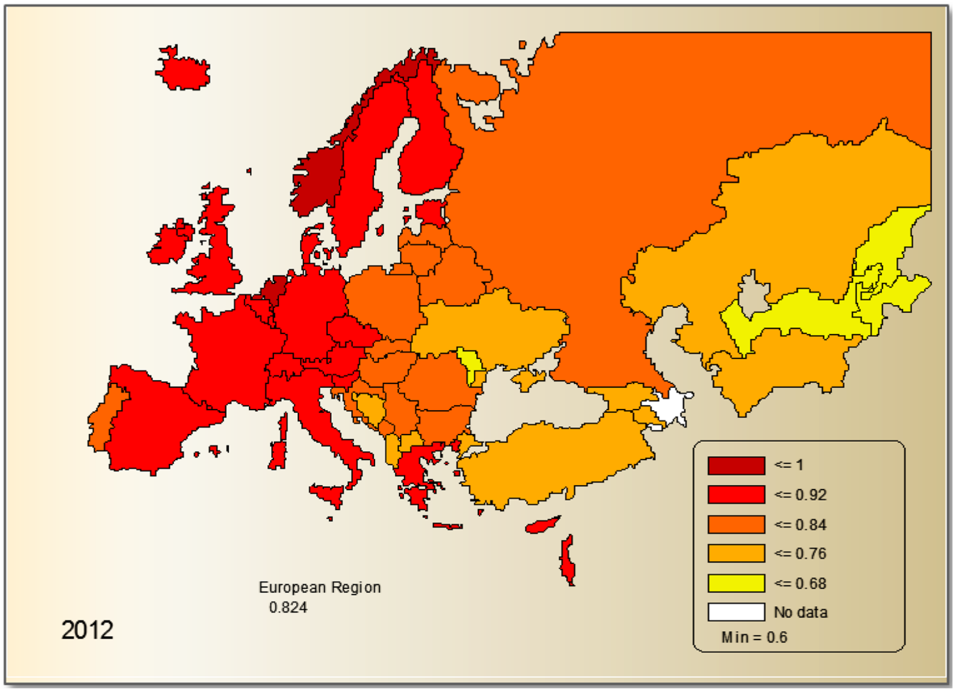
Source: World Health Organization, 2015b

Another major aspect that determined some shifts in the consumer basket has been the diminished amount of free time, due to increase in the workload, crowded cities, traffic jams etc. Therefore, new appliances and houseware that can make life easier and get more work done in less time made their way into consumer preferences.

However, in terms of nutrition, these changes of the lifestyle of the population, determined the flourishing development of the fast-food and pre-cooked frozen meals suppliers.

A deeper analysis of the circumstances brings to the attention the fact that food consumption is determined and highly influenced by several factors such as food availability, food accessibility and food choice, which at their turn may be influenced by geographic and demographic determinants, disposable

Figure 4. Human Development Index
Source: World Health Organization, 2015b



income, level of urbanization, marketing, religion, culture and consumer behavior. Some of the determinants that are directly related to the nutrition transition are briefly comprised in Table 6.

NUTRITION FACTS

The changes determined in the food consumption patterns influenced by the factors previously described have altered the intake of healthy nutrients for the European citizens. While the World Health Organization encourages consuming at least 400 g of fruits and vegetables a day[4] for the prevention of chronic diseases such as heart disease, cancer, diabetes and obesity, as well as for the prevention and alleviation of several micronutrient deficiencies (World Health Organization, 2015a), actual data show that some EU countries do not meet this threshold (Table 7 and Figure 5).

Table 7 presents the availability of fruits and vegetables among Member States. Data shown in red cells account for fruit and vegetable below the amount recommended by the World Health Organization, while the green cells show an annual availability of more than 200 kg per person. Bulgaria and Slovakia show several years of low availability of fruits and vegetables, with the first country ranking last even in 2009 (year with last available data). Mediterranean countries Greece and Italy and Malta rank first, which can be attributed to the high capacity of fruit and vegetable production of these countries due to their geographical position and climate. On the other end, Bulgaria and Baltic States rank last among the EU Member States, well below the EU average of 221.1 kg per person per year. Figure 5 shows the European map on fruit and vegetable availability pointing out the areas in which this indicator needs improvement.

Table 6. Determinants of nutrition transition

Determinants of Nutrition Changes	Main Implications
Income	● According to Du et al. (2004), *over the next three to four decades, global per capita income is projected to rise at a rate of over 2 per cent per annum, with developing countries that are starting from a low base expected to rise at even higher rates*. ● *Rising incomes means higher fat diets* – Kearney (2010) points out that *increased incomes or lower prices have led to the increased consumption of animal-based foods and processed foods*. ● People with low income have fewer food choices and more limited access to nutritional education.
Education	● *Better educated adults show higher vegetable consumption. Since higher education generally means higher income, this could also be related to greater knowledge and awareness of healthy eating habits in those with higher education levels* (European Food Information Council, 2012).
Gender and age	● Based on previous studies, the EUFIC report shows that *in general, girls and women consume larger amounts of fruit and vegetables than do boys and men. This seems to be the case also for pre-school children, thus the gender difference already shows at an age when nutrition knowledge is unlikely to have any impact* (European Food Information Council, 2012).
Urbanization	● *Rapid urbanization has had, and will continue to have, a profound effect on food consumption patterns (Popkin, 1999): a higher caloric intake (cities offer a greater range of food choices), combined with a reduction of physical activity compared with rural work and more inactivity in leisure time, means that obesity and diabetes in developing countries are advancing more rapidly in cities than in rural areas*. ● *Also, urbanization can affect food consumption by changes in dietary behavior and this niche has been seized by the fast-food industry by providing quick access to cheap take-away meals*. ● The most popular fast-food items, including hamburgers, pizzas and fried chicken, have 30 per cent of their food energy as fat. Thus, Kearney (2010) highlights *that major consequences from a nutrition perspective of urbanization are a profound shift towards higher food energy, more fats and oils and more animal protein from meat and dairy foods*, resulting in a diet that is lower in fiber, vitamins and minerals and higher in energy and saturated fat.
Trade liberalization	● Trade liberalization can affect the availability of certain foods by removal of commercial barriers; processed food has become more and more available especially in developing countries. ● *Thus, changes in trade policies have facilitated the rising availability and consumption of meat, dairy products and processed foods* (Thow & Hawkes, 2009), with direct implications for health by increasing rates of obesity and chronic diseases such as cardiovascular disease and cancer.
Transnational food corporations (franchises and manufacturers)	● Hawkes (2005) argues that *transnational food corporations (franchises and manufacturers) such as KFC, McDonalds, Kraft and Nestlé are all drivers of the fast-food market, processed foods and Western lifestyle that have become so widespread in developing countries* as well.
Retailing	● Supermarkets have gained an extended market share and have had a high impact on the food economy. Their benefits consist of availability and safe products, addressing a large part of the population. However, supermarkets also offer fast food type of meals, being large providers of processed, unhealthier food which is more often preferred by the low-income class.
Food industry marketing	● *Recent and radical changes in the food marketing and distribution system (through their globalization) have had a profound effect on food consumption patterns. Exposure to TV advertising is perhaps the single largest factor responsible for the epidemic of obesity among children* (Skerrett & Willett, 2010). ● *Greater regulation of marketing and advertising of food, especially to children, is now receiving much more attention* (Nestle, 2002).
Consumer beliefs and behavior	● Since food has become a social incentive, not just a basic functional one, people tend, when going out, to eat out more than they need to. ● However, *consumer health awareness continues to grow with the increasing availability of health information going hand in hand with the ageing of populations and increased risk for lifestyle diseases* (Kearney, 2010).
Changes in lifestyle	● Women nowadays are employed just like men; therefore there are a lot of two-income families than half a century ago. These families eat out more and spend less time on meal preparation. ● Women in the work force have generated an increase in convenience and processed food consumption in Europe (Gracia & Albisu, 2001). ● European Commission's Eurobarometer survey from 2006 states that *lack of time and control over what they eat are the two main reasons Europeans give to explain the difficulty of eating a healthy diet* (European Commission, 2006). ● The main reasons for low vegetable consumption are irregular working hours and a busy lifestyle.
Family factors	● Literature shows *that in adults, particularly in men, being married positively impacts on the amounts of fruit and vegetables consumed, women having a positive influence on their husbands' intake frequency, amounts and variety of the fruit and vegetables eaten* (European Food Information Council, 2012). ● On the other hand, *children's fruit and vegetable intake levels are related to how much their parents consume. Home availability and other factors in the shared environment as well as genetic pre-disposition (inborn food preferences) could explain the link between parents' and children's intake levels* (Cooke et al., 2004). ● *Consumption can be enhanced when parents are good role-models and encourage children to eat fruit and vegetables* (Pearson, Timperio, et al., 2009; Pearson, Biddle, et al., 2009).

Source: Author's synthesis based on literature review

Table 7. Average amount of fruits and vegetables available per person per year (kg)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
AT	208.6	223.5	210.7	231.4	242.8	236.7	238.7	245.8	259.9	228.6
BE	190.5	184.1	194.1	201	209.9	189.8	208	212.3	223	218.3
BG	193.2	165.5	147.5	172.9	149.1	95.3	114.9	119.4	105.2	105
HR	179.3	194.6	201.4	191.4	153.5	138.9	176.6	190.6	194.3	203.8
CY	245.1	234.7	229.8	210.5	218.9	227.8	232.2	230.4	205.4	225
CZ	146.8	138	148.6	151.5	164.2	159	147.7	143.5	152.3	152.9
DK	192.4	183.2	259	237.7	237.5	234	227.1	208.9	210.5	235.4
EE	151.8	158.4	149	169.3	157.1	151.7	144.9	175.1	175	184.5
FI	153.4	161	155.8	164.5	171.1	173.2	164.5	172.7	165.3	172.7
FR	207.3	204.8	210.9	204.1	219.8	218.8	209.3	215.3	209.2	207.9
DE	206.1	195.2	196	184.7	181	175.6	173.4	173.9	172.3	176.2
EL	452.9	452	427.5	436	485.9	432.8	391.7	388.5	360.2	385.6
HU	197.9	189.9	190.6	192.7	219.1	202.6	234.2	199.1	217.5	218.2
IE	138.1	160.7	191.4	213.8	196	183.9	192.2	225.6	244.1	244.3
IT	343.9	295.3	288.6	308.5	352.4	335.1	309.1	300	284.1	312.4
LV	130.2	149.2	153.2	162.8	158.1	166.1	164	165.2	152.5	151.3
LT	162.8	161.9	150	161.2	162.8	178.5	184.6	173.8	171.3	171.9
LU	300.8	301.5	326.5	321.2	292.8	281	288.8	283	291.2	277.3
MT	294.2	289.4	284.7	291.8	324.9	318.4	319.6	307.4	311.6	305.6
NL	215.7	222.6	228.4	207.8	228.6	219.2	235.9	239.3	221.1	212.6
PL	175.1	172.8	149.1	157.7	170.9	166.2	164.7	173.7	170.7	182.4
PT	295.7	306.5	274.6	262.4	340	296.8	266.1	291.2	279.7	313.1
RO	201.7	217.2	212.8	263.9	269.8	259.6	261.1	209.5	229.2	226.6
SK	147.9	130	124.2	132.3	131.8	137.4	143.7	151.3	163.2	169
SI	233.6	186.2	222.3	217.4	245.8	242.1	223.2	203.5	210.7	224.5
ES	274.5	265.7	282.3	265.4	256.1	261.3	258.4	236.5	247.6	231.8
SE	173.2	178.6	187	194.8	200	195.2	202.1	204	223.1	208
UK	172.7	187.7	187.1	208.3	207.4	223.7	233	219.1	228.1	214.6
EU	223.95	217.63	217.24	221.65	232.7	226.86	223.83	218.9	218.71	221.06
EU-15	236.6	228.93	230.99	231.94	244.13	239.21	233.94	230.31	228.68	230.3
EU-13	180.47	178.53	169.04	185.28	192	182.61	187.29	177.37	182.19	187.13

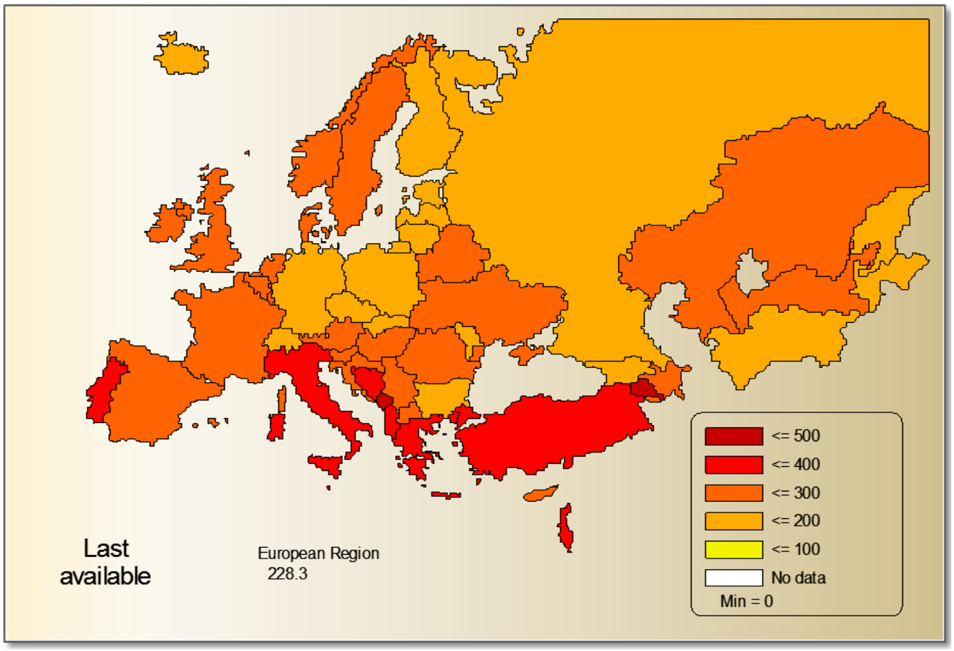
Source: Author's interpretation based on WHO data

However, recent studies conducted by several international organization point out the fact that even if fruit and vegetables are available, the actual consumption is scanty among several Member States.

The European Fresh Produce Association Freshfel Europe released in June 2015 the latest edition of its *Freshfel Consumption Monitor*, analyzing *trends in the production, trade and supply of fresh fruits and vegetables across the EU-28. This study is part of the actions undertaken by Freshfel in the framework of the EU Platform for Action on Diet, Physical Activity and Health* (Freshfel Europe - European Fresh Produce Association, 2015).

According to the latest Consumption Monitor, taking into consideration information from the time frame 2008-2013, *the consumption of fresh fruit and vegetables in the EU-28 stood at 341.81 g/capita/day in 2013. This is an increase of 5.6% compared with 2012 but a decrease of 1.9% compared with the average of the years 2008-2012*. Figures comprised in this report actually show that consumption in the

Figure 5. Average amount of fruits and vegetables available per person per year (kg)
Source: World Health Organization, 2015b



EU-28 *remains under the recommendation of the World Health Organization to consume a minimum of 400 g of fresh produce per day, out of the 28 Member States of the European Union, 22 being below the level recommended by the WHO*.

As the General Delegate of Freshfel Europe states, the *Consumption Monitor shows that fresh fruit and vegetable consumption in the EU have slightly increased in 2013. Nonetheless, it still shows an overall decreasing trend in EU consumption therefore the continuous low consumption makes it urgent to continue to stimulate fresh fruit and vegetable consumption* within the European Union (Freshfel Europe - European Fresh Produce Association, 2015).

However the European Health Interview Survey (EHIS) 2009 points out that self-assessed fruit and vegetable consumption is higher than the actual consumption figures. According to Eurostat data on EHIS all 15 Member States which responded to this study show that more than 45% of their total populations (regardless of age, sex and level of education) consume fruits at least once a day (Table 8 and Table 9). Citizens of Slovenia and Spain consume fruits more frequently, while Romanian and Bulgarians consume less fruits.

The Belgian and French populations eat more often vegetables than fruit. On the other hand, only little over half of the Maltese and Slovakian population consume vegetables on a daily basis. Moreover, both tables show some concerning figures on the column which points out proportions of the population which never consumes fruits or vegetables – the larger the size of the population, the higher the absolute figures of persons which never eat fruits or vegetables are (for example, 1.6% of the Spanish population accounts for approximately 750,000 persons which in absolute values is much higher than 3% of the Maltese population – approximately 13,000 persons).

Table 8. Self-reported consumption of fruits (%)

Country	Once A Day	At Least Twice A Day	Less Than Once A Week	From 1 To 3 Times A Week	From 4 To 6 Times A Week	Never
Belgium	35.7	27.6	8.3	7.1	17.9	3.5
Bulgaria	34.8	10.4	11	26.1	16.8	0.9
Czech Republic	38.3	27.9	4.2	20	8.8	0.9
Estonia	56.7	:	:	16.9	22.3	4.1
Greece	39.7	21	7.4	11.9	17.5	2.6
Spain	32.1	38.2	4.3	12.4	10	3
France	21	44.8	7.2	8.7	14.8	3.6
Cyprus	38.4	27.4	5.3	15.8	11.9	1.3
Latvia	42	18.2	4	25	10.4	0.6
Hungary	37.4	30.9	4.7	15.6	10.9	0.5
Malta	29.6	44.3	2.9	10.6	9.7	2.8
Poland	41.7	19.9	6.1	15.6	16.1	0.6
Romania	28.7	16.9	11.3	26	16.6	0.5
Slovenia	37.7	37.0	3.6	9.6	11.1	1.1
Slovakia	42	22.2	3.8	21.5	10.1	0.4

Source: Eurostat, 2009

Table 9. Self-reported consumption of vegetables (%)

Country	Once A Day	At Least Twice A Day	Less Than Once A Week	From 1 To 3 Times A Week	From 4 To 6 Times A Week	Never
Belgium	71.9	13.3	1.0	8.2	5.2	0.5
Bulgaria	45.3	13.8	6.7	2.3	11.0	0.3
Czech Republic	38.7	20.9	3.3	22.4	13.1	1.6
Estonia	51.7	:	:	21.3	24.2	2.9
Greece	47.0	16.9	4.1	15.4	15.6	1.1
Spain	45.8	15.8	3.0	21.5	12.2	1.6
France	27.6	49.3	2.6	8.6	11.0	0.8
Cyprus	48.1	20.1	2.4	17.3	11.3	0.8
Latvia	47.9	15.2	2.6	25.8	8.2	0.3
Hungary	37.0	15.7	4.9	23.8	17.8	0.9
Malta	31.8	19.0	5.1	20.6	20.5	3.0
Poland	47.7	15.5	3.2	19.2	14.2	0.2
Romania	36.9	17.2	5.3	27.8	12.7	0.2
Slovenia	55.1	19.9	2.1	13.1	8.5	1.3
Slovakia	37.5	14.0	4.8	28.7	14.5	0.6

Source: Eurostat, 2009

Apart from the minimum consumption of 400g per day of vegetables and fruit, the World Health Organization also recommends lower level of carbohydrates coming from free sugars, lower levels of fat and cholesterol, low intake of salts and 10-15% of dietary energy supply coming from protein (Table 10).

However, WHO data presented in Table 11 show that most of the EU countries exceed the recommended threshold of 30% of fat within the entire dietary energy supply. Data comprised in the red cells reveals the higher values, while data in green points out the lower values. France and Spain record the highest percentage of fat in nutrition – 42.3% and respectively 42.1%. The most alarming fact is that only 4 countries meet the WHO recommendation, namely Estonia, Lithuania, Malta and Romania (white cells of the table).

The percentage of protein derived energy meets the WHO criterion in all Member States, the values in this case proving to be rather homogenous within the time frame 2000-2009; highlighted cells show the values which are closest to the minimum and maximum limits (Table 12).

As data from various international entities show, there are many aspects concerning a healthy life that must be addressed at individual, national and regional levels in order to improve health and health-related indicators and to reduce disparities among European regions and Member States.

NUTRITION IMPLICATIONS UPON HEALTH

According to the World Health Organization, fruit and vegetables are important components of a healthy diet, and their sufficient daily consumption could help prevent major diseases, such as cardiovascular diseases and certain cancers. WHO reports show that approximately 16.0 million (1.0%) disability adjusted life years (DALYs, a measure of the potential life lost due to premature mortality and the years of productive life lost due to disability) and 1.7 million (2.8%) of deaths worldwide are attributable to low fruit and vegetable consumption. Moreover, *insufficient intake of fruit and vegetables is estimated*

Table 10. Ranges of population nutrient intake goals

Dietary Factor	Goal (% of Total Energy)
Total Carbohydrates	55 – 75%
Total dietary fiber/Non-starch polysaccharides (NSP)	(>25 g, or 20g/d of NSP) from whole grain cereals, fruits and vegetables
Free sugars	< 10%
Total Fat	15 – 30%
Polyunsaturated Fatty Acids	6 – 10%
Saturated Fatty Acids	< 10%
Trans Fatty Acids	< 1%
Cholesterol	< 300 mg/day
Protein	10 – 15%
Sodium chloride *(sodium)*	< 5 g/day *(< 2 g/day)*
Fruit and vegetables	> 400 g per day

Source: World Health Organization, 2003

Table 11. % of total energy available from fat

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
AT	39.1	39.4	38.8	38.6	39.8	37.8	39.4	39.4	40.0	40.4
BE	39.3	39.6	39.9	39.7	39.4	40.0	40.2	39.7	40.9	39.7
BG	29.6	29.6	30.1	31.0	31.1	31.0	31.1	31.8	32.1	32.7
HR	28.4	27.3	28.4	29.4	31.1	32.7	33.2	35.2	35.8	35.6
CY	37.0	37.8	36.4	36.6	36.9	39.0	41.1	38.0	39.0	39.3
CZ	32.7	32.5	31.6	32.3	30.9	34.2	38.3	37.0	38.1	38.6
DK	36.0	36.9	35.7	35.7	36.0	36.5	35.5	36.2	36.0	36.7
EE	26.2	26.7	29.5	29.9	28.5	26.1	26.5	25.9	24.9	25.7
FI	35.3	36.1	36.4	36.0	35.6	35.8	36.1	36.2	38.1	37.1
FR	42.3	42.3	42.0	42.1	40.8	41.1	41.5	42.1	41.4	42.3
DE	38.4	36.6	36.3	37.1	36.6	36.1	36.5	37.3	37.2	37.1
EL	34.7	34.9	35.8	35.5	35.1	36.2	36.8	37.1	37.5	37.7
HU	37.8	36.8	38.4	37.5	38.1	39.0	38.4	39.6	39.2	38.8
IE	33.6	32.7	33.5	33.5	33.8	34.7	31.4	32.5	32.6	32.3
IT	38.2	38.4	38.7	38.4	38.6	38.4	39.1	39.2	39.0	39.2
LV	29.8	31.3	32.7	33.5	35.5	34.5	36.3	36.1	34.9	35.7
LT	21.6	21.3	23.9	26.0	25.8	26.4	27.1	27.3	29.0	27.9
LU	38.6	38.1	38.3	38.3	38.0	38.9	38.5	37.9	37.7	37.1
MT	28.8	29.5	28.0	28.0	29.4	28.8	30.1	29.8	31.2	29.8
NL	39.2	38.9	38.9	36.5	36.9	38.5	37.5	36.7	37.7	37.5
PL	29.9	29.9	30.4	30.0	30.0	30.2	30.1	30.1	30.4	30.4
PT	34.0	33.9	34.3	34.3	33.1	33.9	34.2	35.5	36.0	36.8
RO	26.2	26.3	26.7	27.3	25.7	27.5	28.3	28.2	28.1	27.6
SK	31.3	34.0	34.0	34.1	33.4	32.1	33.5	33.3	31.5	33.5
SI	31.9	34.0	33.8	34.8	35.0	33.7	34.2	33.9	34.2	34.5
ES	40.9	40.6	40.3	40.4	40.8	40.7	41.0	41.4	41.2	42.1
SE	35.7	35.9	35.9	35.8	35.6	35.9	35.6	35.6	36.3	36.8
UK	37.7	37.4	35.8	35.3	36.0	36.5	39.1	37.6	37.3	37.3
EU	36.8	36.5	36.4	36.4	36.2	36.5	37.2	37.3	37.3	37.5
EU-15	38.8	38.4	38.1	38.0	37.9	38.0	38.7	38.8	38.7	39.0
EU-13[5]	29.9	29.9	30.5	30.7	30.4	31.2	31.8	31.9	32.0	32.1

Source: World Health Organization, 2015b

to cause around 14% of gastrointestinal cancer deaths, about 11% of ischemic heart disease deaths and about 9% of stroke deaths globally (World Health Organization, 2015a).

The major risk factors and their impact on health are comprised in Table 13. According to the World Health Organization, overweight and obesity as well as low fruit and vegetable intake are nutritional direct factors that impact human health.

As presented in Figure 6, according to World Health Organization estimates, the prevalence of overweight and obesity among European countries is extremely high. The red areas of the map of Europe show countries where overweight prevalence is higher than 60%. Among EU Member States, Malta ranks first (64%), followed by Czech Republic and United Kingdom (both with 63.4% of the population affected by overweight problems. At the lower end, we find Austria (53.1%), Germany (54.8%) and Denmark and Finland (both at 55.2%). However, as the map highlights, more than half of all European

Table 12. % of total energy available from protein

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
AT	11.7	11.7	11.9	11.6	11.4	11.7	11.2	11.3	11.1	11.31
BE	**10.3**	**10.6**	**10.6**	**10.5**	**10.5**	**10.6**	**10.5**	10.8	10.7	**10.59**
BG	12.2	12	11.8	11.4	11.6	11.5	11.4	10.9	11.2	11.22
HR	**10.4**	**10.6**	10.8	**10.5**	**10.1**	**10.2**	**10.6**	10.8	10.6	10.8
CY	12.7	12.9	12.8	12.3	12.4	12.3	12	12.4	12.3	11.99
CZ	11.7	11.7	11.2	11	11.4	11.8	11.4	11.5	11.3	11.16
DK	12.7	13.1	12.5	12.5	12.6	13.2	13.1	12.8	13.1	12.75
EE	11.5	11.4	12.1	11.7	10.9	11.7	11.5	11.8	12.1	11.67
FI	12.8	12.9	13	13.2	13.3	13.3	13.3	13.5	13.9	13.52
FR	13.1	13.1	13.1	13	12.9	12.7	12.7	12.8	12.6	12.48
DE	11.2	11.5	11.5	11.6	11.3	11.3	11.4	11.5	11.5	11.51
EL	13.1	12.7	12.5	12.8	12.6	12.6	12.9	12.9	12.5	12.64
HU	10.8	10.9	11	10.7	10.8	**10.4**	**10.5**	**10.2**	**10.2**	**10.08**
IE	12.4	12.9	12.9	12.9	12.9	13	12.7	12.3	12.3	12.25
IT	12.5	12.4	12.3	12.3	12.2	12.3	12.3	12.3	12.3	12.3
LV	11.1	10.8	11.1	11.2	11.2	11.4	11.7	12.1	12.1	11.71
LT	13.3	13.3	13.5	13.2	13.9	13.9	13.9	14	14.1	**14.47**
LU	12.1	12.1	12.3	12.4	12.5	12.8	12.9	12.6	12.6	12.67
MT	13.1	12.9	13.2	13.3	13.2	13	13.2	13.5	13.1	12.94
NL	13.3	13.5	12.7	12.5	13.1	12.9	13.2	12.9	13	13.16
PL	11.7	11.7	11.8	11.8	11.7	11.8	11.8	12	11.8	11.93
PT	12.7	13	12.7	12.6	12.7	12.7	12.8	13.1	13.1	13.13
RO	12.1	12.2	12.5	12.6	12.7	12.7	12.5	12.7	12.7	12.88
SK	**10.3**	**10.2**	**10.5**	**10.5**	**10.1**	**10.4**	**10.3**	**10.4**	**10.5**	**10.11**
SI	13.4	13.1	12.7	12.9	12.4	12.7	12.5	12.5	12.6	12.6
ES	13.2	13.3	13.5	13.5	13.2	13.2	13.7	13.8	13.2	13.08
SE	13.1	13.2	13.6	13.8	13.7	13.8	13.9	13.8	13.8	13.81
UK	11.8	11.9	12	12.1	12	12.1	12.2	12.2	12	12.13
EU	12.1	12.2	12.2	12.2	12.2	12.2	12.2	12.3	12.2	12.18
EU-15	12.3	12.4	12.4	12.4	12.3	12.3	12.4	12.4	12.3	12.29
EU-13	11.7	11.7	11.8	11.7	11.7	11.8	11.7	11.8	11.7	11.77

Source: World Health Organization, 2015b

Union population struggles with overweight issues, since none of the Member States records an overweight prevalence of less than 50%.

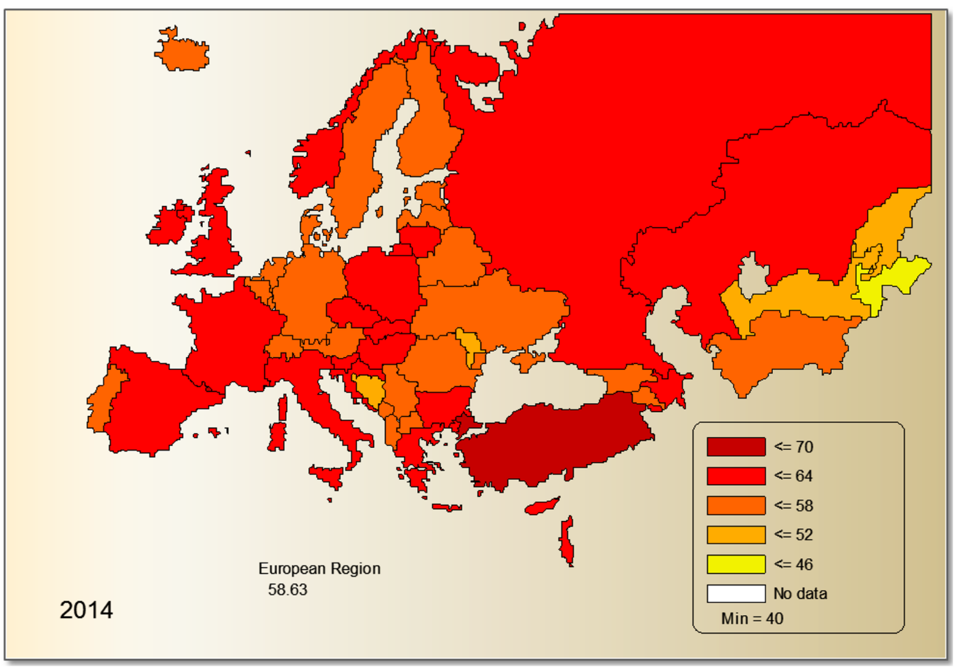
The direct consequences of the factors that influence nutrition previously discussed in this chapter is that *there are now more overweight and obese people than underweight or malnourished in the world* (Popkin, 2006), which brings to the foreplan new and different challenges that must be tackled nowadays

Table 13. Top 10 health risk factors and their estimated relative contribution to the burden of disease

Risk Factor	Burden of Disease (%)
1. Tobacco use	11.7
2. Alcohol use	11.4
3. High blood pressure	11.3
4. Overweight and obesity	7.8
5. High cholesterol	5.9
6. Physical inactivity	5.5
7. High blood glucose	4.8
8. Low fruit &vegetable intake	2.4
9. Occupational risks	1.7
10. Illicit drug use	1.6

Source: World Health Organization, 2009 and European Food Information Council, 2012

Figure 6. Age-Standardized prevalence of overweight in people aged 18+ (%)
Source: World Health Organization, 2015b



compared to the last decades of the previous millennium. During that time, international organizations fought for eradicating hunger in the world, while now they are facing the opposite problem of obesity.

According to OECD as well, obesity is a known risk factor for numerous health problems, including hypertension, high cholesterol, diabetes, cardiovascular diseases, respiratory problems (asthma), musculoskeletal diseases (arthritis) and some forms of cancer. As previously seen, the rise in overweight and obesity is a major public health concern, threatening progress in tackling cardiovascular diseases (OECD, 2015a).

Concerning facts for the European Union and the world as a whole is that overweight problems are increasing in young populations also, especially children.

Overweight (including obesity) rates based on measured (rather than self-reported) height and weight are about 24% for boys and 22% for girls, on average, in OECD countries, although rates are measured in different age groups in different countries. According to OECD (2015b) boys tend to carry excess weight more often than girls, with the largest gender differences observed in Denmark and Poland; in contrast, Ireland shows larger overweight rates among girls. More than one in three children are overweight in Greece, Italy and United Kingdom (England) and about one in three boys in Spain, and one in three girls in Portugal.

Various authors (Lobstein et al., 2015; Currie et al., 2012; OECD, 2010) highlight that *children who are overweight or obese are at greater risk of poor health in adolescence, as well as in adulthood*. Among young people, being overweight can result in sleep apnea and orthopedic problems, psychosocial repercussions, such as poor self-image, stigmatization and depression, thus generating lower quality of life. *Excess weight problems in childhood are associated with an increased risk of being an obese adult, at which point cardiovascular disease, diabetes, certain forms of cancer, osteoarthritis, a reduced quality of life and premature death become health concerns*.

RECOMMENDATIONS AND CONCLUSION

Consuming a healthy diet and having access to a nutritious supply of food are important to ensuring good health, since good nutrition is a key factor in the overall health and well-being of the population in Europe and worldwide as well.

As previously seen, *fruit and vegetables are important elements of a healthy, balanced diet, be it as part of a main meal or as a snack. They offer vitamins, minerals and fiber, some energy (mainly in the form of sugar), as well as certain minor components, which are potentially beneficial for our health. Epidemiological studies have shown that high intakes of fruit and vegetables are associated with a lower risk of chronic diseases; particularly, cardiovascular disease, also type 2 diabetes, and certain cancers i.e. of the mouth, pharynx, larynx, esophageal, stomach and lungs* (European Food Information Council, 2012).

According to the previous source, *dietary habits learnt in childhood seem to be predictive for intake levels in adulthood*. Therefore, *the earlier children are introduced to vegetables the more likely they are to have higher consumption levels at pre-school age* (Cooke et al., 2004).

Childhood is an important period for forming healthy behaviors, and the increased focus on obesity has stimulated the implementation of many community-based initiatives in OECD countries and in the European Union in recent years. Studies show that locally focused interventions, targeting children up to 12 years of age can be effective in changing behaviors (OECD, 2015b).

Among these initiatives, school-based programs are of high importance nowadays, since a large part of the day is spent by children in schools. Some of these programs aim at making fruit and vegetable intakes more fun and take the form of cooking lessons, school gardening or eating with special cartoon characters.

In the European Union, the formal aspect of the matter has been tackled since the school year 2009-2010 through the *EU School fruit scheme*, as an attempt to fight child obesity, since *increasing fruit and vegetable consumption is one of the goals identified in the European Commission's White Paper on Nutrition from 2007* (European Commission, 2007).

However, adults are the role models for their children, subsequently is of high importance to acknowledge the magnitude of a healthy conduct throughout the entire life. Avoiding sedentariness, exercising and spending time outdoors, reducing the intake of processed foods and carbonated sweet drinks, as well as maintaining a good balance between the needs of the body and the actual consumption of food become key factors in determining adult and child susceptibility to overweight and obesity and other nutrition related diseases.

As the first part of this chapter highlighted, health services can only be held accountable for a small proportion of preventing and curing certain illnesses, whilst individual behavior (corroborated with genetic inheritance) can assure a much better quality of life.

Lastly, but having the same weight and the same impact, community and administrative interventions are much needed in order to lower the burden of disease. As described before, high quality of life can be achieved through national and regional economic growth, better income and low socially-assisted rates, access to decent standards of living (access to water, energy, hygienic sewage, transport etc.), investments in education and health. Also, national deciders must take into account that improvements take more time to become noticeable than negative effects' evolution. Moreover, national and regional priorities must be clearly set and the costs that these priorities entail must be seen not as expenditure, but as investments in the well-being of current and future generations (which would ultimately translate into higher productivity and economic and social welfare).

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KEY TERMS AND DEFINITIONS

Health Determinants: Various factors which influence the health status of a person, including genetics, lifestyle, environment etc.

Healthy Diet: A diet which comprises enough vitamins, minerals and fiber to ensure energy without increasing body fat.

Life Expectancy: The estimated duration of life (in years) at birth or at various ages.

Member States: All 28 countries that are currently part of the European Union.

Processed Food: Food that has undergone a process of preserving, freezing, refrigeration, dehydration, aseptic processing etc. before consumption.

Urbanization: Increasing dimensions and number of cities and proportion of population living in urban areas.

ENDNOTES

1 Lalonde model – after the name of the Canadian Health Minister at that time.
2 EU-13 refers to countries which joined the European Union since 2004.
3 This recommendation would translate into an approximate consumption of 146 kg of fruits and vegetables per person per year.
4 Defined as Body Mass Index higher than 25 kg/m^2.

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Chapter 2
Truly Nourished

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ABSTRACT

A nutritionist presents case studies of patients who learned not only lessons about nutrition but also lessons about life. Details about the patients' stories are fictionalized, but the life lessons learned by the patients and the nutritionist lead to reflection on healthy choices. The nutritionist uses her faith and conversations with God to guide her as she helps patients.

To my Heavenly Father, first and foremost. Thank you for your master plan and my place in it. You and everything about you blows my mind. You and how you work are awesome and amazing. I am on your Public Relations (PR) team, Lord. My mission is to continue to declare and reflect your glory at all times. May your light and love work through me and be an extension and connection to everyone that I come in contact with. Your Spirit truly nourishes me. Help me nourish others. In Christ Jesus, Amen.

I am the living bread that came down from heaven. Whoever eats this bread will live forever.
This bread is my flesh which I will give for the life of the world. (John 6:51 NIV)

INTRODUCTION

When most people come for a consultation in my office they have expectations of being counseled and educated on health and nutrition. The Registered, Licensed Dietitian/Nutritionist (RD, LD/N) is the only health care professional specifically educated and trained in the science and application of nutrition. Nourishing our bodies to help treat or even prevent a variety of health-related diseases is the focus. Nutritionists need to have training and education on a variety of disease conditions, anatomy & physiology, medication interactions, diagnostic procedures, counseling and behavior modification, laboratory tests, and work with a variety of different health professionals. I studied in college for seven years receiving a Master's degree in 1991 and then other advanced certifications and ongoing training. It has not been

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until the past few years, however, that I feel my true training has really begun. What I call my true nourishment and the true nourishment that I bring to others.

Food and the eating experience are highly individualized. We celebrate with food. We mourn with food. We manipulate food with our emotions. Some overeat when they are depressed. Others eat less when depressed. We have specific childhood memories of foods. Some of these memories may include having to choke down Brussels sprouts at dinner before you can leave the table. Yep, that was me and I have not eaten a sprout since! Another memory may be that fantastic smelling and tasting sweet potato pie that Grandma is known for and how it reminds you of feeling loved and safe. I have also learned about and enjoy working with a variety of different food cultures and customs.

The main focus of my education and counseling is a whole food, balanced focus. This means focus on what came right from the earth most often. More of the best (real, whole food) and less of the rest (sweets, snack chips…). The foundation of eating vegetables, fruits, low fat dairy, lean proteins, whole grains and healthy oils, nuts and seeds. Once in a while we can enjoy special holiday and celebration treats and meals or "wiggles" as I explain in my office. Balancing a week of eating should start with a foundation of real, whole food and then we can balance with some "wiggles" throughout the week. This is a good and realistic balance. I see how extremes with dieting and very unhealthy extreme restriction lead to negative emotional and physical health. The most healthy food choices, the whole food choices are the real deal. All the vitamins, minerals, protein and other components necessary for health. The processed, non-real-foods, are devoid of anything of long-term substance. We do not need these foods to survive. I think of the true bread of life, our savior and Lord Jesus Christ when I think of this type of true nourishment. He is the whole food, the real truth to our true nourishment. And since I am to reflect His character, I must give all of me when I am interacting with people. I can't just give part of me, or the processed, non-nutritious stuff. I want to express to others a "whole me" like the whole foods perspective. The true me, the important part of me, all of me.

Every hour is a new adventure. My day may start with a diabetic, move on to a family with a three year old picky eater, switch to a forty-something bulimic, a migrant farm working family who all have high cholesterol, a few more digestive conditions, some weight loss education, and the day may finally close with a sixteen year old with anorexia. Throughout my day, I also receive random texts and emails from clients with questions or pressing concerns. I often receive requests to just send them some encouragement or words of wisdom because they are stuck in their food and nutrition planning. Or in some cases with eating disorders and patients in recovery for addictions, I receive panic texts of fear and anxiety. Yes, food and eating related. These clients are also working with professional therapists and physicians and are encouraged to talk to them and I am in constant communication with these professionals as well. There is nothing better than a team of sensitive and smart people!

I spend most of my counseling in individual client and family sessions. I also enjoy speaking in groups and giving lectures. I did a lot more workshops and public speaking when my time was more flexible. This was before I was a mom! I love to share information in new and interesting ways. I feel very comfortable facilitating groups. It comes naturally. It feels best, of course, when I am God-centered. I really enjoy bringing out the best in people. I get such a kick out of seeing a person's reaction when they understand a concept. When they get that light bulb moment. I clearly feel the most reward when I can help someone make a God connection; not only a nutrition connection.

I absolutely love working with all different types of people and personalities. I truly respect each and every person that I meet as a unique individual. I think that God wired me with a personality that was made to be a counselor. I feel deeply and I am highly intuitive. I do not always express my feelings, however. I can discern when expressing my feelings are appropriate. Kind of like a poker face. An absolute non-judgment zone. I think that this is what makes me a good, active listener. Very little actually surprises me anymore. I have heard it all. Just some recent tidbits include; the twelve year old who told me her mom gave her some of her diet pills to help her lose some weight for her to fit in her Bat-mitzvah dress, the sixteen year old who randomly during our session rolled up the sleeve of her shirt to show me recent self-induced cuts on her arm that she had been hiding from everyone, the sixty-two year old married woman who shared with me that she just recently ended an affair with a man half her years, the fifty-something couple that could barely speak about anything other than the tremendous grief they felt after recently losing their daughter to breast cancer, the thirteen year old girl who told me in confidence that the only reason she is not starving herself anymore is so that her parents will let her stay in her private school and buy more new clothes, the thirty-nine year old childhood diabetic with two small children who told me she does not take her life-sustaining insulin sometimes when she feels like she has gained weight and needs to diet, and on and on and on. Real life, real people, real stories.

Give them words of wisdom? Am I seriously equipped for that? I think that all of my forty-four years are still too young and inexperienced for that! Doesn't everyone remember that I am a trained *Nutritionist*? Seriously? And I don't want anyone to think that I am a know-it-all. Then I sit and ponder a bit. Don't *I* have a story? Don't *I* have life experiences that I have learned from and I can draw from? This is especially true when what a patient shares with me is relevant to my own life experiences. I never give advice. I do empathize with others and lend a listening and understanding ear. I help others make their own connections and to facilitate their own behavior awareness and behavior change. I definitely refer to mental health professionals, addiction centers, support groups and medical physicians when appropriate. When my eyes are open to where God is working and my ears are open to what the Holy Spirit is truly telling me and my heart is soft enough to receive it all; well, yes then, I am able to perhaps provide a few words of comfort and wisdom from my perspective and experiences. And if this is what God has equipped me to do, to be open and listen, then He will provide the tools I need and the strength and the wisdom to do the assignment correctly. I trust Him.

GRIEF-CONNECTION

I know grief far too well. I lost my hero, my father, when he was 57 years old to metastatic cancer. He went to the doctor one day and two days later received the terminal diagnosis and died in six months. I was pregnant at the time. Talk about a hormonal and emotional roller coaster ride! My heart will always be broken to know that my kids will never be able to have known their grandfather. At least, not on this earth. I lost my best friend from my youth Eric (37 years old), his father, and his father-in-law in a tragic plane crash about five years later. Eric was an integral part of my life when I started my walk with Jesus as a teenager. I re-committed my life to Christ and completely surrendered to Him a few days after Eric's death. I believe that God came to me in an amazingly vivid dream. You must know that I very rarely remember any dreams. This dream was so real that I could not shake it for the next few days. The impression that I received from this dream was an incredible love and warmth and the Spirit centering me.

I felt an overwhelming peace. I also felt a need to go and use my gifts and do God's work. To work on my one-on-one with God my Creator and Master. It made more sense to me to use this tragedy to strengthen my faith and my relationship with God. I just felt as if I was wasting time trying to figure out the "why did this happen?" For me, it was more "what do I do now with what has happened?"

Eric's wife was pregnant at the time of the accident with a one year old daughter. Those babies will never know their dad. I still have a difficult time believing that both of these men that were so important to me and were so critical in shaping the person I am today are no longer here. These men left a legacy of caring, love, feistiness, and intelligence that I will always respect and treasure. There will always be a hole in my heart for them. I felt as if I re-lived my father's death when Eric died. I must have numbed out in the years between as I was so busy "doing"; having babies, running a business, etc. I was coping by "doing." Eric's death woke me back up and re-directed me to God. I know we will have an awesome conversation about it when I see him again! I understand the grief process. I totally get it. I get people's grief.

DEPRESSION-CONNECTION

I know depression far too well. I have seen it in my family, friends, and I see it almost daily in many of the clients I work with. Depression and anxiety seem to be particularly high due to the state of the world we currently live in. Normal transitions in life bring seasons of depression: death, job change or loss, marital problems, sickness, financial issues and more. There are the normal life depression events and the more unusual life depression events. These unusual events are perhaps the made-for-TV-movie, *Desperate Housewives*-type situations: men living two lives with families in different towns, the adulteress showing up at the front door of the cheating husband's home, the alcoholic soccer mom in denial who gets arrested for DUI, the sociopathic secretary who stole her bosses' identity and charged hundreds of thousands of dollars in the bosses' name or the cross-dressing local doctor. Yes, these are just the tip of the iceberg life situations that people have shared with me. I also work with people who have mental health disorders and for them even normal life experiences take on a whole different meaning. I sometimes work with various personality disorders including borderline personality disorder, dissociative identity disorder (formerly multiple personality disorder), bipolar disorder, Obsessive-compulsive disorder, trauma abuse, etc. With regular, and often intense, professional mental health therapy and or medications many people are able to function and work through the anxiety and depression. Then there are the saddest times when the depression is so severe that people just check out from reality to cope. Some want to kill or have attempted to kill themselves. I have unfortunately worked with clients that have done both. I will never forget the twenty-two year old trauma victim, Sally. I worked with her about seventeen years ago for help with the eating disorder bulimia. She also had a dissociative, or multiple personality, disorder. Her pain was so great that she shot herself in the head while in her car outside of her psychologist's office.

Heartbreaking pain. I see the pain that depression and anxiety brings to the person experiencing it, to their family and their friends. I see how this can even translate to a community feel of negativity. Do you feel it too? It seems as if everywhere I go recently that there is a negativity cloud, a lack of joy. I see it in faces at the grocery store, at my kids' schools and after school activities, at the mall, even at my church. It is palpable to me and I feel it very strongly at times. I get people's depression and anxiety.

IMAGE/PERFECTION-CONNECTION

I know what it is like to feel tired and what I call “fuzzy-headed.” You have to understand this is coming from someone with a ridiculously high energy level. I am talking energizer-bunny energy level. Multi-tasking, no problem! Be the best, well, everything, no problem! Be a super-student, super-Nutritionist, super-wife, super-mom, super-friend, super-volunteer, super-body, super-everything… Houston, we have a problem! Super-Crash! My own high expectations and perfectionism basically burned me out. I have never had a clinical eating disorder. I get that question often. What I had, I believe, was worse. When a client comes to me with an eating disorder it is their way of controlling life situations that are out of control. It is a coping mechanism. When I went through a period in college through my twenties of controlling my weight it had nothing to do with coping. It was all about pride and vanity. I can control my weight and my body right where I want it to be so that I could look perfect. Not too thin, just thin enough that I controlled every bite that went into my mouth. I could not be “average” of course. I had to be thin and lean, but not sick thin. Because then how could I be the super-Nutritionist? This had nothing to do with anxiety, simply pure vanity. This tight control faded a bit after a few years of marriage and then wouldn’t you know I was diagnosed when I was thirty-five years old, after my second pregnancy with Hashimoto thyroid disease. My thyroid does not behave the way I would like it to! Weight gain, or difficulty controlling weight, can be a result. I gained and subsequently lost about sixty pounds with each of my two pregnancies. The obstetrician loved teasing me, the Nutritionist, about it! Fatigue is also an issue with thyroid conditions. This thyroid condition is controlled with medication but there are days when I really need the extra cup of coffee if you know what

I mean. I am a naturally thin, small-boned, body type and I do take care of myself. The goal now is to take care of the Temple of God and not the temple of Chris. I get people’s issues with weight control and fatigue. Interesting how God works, isn’t it? I tried it my way and attempted to control things and then in His perfect timing, He steps in and steers me back to Him. I get people’s issues with self-image and expectations.

So, let me share a funny thing about perfection. My office is in a small professional building with a variety of signs of our business names and organizations on the outside wall. Living in Palm Beach County Florida, there is the occasional tropical storm or, thankfully not as often a hurricane that manages to cause the letters of the names to get misaligned. I have particularly noticed that for the past three years the letter “N” in “Nutritio*N*al” on my sign that reads “Christine Bandy, RD Nutritional Consulting” has been obviously slanted. I look at that sign every time I pull up and park outside my office. The first few months I would look at it and just get irritated. I even mentioned it to my husband and suggested that maybe he could come and fix it soon. Well, that never happened! Months passed and I assumed the office building manager would probably have it corrected. Nope, nothing. A few years passed and I found myself looking at that letter N which appears about to fall off and I smile. I think of that sign when I think of myself and my attitude about always having to get things “perfect.” How the little things, what I call fluff-stuff, could be so annoying and I would let myself get so worked up about it. Oh my goodness, the pressure I put on myself! Now I look at that sign as a reminder of how perfectly imperfect I am. It is a daily dose of humility. If that sign should ever get fixed that would be just fine, but it will not be initiated by me! By the way, the minivan that I have been driving for the past six years with the unique bumper scratches and numerous dings also helps my dose of reality and I now giggle and just shake my head when I look at it. That kind of fluff stuff would have made me totally nuts in the past. Not to mention the fact that I drive an image-killing minivan! “Thank you, God for not allowing me to be too caught up in the comparison game. Continue to make me a wiser woman. Thank you for equipping me for my good and my bad and not equipping me for anybody else's." I refuse to let myself be defined by what I drive! And, remember I shared with you that I giggle when I look at my vehicle. Well, that is called contentment. And for me, contentment is joy. It feels good to not take myself so seriously. What a relief! Yes, I definitely get people's perfectionism and image consciousness.

ADDICTION-CONNECTION

I know what it is like to have a family member with an addiction. My father smoked cigarettes since he was a teen. I never knew him without multiple, daily smoke breaks. Luckily he respected us enough to never smoke in the house. He tried many times throughout his life to quit and the addiction proved to be too much for him. As heart-breaking as it was to learn that he had terminal lung cancer, it was not really a shock. Ironically, his mother, my grandmother, smoked like a chimney until she passed away at 90 years of age from non-smoking-related issues. I am so sensitive to any cigarette smoke that I call myself "the bionic nose." My children see people smoking and immediately relate it to their health. It can be quite embarrassing when they say in a loud voice,

"Mommy look; they are smoking and they are going to die!" They know that they never met their grandfather because he died from complications of smoking. Good life lesson learned, but still heart-breaking. My daughter looks at the picture of her grandpa Fred and cries because she never got to meet him. So do I. I have other family members that struggled with alcohol and drug addictions in their youth. The emotional strain on the family cannot be put into words. Praise God they are recovered and healthy today. I get people's addictions and addictive tendencies.

I have learned to switch gears quickly and assimilate information even quicker. I also have learned to be a keen observer. Isn't it interesting how food and meal planning brings people together? Everyone has to eat! I have been counseling and coaching people on their health for twenty years. The past five years I have observed that many of the clients and their circumstances have been more challenging and their stories have been more extreme. Then, a thought hit me (or should I say, the Holy Spirit) during my weekly Bible study exercises. The circumstances in my work have not really been changing. It is God changing me and working in and through me! The more God-centered I am, or as I call it having my "God antennae" on, the more in-tune I feel in my connection to the clients I am working with. The more confident I feel in asking spiritual questions or making comments. The more I connect to impressions on my heart that I feel are Spirit-lead. As a younger health counselor who was also less mature in my spiritual journey, I would hesitate to talk about my faith for fear of not being "PC" professionally correct. Or even "politically-correct."

So what happens when an experienced, health and nutrition counselor begins to realize that as she grows in her faith and connection to the Spirit's gentle nudging, that a new dimension to her health counseling emerges. A deeper, more meaningful type of nourishment. More than just the food planning and the nutrition education that is typically provided in a counseling session. What happens when this professional Nutritionist opens all of herself up and is fully present in the session? What happens when she is actively listening to the Spirit to guide and direct her in the session? What happens when she no longer ignores a heartfelt impression to say something or to act? What happens when Christ in me is expressed as an integral part of this interaction? True nourishment, that's what happens! My client is truly nourished on a spiritual level because a Christ-connection was made. I am rewarded as the counselor with a true nourishment and blessing as well. I have always known that god has given me special talents and gifts. There is no better affirmation than knowing that how I use this talent is my special gift back to God. Glorify His name! The more I choose to be authentic and give all of me, the more I receive and the more nourished I become. This type of bread of life interaction is life-changing for all involved when you feel the Spirit directing and then you act.

People often just seem to open up to me. One day, the kindest elderly woman caught me off guard as we were finishing our session together. "Doctor Christine" she says, (I ask her to just call me Chris, I am not a doctor) but she sternly corrects me and continues

"Oh but you *are* my doctor, my food doctor. And my blood sugars will be better now thanks to you. And thank you for listening to me go on and on and tell you about how lonely I have been since my husband died last year; I feel better talking about it. And by the way, may I ask you… what is it with you? Are you always this happy and positive? I believe you are contagious!" I tell her it is God in me that lights me up. She gives me that all-knowing smile and nods and hugs me before she leaves. Now that's what I call being truly nourished! An interaction that started as strangers and about an hour later we end with a hug and smiles. I am so thankful that some clients feel trusted and respected enough to share their stories with me. There are times when they have even commented that they didn't expect to share what they did especially since they thought it would only be a "food" conversation. Guess they were not anticipating some spiritual fuel or food! I often will receive voicemails from clients and they only leave their first name because they feel so comfortable with me and they assume I know who they are. I can usually figure it out although it may take a little time and backtracking into my agenda research! I smile every time that happens because I know that they feel that I cared about them and they made a personal connection. That's what happens when God is working. Real conversations between people build real relationships. Even if this is a professional type of relationship there is a connection that takes place. An interaction between people that is authentic. My mission is to reflect God's glory in every interaction I have.

It is incredible to see how God works in the wake. You know, that ripple effect that happens when you connect with someone in a very deep way and change that person in a positive way somehow. By a word of encouragement, a pat on the back or a high-five, a listening heart. That person is changed for the better, has been built-up and if even for that moment or for the next few days feels that someone empathizes with them and was understanding or even actively and intentionally makes a life change because of their interaction with you. They are changed and then every person that they may come in contact with experiences their positive change and so on and so on. God is working in that wake. He is there; in every relationship and human interaction. There is that body-of-Christ connection. I save letters and notes from clients and professionals that are expressions of gratitude for making a difference in clients' lives. Helping them prevent or treat a health condition or even a thank you for exceptional encouragement and motivation are so rewarding to receive. The notes that I find to be most joyful and meaningful to me are those that thank me for making a heart-connection or God-connection in their life. A thank you for helping to strengthen their faith. There is truly no better affirmation for me than that.

Father, I present myself to you today, a living sacrifice, holy and pleasing to you. Guide me and direct me though your Spirit. Open my eyes so that I truly see where you are working. Open my ears so that I truly hear and understand what the Spirit is telling me. Soften my heart so I am receptive. Purify my motives so it is all about you and not about me. Help me to do your good. Help me to reflect your glory. Amen. This is part of my conversation with God before I begin my day of work. This is my daily dose of joy every morning along with my nice cup of coffee. I need His strength to get me through the day… and the caffeine doesn't hurt! And yes, I *am* a Nutritionist and I won't give up my coffee!

The following stories describe interactions with a few clients. The purpose in sharing is to seek good nutrition but even more so healthy spiritual nutrition in order to focus on spiritual nourishing and connecting. Their names and personal identifying details have been changed for privacy. The stories you read are composites and are not one hundred percent true due to protecting patient confidentiality; specific identifying facts have been fictionalized and several patients' experiences have been combined into one story. The stories are told with the intent of illustrating experiences common to multiple patients without describing the personal story of any specific patient. My purpose in sharing the lessons learned is for you as a reader to apply healthy nutrition to your life and ask for help when needed.

A list of references from websites such as www.apa.org from the American Psychological Association and www.allianceforeatingdisorders.com follow the narratives and provide more specific information about the medical conditions such as multiple personality associative identity disorder experienced by the patients in the stories.

This would be a typical day of counseling for me. Everyone I meet has amazing stories. I see some patients only once or just a few times. I work with others on an ongoing regular basis. What I have included in parenthesis within these interactions are what I am thinking, what I am experiencing being in the moment and the impressions that I am feeling from the Spirit while I am in session with my client. The true nourishment exchange is when I am fully aware of God's presence and He is centering me and I am using my gifts and talents that He has given me to serve and love whom I am with and give this as a gift back to God in the hope of pleasing Him and glorifying His name. It is a win-win interaction. I can almost hear Him whisper in my ear softly, yet very clearly "Well done, my good and faithful servant, well done." My heart automatically smiles. There is no better affirmation for me than that! The following patients remind me of Christ's example of true nourishment. My hope is that you will feel inspired by the genuine interactions that we share and you, in turn, will feel inspired to share some spiritual nourishment with those that God has put in your path as well. This is reinforced in 1Timothy 4:6 (NIV); "If you point these things out to the brothers and sisters, you will be a good minister of Christ Jesus, nourished on the truths of the faith and of the good teaching that you have followed".

The generous will themselves be blessed, for they share their food with the poor. (Proverbs 22:9 NIV)

Zora

Zora is a sweet African-American woman from the Island of Antigua. Her island accent is so pretty that it sounds as if she sings when she speaks. She is almost five feet tall and is put together from head to toe. She is wearing a burgundy and floral tailored skirt outfit and matching hat. She is freshly lipsticked with a bright, beautiful smile. She is about to have her 87th birthday. She was referred to me to help her with a diabetic meal plan. I also noticed that she was carrying about three or four large bags. I wondered to myself why she didn't just leave these things in the car. She also appeared to be limping a bit as she entered my counseling office. Was it because of the bags she was carrying? We would get to that later in our conversation.

"I just want you to know from the start that I live alone," she tells me in a matter-of-fact tone. "I do not cook, I do not want to start cooking, and I am just too old and tired to spend a lot of time preparing food." (I hear you loud and clear. I feel the need to ask about her family and friends). I respond by reassuring her that we can put a healthy plan together for her that will require limited preparation and cooking. She was pleased and I felt her relax a bit. I ask her if she has any close family or friends that help her. She tells me that she has never married and she came to the states to train as a nurse. She spent most of her life working as a nurse helping sick people. Her only family is an ill sister in England and an estranged brother who lives in the Islands. She is, in fact, on her own.

We finish working out a basic diabetic meal plan for her. I finally ask this kind, gentle lady why she is carrying so many bulky bags. “I told you that I don’t cook” she laughs,

“Well, I don’t drive either! I take the bus everywhere,” she continues, “I was ready three hours before our appointment today so that I could get to the bus stop and then get dropped off at the mall down the street to be here on time.” I am calculating that she walked about a half mile to get here from the mall. This beautifully dressed, independent 87 year old lady! She does this routine to get to all of her doctors and appointments. She also takes the bus to the grocery store and somehow manages to carry the items back on the bus and then walks back home. Of course she doesn’t cook! She is always on a bus or walking to a bus! I am really liking this lady. (I feel a genuine warmth and connection to her).

I find out she only lives about ten minutes away from where I live. The route would take me from my office and only a few minutes off my normal route home. (I feel such a deep impression within me to offer more of me to her). “You know, Ms. Zora,” I explain, “You live right in the middle of the route from my home to my office,” I tell her that it would be no trouble at all to swing by and drop off things to her from the grocery store now and then if she ever needed it. She looked shocked when I told her this. I could tell that she did not want to inconvenience me.

We finish our counseling session and complete a practical meal plan for her lifestyle. She tells me that she would like a follow-up appointment but that she is having a knee replacement procedure in one month and will be unable to get around for a short time. Now I understand why she was limping into my office. We close by scheduling a follow-up appointment for three weeks. Ms. Zora leaves my office on route to her walk back to the bus stop. I have to admit that I was left with a feeling that I could not shake. I would have driven her home if I did not have back to back appointments that morning. She left an impression on my heart and I just knew that I would be seeing her again sooner than our next scheduled meeting. I remember telling my husband about her later that evening. There was just something about her!

My week of counseling continues normally. Three days after meeting Ms. Zora, I get a call from her. I am between sessions so I can actually pick up the phone and speak without the usual voicemail retrieval. She asks me if it would not be too much trouble to bring a few items by her home on my way home from the office today. She explains that her knee was really uncomfortable and the thought of hiking it on the bus was too exhausting. I was so happy that she called me. I also knew that she must really be hurting for her to reach out to me. Did she have the same impression that I did when she left my office? Did she feel a heart connection? I write down her food list: milk, bread, cheese, peanut butter. She tells me that she can wait for the vegetables and fruits until next week.

I leave my office that afternoon and drive straight to the grocery store. The timing was perfect to drop the items off to Ms. Zora and then pick up my kids from school. I find her apartment easily. There are very few low income housing areas in our town. This was a small section of apartment buildings a few blocks from the local hospital and close to medical offices. I remember her sharing that she lives in close proximity to her medical doctors. I arrive at her apartment. She lives in a corner unit with a small front covered patio area. She has a chair, a few potted plants and other nick-nacks. The front door and window of her apartment displays a variety of pictures, writings and signs. Most of these were expressions of faith, praise to Christ Jesus, and other joyful and positive affirmations. My heart smiles as I read all of them and wait for her to answer the door.

She opens the door and I have to concentrate harder to recognize the lady that I met at my office just a few days earlier. She is without her makeup, hairpiece and fancy clothing. But I definitely recognized the bright eyes and big smile. I bring the food bags in with a few extra items, fruits, vegetables and other staples that she could freeze for later. I look around the tiny home. There are piles of household items everywhere. She shows me around and we put the food away in her kitchen. While we are unpacking we have a wonderful conversation and we learn more about each other. I tell her about my family and she tells me more about her younger years. Currently, she is trying to organize for her knee replacement procedure. She plans to go to a rehabilitation facility and is not sure when she will return home. She has also been attempting to find a nursing home facility to move to as she requires more assistance and she finally admits that she needs more help.

I would have liked to stay longer but it was time for me to leave and pick up the kids. I tell her to call any time as I pass near her home often. "Ms. Christine," she states in a quiet, serious voice, "I am between my assistance payments and will you please not deposit this check for the food until next week?" "No problem, Ms. Zora," I answer knowing full well that I will not be depositing the check at all (it simply feels wrong to take her money from her). There are many times, most times, I feel the need to pray about something and get direction from the Holy Spirit before making a quick decision. And then, there are those times when I feel in the moment what direction the Spirit is leading me. No question, just act.

I see Ms. Zora a few weeks later for her follow-up appointment. Instead of her spending half of her day to come to my office I decide to make a home visit. Her diabetes is stable and she is ready for her knee procedure. She is obviously anxious. I stay a little longer and we just visit. The conversation shifts to faith. I tell her about how important my faith is to me and I talk about my church family and she shares her faith in Jesus with me as well. She is familiar with my church as it is only a few minutes from her home. She asks if she can come to church with my family some time. "Want to come this Sunday?" I ask her. "I would love to," she answers. You know how some conversations are so natural and easy? This was one of those conversations.

That Sunday my husband, myself, and our two kids pile in the car and pick up Ms. Zora for church. She is perfectly dressed with a big, bright smile. We enjoy the sermon and fellowship together. I have a chance to introduce her to some friends and she actually reconnects to an elderly lady friend that she had not seen in a long time. Was this out of our comfort zone as a family a bit? Escorting an elderly African-American little lady to our affluent, mainly Caucasian church? Yes, it was! It was a wonderful learning moment for our kids as well as for my husband and for myself. Isn't it always in the moments that we make ourselves more intentionally vulnerable and get out of our comfort circles the times when we inevitably grow the most. This was one of those times. It was a blessing for us and it most certainly was a blessing for Ms. Zora.

Ms. Zora had an unremarkable knee replacement with subsequent long-term rehabilitation and was away from her apartment for about two months. The rehabilitation was longer than anticipated. We spoke on the phone a few times during this time. She called again when she was settled back in her apartment for a week. My daughter and I brought a few groceries to her and visited. This time she was noticeably upset and anxious. She was having a difficult time calling and coordinating her continued care at home and she was in desperate need of assistance with basic needs such as bathing. I felt her desperation. I was frustrated for her as I listened to her struggles. It only took a few hours of my time, but I was able to make some calls for her to coordinate home care, doctor questions, transportation and medication needs. She was so grateful and it was a pleasure to be able to help her. As we were leaving she looked at me with her smiling eyes and told me that she saw Jesus in me. Of course my eyes then filled with tears at her sincerity. Honestly, it was the least I could do but it made all the difference in the moment. Wasn't *I* seeing Jesus in her though? Then, I think of the scripture, "whatever you did for one of the least of these brothers of mine you did for me." (Matt.25:40 NIV).

I was looking at Jesus when I looked into Zora's eyes! Many people who come to my office are poor to some degree; poor financially, poor in health (physical or mental), or poor in spirit. When you think of that exchange as taking place between you and Jesus, it really changes perspective! Another bread of life exchange. I call it part of my circle of joy!

Today, Ms. Zora is still in her apartment on a waiting list for a skilled nursing facility. Her new knee gets her to the bus stops more efficiently and with less pain. She gets together with neighbor friends more often and is less isolated. We speak on the phone and to each other's voicemails often. When I hear her beautiful island accent it always makes me smile. She is to call as soon as she hears that she has found a space in a nursing facility. My family plans to help her pack and she has already showed me what items she wants us to bring to charities. She is still sharp and funny. We are planning another Sunday church time together now that the New Year has begun. And to think this relationship started months ago at my office like any other normal consult. The prompting that I felt from the Spirit and my subsequent acting is what made the ordinary become extraordinary. Truly nourished!

A poor man's field may produce abundant food, but injustice sweeps it away. (Proverbs 13:23 NIV)

Eduardo

I was introduced to Eduardo when I received a referral from an insurance agency asking if I would help to evaluate one of their patients. This was a workman's compensation consult. I rarely work with these cases as nutrition is not usually relevant. I basically knew that this must have been some sort of accident or injury related situation.

The insurance representative explained that Eduardo was a paraplegic and has had a history of unresolved skin breakdown or skin ulcers on his lower backside. This can happen in paralysis cases due to lack of mobility and long periods of inactivity. He also suffers from recurrent urinary tract infections. This cycle of chronic infections as well as skin breakdown puts him in and out of the hospital for long periods of time. The insurance company asked that I consult on this case to evaluate Eduardo's nutritional status. Proper nutrition is critical in wound and skin healing as well as for optimal immune system support.

The agency coordinated his transportation to my office. I was not prepared for him to actually arrive lying belly side down on a stretcher. He told me later that he was not allowed to be sitting and the doctor wanted him to be in this position to allow for better skin healing. I have a very small counseling office so I immediately re-arranged some chairs to clear a path for him and we spent the consult talking. I am sitting next to his head as he is turning to speak with me while lying in that position.

I know very little about the details of his accident. I only was told that he was working for a roofing company and one day on a job he fell off a roof and was left as a paraplegic. Eduardo is a 25 year old, Latino, soft-spoken, young man with noticeable tattoos up and down both arms, shoulders and up his chest and neck. I even noticed one tattoo behind his ear along his hairline only because of the position he was in while speaking to me. His face lights up with a big toothy smile. He tells me that he lives by himself and has a home health aide that comes daily to assist him with activities of daily living. He was quite independent, able to cook for himself and do other things around his apartment. However, due to the skin breakdown he is unable to do any of these things now.

Our conversation reviews in detail what a typical day of eating is like for him. He tells me that after he wakes up his aide prepares a hot meal of eggs, bacon or other meat, and bread. His lunch currently is take-out food from a close Spanish restaurant and is usually beef, rice and beans. His aide leaves about four o'clock in the afternoon but puts food near his bed for him to eat for the remainder of the day. He may have some lunch meat sandwiches and snack chips. Throughout the day he snacks on chips, crackers, breads, and desserts like cookies. His main beverage is soda and some milk. He was prescribed to drink a fruit-flavored drink that is for skin integrity although he does not drink it consistently. I also learn that he takes no vitamin or mineral supplements. He also shares with me that his budget is very tight and his attorney is helping to provide him with more long-term support.

Eduardo is a charmer and he gets a mischievous look in his eye when he tells me that I am a pretty lady and asks if he can take a picture to put in his phone. I smile and tell him to take it quickly so we can get back to work! He laughs. (It hits me at this time how heartbreaking this situation is and I am deeply moved and feel overwhelming empathy for him.) This young man was probably hanging out with his buddies and meeting girls and just starting his life when the accident happened. His friends don't come around as often now and he is flirting with his Nutritionist who is more than fifteen years older than him. His day consists of just trying to get through the basics; cleaning, dressing, eating, etc. He needs to use a catheter to be able to urinate and has constant urinary tract infections. He tells me how depressed he is. All I can do is be there to listen. Believe me, I did the absolute best listening that I could do. Heart, body, soul and mind listening!

We finish our meeting and I explain my concerns for his nutritional status. The greatest concern was the lack of any nutrient-dense foods in his diet. His diet was totally lacking in healing vitamins and minerals that are mainly found in fruits, vegetables and whole grains. These nutrients are crucial for skin healing and immune support. And to make matters worse, he was never prescribed or recommended to take multivitamin and mineral supplements in addition to wound healing antioxidant supplements. This is nutrition 101 for this type of case. We schedule a follow-up consult for a few weeks and I work on putting a consultation report together with my treatment recommendations. My heart breaks as the transportation personnel come to wheel Eduardo out on the stretcher out of my office and through my small waiting room in which my next client and family is waiting. Everyone is moving out of the way and clearing a path. He waves to me and gives a shy wink as he is pushed out the door and is lifted into the medical van. Before meeting my next client, I need to be still in my office and talk to God a bit. (Father, how may I best serve this young man?) I could not shake the memory of him lying on that stretcher.

I immediately send my consultation report out to the referring agency as well as to Eduardo's physician. Little did I know that this would start a litigious chain of events that I have never dealt with or been exposed to before in my work. A few days later I receive a call from Eduardo's attorney asking to review my impressions and recommendations. I am happy to explain the nutritional needs and treatment recommendations as I want him to receive help as soon as possible. We speak for about a half hour and review Eduardo's nutritional goals.

A few weeks pass and it is time to follow-up with Eduardo. He comes to the office via stretcher procedure as before. After reviewing his diet and interviewing him again I learn that none of my recommendations have been put into practice. Everything has remained exactly as it had been when we saw each other initially. The skin breakdown is the same and apparently he is just coming off another round of antibiotics from another urinary tract infection. I send another report. Eduardo seems much more depressed today. I try to remain positive and encouraging for him. I also tell him "Eduardo, I want you to know that I am here for you, not for any attorneys or agencies, just for you. I really want to help you in any way I can." He smiles back at me and tells me how much he sincerely appreciates that and it means a lot to him. I see a little more light in his eyes now before he leaves.

The following week I receive a message from a consulting physician regarding Eduardo's case. I return the call hoping that this physician will be able to get some positive action. As it turns out, the physician is calling to understand and clarify my recommendations and to actually warn me that it looks as if what I have recommended is excessive. He also warns me that it looks as if I am trying to "milk the system," I am dumbfounded. He continues to explain that Eduardo's attorney put a package of recommendations based on my conversation with him. To say that he embellished a bit would not do this justice! Apparently, the attorney recommended, based on what he stated was my recommendation, that Eduardo receive home-delivered gourmet meals from a private chef, nutrition follow-up consultations monthly, high-end supplements, continued personal home health care, an excessively high food budget, and other "padding's." All of these requests were also extrapolated to basically cover his entire lifetime which amounted to millions of dollars. Furthermore, the attorney gets paid according to the percentage of what the settlement amounts to. The larger the settlement, the larger the law firm's paycheck. I could not believe what this case was becoming. I was also feeling very naïve. I clarified with this physician what my basic recommendations were and he documented this in his report as well. I was under the impression that Eduardo's attorney was requesting extra help until his wounds healed. It turns out that he was estimating costs for the rest of his life. This physician was also there, in part, as an expert for opposing counsel. Was anyone truly on Eduardo's side?

The next week I received a call from Eduardo's opposing attorney. They were also calling to clarify what my actual recommendations were. I was put in the middle of opposing counsels. I was a pawn. Eduardo was a bigger pawn. One side wanted the biggest settlement they could obtain and the other was attempting to give the least amount as possible. Yes, I know, not surprising but I had never experienced this before and I felt in over my head. And my thoughts come right back to the client, Eduardo. No wonder he is depressed! Look what he has to deal with. I want him to get what he deserves and requires but I know that he does not need a personal gourmet chef to heal!

So what do I need to do to obtain clarity? I talk to God. (How do I help serve Eduardo with the most integrity?)

What came to me next was a very clear impression. This case is all about money. (Chris, be a consultant for this case and don't make it about money at all. Be truly on Eduardo's side). Another week passes. Then I am visited by a representative of the court. Yes, I was served legally to be an expert witness at a deposition for this case. These attorneys could not negotiate without an actual formal deposition. This drags out the case even further. Eduardo, by the way, is still not eating any fruits, vegetables, enough protein or consuming any immunity supporting supplements.

The deposition day finally arrives. This is my only deposition that I have been served in my twenty years of counseling. I have been served many subpoenas requesting medical records but it has never come to a deposition. It is Eduardo's primary counsel that requests the formal deposition. His associates are in the deposition via speaker phone. Opposing counsel is represented there as well. The questions keep coming to me. We review my education, certifications and experience. Finally, long-term care cost questions come up. "Eduardo will be seeing you monthly for consultation," the attorney states. "How much do you estimate that to cost?" he asks. "Nothing," I answer. "There is no charge for my services". Everyone is quiet and they just look at each other. "Eduardo is unable to have food prepared correctly with his home health aide so we are recommending a private chef for daily meal preparation," he continues. He asks me, "Do you agree with this recommendation?" "No, I do not feel that a private chef is necessary. If Eduardo's aide is educated on nutrition requirements and practical menu planning there should be no reason that he can't get what he needs," I answer. The attorney continues his questioning, "What do you estimate the cost of working with the aide to be?" "Nothing," I answer. "There is no charge for my services and I would be happy to work with the aide and any translators to work out a healthy plan for Eduardo". Now, the transcriptionist is smiling as she is recording the conversation. The deposition finally ends cordially after the other requests were all reviewed. The settlement, I believe, will probably fall in the middle of both counsels' requests but it will certainly not be slanted anymore to either extreme. I left there with a sense of peace knowing that my services were not caught up in the money battle and I felt that I was a true patient advocate.

I am happy to report that Eduardo's nutritional plan has changed for the positive. He is eating more balanced, nutrient-dense foods. He has the appropriate immune and wound healing supplements and protein supplements. It took a few hours of my time to work with translators, Eduardo and his home health aide but it was fairly simple and straightforward to accomplish. I remain a consultant for Eduardo and his agency, pro bono, if they should require nutritional consulting services in the future. Maybe I am naïve to think that my actions would help change the way people think about their actions. Maybe that transcriptionist will tell the story of her day because it made an impression on her and then that ripple effect will continue. Well, I can hope it may have!

It was just the right thing to do, you know? To God, I give the glory! Truly nourished!

For the kingdom of God is not a matter of eating and drinking, but of righteousness, peace, and joy in the Holy Spirit. (Romans 14:17 NIV)

Dan

I worked with Dan for two years before his recent move to Connecticut with his family. He was referred to me by his psychologist. Dan is a very successful CEO in his mid-fifties. He is soft-spoken, handsome, intelligent, tall, well-dressed and always ahead of schedule. Dan has a very unassuming energy about him considering he is in the high finance field and is responsible for a multi-billion dollar organization. He travels often for his work and because of his demanding schedule we have consultations about every one to two months.

The referral for nutrition counseling was due to the fact that Dan had begun a weight reduction program on his own but was continuing to lose weight when he should be maintaining his new healthy weight range. Dan has only recently started seeing the psychologist as well. He shared with me that he sought psychological help when he realized that his eating was not normal. He reached out for help when he could not change this eating behavior on his own. He was also saturated with anxiety.

Dan grew up in a family that loved food and everything about food and eating. He was overweight most of his early years and became quite overweight as an adult. On and off dieting, weight loss and subsequent weight regain became an ongoing pattern throughout his adult life. He started another weight loss diet nine months ago and lost fifty pounds. His weight was 185 pounds. A very healthy weight for his six foot frame that he has not seen for a very long time. Something was different this time though. He continued to keep losing weight. He checks his weight and he is now down to 175 pounds. A few months later his weight hits 168 pounds. People begin asking him if he has an illness or cancer. None of his clothes are fitting. He recognizes that this is not a healthy place for him to be but he simply cannot bring himself to change the strict eating regimen that he put himself on. He was also exercising in the gym for at least one to two hours daily.

Dan recorded a food journal for me so that I could get a more accurate account of his intake. He had a very small variety of foods that he felt comfortable eating. Most of his choices were pre-packaged food items so that he could be absolutely certain of the nutritional breakdown. He totally avoided fats such as oils, butter, mayonnaise, and salad dressings. He also avoided foods containing fat such as cheese and nuts. His dessert treat every evening was an unusual concoction that he made for himself. Fat free Cool Whip, a little sliced fresh fruit and topped with fat free chocolate syrup. He said it helped with his sweet tooth but did not leave him feeling guilty after eating it. His comfort circle was limited to fat free milk, fat free yogurt, egg whites, skinless poultry, most fruit and vegetables, low fat granola bars, low fat cereal, oatmeal and other limited whole grains in very small portions. He grazed throughout most of his work day, eating a little something every hour or so and then had a dinner meal at home with his wife and high school aged daughter. Their two other children are in college. I remember thinking to myself that this food recall reminds me of some of my adolescent anorexic patients that are barely one hundred pounds.

Traveling did not really seem to bother Dan's plan because he found it fairly easy to select his safe foods while out in restaurants. Grilled fish or chicken, dry salad and vegetables was a constant choice. He would just bring his safe granola bars with him and rely on fruit until dinner. What did bother Dan, however, was any special occasion dinner with his family or even worse, a work related fixed dinner where he could not modify the choices. He explained to me that he would have panic attacks and become paralyzed with anxiety. If he did in fact eat more than what he thought was reasonable, he would beat himself up later that evening and for the next few days. He told me that the guilt and shame that he feels is suffocating. He loves his family dearly and they are a great support to him but even they were losing their patience with his compulsive behaviors. I remember this conversation in particular because his face lights up when he talks about his family and having them all together.

We have this following conversation almost every time that we meet together. He is such a rational, logical thinker. He tells me that he feels ludicrous coming to see me and he hears how ridiculous his behavior sounds. He is learning with the help of his therapist that recent and past life circumstances have contributed to his overwhelming anxiety and he has been using food to cope. He is very committed and is one of the most compliant and motivated clients that I have ever had.

Every meeting we would modify his eating plan gradually and begin adding to his food variety and improving the balance of his plan. His goal planning consisted of small risk-taking trials and over a short period of time he regained his weight back to the healthy 185-190 pound range and felt much more comfortable with the process. Now we have the challenge of helping him to continue to normalize his eating and take more risks with food choices. He also challenged himself by being more spontaneous with choices and was even feeling better in the fixed social dinner environments and often over-did it and was able to be more at peace with it. He always checked in with me and only had weight checks at my office so as to desensitize the hold that the scale and the numbers have on him. I see this CEO visibly shaking with anxiety at times when he first gets to my office so that we can get his weight check over with. If we did not complete the weight check at the beginning of the consult, he has told me that he would not be able to concentrate on one word that I say to him.

Then just when things seem to be moving forward I get a voicemail from Dan that he has to cancel his follow-up and he will call back to reschedule. That is not like him. He usually asks for another time slot immediately. (I am feeling like I should call him and talk in person). I called him right back and he admitted to me that he backslid and was too ashamed to see me. We set up a time to meet in one week. I don't think that I would have heard from him for at least a few months if I hadn't called him then. I probably would not have seen him until after his family reunion and he would have missed a great growth opportunity.

At our next consult we get the forward momentum back in gear. He has his nutritional goals and strategies back in full force. His next big social event is his nephew's Bar-Mitzvah. His whole family will be there for a reunion and he seems very excited to see his college kids. He reminisces by sharing with me some stories about his own kids' ceremonies. I had recently been to a family friend's Bar-Mitzvah and had a wonderful time. The conversation turned to the religious meanings and parts of the ceremony that were particularly heartfelt for both of us. He was surprised when I told him that I have a Jewish heritage. My mother's family is Jewish and I know that one grandparent migrated from Lithuania. His eyes opened wide as he told me that it is the mother's bloodline that determines it and he has the same ancestry. I think I am somewhat of an enigma when I share this with Jewish clients. I have many close Jewish friends who tease me a little about my heritage as well. They really don't know quite what to make of it because they know that my Christian faith is very important to me. We sometimes refer to the Hebrew Bible stories that are common to us all. I have overheard our kids chatting together at family get-togethers about what they both learned in Sunday school and once they studied and learned the same scripture! I also have celebrated with them on various holidays and broke fast with some close friends during last year's Yom Kippur, the high holy day of the year. I look at it as a neat witnessing opportunity. What is very palpable in my experience with my Jewish friends is their expression of great joy and celebration during these ceremonies as well as when we are gathered together socially. I feel their strong bond, their hope, and their expression of community and it is very beautiful.

I felt that our religious conversation naturally lead me to probe his thoughts a bit more. (This isn't about food. Ask him what brings him joy, I felt a prompting) “Dan”, I ask, “What is your joy?” Without hesitation he answered that his joy was his wife, children and family. I continue to ask some follow-up questions. “How much time and energy do thoughts of food and eating distract you from being fully present with them and enjoying your family and your time together?” We ended that session with a risk goal. Dan was going to try to be as present as possible at the family reunion, eat any food that he really wanted, and make it all about the ambiance and the people. Not the food.

Just for this one particular time. He was then going to process the event and his feelings at his next therapy session.

Dan accomplished this risk goal. It was not at all easy and uncomplicated but he definitely pushed himself and gave the food much less focus. He beamed when he told me about the great time he had with his family and close friends. His wife told him later that he seemed more relaxed and he acted like his old, happy self. The best part was that he was able to let the evening go the next day. There were no checks and balances and there was no guilt. For every three steps forward, Dan will probably have a few steps backward here and there. What he shared with me that was the best part of this risk challenge was that he put all of his energy into people and relationships. Being together, great laughter, fun and meaningful conversations. “Isn't that what living is all about?” he comments with a big smile. I think back to the anxiety-ridden man that I first saw in my office almost two years ago. What a wonderful transformation!

Dan gave me a giant goodbye hug on our final meeting before he packed up and relocated due to his company's restructuring. This was a positive move for him and his family. He promises to send an email update when he can. “Thanks for your constant encouragement” he says as he is leaving. “You have a strange job, you know. I work with concrete facts and numbers every day. You have to deal with trying new methods and being flexible. I've thought a lot about your joy question. I make sure to think about it every day. Thank you." As he is leaving I think, no, thank *you* Dan. And thank you God. Truly nourished!

He upholds the cause of the oppressed and gives food to the hungry. The Lord sets prisoners free. (Psalm 146:7 NIV)

Tina

Earlier in this manuscript I mentioned that very little surprises me anymore in my counseling experiences. Well, this is one story that is an exception. I am still getting more chapters of this story as I continue to work with Tina. But the chapters I have heard thus far have seriously shocked me to my core.

I met Tina as she was referred to me by her long-term psychologist. He recommended that she have a consultation with me as she is struggling with the eating disorder bulimia. She was quiet and slightly guarded at our first meeting and I could tell she was seriously checking me out. She presented as overweight and slightly disheveled. She looks much older than her forty two years. I discover that she has lived by herself for the past few years and is on disability assistance due to her physical and mental conditions. She appears very pale and her eyes are bloodshot. I later come to find out that she probably appears that way because she purged (self-induced vomiting) her lunch an hour before our consultation. We concluded our initial visit and her assignment was to keep a food journal of everything she eats, the time, and the quantity and bring that back to review in one week. I also asked her to journal any time that she purged. The meeting was fairly unremarkable but I had a sense that she was holding back, as most of my new clients do until they get to know me and feel more comfortable with the process. I had not spoken to Tina's psychologist yet as I wanted to review her journal first to have more details to discuss with him. The clear message that I did get at this initial consultation was that Tina was in great emotional pain and her active bulimic behaviors were also adding to significant physical pain. Her limited finances also made it challenging for her to receive thorough and regular medical care. To add fuel to the fire, most of Tina's scarce monthly budget is spent on large volumes of food due to the nature of this condition. She may eat large volumes of food and then immediately purge it and go on to consume more later. This may lead to her falling short on her budget at the end of the month and unable to buy fuel for her car so she can't make any scheduled appointments or important meetings.

Tina returns one week later with her complete food journal. She appears to be more talkative and is wearing nice clothes and fresh makeup. She shares with me that just keeping the food journal and trying to follow some of the guidelines that we discussed helped to make her feel a little better. She still struggled with a large amount of purging this week. Throughout our discussion I learn more about her daily routine and weekly schedule. I learn that she attends a small church that is led by a young pastor. She sometimes works at the church and helps with small jobs. She also has a dear friend that she meets with regularly who is a spiritual support person. She has no family that she keeps in contact with and I learn that most of her family, including daughters, grandchildren and parents are out of state. She was divorced from her husband a few years ago and that is when she went on disability. The conversation diverts back to her meal plan and food journal. She explains that she is going through a particularly difficult time emotionally right now because of the time of the year. It happens to be the week before Halloween. "People talk about their kids trick-or-treating and what costumes they will be wearing" she says, "But they have no idea what is really going on." Tina's eyes start to well up and tears fall down her face. I bring her tissues and listen. "Halloween is the most horrible day of the year," she continues, "This day is celebrated by certain groups of people. I used to be the person who celebrated this day." After she is able to compose herself she goes on to tell me that she grew up as a child in a satanic cult in the western states. There were satanic customs, ceremonies and "sacrifices" throughout the year but especially on Halloween. She also tells me how heart breaking it was for her to learn that her daughter recently had a baby boy and her ex-husband, the baby's grandfather, was the only other person there for the delivery. It was the satanic custom to dedicate the new birth to satan. I did not even know, nor did I want to know exactly what that meant. Her entire family was part of this cult and her father was a leader in it. Her marriage was arranged within the cult and her entire family remains a part of it today.

I am sitting there and actively listening to her. Quite honestly I felt like I could have been in a candid camera show or one of the newer "punked" shows. I felt as if at any moment someone would jump out from behind a curtain and tell me that I was on a show and everything was made-up and "ha-ha" wasn't that funny. There aren't really satanic cults around, are there? I am thinking, isn't that all movie and book stuff? That couldn't possibly be true? My thoughts are spinning as she is telling me these things. Then my thoughts shift to her mental health. Maybe she is a histrionic and she is embellishing a bit? Maybe she is just delusional? I remain poised with my professional poker face. She continues to tell me some more memories. She remembers being a teen and her mother actually brought her to a local church counseling pastor. She was brought there for help with depression. She confirms my surprise at how her satanic family would bring her to a church for counseling but she did tell me that they would never step foot in the worship center. They only went to the office section. Then she tells me that for the next year, this male pastor sexually abused her during the regular "counseling" sessions. She never told anyone at the time. OK, when is the camera guy going to jump out and tell me it is all a made-up story? I'm waiting. I cannot even wrap my head around what she is sharing with me. And honestly, I am not even sure it is true. So, I listen and empathize with the pain that I see her express in the moment. It really is not my place to determine if this is true or not. We finish our session, establish continued nutritional goals and plan on another follow-up in one week.

I make it a priority to speak with her psychologist as soon as possible. I need to process this with him and determine how I may best be able to help with her treatment. So, I finally hear back from the psychologist and he confirms that these are true stories. He goes on to tell me that Tina's abuse history is the worst he has heard in over twenty five years of practice. You name it, it happened! This therapist continues by saying that despite it all, Tina has found a way to live and grow; mostly due to her relationship with the Lord and her strong determination. What complicates her case even more is that she has major Borderline Personality Disorder characteristics in addition to her trauma abuse, alcoholism, drug addiction, eating disorder issues, bipolar disorder, anxiety, major depression and Dissociative Identity Disorder. She has only recently integrated her personalities in therapy. We end our conversation with him expressing that Tina is truly a testament of God's grace and the human will to survive. I have not yet had a chance to discuss when she found the Lord and made that amazing transformation. You can bet I will though; when the time is right. I cannot even imagine what Tina has witnessed and experienced in her life. And what a reality check for me! Evil *is* alive in this world. It is *not* just in the supernatural realm. It is alive in ways that I truly could never imagine as I live in a normal, sheltered slice of suburbia.

I feel better equipped when I meet with Tina for our next follow-up session. I am no longer distracted with the details of what she is sharing with me. I am focused on listening to her and helping her to figure out how she will best meet her nutritional goals. We review her food journal together. Every day of the week she has purged about seventy five percent of any food consumed. This means that she is purging at least three to four times a day every day. Her throat is hurting, her back and neck are hurting. Her voice is horse. She tells me how hopeless she is feeling. She is alone, broke and isolated. She is full of painful memories and nightmares. Then she just sits and breathes deeply and lets out a big, ugly sigh. She is looking at me, eyeball to eyeball. What am I supposed to say? I sit silently looking right back at her. (The prompting I feel from the Spirit is palpable) I calmly ask her, "Tina, have you prayed about this?" "What?" she asks back. "*You* are asking me that? My pastor asked me the same thing!" I continue gently. "Well, have you?" She answers me with a shy smile, "No, I haven't," I tell her that I will be praying for her as well. This is the conversation that has started a wonderful bond and relationship. I believe that this was also the conversation that pushed me totally outside of my comfort zone for what was yet to come.

I often have clients call and leave messages regarding schedule changes or quick questions. I normally do not return calls over weekends and clients are aware of this. The weekend after my last consult with Tina I noticed that she left me a message when I was getting ready for bed. It was late on a Friday night (I felt the deepest impression to listen to the voicemail). The message simply stated to please return the call when I was able. Nothing more (I knew that I had to call her; it was my voice in my head telling me to call her now). I called her back and she was very quiet at first. I immediately sensed that something was not right. She said that if she told me something she was not sure what I would do. I knew it. I felt it right then and there. And then she said it. "I am having thoughts about killing myself," she tells me. I remain very calm. (I feel the Spirit's calming presence). She continues by telling me she has a plan in mind (the Spirit is strong). I immediately direct her and give her exact and specific things to be doing. I tell her to call her psychologist and her pastor and 911 herself and that if I do not hear back from her in exactly 2 minutes, that I will be calling 911 to her home. She does what I ask and I hear right back from her. In the meantime I have also called her psychologist.

During our next phone call she tells me that her pastor is on his way to pick her up and bring her back to his home with his young family for the weekend. Until he got there, I just continued to keep her talking and I kept giving her specific directions and I helped her pack her bags by phone. Tina ended up having a very nice, therapeutic weekend with her pastor's family. Although she was a little anxious to go back to her home and be alone she shared with me that it actually felt good to have her space back. For the first time she told me that it felt more like coming home when she returned. Crisis resolved!

I have to admit that my adrenaline was still pumping two days later! "Why me?" I asked God. I had only met with Tina a few times. I am the Nutritionist, remember? I remembered the last time I met with her. I asked her if she prayed about her situation. Was that the connection that made her think of me? I wrestled with God on this one a bit. I was totally out of my comfort zone and I felt inadequate. I finally threw my hands up, shaking my head, and said "OK, God. If this is where you want me, bring it!"

Two nights later I received a text message from a fifteen year old client's mother. I actually heard my phone chirping from the other room. I was already in bed. (I feel a strong prompting to get out of bed and go check it out) This is what I read: "Lisa just swallowed some pills and told me that all she wants to do is go to sleep and never wake up. What do I do?" Are you kidding me? Seriously? This is what I am saying in my head. This particular incident was not as scary because my client was a minor and her family was there. I call her and tell her to go directly to the emergency room, call her therapist and her doctor! This teen stayed in the hospital for the next few days. "OK, God. What are you trying to tell me? Did you need to put this situation in my path so that I knew you were really working here and in the crisis with Tina? Did I need this invisible slap across the face to actually hear you speaking to me and telling me to get outside of my comfort zone and act on the impressions that I was feeling?" My head was spinning. I also remember speaking to this mother about faith and I knew that they had a church family.

Is that why they thought of me and reached out to me? "OK, God. I hear you loud and clear. I'm in. Your will be done."

I have not seen Tina for a few weeks. It turns out that during one of her purging episodes she fell in her bathroom directly on her face and actually broke her nose. She has not purged since because the pain is unbearable. Distancing herself from this purging behavior will really help her because it is such an addictive and unhealthy cycle. I text her knowing that what I wrote would make her smile, "OK, God, whatever it takes!" She writes back, "Thanks a lot, it hurts a little when I laugh too. Ha ha!" We have another follow-up scheduled soon.

I received a Christmas letter from Tina and it is an honor to share part of it:

Dear Christine, There are no words to thank you for all you've done for me. Your guidance, teaching me, patience, compassion, even guiding me to the Lord. You brought light into my life in a very dark time, you still are. I pray the Lord brings you abundant blessings. Merry Christmas. Love, Tina.

Reading that letter was like hearing God speak directly to me. "Yes, God. If this is where you want me, bring it!" Truly nourished!

I will be fully satisfied as with the richest of foods; with singing lips my mouth will praise you. (Psalm 63:5 NIV)

Liz

Some stories are great testimonies to the absolute faithfulness and grace of God. This is one of those stories. My main role in this client connection was to be an active listener and to be totally inspired. Liz was referred to me by her gastroenterologist due to her recent diagnosis of Irritable Bowel Syndrome. Her symptoms of chronic diarrhea, bloating and pain were slowly resolving and she wanted nutritional counseling and education on a long-term approach to help in controlling this condition. Liz, her husband Sam, and three children ages five, seven and ten recently moved here from North Carolina. Liz is a Licensed Mental Health Therapist and they relocated for Sam's new engineering job. I liked her immediately and felt a connection right away. They are in their mid-forties. She shared with me that they were settling into their new Florida surroundings very well and had family and close friends in the area as they visited the state often. They have also already found a church home. We review the nutrition education information fairly quickly and have a lot of the hour remaining. The last educational tidbit that I reinforced with her was to be careful with too much stress as that may aggravate the syndrome. "Stress?" She laughs, "Let me tell you about some stress that changed my life before our move!"

About a year ago, Sam was experiencing a lot of anxiety at work. That is one of the reasons they relocated. He was able to find a new position, actually a promotion, in Florida with the same organization. During this anxiety period Sam started to have insomnia. The fatigue factor seemed to fuel the anxiety so he finally went to his doctor who prescribed sleeping medication. Sleep was better regulated but Sam was still experiencing job-related anxiety. Liz also shared that she thought he was having some mid-life issues as well. This was just fuel to the fire. After discussing this at his next doctor's visit Sam agrees to try an antidepressant medication that is also indicated for anxiety. He took this medication daily for about four months but felt that it made him too drowsy during the day and the anxiety was still lingering. The medication was not really helping the situation. The doctor suggested switching to a new medication but Sam decided to just stick to the sleep medication and go off of the antidepressant. Liz worked with many clients, as a professional therapist, who did well with this medication but also told me that there is such an individual tolerance and many clients trial a variety of medications and combinations until they experience relief. I see this in my practice as well. With Liz's complete support, Sam decided that he would not pursue any more meds.

The next chain of events as Liz continues her story, was an emotional roller coaster. A few weeks after stopping the antidepressant, Sam begins to feel very energetic and his outlook is very positive and strong. He sleeps less hours, even while still taking the sleep medication, but does not feel tired. He starts doing all of these jobs around the house that he was putting off. He even tackles new jobs like redoing and renovating the garage and installing recess lighting in the kitchen. He is more boisterous and at times even annoying. His normal soft spoken voice is loud. Liz tells me that Sam has always been a very laid-back, reserved and sweet man. Think of an intelligent, absent-minded professor type with attention deficit tendencies. His aggressive behavior is starting to get on her nerves but she enjoys his new assertiveness and take-charge attitude as she normally performs that role. This new, take-charge behavior continued for another few months.

Then things began to change. It was subtle at first. Sam's aggressive behavior faded and he seemed to present more like his normal self. He was back to not doing much around the house anymore! But something was different. He actually became even more quiet, reserved and started isolating himself. Liz noticed him pacing more and rubbing his head in a nervous manner. He would not open up to her.

Sam and Liz are connected on a very spiritual level. They plan a weekend retreat together at a Christian center a few hours from their home in North Carolina. Liz is thinking that the timing is perfect and maybe Sam can take this time to relax and get spiritually renewed. The trip was even his idea. They begin the drive and are about two minutes out of their driveway when Sam turns to look at Liz and tells her he can't go. He feels as if he can't breathe and his heart is pounding. He looked scared. Liz thinks he is having a panic attack. They turn around and go home and sit and talk calmly. Then together holding hands they both got on their knees and prayed for strength and guidance.

Sam told her that he felt better just talking with her and connecting to God together. They decide to continue their trip. The weekend turns out to be a beautiful retreat. They were both engaged in the lectures and participated in the small group experiences. Sam even chose the prayer focused small group which was surprising to Liz because he is normally introverted. He told her that it was where he felt the Spirit leading him. Liz reads scripture and inspirational readings aloud as Sam drives them back home when the retreat ended. Two days later Liz notices Sam doing that weird pacing thing again and mumbling. He isolates again. She is very concerned. They discuss this and Sam agrees to see a mental health therapist for counseling.

A month goes by. Sam has seen the counselor, who is also a minister, two times. His anxiety remains high; it has become toxic. He still continues to function but any work related thoughts shoot his anxiety through the roof. His home, family and faith are his peace. Throughout this year Sam has been training in prison ministry with his cousin, Chuck, who has been involved for many years. They attend weekly studies together and plan on a weekend visit to a local prison to meet and witness to the inmates. As introverted as Sam is, he is open to the leading of the Spirit, and intentionally gets out of his comfort zone. He has been looking for opportunities to serve and when a potential opportunity did not work out at his church he put his time and energy into the prison ministry program. The morning Sam and Chuck were planning to meet the ministry group at the prison he had another panic attack. The computer system at his national office crashed and it completely paralyzed Sam. He is extremely professional and felt, even though other associates could step in to help, that he should stay until the problem was resolved. After an hour of intense work and coordinating, Sam still went on the weekend. The weekend proved to be extremely therapeutic for the prison inmates and especially for Sam. At the end of the program Sam began to open up and be honest with the group and poured out his anxieties. Liz told me that the ministry team saw this as an exceptional gift to the inmates, who were all believers. Many of whom will never be released. They were given the opportunity to actually support Sam! Think how rewarding that must have been for them. These prisoners, crimes unknown to the group, were providing words of comfort and scripture that was meaningful to them during their incarceration. Aren't we all at some point, prisoners and slaves? The Lord sets the prisoners free!

Now the reality check part of Liz's story. While driving home from the ministry weekend, Chuck called Liz to say they were on their way and that he needed to speak with her as soon as they got there. Liz immediately felt her heart pound out of her chest. She sensed that something was off. They arrive at her home and Chuck immediately asks where they can talk while Sam quietly walks into their bedroom. Liz notices him curling up and just lying in the bed. Chuck explains that the weekend can be very emotionally and physically exhausting. He adds that, in Sam's circumstance, it had been exceptionally demanding because he shared a secret that he had been keeping to himself for the past two years. Liz told me she felt the room they were in closing in on her. Chuck then tells her how much Sam puts her on a pedestal and how she is his life. "Remember Liz," he continues, "It's all about love. It's not about material things. Love is everything". Liz told me she was thinking, yes, of course I know that, what is he telling me? Chuck continues to report that Sam told them that he was a failure and that he did not do a project at work correctly and he thinks it is only a matter of time before he is found out and he will probably lose his job. Because Sam is in a very small field and he has a high paid position, he will probably not be able to find a comparable job. He also has a non-compete clause in his contract. "Liz, be prepared to lose this house, your savings and probably your retirement." "Make sure you tell Sam how much you love and forgive him." Liz told me that she felt like she was being "punked." I laughed when she said this because I have often used this description. Chuck left and Liz went straight in to talk to Sam. Sam told her more about the report that he did not complete and that he felt as if he was a total imposter. Liz told Sam that they would get through this together and that she did love and forgive him. "What are we going to do?" Sam asks her like a small child.

Liz immediately goes into "fix it" mode. For the next forty eight hours Liz educates herself on engineering equipment policies and protocols and actually puts what little information Sam has gathered for the past few years together into a completely organized report. Her anger grew as she shouted orders to Sam to do this part of the report and follow-up on those emails! Sam seemed to implode. The more Liz pushed him, the more he went into his own world. He did not even attempt to do the things she asked him. He kept telling her it was too hard and it wouldn't make any difference and what if it isn't good enough? Liz is thinking that he has become her fourth child. She is also thinking very unkind things about her husband. She did not sign up for this! She confides that she can forgive and love but he is not even making an effort to fix anything. He is not even willing to help his family try to salvage any shred of dignity they may have left. "That I cannot forgive!" she tells me. Sam regresses further into now what seems to be a twilight zone of behaviors. They barely talk to each other for the next few days. Liz's cold shoulder toward him is obvious. Liz finally gets a call from Sam's boss. He says how concerned he was after speaking on the phone with him. Sam was speaking in broken sentences and he wasn't even sure that it was him because he sounded so odd. Liz is desperate. She asks about the report. His boss has no idea what she is talking about. Sam is a superstar in their eyes and he keeps the company afloat! He goes on to explain that that particular assignment is in the planning process and Sam is not even responsible for it! Liz feels that she is smack in the middle of a twilight zone. Why in the world was Sam behaving this way? Sam's boss said he would drive to their office and speak with Sam directly. Liz went home. Her head is spinning. She immediately feels guilt for acting the way she did toward Sam when he was in obvious pain. Liz told me that she was alone in her house, dropped to her knees and prayed. She completely surrendered herself to the Lord and His will. She asked for forgiveness when she tried to fix this mess on her own and closed Him out. She was completely broken. She asked Him what she should do. She remained there on the floor on her knees and told me that she felt a thought, heard her voice in her head, saying "pack a bag," She immediately packed a few clothes, toiletries and a Bible.

After speaking with Sam's doctor and therapist, she met Sam and his boss at their office. Sam was barely speaking. He asked her where they were going. Liz answered that they were getting more help. They drove to the local hospital emergency room which is standard procedure to rule out any medical reason for his bizarre behavior. Nothing medically significant was revealed and Sam went voluntarily to the psychiatric facility on the hospital grounds. He remained there for four days. He was put on mood stabilizing medication and taken off his sleeping meds. Sam rested as best as he could in the facility but he really could not relate to any of the other patients or their situations. These patients, all ages, had long term psychiatric conditions that they were struggling with for their whole lives. Sam had always had a stable, secure, non-eventful mental health history. After a thorough psychiatric evaluation this is what the doctors determined. Sam had a very rare medication induced mixed episode reaction, like a bipolar event, when he was taken off the antidepressant months ago. It was like a rebound effect. He experienced a milder manic episode, which makes more sense during the time of his unusual assertiveness, and then as the doctors described it, when you go that high you can inevitably crash back down. And Sam certainly crashed. His mind fixated on a project at work and for some reason twisted it and escaped from reality for a short time to cope.

The doctor told Liz, who also knows her professionally, that this has only happened to one other patient that she has worked with. She reassured Liz that this was most likely an isolated event and for Sam to stay away from a certain class of antidepressants. The hospital was not the best therapeutic environment for him. He needed to be with Liz and his family. Liz brought him back home and he took off work for the next two weeks. They prayed together daily and Sam was able to recuperate and try to wrap his head around the chain of events that they had experienced. His work was totally supportive of him as well. In time, life returned to a normal rhythm again. Sam is currently thriving and taking no medications; not even for sleep. Medications are critical for so many individuals. Most of the patients with eating disorders that I work with would not recover without them. For Sam, however, these meds were like poison.

Liz has been able to meditate on and process the events of the past six months. Sam is still processing it. Liz shared with me that her marriage has never been stronger. They have both been spiritually renewed as well. Liz was able to tell me some intriguing thoughts that she discovered while looking back at the entire situation. She pointed out that the closer she and Sam drew near to God, the weekend retreat and Sam's prison ministry, it seemed as if the evil one lashed out even stronger. During both of these times, when Sam was paralyzed with panic, they prayed and surrendered to the Lord. They did not let evil in. They could have easily not gone on the retreat or participate in the ministry weekend. But that was what the evil one wanted. Don't mess with the children of God!

Liz also thought about the variety of different outcomes they could have experienced. Sam could have, in fact, screwed up at work and lost everything. Would their marriage have survived? Where would they be living? Would Liz have to try and be the main breadwinner for her family? Or maybe Sam would keep his job but mentally never be the same person again. Would she be strong enough to handle that? Did Sam actually have an underlying mental condition that did not express itself until he was in his forties? What would have happened if Sam did not go away and open up and talk during the prison weekend? Would he eventually have become so depressed that he would not have been able to voluntarily check into the hospital? That would have had a negative impact on his professional future for sure. But, nope, none of the above. God was merciful and faithful and His grace was absolutely amazing. Not only did the worst case scenario not even come close to happening, nothing even potentially negative resulted. Apart from a very large piece of humble pie for them both, and Sam still trying to get over the feeling of embarrassment caused by his behavior, God closed this chapter in the best possible way.

They are both better for it and hopefully, in time, they will be able to share their story with more people as an example of the faithfulness of God. Without question, their story had a great, positive and inspiring effect on me. Maybe this was God's master plan all along! Surely it was. A wake up call to reinforce having a complete dependence on God and relying on Him for everything, especially when you feel as if your life and everything you thought was real was suddenly pulled out from under you.

Before Liz leaves my office we pray together, a prayer of praise and thankfulness to God. Was I expecting this consult to end this way? Not at all. Was I surprised that we spent most of the time talking and sharing stories of faith? Not really. That is how God works. Truly nourished!

CONCLUSION

So this is only a sampling of some of the clients that I see. Each of these clients is being encouraged and listened to, and then each interacts with others and so on and so on. The God ripple continues. I work part-time at my office and see about 20-30 clients a week. This is a lot of connections!

What would have happened if I did not act on the impressions that I was feeling? The nutrition counseling sessions would have probably continued. Would they have been reflective of all of me? Absolutely not. Would the outcomes have been different? Only God can answer that. From my perspective, however, opening my whole self up has made me a much better counselor and person. I know myself better than I ever have (the good, the bad, and the ugly!) Without hesitation, I now know my place in the body of Christ better than I ever have. I need less and less affirmation from this world because the affirmation that I get from God is most meaningful to me. That is what motivates me. I still constantly remind myself to slow down and be still and yield to God's will all the time. I still struggle with my motivations. Am I doing this to look good or am I doing this for God's glory? This is a slippery slope for a high-achieving personality! I constantly ask the Spirit for guidance on this one. I still mess up often. The mess up times are when I am not God-centered of course!

Wouldn't anyone benefit by wearing their God antennae wherever they spend their time? The accountant, financial planner, doctor, secretary, teacher, technician, waitress, etc. Being fully present in every human interaction and making a God connection. Look into the face of everyone who comes across your path as if you are looking right into the eyes of Jesus. That is what motivates me beyond measure. An extra conversation with the secretary at your kid's doctor's office because she seemed a little down, making the extra effort to have eye contact with your cashier at the grocery store, a friendly smile and conversation with the elderly neighbor walking his dog, a more intentional and meaningful interaction with the moms at the bus stop, actually stopping to say hello and thank you to your lawn care worker, you get the point I hope.

Don't be fearful or hesitant. Get out of your comfort zone. Be a little more vulnerable. Be intentional. It is a joyful ride. I live every day with the expectation of God's goodness. There is no better encouragement for an encourager like me than that truth. Who knows what God will bring? For me, the joy circle is amazing and I am so very thankful. Truly nourishing!

My Father, Abba, I present myself to you as a living sacrifice. Holy and pleasing to you. Help me to declare and reflect your love, your light, and your glory. Spirit, work with me and through me, guide and direct me. Open my eyes to see where you are truly working. Open my ears to truly hear and discern your voice. Soften my heart and purify me so that my motives are not about me but all about You, pleasing You and following Your will. Help me to love completely like your son, my savior, my Lord, Christ Jesus. Amen.

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KEY TERMS AND DEFINITIONS

Emotional Hunger: Evaluating your S.E.T. (situation, emotions, thoughts) to nurture yourself without food.

Registered Licensed Dietitian/Nutritionist: The only health care professional specifically educated and trained in the science and application of nutrition.

Physical Hunger: Identifying where you are on the hunger scale, assessing when you last ate, and exploring healthy eating options to satisfy the hunger.

Processed Foods: Foods devoid of any nutrients of long-term substance.

Whole Foods: The foundation of eating vegetables, fruits, low fat dairy, lean proteins, whole grains, and healthy oils, nuts, and seeds.

Wiggles: Special holiday celebration treats and meals.

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Chapter 3
Nutrigenomics and Nutrigenetics and the Medicinal Values of Vegetables and Fruits

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ABSTRACT

Since the accomplishment of the human genome sequencing project by March 25, 2003, nutritionists, biochemists, and modern genome epidemiologists became involved in genome-based nutritional research studies. In fact, the completion of a high-quality, comprehensive sequencing of the human genome derived from the discovery of the double-helical structure of the DNA became a landmark event that has influenced several realms of academic research disciplines and their applications to maximize public health and minimize harm to health care consumers.

INTRODUCTION

The phenomenological approach has been adopted to investigate the concept of nutrigenomics and nutrigenetics regarding the medicinal values of fruits and vegetables in terms of worldwide application of basic foods to promote human health and minimize the onset of the incipient stages of diseases. Innovatively, within the realm of public health genomics, the influence of nutrients on human gene expression is characterized as nutrigenomics. While the heterogeneous response of gene variants to nutrients, dietary components and developing nutraceuticals is called nutrigenetics. At a global scale, genetic variations have been observed to affect food preferences and tolerance among human groups from several regions of the world. These ecological, environment and other haplotype characteristics influence dietary requirements, preferences, and metabolic tolerance between the onset of diseases in human groups and individuals. Essentially, nutrigenetics characterizes the genetic profile, which has an impact on how the human body reacts to bioactive food components be modifying or influencing absorption, metabolism and site of action (Farhud et al., 2010). Specific illustrations of known phytochemical nutritional applications have been illustrated regarding their efficacy and control of hypertension and high blood pressure,

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which is one of the leading pandemic disease and the precursor for the incipient onset of cardiovascular disease, stroke, type 2 diabetes, and other nephritic syndromes. The relevance of nutritional epidemiologic techniques in the elimination of vitamin-deficiency diseases was outlined. Besides, the quantitative techniques for detecting and diagnosing these diseases were meticulously illustrated and the relevance of prompt referral of at-risk patients to physicians and other clinicians was resounded.

A monumental scientific feat of the twenty first century has been the accomplishment of the Human Genome Sequencing Project (HGSP) by March 25, 2003 which led to numerous scientific breakthroughs. Evidently, those economically sufficient industrialized nations in a breathtaking manner rapidly developed numerous genome sequencing technologies. The human genome sequencing project, which began in 1990, involved highly committed scientists from several parts of the world and led to the generation of a high-quality reference sequence for three billion base pairs of nucleotide sequences, which make up the human genome. From this scientific project, geneticists, molecular biologists, and modern genome epidemiologists revealed the DNA sequence present in a genome contains the complete code, which determines specific genes and proteins that are present in human cells. The scientific feat achieved from the HGSP has led to the advancement of science and the requisite technologies to improve clinical therapeutic interventions to enhance human health and cure hitherto chronic and degenerative diseases. Human genome sequencing has increased and enhanced the emergence of commercial genomics, as well as the analysis of the rise of the biotechnology subsector in this era of genomic science.

In spite of the innovations derived from genomics, biochemists and modern genome epidemiologists have specific functions to play in creating awareness about the global ecological phenomenon and the cultivation of fruits and vegetables which, for several years, have been utilized for their medicinal properties. Advances in genomics and the biochemical analysis of these foods have revealed their naturally phytochemical nutrients, which have specific therapeutic impacts against high blood pressure, stroke, certain forms of cancers, scurvy, several topical infections, gastroenteritis, atrial fibrillations, and associated chronic and degenerative diseases.

Many fruits and vegetables have the ability to interact with and modulate specific molecular mechanisms which guide an organism's physiological functions. In the age of genomic science, it is this awareness of the incipient stage of nutritional scientific breakthrough that has spurred a revolution in the field of nutrition.

Nutritionists and biochemists have crucial roles to play in public health genomics because large-scale population-based epidemiological studies involving nutritional interventions may use imprecise but comprehensive data without insights from genetic knowledge. In addition, erroneous scientific conclusions and misinformed nutritional recommendations could be made in very dire clinical settings (Wahli & Williamson, 2005).

Quite emphatically, to avoid such clinical issues and conscientiously research the relationships between genes and diet, the field of nutrition has been to capitalize on harnessing innovative genomic technologies, bioinformatics, and supporting analytical software and other sophistical statistical tools to conduct meaningful nutritional studies which have the potential to unravel hitherto unknown scientific facts about fruits and vegetables that we consume for healthy living.

Naturally we consume these fruits and vegetables to maximize human healthy living and to eliminate potential protein energy malnutrition.

NUTRITIONAL AND THERAPEUTIC BENEFITS OF VEGETABLES

Hypertension and Nutritional Intervention

The various chronic and degenerative diseases in which the pharmaceutical make astronomical income includes high blood pressure, various other cardiovascular diseases, cancer, Alzheimer's disease, and other cerebrovascular diseases. Medication for high blood pressure are not only numerous, but also these medications are among the most lucrative prescription drugs in the world. From an ecological perspective, the onset of high blood pressure is associated with the current stressful lifestyle which human civilization has ushered into human social interactions and daily social engagement in the workplace, in academic environment in combatant military activities and other highly stressful work-environment.

Chauncey Crandall, MD, director of the preventive cardiology at the Palm Beach Cardiovascular clinic has observed that by eating specific five food items we are most likely to significantly lower our blood pressure to the point of reducing the number of blood pressure medications that one consumes or eliminate them completely (see Figure 1). The five food items which if consumed could lower our blood pressure include: 1. Asparagus – This vegetable is unique in lowering blood pressure because it is rich in potassium. Nutritionist have identified other foods which are high in potassium to include bananas, citrus fruits, dried apricot, wild salmon fish, whole grain and legumes. Asparagus is a natural diuretic and this give it an extra hypertension-lowering properties. 2. Hawthorn Tea – This tea which is made from the anti-oxidant-rich berries of the hawthorn plant has been reported to be useful in the management of cardiovascular disease such as assisting blood vessels to relax which lowers blood pressure. 3. Oatmeal – This meal has a therapeutic benefit not only in lowering serum cholesterol level but also reduce blood pressure 4. Blueberries are known to be rich in antioxidants which can enhance normal functioning of the cardiovascular system. Blueberries contain anthocyanins which are molecules known to open blood vessels, which facilitate blood flow more readily thereby lowering human blood pressure. The fruits and vegetables in Figure 1 have widely used nutrients for human health. 5. Baked potatoes with margarine butter can be helpful in reducing blood pressure depending on how it is prepared. The addition of excessive salt and butter compromises the effectiveness of potatoes as medicinal food against blood pressure disease (Crandall, 2013).

Figure 1. Dietary sources of naturally-occurring antiangiogenic substances
Source: Anglogenesis Foundation (www.anglo.org).

Green tea	Red grapes	Lavender
Strawberries	Red wine	Pumpkin
Blackberries	Bok choy	Sea Cucumber
Raspberries	Kale	Tuna
Blueberries	Soy beans	Parsley
Oranges	Ginseng	Garlic
Grapefruit	Maitake mushroom	Tomato
Lemons	Licorice	Olive oil
Apples	Turmeric	Grape seed oil
Pineapple	Nutmeg	Dark chocolate
Cherries	Artichokes	Others

The DASH Food Plan

The dietary assistance to stop hypertension involves specific nutritional interventions which if meticulously complied with can systematically lead to a decline in the blood pressure reading from the electronic sphygmomanometer. While this nutritional intervention demands discipline some of the precursors and risk factors must be monitored. Stress plays a major role in the onset of hypertension, consumption of palatable foods cuisine embedded with lipids, red meat and alcohol are some of the other allures which pose tantalizing challenges to improved cardiovascular health.

However, augmenting our menu with other health enhancing vegetables and fruits are additional nutritional mechanism to avoid the lethal consequences of associated risk factors to cardiovascular diseases. The adoption of a combination of multiple phytochemical nutrients derived from broccoli, spinach, oatmeal, and Brussels sprouts can further fortify the human immune system and protect the heart from deadly toxins and those nutritional risks that can lead to sudden death, myocardial infarction, and arterial sclerosis and congestive heart diseases, which constitute the leading causes of death in the highly developed nations.

Mild exercise and recreation activities such as gardening and indoor aerobic exercises such as table tennis, chess games, and wholesome interactions with loved ones and friends and other social therapeutic interventions are useful interventions against cardiovascular disease.

These exercises are known to reduce cardiovascular diseases, improve sex life, make one's skin glow, and they can reduce the risk associated with dementia (Figure 2).

Physical activities such as walking for upward of 30 minutes a day can improve cognitive function and reduce the onset of Alzheimer's diseases. Besides, exercise decreases the incipient stages of osteoporosis, most so, if the exercise includes weight-bearing activities. Walking and other aerobic exercises can prevent muscle loss more so when one is consistent in waking up to such exercise on a daily basis.

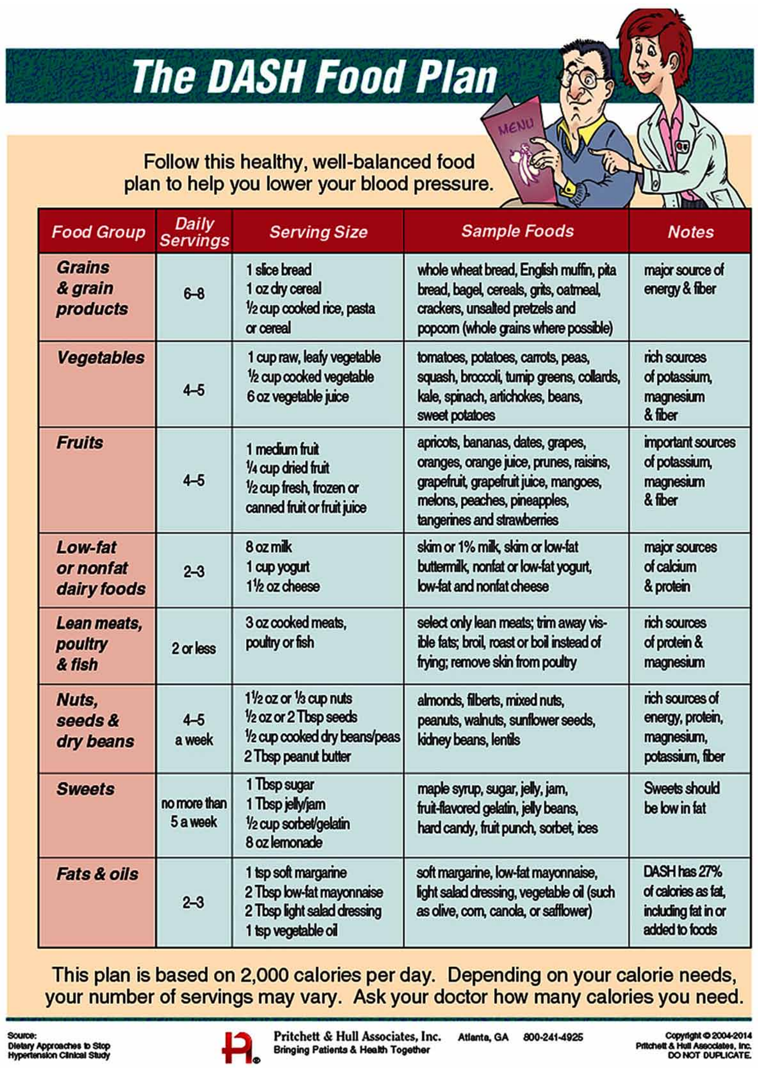
To a large extent, exercise not only reduces depression in the elderly, but it also enhances mental acuity, cognitive performances, and work productivity. Coupled with the use of the DASH food plan and the consumption of fruits and vegetables exercise can fortifies one's immune system against various cancers

Edible Fruits and Vegetables and Their Phytochemical Nutritional Values

Why Phytochemical Nutrients?

Phytochemical nutrients are basically non-nutritive agents found in vegetables and several fruits (see table 1). Nutritionists have determined scientifically the molecules in phytochemical nutrients which play a significant role in human health. From ecological perspectives, the fruit and vegetables that people have consumed for healthy living worldwide have specific phytochemical nutrients, which have not been scientifically analyzed. Biochemists, nutritionists, human genome scientists, and molecular biologists could confront a daunting academic and scientific challenge to attempt to analyze the dietary phytochemical nutrients that people consume in different continents at global level. Even the internalized prohibitions of relatively editable fruits and vegetables which, on the ground of cultural norms that occur in many cultures, constitute an academic and scientific hindrance. However, in the age of genomic science, efforts are made to respect the cultural dictates and norms of society due to religious and cultural observances. A plethora of studies have revealed that phytochemical constituents in the human genetic and biological make-up can influence human hormonal level, predisposition to disease risk, and the

Figure 2. The Dash food plan


The DASH Food Plan

MENU

Follow this healthy, well-balanced food plan to help you lower your blood pressure.

Food Group	Daily Servings	Serving Size	Sample Foods	Notes
Grains & grain products	6–8	1 slice bread 1 oz dry cereal ½ cup cooked rice, pasta or cereal	whole wheat bread, English muffin, pita bread, bagel, cereals, grits, oatmeal, crackers, unsalted pretzels and popcorn (whole grains where possible)	major source of energy & fiber
Vegetables	4–5	1 cup raw, leafy vegetable ½ cup cooked vegetable 6 oz vegetable juice	tomatoes, potatoes, carrots, peas, squash, broccoli, turnip greens, collards, kale, spinach, artichokes, beans, sweet potatoes	rich sources of potassium, magnesium & fiber
Fruits	4–5	1 medium fruit ¼ cup dried fruit ½ cup fresh, frozen or canned fruit or fruit juice	apricots, bananas, dates, grapes, oranges, orange juice, prunes, raisins, grapefruit, grapefruit juice, mangoes, melons, peaches, pineapples, tangerines and strawberries	important sources of potassium, magnesium & fiber
Low-fat or nonfat dairy foods	2–3	8 oz milk 1 cup yogurt 1½ oz cheese	skim or 1% milk, skim or low-fat buttermilk, nonfat or low-fat yogurt, low-fat and nonfat cheese	major sources of calcium & protein
Lean meats, poultry & fish	2 or less	3 oz cooked meats, poultry or fish	select only lean meats; trim away visible fats; broil, roast or boil instead of frying; remove skin from poultry	rich sources of protein & magnesium
Nuts, seeds & dry beans	4–5 a week	1½ oz or ⅓ cup nuts ½ oz or 2 Tbsp seeds ½ cup cooked dry beans/peas 2 Tbsp peanut butter	almonds, filberts, mixed nuts, peanuts, walnuts, sunflower seeds, kidney beans, lentils	rich sources of energy, protein, magnesium, potassium, fiber
Sweets	no more than 5 a week	1 Tbsp sugar 1 Tbsp jelly/jam ½ cup sorbet/gelatin 8 oz lemonade	maple syrup, sugar, jelly, jam, fruit-flavored gelatin, jelly beans, hard candy, fruit punch, sorbet, ices	Sweets should be low in fat
Fats & oils	2–3	1 tsp soft margarine 2 Tbsp low-fat mayonnaise 2 Tbsp light salad dressing 1 tsp vegetable oil	soft margarine, low-fat mayonnaise, light salad dressing, vegetable oil (such as olive, corn, canola, or safflower)	DASH has 27% of calories as fat, including fat in or added to foods

This plan is based on 2,000 calories per day. Depending on your calorie needs, your number of servings may vary. Ask your doctor how many calories you need.

Source: Dietary Approaches to Stop Hypertension Clinical Study

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utilization and assimilation of specific medications, which are not in agreement or tolerated by a group of people and ethnic groups worldwide. From biochemical analysis and nutritional interventions specific and efficiently documented phytochemical nutrients exist in reserveratrol in grapes/grade skin, isoflavones in soy milk, lycopene in tomatoes, lycopene in watermelon, lutein in spinach, and naringenin in grapefruit (Berardi, 2014). A list of phytochemical nutrients, as well as their food sources and effects, were efficiently compiled by Berardi (2014).

Phytonutrients That Have an Impact on Blood Thinners

There are several phytochemical nutrients that have an impact on blood thinners. For most patients with cardiovascular disease, the physician may periodically choose to use warfarin, which is a blood thinner to treat patients with blood clot and monitor atrial fibrillation. In many hospitals in the United States, a

Table 1. Photochemical and food items and their effects

Class	Food Source(s)	Action(s)
Phytoestrogens	Soy products, flaxseed, seeds and nuts, yams, alfalfa and red clover sprouts, licorice root (not candy)	May block some cancers. Aid in menopausal symptoms. Help improve memory.
Phytosterols	Plant oils, corn, soy, sesame, safflower, wheat, pumkin	Block hormonal role in cancers. Inhibit uptake of cholesterol from the diet.
Saponins	Yam, beets, beans, cabbage, nuts, soybeans	May prevent cancer cells from multiplying.
Terpenes	Carrots, yams, winter squash, sweet potatoes, apples, cantaloupe	Antioxidants—protect DNA from free radical-induced damage.
	Tomatoes, tomato-based products	Help block UVA and UVB. May help protect against cancers (prostate, etc.)
	Citrus fruits (flavonoids), apples (quercetin)	Promote protective enzymes in the liver. Antiseptic properties.
	Spinach, kale, beet and turnip greens, cabbage	Protect eyes from macular degeneration.
	Red chili peppers	Prevent carcinogens from binding to DNA
Phenols	Fennel, parsley, carrots, alfalfa, cabbage, apples	Prevent blood clotting. May have anti-cancer properties.
	Citrus fruits, broccoli, cabbage, cucumbers, green peppers, tomatoes	Antioxidant function. Flavonoids block membrane receptor site for certain hormones
	Grape seeds, apples	Strong antioxidants. Fight germs and bacteria. Strengthen immune system, veins, and capillaries.
	Grapes (skins)	Antioxidant and antimutagen properties. Promote detoxification. Act as carcinogen inhibitors.
	Yellow and green squash	Antihepatotoxic and antitumor properties.
Sulfur compounds	Onions, garlic	Promote liver enzyme activity. Inhibit cholesterol synthesis. Reduce triglycerides. Lower blood pressure. Improve immune function. Fight infection, germs, and parasites.

Source: John Berardi (2014).

weekly visit to a clinic that administers the drug is imperative. Once the correct level has been determined, the physician proceeds to treat the patients' blood clots. The International Normalized Ratio (INR) is usually 2 and 3. If the value is less that 2, it means that the drug is not exerting its therapeutic effect, and if the value is above 3, the patient may bleed. It is as a result of the innovative genomic intervention that Coumadin and the associated innovative therapies were developed to rectify specific clinical errors, which previously occurred in medical management of a patient's cardiovascular health issue.

The United States Food and Drug Administration (FDA) not only emphasized how warfarin levels can be partially determined by one's genetic profile, but it announced the approval in the latest labeling for Coumadin as a blood-thinning drug. Coumadin administration involves a simple test that analyzes the genetic variation in the genes VKORC1 and CYP2C9. Foods rich in vitamin K are listed in Table 2.

Liver, and the fruits and vegetables listed in Table 2, are very rich in vitamin K, and the patient must consume about the same amount each week before visiting the Coumadin clinic. If the patient consumes high amounts of these foods, the therapeutic effects of Coumadin could be impaired and the patient may run the risk of blood clot and possible stroke.

Table 2. Foods rich in vitamin K

Asparagus	Cauliflower	Kale	Sauerkraut
Avocado	Coleslaw	Lentils	Soybeans
Broccoli	Collard greens	Lettuce	Spinach
Brussels sprouts	Endives	Liver	Swiss chard
Cabbage	Garbanzo beans	Mustard greens	Turnip greens

The phytochemical identified in yams contain carotenoids. They not only prevent the oxidative damage against free radicals, but they enhance cancer and cardiovascular disease prognosis. Specific phytochemicals such as capsaicin, which make some variants of pepper very spicy, have the potential to protect the DNA against free radicals and some lethal carcinogens.

Lycopene Found in Tomatoes and Watermelon Can Protect At-Risk Patients Against Prostate Cancer

There are several varieties of tomatoes; however, they contain an ample amount of lycopene. Scientifically, this deep red color which we observe inside tomatoes and watermelons enable us to promptly assume their content of the phytonutrient lycopene. Nutritionist have maintained that tangerine and orange-colored tomatoes contain an abundant amount of lycopene. Biochemists and nutritionists agree that the deep-red tomatoes have trans-lycopene, while the lycopene in orange/tangerine tomatoes is mostly tetra-cis-lycopene (The George Mateljan Foundation, 2014).

Personalized Nutritional Genomics and Health Benefits of Tomatoes

Tomatoes are produced in numerous varieties. This is a ubiquitous natural food that has numerous nutritional benefits for human beings worldwide. Tomato is a fruit of the plant *Lycopersicon esculentum*. From a botanical perspective, tomato is not only a fruit, but it is also a berry since it is formed from a single ovary. Multiple varieties exist, and they include the "love apple," the "Ife plum," golden apple, green apple, and heirloom tomatoes. This fruit is enjoyed worldwide and China is the largest producing nation with approximately 34 million tons of production. The other competitive nations are the United States, Turkey, India, Italy, and Nigeria in sub-Saharan Africa.

After the successful accomplishment of the human genome sequencing initiative, advance sequencing techniques will accelerate the scientific knowledge about the health benefits of tomatoes. Nutritional epidemiologists will be able to confirm with precision, how the antioxidants in tomatoes interruption some chemotherapeutic drugs used for the management of prostate cancer. The United States Food and Drug Administration has remarked:

Very limited and preliminary scientific research suggests that eating one-half to one cup of tomatoes and/or tomato sauce a week may reduce the risk of prostate cancer. FDA concludes that there is little scientific evidence supporting this claim.

The FDA intends to consider exercising its enforcement discretion for the above claim.

Tomatoes known for an outstanding amount of antioxidants and a high concentration of lycopene have the potential to enhance bone health in humans. The other major therapeutic benefits of tomatoes focus on the improvement of heart health in at-risk cardiovascular patients.

A plethora of scientific reports pinpoint the heart-protective benefits of tomatoes to be associated with specific phytonutrients, which is a glycoside termed esculeoside A, a flavonoid characterized as chalconanringenin, and a fatty-acid molecule known as 9-oxo-octadecadienoic acid. As innovative genomic technologies facilitate and improve sequencing and analysis of these phytonutrients, a higher frequency of these beneficial biochemical agents will be documented. Suffice it to say, tomatoes currently contain vitamin C, biotin, molybdenum, vitamin K, copper, potassium, manganese fiber, vitamin A, vitamin B6 foliate, vitamin B3, vitamin E, phosphorous, vitamin B1 magnesium, chromium, a minute quantity of protein, chlorine zinc, and iron, and trace amounts of pantothenic acid. From an epidemiological standpoint, the application of tomatoes is most efficacious for human health maintenance instead of a therapeutic agent.

The additional benefits of tomatoes are associated with the presence of the following phytonutrients in the fruit. There nutritional agents include: flavonones made of naringenin and chalconaringenin, flavonols which contain rutin, kaempferol and quercetin, and hydroxycinnamic acid. The most commonly recognized nutrient is carotenoids, which consist of lycopene, lutin, zeaxanthin, and beta-carotene. The glycosides have esculesoside A and a minute amount of plant fatty-acid derivative such as 9-oxo-octadecadienoic acid. Clinically, the U.S. FDA has approved many drugs for the management of prostate cancer. In the age of genomic science, our main concern is to ensure that through the process of pharmacogenomics, these drugs are tailored to the requisite gene -chromosome of the patients. From the saliva or blood sample of the patient, the DNA can be characterized so as to adopt precision medical techniques in the treatment modality of the patient. For years, and not until relatively recent times, most patients who were prescribed the right dose of the some of the several prostate cancer drugs died needlessly due to imperfect specificity and iatrogenic diseases. The U.S. FDA has approved the following drugs for the treatment of prostate cancer. They include Drugs Approved for Prostate Cancer.

This page lists cancer drugs approved by the FDA for prostate cancer. The list includes generic names and brand names. The drug names link to National Cancer Institute's Cancer Drug Information summaries. There may be drugs used in prostate cancer that are not listed here.

Abiraterone Acetate, Bicalutamide, Cabazitaxel, Casodex (Bicalutamide) egarelix, Denosumab, Docetaxel, Enzalutamide, Goserelin Acetate, Jevtana (Cabazitaxel), Leuprolide Acetate, Lupron (Leuprolide Acetate), Lupron Depot, (Leuprolide Acetate), Lupron Depot-3 Month (Leuprolide Acetate), Lupron Depot-4 Month (Leuprolide Acetate), Lupron Depot-Ped (Leuprolide Acetate)Prednisone, Prolia (Denosumab), Provenge (Sipuleucel-T), Radium 223 Dichloride, Sipuleucel-T, Taxotere (Docetaxel), Viadur (Leuprolide Acetate), Xgeva (Denosumab) Xofigo (Radium 223 Dichloride), Xtandi (Enzalutamide), Zoladex (Goserelin Acetate), Zytiga (Abiraterone Acetate). (National Cancer Institute, 2014)

As a component of the comprehensive treatment for most prostate cancer patients, the patient may undergo surgery, radiation therapy, or radioactive seed implants called brachytherapy, chemotherapy, hone therapy, or freezing therapy (cryosurgery). While physicians admit that no complementary or alternative treatment can cure prostate cancer, such treatment may be palliative and such therapy could assist the patient in copying with stress and anxiety after diagnosis. Such therapies include art therapy, dance or movement therapy, exercise, meditation, music therapy, relaxation techniques (such as guided imagery and muscle relaxation), and spirituality (Mayo Clinic Report, 2014).

Impact of Tomatoes on Heart Health

With this comprehensive amount of phytonutrients, tomatoes also enhance heart health by facilitating the smooth movement of oxygen from the lungs and circulating it throughout the body. Whenever oxygen flow through the body is impeded by lipids and other free radicals, the risk of stroke become imminent.

Tomatoes Can Lower the Risk of Lipid Peroxidation

Lycopene in tomatoes has the therapeutic effects of lowering the risk of lipids peroxidation in the human blood stream. Besides, the dietary intake of tomatoes has been reported to improve constituents of lipids in blood stream and the process decreases the low-density lipoprotein (LDL) while increasing high-density lipoprotein (HDL). It has been reported by nutritionists and many scientists that the several phytonutrients in tomatoes can prevent excessive coagulation of platelet cells which culminate in "anti-aggregatory effects" (The George Mateljan Foundation, 2014).

Therapeutic Benefits of Tomatoes against Cancer

Tomatoes have been reported to reduce the incipient stages of prostate cancer by potentiating the concept of apoptosis which is cell death in prostate cancer cells that have been fully formed. The sterol in plant and other phyto nutrients in tomatoes are known to combat non-small-cell lung cancer, prostate cancer, pancreatic cancer, and breast cancer. Carotenoid lycopene serves as the active nutrients in reducing the onset of breast cancer in patients. However, once these cancers have undergone metastases, the benefits of these phyto-chemical nutrients become medically insignificant, as seen in table 3 (ALippi & Targher, 2011; The George Metaljan Foundation, 2014).

The Medicinal Value of Edible Garlic

Garlic (*Allium sativum*) belongs to the onion genus *Allium*. Although garlic is widely used for flavoring in cooking, traditional healers have used garlic as a medical herb for centuries. For thousands of years, garlic has been used not only in food seasoning but for its medicinal properties. Historically, it has been reported that the Greek physician Hippocrates (circa 460–370 BC) the father of modern medicine had used garlic for treating respiratory problems, parasitic infections, poor digestion, and as performance-enhancing agents for athletes.

From historical perspectives, the functions and medicinal applications of garlic consisted of enhancement of sexual performance (aphrodisiac), as a stimulant, for the treatment of hypertension, liver disorders, intestinal disorders, and as a worm expeller. While some of these therapeutic uses are supported by scientific evidence, others could just be habit forming without cogent scientific validity. However, there some crucial benefits of garlic which traditional healers and nutritionist have confirmed over the

Table 3. In-depth nutritional profile for tomatoes

Tomatoes, Sliced, Raw
1.00 cup
180.00 grams
Calories: 32
GI: very low

Nutrient	Amount	DRI/DV (%)	Nutrient Density	World's Healthiest Foods Rating
Vitamin C	24.66 mg	32.9	18.3	Excellent
Biotin	7.20 mcg	24.0	13.3	Excellent
Molybdenum	9.00 mcg	20.0	11.1	Excellent
Vitamin K	14.222 mcg	15.8	8.8	Excellent
Copper	0.11 mg	12.2	6.8	Very good
Potassium	426.60 mg	12.2	6.8	Very good
Manganese	0.21mg	10.5	5.8	Very good
Fiber	2.16 g	8.6	4.8	Very good
Vitamin A	74.97 mcg RAE	8.3	4.6	Very good
Vitamin B6	0.14 mg	8.2	4.6	Very good
Folate	27.00 mcg	6.8	2.8	Very good
Vitamin B3	1.07 mg	8.2	3.7	Very good
Vitamin E	0.97 mg (ATE)	6.5	3.6	Very good
Phosphorus	43.20 mg	6.2	3.4	Very good
Vitamin B1	0.07 mg	5.8	3.2	Good
Magnesium	19.80 mg	5.0	2.8	Good
Chromium	1.26 mcg	3.6	2.0	Good
Pantothenic acid	0.16 mg	3.2	1.8	Good
Protein	1.58 g	3.2	1.8	Good
Choline	12.06 mg	2.8	1.6	Good
Zinc	0.31 mg	2.8	1.6	Good
Iron	0.49 mg	2.7	1.5	Good

Source: The George Mateljan Foundation, 2014.

years: Garlic and garlic-derived organosulfur compounds have been shown to decrease the synthesis of cholesterol by hepatocytes (liver cells). Several garlic-derived organosulfur compounds, including S-allylcysteine and ajoene, have been found to inhibit 3-hydroxy-3-methyl-coenzyme A reductase, a critical enzyme in the cholesterol biosynthesis pathways.

Besides, garlic-derived organosulfur compounds have been shown to inhibit the activity of the inflammatory enzymes, such as cyclooxygenease and lipoxygenase, and the production of inflammatory signaling molecules in cultured macrophages and human whole blood (see Table 4 and Figures 3, 4 and 5) (Linus Pauling Institute, 2014)

Table 4. Therapeutic benefits of garlic against chronic and degenerative diseases

Principal Organosulfur Compounds in Commercial Garlic Preparations		
Product	**Principal Organosulfur Compounds**	**Delivers Allicin-Derived Compounds?**
Fresh garlic cloves	Cysteine sulfoxides (Alliin) Gamma-glutamyclsteines	Yes, when chopped, crushed, or chewed raw. Minimal, when garlic cloves are cooked before crushing or chopping
Powdered garlic (tablets)	Cysteine sulfoxides (Alliin) Gamma-glutamylcysteines	Varies greatly among commercial products. Enteric-coated tablets that pass the USP allicin release test are likely to provide the most.
Steam distilled garlic oil (capsules)	Diallyl disulfide Diallyl trisulfide Allyl methyl trisulfide	Yes
Garlic oil macerate (capsules)	Vinyldithiins Ajoene Diallyl trisulfide	Yes
Aged garlic extract (tablets or capsules)	S-Allylcysteine S-Allylmercaptocysteine S-1-Propenylcysteine	Minimal

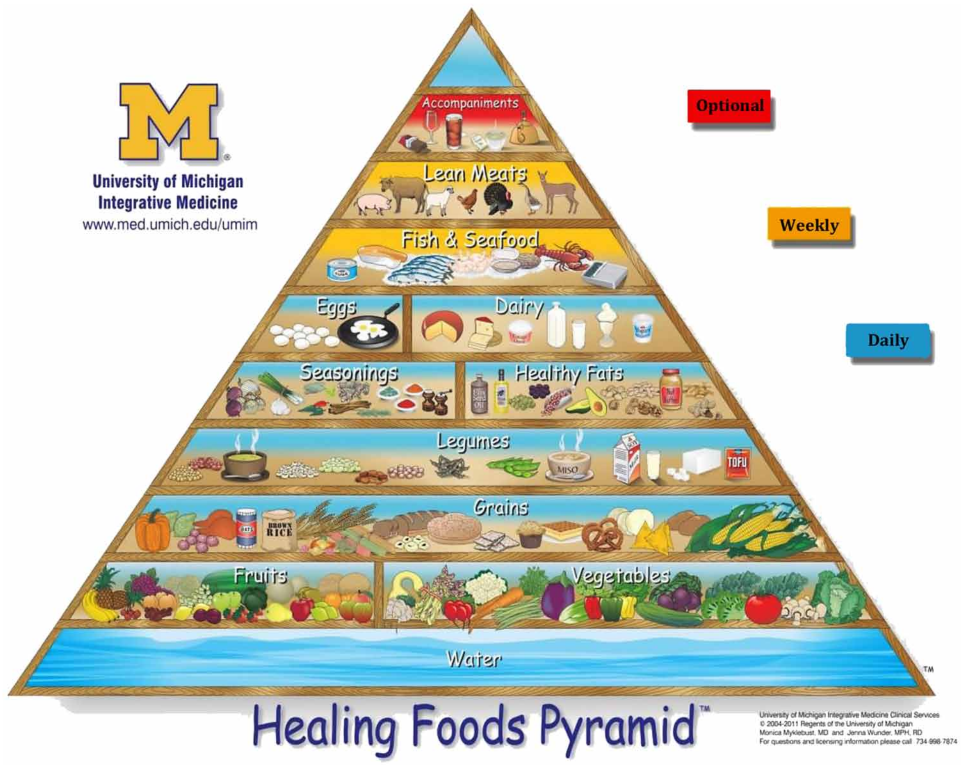
Source: Linus Pauling Institute (2014).

Figure 3. FDA-Approved MyPlate

PHENOMENOLOGY, WOMEN, INFANTS, AND CHILDREN

Since 1972, in the United States, the supplemental food program for women, infants, and children (WIC) was established to improve the nutritional status of low-income, pregnant, and lactating mothers, including infants and children less than five years of age. Foods provided to WIC recipients represent all four major food groups, and they include:

Figure 4. Healing foods pyramid



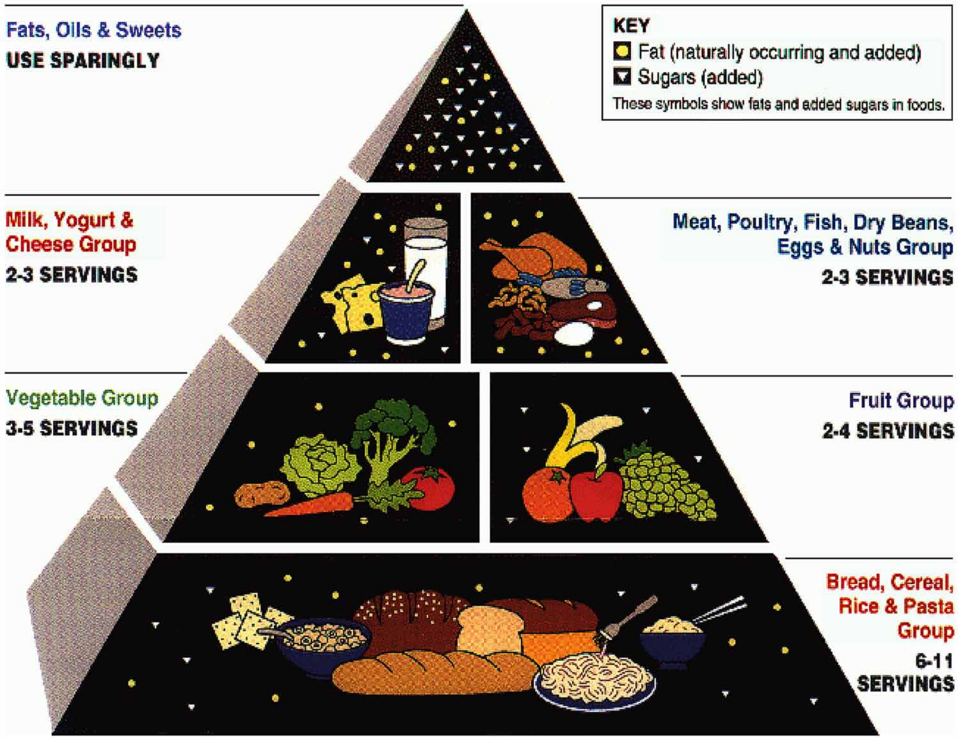
- Milk (skim, low-fat, whole, or buttermilk), infant formula, and cheese;
- Eggs and peanut butter;
- Juice (orange, grapefruit, pineapple, tomato, or apple) with vitamin C; and
- Cereal (iron-fortified infant cereal; others for children, mothers).

These food requirements are effectively illustrated in the food pyramids in Figures 1, 2 and 3. The amounts of food provided include three and a half servings from the milk group, one serving from the meat group, two servings of fruit, and one to two servings of cereal per participant per day. Although all WIC programs must provide foods from each major food group, there is some flexibility at the local level. For example, a program may choose to exclude sugar-coated cereals since excessive sugar can trigger tooth decay in children. Although nutrition education is required, the level provided depends on the local program. In many situations, nutrition education occurs only at the clinic visit required once every six months for recertification. The frequency of nutrition education in this era of the Affordable Care Act needs to be increased so at to emphasize the primary preventive initiative of this progressive program.

Meals for the aged (Title IIIC) and senior centers provide excellent opportunities for nutrition education in a group setting. Although some form of nutrition education is available at most meal sites, the actual time spent and the type of instruction presented are quite varied. Distribution of printed materials or posting of visual materials is most common.

Group discussion, recipe tasting, and trips to the market provide informal opportunities for older adults to talk and learn about nutrition. These activities are more successful than “lecture” sessions in

Figure 5. FDA-Approved food pyramid



teaching older adults. For those receiving home-delivered meals, printed materials that suggest healthy snacks or easy-to-prepare meals when no meals are delivered would be helpful. Older age groups also benefit from materials with large print that can be read easily.

NUTRIENTS IN THE FOOD GROUPS

For ecological reasons, various geographical areas have different food items. Some foods are ubiquitous. The classification of foods into the basic five food groups (BFFG) is done to specify nutrients that can be found in each group. Nutritionists adopt the BFFG to delineate the variety of foods for a balanced, nutritious diet. The groupings consist of:

1. Milk group, consisting of dairy products fresh milk, buttermilk, skim milk, condensed milk, ice cream, powdered milk, yogurt;
2. Meats, fish, nuts, and beans group including various meat products such as beef, veal, eggs, fish, locust beans (*Parkia biglobosa*), "iru," cowpea (*Vigna unquiculata*), and groundnut (*Arachis hypogaea*);
3. Cereals and grain group consisting of rice (*Oryza sativa*), maize (*Zea mays*), guinea-corn (*Sorghum* spp.), millet (*Pennisetum* spp. and *Sorghum vulgare*), and bread (*Triticum vulgare*);

4. Roots, starchy fruits, and tubers consisting of yam (*Dioscorea* spp.), cassava (*Manihot esculenta*), cocoyam (*Colocasia esculenta*), and sweet potatoes (*Ipomoea batatas*); and
5. Fruits and vegetables consisting of mango (*Mangifera indica*), pawpaw (*Carica papaya*), guava (*Psidium quajava*), sweet orange (*Citrus sinensis*), pineapple (*Ananas Cosmosus*), avocado pear (*Persea americana*), lemon (*Citrus aurantifolia*), and okra (*Hibiscus esculentus*).

The rationales underlying this classification system stem from the premise that no single food contains all the nutrients that any individual requires for bodybuilding or providing energy to maintain life. Instead, each food item contributes significant amounts of two or more nutrients. Logically, all foods perform body building, energy-giving, and protective functions based on their quality and quantities (Ebomoyi, 2011).

SOURCES OF CARBOHYDRATES

As energy foods, carbohydrates ($C_6 H_{12} O_6$) provide 45% to 50% of the calories in the American diet. In contrast, among the peoples of Africa, Asia, the Middle Eastern nations, and Latin America, dietary carbohydrates from grains, yams, potatoes and associated root vegetables make up more than 80% of their calories. Foods that are rich in carbohydrates occur naturally in virtually all parts of the world. Common sources of carbohydrates include grains, syrups, sugars, fruits, and vegetables. Carbohydrates enable the body to move, work, and survive. Glucose is oxidized in the body cells to release energy. This energy is stored in the liver and muscle as glycogen, called complex carbohydrate. A prominent function of carbohydrates is the protein-sparing phenomenon, whereby they supply the body's energy needs, thereby sparing proteins for their regulatory functions when the supply of protein is limited. If the diet contains insufficient carbohydrates, the body converts protein to glucose to enable it to release energy (glycogenesis).

Bread, which is made up mainly of carbohydrates, is essential to human survival. Unfortunately, wheat is not a ubiquitous crop such as rice and does not grow in sub-Saharan Africa. Lack of carbohydrates in the diet may gives rise to acidosis (accumulation of acidic intermediate products). Glucose, a product of dietary carbohydrate, is a necessary source of energy for the brain. Either a complete lack of or an insufficient supply of glucose and oxygen to the brain can lead to severe impairment. Also, lactose (another product of carbohydrate) in the intestine facilitates the growth of beneficial bacteria. Therefore, its lack leaves the body vulnerable to infestations of intestinal bacteria.

Compared to the well-developed kidneys of children less than two years of age, the glomerular filtration rate may be impaired. Because of insufficient amino acid production, the immune system may be seriously impaired. Finally, cognitive functions of children who are starving are usually below average because victims of starvation develop fewer brain cells than their well-nourished counterparts.

EFFECTS OF STARVATION IN ADULTS

In adults, the effects of starvation are many and varied. Clinical features include wasting of tissue, edema, depigmentation of hair and skin, loss of hair, and deterioration of cognitive ability. If starvation involves severe restriction of carbohydrates, normal glucose metabolism and insulin production are affected. In total starvation, fat oxidation predominates, with low insulin production, leading to ketosis. Energy utilization by the brain, kidney, and muscle is profoundly affected as the brain switches from predominantly glucose to ketone body oxidation.

In many parts of the world, people fast as a religious observance. This fasting is practiced by followers of Islam, Christianity, Judaism, and Animism. If the starvation is prolonged, for both physiologic and biochemical reasons, the total amount nutrients ingested while attempting to break the fast should be relatively small. Ingesting a large quantity of food at one time can create a digestive catastrophe. Before engaging in therapeutic starving, participants should consult a counselor. When people fast for either religious or cosmetic reasons, the advice of a clinician or nutritionist can be most useful in preventing unintended health hazards.

ROLE OF BIOFORTIFICATION

Rebecca Bailey (2011) defined biofortification as a method of breeding crops to increase their nutritional value. Biofortification is unidentical to ordinary fortification because it focuses on enhancing plant foods and making them more nutritious as the plant grows rather than having nutrients added to the foods when they are being processed. This process is an improvement on the mere fortification adopted when attempting to provide nutrients to the impoverished at the primary health care center worldwide, more so as they do not have access to commercially fortified foods. Besides, the process can be carried out through conventional selective breeding or through genetic engineering. Biofortification is conceived as an innovative and upcoming technique for addressing the protein energy malnutrition problems in many developed and developing nations. Since there are many fruits and vegetables that can be utilized to supplement the diet of the school-aged children worldwide, innovative scientific interventions are required to fortify the following ubiquitous fruits in several parts of the world. These fruits include the African pear (*Dacryodes edulis*), soursop (*Anona muricata*), pineapples, bananas, and African mangoes (*Irvingia gabonensis*). These fruits grow in several rural areas of world the examples of other food crops which can be enhanced through biofortification are maize, yams, cassava, soybeans, sunflower, sweat potato, and tomatoes. Maize is rich in lysine, tryptophan, protein, and phytate, while potato has protein and methionine and tomato is very rich in fats, oil, gamma-linoleic acid, foliate, carotenoids, lycopene, beta-carotene, zanthophylis, and flavonoids. Owing to the increased prevalence of PEM and other infections among children in developing and the least developed nations, it seems expedient to educate rural parents and farmers to incorporate animal husbandry into their agricultural practice so as to reduce the incidence of protein energy malnutrition and obesity (other caloric excess situations). The provision of a balanced diet to school-aged children can ameliorate not only their cognitive and physical development, but also enhance their resistance against viral and parasitic diseases, which are very endemic in many parts of the world.

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Chapter 4
Evaluation of the Relationship Between Nutritional Status and Quality of Life Among Nursing Home Residents With Alzheimer's Disease

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ABSTRACT

The purpose of this study was to determine nutritional status and its influence on their quality of life in Alzheimer's disease (AD) patients with Mini Nutritional Assessment (MNA) and anthropometric measurements. This study was conducted with 57 Alzheimer type dementia patients between the ages of 52 and 89 who live in nursing homes in Ankara/Turkey. In this study, it was found that the 57.9% of the AD patients were at risk of malnutrition, and that 19.3% were malnourished. Malnutrition risk rises as the length of stay increases ($p < .05$). A significant correlation between body weight and quality of life as well as one between calf circumference and quality of life was detected ($p < .05$). In this study, nutrient intake among aged individuals with AD was found unbalanced; a statistically significant correlation between energy / nutrient intake and quality of life also was not detected.

INTRODUCTION

It is estimated that each year, 4.6 million new cases of dementia were predicted (one new case every 7 seconds), with numbers affected nearly doubling every 20 years to reach 81.1 million by 2040 (Ferri et al., 2005). As the most common cause of neurodegenerative dementia in the elderly population Alzheimer's disease (AD) is a growing health issue and one of the leading causes of death among elderly

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people (Gillette-Guyonnet et al.,2000; Gurvit, 2004). Two-thirds of all dementia cases are caused by AD, which affects roughly 10% of the elderly. This prevalence increases with age, and reaches 45% among those over 85 years (Gurvit, 2004). In Turkey, the epidemiological data on Alzheimer's disease is not sufficient; however, a relevant study indicates that the AD prevalence among those over 70 years is 11% (Gurvit et al., 2008).

In the present day, quality of life is one of the most important factors considered in the treatment of Alzheimer's disease (Akyar & Akdemir, 2009). On the other hand, it is particularly difficult to define quality of life for these patients due to cognitive, physical, emotional and social factors that are specific to this disease. Moreover, it is not always possible to determine the life quality of Alzheimer's patients using their own assessments since they may lack sufficient cognitive skills (Akyar & Akdemir, 2009; Akpinar & Kucukguclu, 2012). Assessing quality of life using subjective and objective indicators is associated with cognitive and behavioral disorders and, frequently, with nutritional disorders (Gillette-Guyonnet et al.,2000). Hyperphagia, hyporexia, sweet cravings, choice of food, refusal and severe feeding difficulties are prevalent eating patterns (Gillette-Guyonnet, Lauque & Ousset, 2005). Weight loss is also frequent, increasing the risk of complications, especially reduced muscle mass, a loss of autonomy, and an increased risk of falls, decubitus ulcers, and systemic infection. All of these increase the burden of the disease and reduce AD patients' quality of life (Gillette-Guyonnet et al., 2000; Gillette-Guyonnet, Lauque & Ousset, 2005). Various mechanisms may be responsible for weight loss. It may be due to physical changes (e.g., impaired taste and smell functions, reduced appetite due to a decline in endogenous opioids, and increased satiety due to increased sensitivity to cholecystokinin), neuropsychiatric disorders associated with the disease (e.g., memory loss, disorientation, mood disorders, indifference, and impaired judgment), a change in autonomy and dietary habits, or changes in neurotransmitter concentrations (e.g., Neuropeptide Y and norepinephrine) (Knupfer & Spiege, 1986; Spaccavento et al., 2009). Weight loss worsens as the disease progresses and itis considered a predictor of patient mortality (Gillette-Guyonnet, Lauque & Ousset, 2005). Spaccavento et al. (2009) investigated the role of nutritional status on cognitive, functional and neuropsychiatric deficits in patients with AD. They found that patients at risk of malnutrition showed greater impairment, both in simple and instrumental activities of daily living and a more severe ideomotor praxis deficit than well-nourished patients. Neuropsychiatric symptoms (such as hallucinations, apathy, aberrant motor behavior and nocturnal disturbances) were more severe in patients at risk of malnutrition. Therefore, an intervention strategy that can prevent or slow the complications of this disease would have important public health benefits (Nourhashemi et al., 2000). It is critical that malnutrition is detected at an early stage since it is very difficult to reconfigure nutrition habits, especially for patients with dementia (Garry & Vellas, 1996).

Studies in the relevant literature indicate that 60% of AD patients in nursing homes are either malnourished or at risk of malnutrition (Elia, Jones & Russell, 2008). Thus, individuals at nursing homes should be examined regularly for malnutrition. Awareness about the influence of malnutrition on the quality of life should be raised. This requires that malnutrition risk and its clinical outcomes be researched with a variety of populations. Therefore, this study used the Mini Nutritional Assessment (MNA) andanthropometric measurements to determine AD patients' nutritional status and its influence on their quality of life.

Purpose of the Research

The main purpose of this research was to examine the relationship between nutritional status and quality of life among nursing home residents with Alzheimer's disease. It was also aimed following objectives in order to accomplish the main purpose:

- Finding out the nutritional status of the aged individuals with Alzheimer's through anthropometric measures and MNA,
- Determining the amount of the energy and nutrient intakes by a 3-day recording of food consumption and evaluating their meeting of Recommended Dietary Allowances (RDA),
- Determining the quality of life of aged individuals with Alzheimer's through Caregivers' Reports on Patients' Quality of Life scale,
- Examining the relationship between the energy intake and quality of life among aged individuals with Alzheimer's.

METHODS

Study Group

This cross-sectional study was conducted with 57 (22 male, 35 female) Alzheimer type dementia patients between the ages of 52 and 89 (76.0±9.84) who live in nursing homes in Turkey's capital city, Ankara, between January 2014 and April 2014. The World Health Organization regards people in the age range 45-59 years as "middle aged", 60-74 as "elderly", 75-89 as "old" and over 90 as "very old" (53). According to this, 8.8% (5 patients) of the participants are middle aged, 31.6% (18 patients) are elderly, and 59.6% (34 patients) are old. Patients who had only lived in nursing homes for less than one year and bedridden patients were excluded in this research. 61.4% of the participants had been staying at nursing homes for 1-2 years, 24.6% of them for 3-4 years and 14.0% of them for 5 and more years. Data were obtained by surveying professional care providers about their patients. In Ankara, there are many nursing homes and elderly care facilities belonging to the public, private owners, associations, foundations and local governments. The patients of two private nursing homes whose owners agreed to participate were included in the study. Before giving the survey to the patients' professional care providers who agreed to participate voluntarily in this study, they were asked to sign a consent form in accord with the Helsinki declaration.

Study Protocol

The participants were enrolled by a dietician and an academic specialist in the field of social work. In the study, authors made appointments with the nursing homes in advance in order to reach each individual. Thus, the authors, who organised the date, the time, and the place of meetings suggested by the institutions/organizations, had the opportunity for a face to face meeting with each professional care providers. In order not to disturb the patients in their living space (their own rooms), authors paid utmost attention during the interviews. Additionally, in advance, after the care providers were informed about the aim of the study and that it was conducted for academic purposes, they were specifically assured that any information that could reveal their identity would not be shared. Afterwards, information about all the patients who participated in the study (age, sex, disease, duration in nursing homes) was collected from their primary caregivers. The Mini Nutritional Assessment (MNA), and anthropometric measurements (weight, height, body mass index, mid-upper arm circumference, calf circumference, waist/hips ratio) were used to evaluate the nutritional status of the each patient. The body weights of AD patients wearing minimal clothing were measured to the nearest 0.5 kg with a portable scale. Height to the nearest 0.1 cm was measured with a fiber-glass tape. Body mass index (BMI) was calculated as weight (kg)/height (m^2). Mid-upper arm circumference (MUAC) were measured in standing position, the calf circumference (CC) was measured in a supine position, using a fiber–glass tape and recorded to the nearest 0.1 cm. All measurements were obtained as described by Lee and Nieman(2003). The BMI is a widely used and generally accepted measure of nutritional status. However, in the elderly, the BMI should be interpreted with caution because of change in body composition (Wellman & Kamp, 2008). Although there has not been an agreement on the best cut-off points for the elderly, BMI categories, that is, the underweight ($\leq$18.5 kg/m^2), normal weight (18.6-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2) and those with obesity ($\geq$30 kg/m^2) were taken as parameters (31). MUAC measures were evaluated compared with 18-74 years of age NCHS Percentile values. According to this, < 5^{th} percentile was regarded as under nutrition (malnutrition) (Frisancho, 1999).Dietary assessment was accomplished as follows for a period of 3 consecutive days. The caregivers kept a food diary recording of everything the patients ate or drank. Portion size was expressed in household units such as cups, ounces, or pieces. The ingredients of mixed dishes were specified. Serving sizes were estimated either by product name, the place of food consumption, standard weights of food items or from the portion size that was determined from a picture booklet of 120 food photographs (Rakıcıoglu et al., 2009). A dietician, who also calculated the energy and nutritional values of the enteral supplements they consumed from their labels, collected and inspected these nutritional surveys. The results were analyzed using BeBİS 6.1 software (the Nutrition Information System), which is based on several international and national food composition tables. The energy and nutrients intakes of the participants were compared to the Recommended Dietary Allowances (RDA). Consuming $\pm$33% of the recommended amount was considered adequate. Consuming less than $\pm$33% of the recommended amount was considered insufficient, and more than $\pm$ 33% of the recommended amount were considered overconsumption (RDA, 1989).

Measurements

MNA, Caregivers' Reports on Patients' Quality of Life (C-PQOL) and personal information form were used to collect data in this research.

MNA

The MNA is a sensitive tool for nutritional screening and assessment of the elderly and provides a multidimensional assessment of the patient. Different sections of MNA assess different components of nutritional status:

1. MNA-1 = anthropometric measurements (4 items), including weight and height to calculate body mass index (BMI), arm and calf circumferences, and weight loss (score: 0–8 points);

2. MNA-2 = general assessment (6 items), including residential status, psychological problems, mobility, medications, and skin ulcers (score: 0–9 points);
3. MNA-3 = assessment of dietetic habits (6 items), including number of meals, food and fluid intake, and autonomy of feeding (score: 0–9 points);
4. MNA-4 = subjective assessment (2 items), including self-perception quality of health and nutrition (score: 0–4 points).

Each item has a numerical value and contributes to the final score, which has a maximum of 30 points. The MNA score is used to classify subjects as well nourished (score above 23.5), at risk for malnutrition (score of 17–23.5), or malnourished (score less than 17), according to the original cut-off point of the MNA full test (Guigoz, 2006; Vellas et al., 1999).

Caregivers' Reports on Patients' Quality of Life (C-PQOL)

Caregivers' reports on patients' quality of life was adapted for Turkish use by Akpinar and Kucukguçlu (2012).

Akpinar and Kucukguçlu (2012) performed the reliability and validity analyses of the (C-PQOL) that this study used. The scale was translated and retranslated from the translation to verify its linguistic validity. Expert opinions were solicited to ensure the validity of its content (Kendall's W=.223, p=.095). The C-PQOL had an internal consistency reliability coefficient, or Cronbach's alpha, of 0.77, and its interclass correlation coefficient was 0.72. Akpinar and Kucukguclu (2012) adapted the C-PQOL for use in Turkey. They also showed that it was a reliable and valid C-PQOL measure for Turkish patients.

The necessary permission was obtained from Akpinar, one of the authors of the scale (Akpinar & Kucukguclu, 2012). C-PQOL consists of 13 items concerning physical health, energy, mood, living situation, memory, family, marriage, friends, you as a whole, ability to do chores, ability to do things for fun, money, and life as a whole. C-PQOL is a likert-type scale and scored from 1 (poor) to 4 (excellent). Score range of the scale is 13-52. It takes 5 minutes in total with caregivers to answer this scale concerning the quality of life of patients. Quality of life improves as scores on the scale increase.

Personal Information Form

Socio-demographic variables included sex, age, length of stay in nursing homes in order to obtain certain information about the participants. These variables were selected according to the literature and their potential effects on the nutritional status and quality of life.

Sex was coded as:

1. Male
2. Female

Age was grouped into three groups:

1. 45-59
2. 60-74
3. 75-89

Length of stay in nursing homes was coded as:

1. 1-2 years
2. 3-4 years
3. 5 and over

Statistical Analyses

Data were analyzed using the SPSS statistical software package. Continuous variables were described using means, and standard deviations. Frequencies and percentages were used as descriptive statistics for categorical variables. Normal distributions were evaluated using the single sample Shapiro-Wilk test. When the hypothesis of normality was not met, nonparametric Mann-Whitney U tests were used. Chi-square test was used in the analysis of categorical data. Pearson Chi-square test could not be implemented where more than 20% of the expected counts were less than 5 in cells and they were tested through Monte Carlo simulation. Mean intakes of energy and nutrient were compared with RDA reference values and analyzed for significant differences using one-sample t tests. To evaluate relations among variables, Spearman's Rank Correlation Coefficient was used. A statistically significant p level was set at .05.

Results

Table 1 shows the patient characteristics at inclusion according to nutritional status. While 22.8% of the patients were well nourished, 57.9% were at risk of malnutrition, and 19.3% were malnourished. Nutritional status of male were better comparing to those of female ($p<.05$). All groups were similar in age and score of quality of life. It was found that those who were at risk of malnutrition (2.8 ± 1.4) had been staying in the nursing home longer than those who were well nourished (1.7 ± 0.6) ($p<.05$). Mean BMI was greater than the normal range (18.6-24.9) in well nourished and risk of malnutrition groups. The MNA mean scores were significantly different among three groups ($p<.05$).

The anthropometric measures of AD patients are given in Table 2. The BMI mean were found 23.9 ± 4.2 kg/m^2 for male and 25.0 ± 4.9 kg/m^2 for female. The waist circumference measures of male and female were 90.1 ± 14.7 cm and 87.6 ± 11.1 cm respectively. The mean ratio for waist/hip was the same(0.9 ± 0.1cm). MUAC mean measured for male and female 26.4 ± 3.7 cm and 25.5 ± 5.7 cm respectively. Calf circumference mean was 31.2 ± 4.2 cm for male and 30.1 ± 4.3 cm for female. As the results of the anthropometric measures for male and female, no statistically significance was found ($p>.05$) except for body weight ($p<.05$). When the MNA scores were examined, it was determined that male's scores (21.2 ± 4.47) were higher than those of female (18.8 ± 4.37) ($p<.05$). No significant statistical difference was observed between quality of life scores between male and female.

Distribution of body weight and disease risk status of the AD patients according to some anthropometric measures is given in Table 3. It was found that majority of the male and female were normal according to BMI (54.5% and 60.0%, respectively), both were also in normal group in terms of metabolic diseases according to waist circumference (54.5% and 40.0%, respectively). While the percentage of women whom abdominal obesity was observed was 94.3% according to waist/hip ratio, majority of the men (77.3%) were found to be normal,. According to mid-upper arm circumferences, 45.5% of the male and 34.3% of the female were found to be below the 5 percentile.

Table 1. Comparison of patient characteristics by nutritional status

Baseline Parameters	MNA Score at Baseline				
	All Patients (n:57)	>23.5 Mean±SD (n:13)	23.5-17 Mean±SD (n:33)	<17 Mean±SD (n:11)	p
n (%)	100.0	22.8	57.9	19.3	
Sex (Male/Female) (%)	100.0	40.9/11.4	45.5/65.7	13.6/22.9	p**=.035
Mean Age (years), SD	76.0±9.8	73.0±11.0	76.7±9.1	77.4±10.6	p>.05
Mean Length of Stay in Nursing Homes (years), SD	2.4±1.3	1.7 ± 0.6^{a}	$2.8\pm1.4^{a'}$	2.1±1.2	p= .015
Mean BMI (kg/m^2), SD	24.5±4.6	25.8 ± 3.8^{a}	25.0 ± 4.6^{b}	$21.7\pm4.7^{a',b'}$	$p^{a,a'}$= .011 $p^{b,b'}$=.021
Mean MNA, SD	19.7±4.5	25.1 ± 1.0^{a}	$19.9\pm1.9^{a',b}$	$12.5\pm2.5^{a',b'}$	$p^{a,a'}$= .000 $p^{b,b'}$=.000
Mean score of C-PQOL, SD	24.9±4.7	26.0±5.8	25.0±4.5	23.3±3.8	p>.05

* $^{a,a'}$, $^{b,b'}$ $p<.05$ Mann-Whitney U testi for continuous variables

** χ^2-test for categorical variables.

Table 2. Anthropometric measurements, MNA and quality of life scores by sex

Baseline Parameters	Sex		
	Male (22)	Female (35)	p^{a}
Mean body weight (kg), SD	67.8±13.5	57.4±13.2	p=.007
Mean BMI (kg/m^2), SD	23.9±4.2	25.0±4.9	p=.313
Mean waist circumference (cm), SD	90.1±14.7	87.6±11.1	p=.718
Mean waist/hips ratio, SD	0.9±0.1	0.9±0.1	p=.305
Mean mid-upper arm circumference, SD	26.4±3.7	25.5±5.7	p=.130
Mean calf circumference (cm), SD	31.2±4.2	30.1±4.3	p=.224
Mean score of MNA, SD	21.2±4.47	18.8±4.37	p=.033
Mean Score of quality of life, SD	25.8±5.6	24.4±4.0	p=.532

^{a}Mann-Whitney U testi for continuous variables and χ^2-test for categorical variables.

Correlation between quality of life and some parameters is illustrated in Table 4. As can be seen, a negative correlation was found between sexes, length of stay in the nursing home and the quality of life ($p>.05$). Only the correlation between body weight, calf circumference and quality of life was found statistically significant ($p<.05$).

In Table 5, the status of meeting the requirements of AD patients by their daily intake of energy and nutrient is shown. Intake of energy (91.2%) and protein (87.7%) in AD patients was found adequate

Table 3. Body weight and disease risk status distribution of the AD patients according to some anthropometric measures

Anthropometric Measures			Male		Female		P*
			n	%	n	%	
Classification of BMI	**BMI (kg/m²)**						
Underweight	<18.5		1	4.5	1	2.9	χ^2=7.619 p=.040
Normal weight	18.5-24.9		12	54.5	21	60.0	
Overweight	25.0-29.9		8	36.5	4	11.4	
Obesity	≥30.0		1	4.5	9	25.7	
	Waist Circumference (cm)						
Disease risk	**Male**	**Female**					
Normal	<94	<80	12	54.5	14	40.0	χ^2=1.525 p=.466
Risk	≥94	≥80	4	18.2	6	17.1	
High risk	≥102	≥88	6	27.3	15	42.9	
	Waist/Hip Ratio (cm)						
Disease risk /obesity type	**Male**	**Female**					
Normal	<1.0	<0.80	17	77.3	2	5.7	χ^2=31.128 p=.000
Abdominal obesity	≥1.0	≥0.80	5	22.7	33	94.3	
Nutritional status	**MUAC (Percentile)**						
Malnutrition	<5		10	45.5	12	34.3	χ^2=0.712 p=.805
Risk of malnutrition	≥5-<25		8	36.4	12	34.3	
Normal	≥25-<75		3	13.6	9	25.7	
Overweight	≥75-<95		1	4.5	1	2.9	
Obesity	>95		-	-	1	2.9	

*Monte Carlo simulation was used as statistical analysis when more than 20% of the expected counts were less than 5 in cells.

Table 4. Spearman rank correlation coefficients for Quality of life (r)

Measurements	C-PQOL
Age (year)	0.011 (p=.938)
Sex	-0.084 (p=.0537)
Duration in Nursing Homes (year)	-0.246 (p=.066)
Body weight (kg)	0.289 (p=.029)*
BMI (kg/m²)	0.243 (p=.069)
Waist circumference (cm)	0.203 (p=.131)
Waist/hips ratio (cm)	0.074 (p=.586)
Mid-upper arm circumference (cm)	0.226 (p=.091)
Calf circumference (cm)	0.340 (p=.010)*
MNA	0.239 (p=.073)
Energy consumption (kkal)	0.079 (p=.562)

*p<.05 indicate correlation between Quality of Life with Spearman rank correlation coefficient.

Table 5. Energy and nutrient intake of Alzheimer's patients not meeting and excess meeting RDA (%)

	Intake M(SD)	**<67**	**67-133**	**133<**	**Intake, %RDA M(SD)**
Energy (kkal)	1723.6±442.5	7.0	91.2	1.8	89.4±21.5
Protein (g)	55.2±14.1	10.5	87.7	1.8	97.3±23.3
Fat (g)	81.2±21.1	3.5	49.1	47.4	124.8±31.1
Carbohydrate (g)	188.9±66.4	49.1	49.1	1.8	68.6±22.5
Fiber (g)	18.8±4.9	42.1	57.9	-	63.1±16.9
Vitamin A (µg)	1060.5±593.3	10.5	56.1	33.3	132.2±73.3
Vitamin E (mg)	33.4±10.3	3.5	-	96.5	280.1±85.5*
Vitamin B_1 (mg)	0.7±0.2	49.1	50.9	-	71.2±21.5
Vitamin B_2 (mg)	1.2±0.5	17.5	56.1	26.3	104.6±44.1
Vitamin B_6 (mg)	1.3±0.3	7.0	68.4	24.6	113.3±29.3
Folat (mcg)	387.2±167.7	26.3	52.6	21.1	97.1±41.8
Vitamin C (mg)	181.9±86.2	7.0	28.1	64.9	179.7±90.4*
Sodium (mg)	1855.1±1323.6	40.4	52.6	7.0	84.4±38.9
Potassium (mg)	2146.5±618.1	63.2	36.8	-	61.8±17.2**
Calcium (mg)	811.6±467.9	52.6	26.3	21.1	81.7±46.2
Magnesium (mg)	214.9±56.2	43.9	56.1	-	69.4±16.8
Phosphor (mg)	964.4±287.6	-	50.9	49.1	138.1±39.9
Iron (mg)	5.9±1.9	82.5	17.5	-	55.0±13.6**
Zinc (mg)	7.1±1.9	8.8	73.7	17.5	103.4±26.8

*Mean intake significantly higher than RDA, p<.05, **Mean intake significantly lower than RDA, p<.05

(67-133), fat (47.4%) excess (133<). However, intakes of carbohydrates (49.1%), dietary fiber (42.1%), vitamin B_1 (49.1%), potassium (63.2%), calcium (52.6%), magnesium (43.9%), and iron (82.5%) were found inadequate (<67). Especially mean intake of potassium and iron weresignificantly lower than RDA (p<.05). On the other hand, mean intake of vitamins E and C were significantly higher than RDA (p<.05).

DISCUSSION

The quality of life of patients with Alzheimer's disease is influenced by nutritional status along with medical, social and psychological factors. Nutritional problems, especially weight loss, are frequent clinical findings in patients with AD (Seth, 1994). Weight loss is always a great concern for the clinical practitioner because it is an indicator of protein and energy malnutrition in the elderly and a predictor of mortality (White, Pieper & Schmader, 1998). For this reason, the nutritional status of the elderly with under-nutrition sensitivity should be monitored regularly via scanning tests and anthropometric measures in order to prevent malnutrition. (Beck, Holst & Rasmussen, 2008). In this study, nutritional status of the elderly with AD staying in nursing homes was examined through MNA and some anthropometric measures.

In this research, it was found that the majority of the patients with AD (57.9%) were at risk of malnutrition, and that 19.3% were malnourished. These rates are considerably higher than rates found in the other countries, with prevalence of malnourished 0.0-4.3 (Cuervo et al., 2009; Droogsma et al., 2013; Spaccavento et al., 2009), and different at risk of 14.1-79.5 (Cuervo et al., 2009; Droogsma et al., 2013; Guérin et al., 2005; Spaccavento et al., 2009; Vellas et al., 2005). In contrast with this, in the study of Khan et al. (2013), malnutrition ratio among AD patients were found higher (62%) while risk of malnutrition ratio was found lower (38%) than this study. Despite different prevalence, all these data show that there is a high prevalence of (risk of) malnutrition among AD patients. The differences in prevalence may be explained by variations in size and demographic characteristics of the research population. In addition, the facility differences between nursing homes, such as having special care units that may result in better clinical outcomes (Aukner, Eide & Iversen, 2013; Luo et al., 2010; Nobili et al., 2008) may have been effective on the occurrence of such different results. Finally, as one of the limitations in this study, the progression of the disease, which varied from one year (Ousset et al., 2008; Spaccavento et al., 2009) to five years (Gillioz et al., 2009), could be the reason for the variation seen in the prevalence. When a cross sex comparison is made, MNA scores of male are higher than those of female ($p<.05$,Table 2) where (risk of) malnutrition is more common among female (Table 1). This outcome could have been expected taking into account that female present higher under-nutrition prevalence than male (Cuervo et al., 2009; Kucukerdonmez et al., 2005; Vellas et al., 2005). It is already known that age is one of the indicators of the total MNA score and that it is in a negative correlation with MNA score (Cuervo et al., 2008; Sanlier & Yabanci, 2006). For this reason, as the age increases, MNA scores are expected to decrease. Considering that, although this study seems to be in accord with literature, the variation between values of mean ages is insignificant (Table 1). The fact that majority (59.6%) of the AD patients who participated the survey were placed in “old” category can explain the situation. Additionally, meanage for female (77.4±8.7 years) being higher than that of male (73.8±11.1 years) (data not show) may be one of the reasons why female’s MNA scores were lower.

Although the exact mechanism of weight loss in AD patients has not been clarified, many hypothesis have been proposed including brain degeneration eliciting impairment of olfaction and taste, inadequate dietary intake, backhanded malabsorption of the nutrition, increased rate of energy expenditure, biological disturbances, atrophy of the part of the cerebral cortex and the presence of comorbid medical illness (Aukner, Eide & Iversen, 2013; Gillette-Guyonnet et al., 2000; Wang et al., 2004). Weight loss and malnutrition in the AD patients have serious negative health consequences, and it often leads to reduced quality of life (Aukner, Eide & Iversen, 2013; Gillette-Guyonnet et al., 2000). Although, in this study, the mean quality of life scores (26.0±5.8) of the well nourished AD patients were higher than those in malnutrition risk group (25.0±4.5) and malnourished group (23.3±3.8), the variation did not show a statistical significance (Table 1). This may have resulted from the fact that the assessment was based on the observations of caregivers. Moreover, including AD patients in different stages in the study, this group’s being a fragile group and the inadequate number of participants in the study sample may have been the reasons why the correlation between quality of life and malnutrition could not be established in the study. When the quality of life scores are compared by sexes, it was seen that female and male had similar quality of life scores (Table 2). In other words, any significant correlation between quality of life and sex was not observed (Table 4). In Winter et al. (2011) conducted on patients with Alzheimer dementia, there was no association between quality of life and sex. In current research, age was not associated with quality of life (Table 4). This finding is consistent with previous literature (Chan et al., 2011; Lucas-Carrasco et al., 2010).

Similar toVellas et al (2005) and Spaccavento et al (2009) studies, in this study as well, as BMI decreases, risk of malnutrition and malnutrition status increases (Table 1). On the other hand, it can be seen that obesity (25.7%) among female and overweight (36.5%) among male are common according to BMI (Table 3), and that male have the mean BMI as 23.9±4.2 kg/m^2 whereas female have an mean of 25.0±4.90 kg/m^2 (Table 2). They may have been overweight or obese before the development of AD. Some studies show that a raised BMI in middle age can be associated with a higher risk of dementia (Kivipelto et al., 2005; Whitmer et al., 2005), and one research showed that in patients with AD, a worse psycho-functional status was associated with obesity (Saragat et al., 2012). In the Cuervo et al (2009) study, BMI is higher among female (28.1± 5.0) with AD patients compared to male (27.7± 4.1), as well. Cuervo et al (2009) and Droogsma et al (2013) found mean BMI of the individuals with AD higher than current study. The reason for this difference may be attributed to the fact that in the other study (Cuervo et al., 2009), individual's height and weight measures were taken self reportedly or that they were newly diagnosed AD (Droogsma et al., 2013). In fact, it is known that weight loss will occur as the stage of the disease increases (Goes et al., 2015). The relation between BMI and quality of life has been investigated in previous studies of elderly people, finding impaired quality of life in both obese and underweight individuals, with the highest quality of life in individuals of the BMI category 20–24.9 kg/m^2 (Groessl et al., 2004; Yan et al., 2004). In a cross-sectional population survey including 1.632 men and 1.654 women aged 65 to 87 years, it was found a significant reduction in quality of life with an increasing risk of malnutrition, and this was more pronounced in men than in women (Kvamme et al., 2011). In the present research, the mean quality of life score of those with an ideal weight (26.7±5.64) was higher than that of those who were overweight and obese (23.7±3.74), and the difference was statistically significant ($p<.05$, data not show). Furthermore, it was found that there was a positive correlation between body weight and quality of life and that this correlation was statistically significant (Table 4). Quality of life in obese individuals may be impaired by associated comorbid conditions, especially pain (Fontaine & Barofsky, 2001).

It is thought, in fact, that it will not be so correct to consider BMI solely in the evaluation of nutritional status since some physical qualities change with aging. For instance, height decreases as a result of vertebral compression. An accurate height measure may be difficult in those unable to stand up straight, the bed bound, those with spinal deformations such as a dowager's hump, and those with osteoporosis. For this reason, in this study, one of the reasons of high BMI despite high (risk of) malnutrition prevalence may be the measurement of height lower due to deformations emerging with aging. Moreover, since MNA tests have been lately inquiring information such as weight losses and food intake as well as present BMI values (Vellas et al, 1999; Guigoz, 2006), even a patient with high BMI might be under the risk of malnutrition or already malnourished. BMI based on questionable heights are inaccurate. Clinical judgment is needed for accuracy. Recent research showed that CC was the best, followed by MUAC and then BMI in predicting the nutritional status and health conditions. CC and MUAC were also more effective than BMI in predicting 12-month follow-up mortality (Tsai, Lai & Chang, 2012). Mid-arm circumference and CC reflect subcutaneous fat and body muscle mass and are influenced by both energy balance and local muscle activity such as arm movement and walking activity. MUAC and CC can decrease in size during functional decline or long-term inactivity even with adequate nutritional intake (Tsai, Lai & Chang, 2012). A calf circumference of <31 cm has been shown to correlate with muscle-related disability and self-reported physical function in elderly men and women (Loreck, Chimakurthi & Steinle, 2012). In this study, mean MUAC and calf circumference measures of both male and female were found similar (Table 2). It can be put forward that nutritional status of the AD patients examined in this study were not adequate according to MUAC and CC, therefore, that their muscle masses were not maintained and that compared to the AD patients examined in some other studies (Goes et al., 2015; Kucukerdonmez et al., 2006; Lecheta et al., 2015; Pivi et al., 2011; Taylor, Albanese & Stewart, 2012), they are in worse condition. Additionally, it was determined that the majority of both female and male AD patients were already malnourished according to MUAC ($<5^{th}$ p, Male: 45.5%, Female: 34.3%) or at malnutrition risk (≥5-<25, Male:36.4%, Female: 34.3%); however, a significant variation was not observed between sexes (Table 3). Although the number of overweight male and obese female are high in this study, lower MUAC and CC values give rise to the thought of sarcopenic obesity. The excess weight and decreased muscle mass together exponentially compound to further decrease in physical activity, which in turn accelerates sarcopenia. Lower physical activity may explain the muscle mass loss, being overweight and obese according to MUAC percentile values and CC measures. That is because maintaining muscle mass is strongly related with physical activity (Landi et al., 2012). On the other hand, an extremely sedentary lifestyle in obese persons is a major detractor from quality of life (Wellman & Kamp, 2008). These mentioned factors may also explain the reason why there was a significant positive correlation between CC and quality of life (Table 4). In this respect, while nutritional therapies in nursing homes are planned, individual-tailored nutrition strategies and physical activities should be considered.

Waist circumference and waist/hip ratio are risk signifiers for chronic diseases and metabolic complications. Waist circumference over 102 cm for men and over 88 cm for women is an indicator for high risk and excessive adiposity (Klein et al., 2007). Women with 0.8 and over waist/hip ratio and men with 1.0 and over waist/hip ratio are accepted as abdominal obese (de Portugal et al., 1997). In this study, although waist circumferences for both female and male were found similar (Table 2), it was determined that the majority of the female (42.9%) and 27.3% of the male were in high risk group in terms of metabolic diseases according to their waist circumference measures. The mean waist circumference value of the AD patients were lower compared to a cross-sectional study conducted with 15.022 participants with 65 and over age group from 7 different countries (Taylor, Albanese & Stewart, 2012) but higher when compared to Kucukerdonmez et al. study (2006). Waist/hip ratio measures indicated that a majority of the women (94.3%) were abdominal obese and that most of the male (77.3%) were normal ($p < .001$) (Table 3). It can be observed that aged women examined in this study undergo abdominal adiposity and are under high risk of chronic diseases according to waist circumference and waist/hip ratios values. In the research (So, 2014) conducted to explore the impact of differential degrees of obesity on health-related quality of life (HRQL) by sex in the Korean elderly, it was found that whereas higher WC quintiles impaired mobility, usual activities, and caused pain/discomfort in women, the fourth WC quintile improved usual activities in men. It was also revealed that after adjustment, only the women of the highest WC quintile reported impaired mobility. As a conclusion, it was stated that extreme obesity worsens mobility and comorbidity in combination with obesity worsening health-related quality of life in elderly women. In this study, any statistical correlation was not found between waist circumference, waist/hip ratio and quality of life (Table 4). According to various anthropometric measures (BMI, waist circumference, waist/hip ratio), it can be observed that among female AD patients participated in this study, obesity ratio was higher than that of male (Table 3). It can be maintained that this stems from less physical activity among female, increased adiposity after menopause, more pronounced height loss among female due to menopause and decrease in the bone mineral density and the fact that increased BMI after middle ages becomes stable earlier among male than female. Due to malnutrition occurrence according to MUAC as well as overweight, obesity and abdominal obesity being common after various anthropometric measures among AD patients, many parameters are strongly suggested to be used including biochemical parameters while evaluating body weight and disease risk status of the aged individuals.

It was observed in this study that length of stay in nursing homes also had an effect on nutritional status. It was determined that comparing to well nourished ones (1.7±0.6 years), those under malnutrition risk (2.8±1.4 years, $p<.05$) and those already malnourished (2.1±1.2 years) had been in the homes longer (Table 1). Higher (risk of) malnutrition among those who stay in the homes longer has been reported by various studies (Kuzu-Kurban et al., 2010; Vellas et al., 2005). This fact gives rise to the opinion that as the length of stay increases, prevalence of malnutrition will also increase among the AD patients examined in this study. Hence, it is important to obtain an accurate nutritional assessment at an early stage of AD to ensure that the dietary needs of each patient are supplied and thus avoid the occurrence of unwanted weight loss. Especially frequent snacks, nutrient-dense foods, and nutrition supplements are needed to combat weight loss. Likewise, behavior modification and the use of altered food choices can improve quality of life (Remig & Weeden, 2008).When the relationship between the length of stay in nursing homes and quality of life was examined, a negative correlation was observed although it was not statistically significant (Table 4). Khader (2011), conducted to assess the quality of life (QOL) as perceived by 140 selected elderly people living in 3 public nursing homes in Jordan, showed also that length of stay in the nursing home was negatively associated with quality of life. Furthermore, in the research (Khader, 2011), it was found that elder people staying in the nursing home 3 years and less had higher quality of life scores. Taking into consideration that daily activities are an important factor that affects quality of life (Low & Molzahn, 2007; Paskulin & Molzahn, 2007), the fact that participants had AD; therefore, were unable to joint leisure activities at nursing homes may be attributed to why this correlation was not found statistically significant in this study.

Food and nutrition is another factor that contributes to quality of life. Adequate and balanced diet play a profound role in leading a quality life. Inadequate nutrient intake may hasten loss of muscle mass and strength, which can have a negative effect on performing activities of daily life (Wellman & Kamp, 2008). A constant change in nutritional habits is generally thought to be related with AD. In the later phases of the disease, anorexia may emerge and support the related weight loss. Possible causes can be given as physical changes such as, worsened taste and smell functions, decreased appetite related to a decline in endogenous opioids, and increased satiety related to an increase in sensitivity to cholecystokinin, neuropsychiatric disorders related to the disease such as, memory loss, disorientation, mood disorders, indifference, and impaired judgment, a change in autonomy and dietary behaviours, or changes in neurotransmitter concentrations such as, neuropeptide Y and norepinephrine (Gillette-Guyonnet et al., 2000). Inadequate and/or imbalanced energy and nutrient intake may occur in such cases. In fact, each factor, nutritional status or food consumption related to nutrition, plays an important role in quality of life of the elderly (Kvamme et al., 2011). Regarding energy intake, 91.2% of the patients presented adequate consumption, according to the RDA. While these results support some of the previously conducted studies (Winograd et al., 1991; Kucukerdonmez et al, 2006), compared to Lecheta et al (2015), energy and protein intake in most AD patients was inadequate. Since energy expenditures were not inquired in this study, an outcome could not be reached regarding the relationship between the (risk of) malnutrition and energy balances, highly observed among these patients. However, regarding their BMI, it can be estimated that their physical activities are low. It has been suggested that patients with AD may lose weight even though they have a positive energy balance (Dvorak & Poehlman, 1998). In this context, these data corroborate other authors that show that weight reduction can be found in patients with AD in spite of their adequate energy intake (Gillette-Guyonnet et al., 2000; Goes et al., 2014; White et al., 2004). It is not known exactly what causes weight loss in patients with AD, however, as explained previously, several hypotheses have been proposed to explain this phenomenon, such as Mesial Temporal Cortex (CTM) atrophy, which is involved with diet; increased energy needs; and organic disorders (Aukner, Eide & Iversen, 2013; Gillette-Guyonnet et al., 2000; Wang et al., 2004). Reviewing literature, any study looking into the relationship between energy intakes of the individuals with AD and quality of life could not be detected. Nor, in this study, could a relationship between energy intakes of the individuals with AD and quality of life be observed. Mostly adequate energy intake among the elderly may be the reason. In addition to low energy intake in old ages, declining in daily growth hormone secretion by 29-70% may lead to sarcopenia (Corpas, Harman & Blackman, 1993). Sarcopenia is an entity which is associated with functional decline, disability, falls and mortality. Despite many underlying factors in its aetiology,resistance training and nutrition is the only treatment yet known of sarcopenia (Tasoglu & Ozgirgin, 2013). Considering the relationship between low energy intake and sarcopenia, it is thought that there could be an indirect relationship between low energy intake and life quality.

As for individual's macronutrient intakes, it was determined that protein intakes of the majority (87.7%) were adequate, fat intakes were high (47.4%), and carbohydrate intakes were low (49.1%) (Table 5). Moreover, 13.4±2.8% of the energy was taken from protein, 42.2±6.1% of it from fat and 44.2±7.3% of it from carbohydrates (data not shown). Depending on this, it can be claimed that macronutrient intakes were imbalanced. For this reason, keeping the energy content, better rearrangement of the dietary pattern (carbohydrate, protein, fat distribution), decreasing fat content while increasing carbohydrate content with the condition of emphasising complex carbohydrate contents in the menus offered to this patient group can be suggested as a necessity. That is because of the fact that not only adequate protein intake and maintaining nitrogen balance for the AD patients who are at the risk of (malnutrition) are important for bodily functions, cognitive functions and immune system (Volkert & Sieber, 2011; Suominen et al., 2015), but also when the carbohydrates do not meet the majority (55-60%) of the energy needs, proteins taken by diet will be used as fuel primarilyto meet energy demand as well (Gallagher, 2012). In addition to this, it should be paid attention to the fact that fat content of diet should be between 25-30%, and over-restrictions should also be avoided within the framework of healthy diet principles. That is also because severe restriction of dietary fats alters taste, texture, and enjoyment of food, which can affect overall diet, weight, and quality of life negatively (Wellman & Kamp, 2008).

It also stood out in this study that 42.1% of the individuals did not consume adequate fiber (Table 5). Current recommendations are for the consumption of approximately 24 to 38 g of dietary fiber per day from fruits, vegetables, legumes, seeds, and whole grains for (1) maintaining the health of the cells lining the colon, (2) preventing excessive intracolonic pressure, (3) preventing constipation, and (4) maintaining a stable and healthful microbial population (Beyer, 2012). Low fiber intakes among AD patients in this study may be attributed to inadequate fruit and vegetable intakes.

The nutrient intakes of older AD persons tend to decrease over time (Shatenstein, Kergoat & Reid, 2007). On the other hand, the patients' food intake was found to be similar throughout the different stages of the disease (Goes et al, 2015). In this research, a high percentage of patients presented an inadequate intake of some micronutrients (Table 5). A majority of the participants indicated inadequate calcium and iron consumption similar to those in Lecheta et.al. (2015) study. However, calcium intake is very important for maintaining bone mineral density and lowering blood pressure (Gallagher, 2012). Main and between-meals should include dairy products which are rich in calcium and patients should be monitored for consumption. Similarly, an adequate iron intake is essential for the normal function of the immune system. Iron deficiencies result in changes in the immune response (Gallagher, 2012).

The subcommittee recommends the same amount of iron RDA for elderly women and men as 10 mg/day (RDA, 1989). Since changes in iron metabolism occur in Alzheimer disease (Gallagher, 2012), amount of iron intake within diet should be paid attention, not to be consumed either less or more. What is more, it was also observed that intakes of antioxidants such as vitamin A, C, and E, known as useful at decreasing oxidative stress which plays an important role on Alzheimer's pathology, were over RDA recommendations. This outcome is surprising as it does not corroborate the other study results (Goes et al., 2014; Lecheta et al., 2015). The high amount of intakes of this group of nutrient among AD patients in this study may be ascribed to enteral nutrition support rather than oral intake. According to Lecheta et.al. (2015), on the other hand, the higher percentage of patients with adequate intake of vitamin A, vitamin C and calcium in severe stage of dementia may be due to the fact that their diets are more often chosen by caregivers, who probably select food of better nutritional quality. It is important to monitor the consumption of these substances since they can act as neuroprotective factors, preventing or slowing the progress of AD (Goes et al., 2014).

The prevailing factors in dementia and Alzheimer's disease are micronutrient and macronutrient deficiency, and it is a fact that undernourishment causes profound outcomes for health, quality of life and survival. Even though, with its many complex-structured causes, loss of body weight is regarded as expected result of the condition, it still needs intervention (Pirince et al., 2014). When adequate energy and balanced nutrient intake among AD patients or the frail elderly is not provided, simple preventative measures such as food supplementation can be effective in stopping and reversing progressive weight loss (Gray-Donald, Payette & Boutier, 1995). Likewise, in Laugueet al. (2004), it was established that 3 months after enteral nutrition therapy of AD patients 65 and over years of age at malnutrition risk, energy and protein intakes significantly improved, resulting in a significant increase in weight and fat free mass. One study of AD patients found that oral nutritional supplementation was more effective compared to nutrition education in improving nutritional status (Pivi et al., 2011). Therefore, it is better for patients with Alzheimer's disease live in special care units since these patients usually have deteriorating eating disorders and health professionals in this field can give them specialized care there. Gillette-Guyonnet et al. (2000) indicated that >40% of AD patients lost significant amounts of weight despite living at home. However, problems with feeding AD patients are related not only to the quantity, but also to the quality of foods consumed (Greenwood et al., 2005). In general, the AD patients who participated in this research seemed to consume enough energy and macronutrients. Still, most of them did not consume adequate quantities of thiamine, which plays a major role in energy metabolism, and other essential nutrients (potassium, calcium, magnesium, phosphorus and iron). This revealed that their diet patterns were sufficient, yet imbalanced. For all these reasons, the diets of individuals with Alzheimer's disease should be prepared by dieticians to ensure that they get sufficient, well-balanced nutrition, that they do not lose weight, that they have a reduced risk of malnutrition and that associated complications are either prevented or mitigated. The nursing homes where data of this research were collected did not employ any dieticians.

It could be argued that measuring quality of life is just as important as measuring severity and progression of the disease, symptom response, cognition, behavioral disturbance and activities of daily living when assessing the effects of the disease and intervention in dementia (Walker, Salek & Bayer, 1998). This research aimed to determine the quality of life of patients with AD staying in private nursing homes based on the assessments of those who gave primary care to these patients. Although the research did not find a significant correlation between quality of life and the consumption of energy and nutrients, it has a significant outcome that the mean quality of life scores of those with an ideal weight were higher than those of the overweight and obese participants. This shows that ideal weight, an important indicator of nutritional status of AD patients, is correlated with quality of life. Although there are studies of nutritional status (Faxen-Irving, 2002; Goes, 2015) and of quality of life (Kuzu-Kurban et al., 2010) in the relevant literature, there are few studies on the correlation between nutritional status and the quality of life (De Sousa & do Amaral, 2014).

SOLUTIONS AND RECOMMENDATIONS

One of the most important results of this study was the high malnutrition and the risk of malnutrition prevalence and imbalanced nutrientsintake among AD patients. In this context, it should be especially highlighted that in the process of the disease, diet influences the nutritional and clinical course of patients and thus, nutritional intervention should be early, appropriate and carried out by qualified dieticians. Early detection of poor nutritional status, and its causes, is crucial for adequate intervention to prevent or diminish the adverse outcomes. Regular scanning and evaluation for the nutritional status of the elderly AD patients, who are sensitive to inadequate nutrition is an essential necessity. However, although the significance in the monitoring the nutritional status is well understood, there have yet been no regulations regarding this at nursing homes in Turkey. It is suggestible that dieticians be employed at nursing homes in order that general and medical nutrition needs of the elderly can be understood better. This is because dieticians are common elements in the teams that will implement algorithms designed to prevent, identify and cure malnutrition among the elderly. Moreover, it is also that they also take place in the core of interdisciplinary team (geriatrists, nurses, dieticians, social workers, psychologists, physiotherapists, occupational therapists) that carry out comprehensive geriatric evaluations. For this reason, so as to prevent and treat malnutrition at nursing homes, it is a necessity that nutrition support teams including dieticians be established, and regular in-service training programs be given in order that the quality of workers in health and nutrition services improved. There have also been various studies claiming that some training programs aiming at caregivers of AD patients may lead to a positive influence on AD patients, improving their body weight, cognitive qualities (Riviere et al., 2001), nutritional and immune status (Pivi et al., 2011) and lower the risk of malnutrition (Salva et al., 2011) in older individuals with dementia.

On the other hand, compliance of AD patients with the treatment, and supporting families of the patients (if any) in the process psychosocially are crucial to ease the treatment process and make it more effective in shorter period. Furthermore, in order that the members of the professional team working with these patients could evaluate disease related risk factors and outcomes in a more holistic point of view, the significance of micro, mezzo and macro level interventions are obvious. It should be kept in mind that social workers occupy an important place in such intervention processes

FUTURE RESEARCH DIRECTIONS

The research also had limitations as in almost research studies. One limitation of this research was that the sample contained only 57 older patients with AD living in nursing homes in Ankara/Turkey. In this research, this was because owners of other nursing homes except for owners of two private nursing homes in Ankara didn't give permission to conduct the research and the sample was limited to 57 older people with AD from two nursing homes giving permission to carry out the research.

Another limitation of the research was that information about older patients with AD was collected from their primary caregivers because they lacked sufficient cognitive skills. Therefore, data about nutritional status and quality of life of 57 aged individuals in the scope of the study were limited by the answers taken from their primary caregivers. At this point, it is believed that a remake of the study with a larger sample will provide enough evidence-based information for the improvement in the health of aged AD patients and for the treatment of the disease.

Additionally, this study aiming at determining the relationship between nutritional status/nutrien-tintake and quality of life of AD patients is important as it contributes to fill the gap present in literature in Turkey. In this study, no significant correlation between quality of life and the consumption of energy and nutrients was observed. However, it determined a significant correlation between body weight/calf circumference and quality of life among aged AD patients. In this research, the indicators for their quality of life was evaluated in the scope of 13 items concerning physical health, energy, mood, living situation, memory, family, marriage, friends, you as a whole, ability to do chores, ability to do things for fun, money, and life as a whole. Yet, it should be stated that quality of life for AD patients aged individuals is a multidimensional concept including these subjective and objective indicators and that quality of life of the participants of this study might have been affected by different factors influencing quality of life (stage of disease, stay in special unit care etc.) apart from these indicators. For this reason, it can be suggested to the future scholars to focus especially on unmet care needs for the treatments of aged AD patients staying at nursing homes. That is because not addressing those needs may cause not only the emergence of new problem areas for dementia patients such as new needs, behavioural symptoms, psychological problems such as anxiety and depression (Kovach et al. 2005), but also increase the work load of the caregivers as well as increased risk of mortality among such patients (Gaugler et al., 2005). In this sense, it can be put forward that planning studies aiming at determining unmet care needs of the dementia patients has a profound significance for their treatments.

Most studies on patients with Alzheimer's type dementia focus on cognition. These patients will, however, in time, present other complications of the illness such as nutritional problems. These problems with the nutritional status, weight loss, inadequate, and imbalanced intake of nutrients observed in the patients with AD, highlight the importance of nutritional care and interventions regarding mealtime difficulties, an aspect relevant to the clinical nursing practice with AD patients. In this context, there is a necessity for raising awareness on nutrition education and for longitudinal studies indicating effects of regular training on the prognosis of the disease and nutritional status of the patients. It is not yet well established in these studies whether weight loss and inadequate nourishment in dementia patients brings about more accelerated progression of the disease,disability, institutionalization and death, or itis just an indicator of natural process of the disease. Observing the effects of nutritional interventions in people with dementia may solve the problem via in randomised controlled attempts. Yet, nutritional interventions will be the most beneficial if they slow down the progression of the disease and increase the quality of life

CONCLUSION

As a result, in this study, the ratios of the ones at risk of malnutrition and those already malnourished among AD patients were found quite high. However, it was also found that majority of the patients were normal according to BMI, in normal group in terms of metabolic diseases according to waist circumference, and below 5^{th}. percentile according to mid-upper arm circumferences. When the relationship between nutritional status indicators and quality of life was examined only body weight and calf circumference were found significantly correlated with quality of life. The mean quality of life score of those with ideal weight was higher than overweight and obese individuals and it was found significant statistically. It was also found that the length of stay in nursing homes had an effect on quality of life. In addition, it was reached in the conclusion that AD patients were fed inadequate and imbalanced.

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KEY TERMS AND DEFINITIONS

Alzheimer Disease: An irreversible and progressive brain disorder considered to be among the most common of deficits.

Health: Refers to state of complete physical, mental, economic, political and social well-being and not merely the absence of disease or disability.

Malnutrition: Malnutrition is the condition that develops when the body does not get the right amount of the energy and macro-micronutrients it needs to maintain healthy tissues and organ function.

Nursing Home: A convalescence place for especially aged individuals with mobility and feeding restrictions and for those with a chronic illness or disability.

Nutritional Status: The condition of the body in those respects influenced by the diet; the state of the body with respect to each nutrient and to the overall state of the body weight and condition.

Nutritional Support: Nutritional support is therapy for people who cannot get enough nourishment by eating or drinking to prevent malnutrition and to protect them from the consequences.

Quality of Life: An important measure used to evaulate objective and subjective indicators of the life.

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Section 2

Economic Development and Sustainability

Chapter 5
Technologies for Food, Health, Livelihood, and Nutrition Security

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ABSTRACT

Intervention of various technologies to improve the food and nutritional status of the population proved the following facts: Promotion of malt based small scale food industry not only provides opportunity for rural women to develop entrepreneurship and employment, but also provides food and nutritional security through income generation. Several technologies were developed under NATP like value addition to fish and prawn products, artificial pearl culture, processing of salted fish, which helped the self help group women of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu to improve their economic status. Received two patents and licensed the technology which helped the women to reduce their drudgery and also preserve the fresh fish for a longer time without getting spoiled. Product development can be taken as income generating activity in the rural areas by the illiterate women. Products can be included in supplementary feeding programs in order to improve the nutritional status of the vulnerable groups of the population. The horse gram which is commonly used for cattle feed can be diversified for human consumption with less investment. Mothers as well as Anganwadi workers preferred amylase rich supplementary foods which reduced Grade 3 and grade 4 malnutrition in Preschool children significantly. The studies revealed that spawn multiplication can be done by women as a co-operative venture and mushroom cultivation can be undertaken at household level as an income-generating activity. Introducing red palm oil is beneficial to overcome vitamin A deficiency. Impact of women's supplementary income on family's nutritional status showed that the supplementary income of women has a positive impact on the socioeconomic status of the family. This impact is particularly felt on the food and nutrient intake of the family contributing towards food and nutrition security.

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INTRODUCTION

Agriculture retains the dominant role in Indian economy even after 65 years of independence-contributing 14% to Gross Domestic Product (GDP); providing 60% of jobs and 70% of primary source of income in rural areas. Agriculture contributes to development as an economic activity, as a livelihood, and as a provider of environmental services, making the sector a unique instrument for development. Climate change, environmental degradation, rising competition for land and water, higher energy prices, and doubts about future adoption rates for new technologies all present huge challenges and risks that make predictions difficult. Despite rapid strides in the agriculture front, still there exist many grey areas which require immediate attention. Favorable policy environment for maximizing the benefits from technological and developmental interventions. The following are some of the issues and areas, where clear and pro-growth policy directions are important to sustain farming and the farmer.

The concept of food and nutrition security implies that every individual has the physical, economic, social and environmental access to a balanced diet that includes the necessary macro & micro nutrients, safe drinking water, sanitation, environmental hygiene, primary health care and education so as to lead a healthy and productive life. A sustainable national nutrition security system should address the three issues of availability, access and absorption. The decline in per capita food grain availability and its unequal distribution have serious implications for food security in both rural and urban areas. The world will have to produce 60% more food than it currently does, while coping with the negative impact of climate change and increasingly degraded soil and water resources. On top of that, in spite of good progress, 800 million people remain undernourished in the most basic sense, in addition to serious micronutrient deficiencies and growing obesity. Achieving sustainability in food and agriculture is a major global challenge and necessarily a long – term process. It must be underpinned by the best available science and it requires conviction, political commitment, knowledge and people's participation- which is often lacking. There is also increasing demand for diversified production. By 2030 in India, cereal demands expected to grow by 11%, but demand for vegetables will grow by 37%, Milk and dairy by 52% and poultry by over 100%. Innovation happens when individuals and groups adopt new ideas, technologies or processes that, when successful, spread through communities and societies. 21st century Agriculture will be knowledge intensive. Knowledge connectivity should there be a key component of Bharat Nirman, designed to provide a new deal for Rural India. There is a need for convergence and synergy among numerous initiatives of Central and State Governments in the area of ICT for good governess and development. The most recent estimates from FAO indicate that 840 million people do not receive enough energy from their diets to meet their needs. Grave consequences, including continued and sustained loss of productivity, permanent mental disability, blindness, depressed immune system function and increased infant and maternal mortality can result from micronutrient deficiencies. Supplementation is most appropriate for targeted population with a high risk deficiency or under special circumstances such as during pregnancy or in an acute food shortage. Nutrition literacy should be promoted at the school level. High priority should go to the elimination of iron deficiency anemia among pregnant women through fortification of salt and kitchen gardens.

Norman Borlaug, the architect of Green Revolution in Asia observed "High yield technology of the 60's, if fully exploited would help us succeed in our war against hunger by the end of this (20th) century. The balance sheet by end of the century, from food-nutrition security angle, is far from encouraging given that over 1.2 billion people around the world go to bed hungry – more than 1200 children die of malnutrition each hour and two billion women and children suffer from one or more nutrient deficiency related health problems. At the national level, India remains home to the largest undernourished and malnourished in the world. We account for one-fifth of the world's underfed. Over 7000 people die of hunger every day. Close to 70% of women and children suffer from hidden hunger. Ironically, India is the 11th largest and 2nd rapidly growing economy. No wonder, eradication of hunger became the one-point agenda of the four successive World Food Summits since 1974. India is the second most populous country in the world; 120 million women live in poverty. Over 70% of India's population - livelihood from land resources (includes 84% of the economically-active women). Population increased- from 1951- 361.1 million to 2011- 1027 millions; 933/1000 Female & Male sex ratio, 22.8% adolescent girls, 16% BPL families, 70% land based livelihood, 84% women agricultural laborers, 75% male and 54.2% female literacy (21.7% gap in literacy), 14% male and 15% female child labour, 54% child marriages, 65% hidden hunger among women and children. Gender disparities are present in nutrition from infancy to adulthood. Anemia in girls of 6-14 years is 95%. As per the National and Regional Survey, prevalence of anemia in 74% children below 3 years of age, in 85% pregnant mothers and among 90% of adolescents girls. India's maternal mortality rate in rural areas is highest in the world. Antenatal care - 40-50% of women, pregnancy related deaths- one-quarter of all fatalities. In gynecological disorder 92% suffered from one or more. Most vulnerable sections are adolescent girls, pregnant and lactating mothers, and underweight children under five age. Receive far less education than men; largest population of non-school working girls. Literacy rate for women is 39% versus 64% for men. Encouragement to private colleges will reduce women's opportunities for higher education, since privatization in education promotes only male-dominated professional and technical courses. In sex-selective abortion, 96% of female fetuses were aborted.

INDIA IS A STRATEGIC PLAYER IN THE WORLD IN THE FOOD SECTOR

India is the second largest producer of fruits and vegetables next to China, Second largest producer of wheat, Third largest in food grains (210 million tones), largest exporter of cashew nut in the world (Amounts 43% of world production), Fifth largest producer of eggs, largest producer of milk (91 million tonnes). Working conditions result in premature and stillbirths, impact of air and water pollution and lack of sanitation. The Food and Agriculture Organization of the United Nations (FAO) estimates that 32% of all food produced in the world was lost or wasted in 2009. This estimate is based on weight. When converted into calories, global food loss and waste amounts to approximately 24% of all food produced. Essentially, one out of every four food calories intended for people is not ultimately consumed by them.Food loss and waste have many negative economic and environmental impacts. Economically, they represent a wasted investment that can reduce farmers' incomes and increase consumers' expenses. Environmentally, food loss and waste inflict a host of impacts, including unnecessary greenhouse gas emissions and inefficiently used water and land, which in turn can lead to diminished natural ecosystems and the services they provide.

India is the second most populous country in the world. 120 million women live in poverty. The livelihood of over 70% of India's population is derived from land resources (includes 84% of the economically-active women). The population increased from 1951 at 361.1 million to 1027 million in 2011; 933/1000 Female and Male sex ratio, 22.8% adolescent girls, 16% BPL families, 70% land based livelihood, 84% women agricultural laborers, 75% male and 54.2% female literacy (21.7% gap in literacy), 14% male and 15% female child labour, 54% child marriages, 65% hidden hunger among women and children.

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As per the recent UN report, India surpasses China in terms of food waste and its impact on natural resources. One in eight persons in the world does not get adequate and healthy food. Apparently, hunger is more of a health risk compared to the commonest diseases like malaria or tuberculosis put together.

Poverty and Nutrition: Background

Indian women in poverty spend about 5 hr per day more than Indian men in work. Taking the economy as a whole, women perform two-thirds of the work, but earn only one-tenth of the income. More than 250 million children in developing countries are at risk of vitamin A deficiency, more than 2000 million women and children are at the risk of iron deficiency, and more than 1500 million people in the World are at risk of iodine deficiency as per the FAO report. The cost of treating malnutrition is 27 times more than the investment required for its prevention. The annual wastage of agricultural produce is almost 30% and equivalent to Rs. 580 crores (5.8 billion), due to inadequate storage and processing facilities. According to India's 3rd national family health survey regarding nutrition for children below 5 years age: 48% are stunted; 20% are wasted; 43% are under weight; 70% are anemic; 50% have a vitamin A deficiency and 75% an iodine deficiency. India has not achieved acceptable child nutrition levels.

People in 33 countries consume fewer calories than required. Food insecurity is due to a lack of access and mal distribution. The World Health Organization (WHO) and World Economic Forum reviled that India will incur an accumulated loss of $236.6 billion by 2015 on account of unhealthy life styles and faulty diet. Food security should address the issue of quantity as well as quality. A balanced diet should supply the required quantity of energy, protein, vitamins and minerals at household and individual level and not stop at calorie sufficiency at national level as is being done in India. India is a country in developmental transition. It has double the burden of disease, pre-transition diseases- under-nutrition, and communicable diseases and post-transition diseases- over weight/ obesity, hypertension, diabetes, cardiovascular diseases, etc. Under-nutrition contributes to both. Nutrition is the fundamental basic requirement for positive health, functional efficiency and productivity. Nutrition science provides abundant evidence of the importance of nutrition not only in promoting proper physical growth and development but also ensuring adequate immune-competence and cognitive development. For a nation to be healthy, strong and productive, the nutritional status of its people must be good. Good nutritional status can be achieved if the community is educated about the way and means for achieving.

In spite of the progress that the country has made in different fields and the explosion of information through various media, the current scenario of nutritional status of the vulnerable sections of the community in India is quite disturbing. An important factor that has led to this dismal situation is the very little involvement of the community in the activities related to nutrition and health. Malnutrition is a public health problem that can be eliminated by various means, such as multimedia, nutrition education efforts, economic aid and food program for the low income groups of society. Adequate information regarding nutrition could lead to many benefits for the people. Nutrition education assumes special significance in the Indian context, because the problem of malnutrition in India is mainly due to ignorance, poverty and lack of knowledge. Knowledge of nutrition is of immense importance for one and all for leading a healthy life.

FAO's Overall Policy to Improve Nutrition

FAO's efforts to improve nutrition worldwide are guided by the recommendations made during international meetings and conferences including FAO and WHO international conferences on nutrition and the world food summit.

Economic growth in India has failed nutrition. At current rates India will not meet the millennium development goal until 2043, and not 2015 as planned. China has already met its 2015 target. China has reduced child under-nutrition by more than half (from 25% to 8%). Brazil has reduced child under-nutrition by 60% (from 18% to 7%). Thailand has reduced child under-nutrition by more than half (from 50% to 25%) Viethnam has reduced child under-nutrition by 40% (from 45% to 27%). Reducing malnutrition is not just about health, agriculture and economics, but it also accounts for politics, governance and power.

The Indian National Nutrition Policy (1993), National Nutrition Plan of Action (1995) and National Nutrition Mission (2001) have not achieved nutrition goals. The reason is nutrition is a poor cousin even in health and agriculture planning and execution. Nutrition improvement is not a stated goal with measurable parameters in National Food Security Mission, National Horticulture Mission or National Rural Health Mission.

Since the chapter deals with the technology for food security, nutrition security, health security and livelihood security, it deals with product development for livelihood and nutritional security; women empowerment for food security; rural development and people participation are discussed in this Chapter.

Product Development Contributes Livelihood and Nutritional Security

A process on home based low cost energy protein-rich preparations using horse gram for vulnerable groups (Vijayakhader and Ashlesh, 1998) reveals that the horse gram which is commonly used for cattle feed can be diversified for human consumption with less investment. Processed horse gram flour was prepared using puffing and roasting, processed soybean flour was prepared by dehulling and roasting. The low cost energy protein rich products namely RAGINA and EPRF were prepared using the simple home scale processing methods like germination, roasting and puffing, to improve the nutritional status. Horse gram has been identified as potential food resource for the tropics and also occupies an important place among pulses because of its ability to resist severe drought conditions. Soya bean (*Glycine max*) is one of the best vegetable proteins and has tremendous potential to meet the protein deficiency in the cereal based Indian diets at a low cost. Product development can be taken as income generating activity in the rural areas by the illiterate women. Products can be included in supplementary feeding programmes in order to improve the nutritional status of the vulnerable groups of the population.

The effect of iron enriched chewing gum/bubble gum consumption on iron nutritional status of anemic adolescent boys and girls aged 12-16 years (Vijayakhader and Shoba, 2008) was studied. This project was taken up to test if a commonly consumed product like fortified chewing gum could be given to overcome iron deficiency among adolescents. Results showed to improve the iron nutritional status of 60 boys and 60 girls aged 12-16 years at Kondurgu village of Mahabbobnagar district. The study protocol was approved by the institutional ethical committee of the college. Children were given either unfortified or fortified chewing gum thrice a day and the iron nutritional status was measured at three points of time at base line ; mid point and end point in a study period of 180 days. The consumption of fortified chewing gum improved the hemoglobin levels.

Vijaya Khader and Umamaheswari (2012) studied the effect of malted food on the nutritional status of vulnerable groups. Two types of Amylase Rich Malted Mixes (ARMM) were formulated using ragi / Wheat and suitable products namely *Laddu, Roti, Kheer, and Porridge* were prepared using formulated malted mix. The ARMM's found to be nutritionally dense. For the supplementation of malted mixes, eight villages of Lepakshi mandal in Ananthapur district were selected. Preschool children (400), pregnant women (100) and lactating women (100) were selected and fed with two types of malted mixes (ragi/ wheat) for a period of three months. Anthropometric data and food intake showed a significant increase in the preschoolers, pregnant women and lactating mothers. Clinical assessment showed considerable reduction (50%) in nutritional deficiency symptoms and morbidity rate of all the subjects. Training programmes were provideded to 40 members by lecture and method demonstrations using developed education material such as posters, flip book, manual and CD-Rom. After the training 60-70% improvement was observed in knowledge, attitude and practice scores of the trainees, project profile for bulk production was also developed. Supplementation of ARMM's helped to improve the nutritional status of the vulnerable groups of population in rural areas especially with regard to protein, energy, iron, and calcium and B-complex vitamins. Promotion of malt based small scale food industry not only provides opportunities for rural women to develop entrepreneurship and employment but also provided food and nutritional security through income generation. The then Honorable Minister for Agriculture Dr. N. Raghuveera Reddy was very much impressed and interested to introduce ARMM in the on going ICDS supplementary feeding programmes based on research results.

Yasoda Devi and Vijayakhader(2004) carried out a study on 2267 children of ages ranging 1-3 years (892 children from rural ICDS project, Saravakota; 507 children from new ICDS project, Kottem; and 778 children from tribal ICDS project, Seethapeta) for a period of 1 year. The three types of supplements were prepared and distributed by A.P. Foods, Hyderabad. The supplements were distributed either in the form of Laddu or as in the form of powder. Nutritive value of 100 g of the supplement provided was 400 to 480 Kcal with 12.5 to 13.8 g proteins. It was very encouraging to note that 92% of grade III children showed improvement in their weight and height. 80% of moderately malnourished, 42% of mildly malnourished and 44% with normal grade showed improvement. It was also observed that there was positive correlation between the calorie and protein intake and also improvement in weight and height. All the mothers as well as Anganwadi workers preferred these supplementary foods as compared to earlier supplied ready to eat food.

Socio Economic Empowerment of Women for Nutrition Security

Economic empowerment of women has been a highly debated topic all over the world over the last few decades. It is well known that women play a key role in all spheres of development. Although women contribute significantly for overall development of mankind and economic development of nations, there is a dearth of hard facts and figures.

India has tremendous potential for developing coastal aquaculture and is now the sixth largest producer of fish in the world. In land fish production, it receives the second position after China. The coastal fishermen have been one of the most vulnerable groups among the poor in India. The seasonal character of their vocation and its hazardous implications coupled with uncertainty of catches casts shadow on their limited livelihood opportunities compounding its cascading effect on their poverty profile. Fisher women often occupy marginal roles and live and work on the periphery of the centres of economic, social and political power. They tend to be especially vulnerable. The basic goal for women in fisheries development is to make them equal partners and productive and self- reliant participants in the process of improving their own and their families nutritional and living standards and to enable them to realize their full potential as human beings in their own right as members of their family and community.

Fisher women must be given the opportunity to acquire appropriate knowledge, develop adequate skills and use appropriate technologies enable them to make the greatest possible economic and social contribution. Studies on fisher women in the coastal eco system of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu (Vijaya Khader *et.al.* 2004) were conducted in 13 districts covering 28 coastal villages and 5744 households based on their method of fishing- mechanized, motorized, non-motorized. The socio economic status of the fisherwomen in the selected states with respect to housing pattern, literacy level, essential amenities like drinking water and electricity is good. Regarding the income generating activities, fisheries are the only source and thus they run a high risk of going out of employment if the fisheries fail. They also do not know any other vocation and do not develop an interest in an alternative source of income unless motivated and supported. Their standard of living is comparatively at a lower level indicated by the higher Engel's coefficient and low rate of savings. Their level of indebtedness is also high because of the low income factor. Their dependency on non–institutional sources for loans is driving them to the brink of insolvency. Hence, there is a need for a comprehensive plan for overall development of the sector.

Cereal consumption was high in Andhra Pradesh followed by Kerala, Karnataka, and Tamil Nadu. Pulse consumption was high in Kerala when compared to other states. The overall energy intake of the fisherwomen was 1827 K.cal/day, protein intake was 50.6 g/day, carbohydrate intake was 343.5 g/day and fat intake was 27 g/ day. The mean intake of micronutrients was less than the recommended dietary allowance. The mean body mass index was 21.3. The nutritional status of 49% of the women was normal, 17% were below normal, 10.5% were mildly malnourished, 4% were moderately malnourished, and 2.9% were severely malnourished. Of the cases studied, 11.5% of the fisherwomen were overweight and 4.6% were obese. Sub samples of 915 women were clinically observed: 34.8% were diagnosed with angular stomatitis, 31.0% with chelosis, 42.8% with bleeding gums, 44.2% with dry skin and 72% of the women were anemic. The assessment of the socio economic status indicated that very few households (15.41%) maintained livestock for domestic support and were wage earners (Vijaya Khader and Sudhakara, 2005; Vijaya Khader *et.al*. 2005).

Two equipments have been fabricated, a low cost ice cream freezer (for nutrition and health security) and multipurpose fresh fish vending and display table (to reduce the drudgery), and have received patents and been licensed to a women entrepreneur. These equipments were fabricated mainly to improve the health security and to reduce drudgery of the fisherwomen. The post–harvest fisheries sector could provide maximum employment to women. Information from the study villages show that the common occupation in which women engaged are beach work, small scale fish trading, fish curing/drying/net making/peeling and processing plant work.

Figure 1. Low cost ice cream freezer

Figure 2. Freezer multipurpose fresh fish vending and display table

Ice cream, the most favorite delicacy of all age groups, needs processing before it reaches our plates. A small effort was made to ease the laborious process of the cream making to a simple method - a low cost ice cream freezer. It consists of a stainless steel shaft carrying a set of blades, rotating inside the steel mixing cylinder and to scrape off the thin film of the frozen cream formed on the inner walls of the cylinder and at the same time thoroughly mixes the ice cream formed. This instrument contains an agitating mixing assembly, cooling chamber, mixing chamber, chasis frame and prime mover or motor.

The multipurpose fresh fish vending and display table has an ice box for storage and has the facility to cut and wash the fish. After washing the fish the water enters into the plastic bucket. A cash box has been arranged to store the money. A chair for sitting and an umbrella also has been arranged for protection from the sun. Hygienic handling, quick and effective chilling and prevention of cross contamination will ensure supply of high quality fish to consumers.

Food and Nutrition Security Is Very Much Needed in Emergencies

A major food shortage can be a primary feature of an emergency, as in droughts or floods that lead to famine, consequence of war, economic disaster or population displacement. The often serious protein-energy malnutrition and micronutrient deficiencies that inevitably follow such shortages add greatly to the burden of disease and mortality.. A food supply should be adequate to cover the overall nutritional needs of all population groups in terms of quality, quantity and safety. In emergency situations, where populations are dependent on food assistance, an adequate food ration would meet the population's minimum energy, protein and fat requirements for survival and light physical activity. An adequate food ration is also nutritionally balanced, diversified, culturally accessible, fit for human consumption and suitable for all sub-groups of the population.

Vijaya Khader et al. (2005) showed that fish eaters in their study area comprised 47% of the total population ranging from 37% in Tamil Nadu to 85% in Kerala. Though the position of Tamil Nadu in terms of number of coastal districts and possession of coast line including the number of landing centers is enviable, the number of fish eaters in the state is minimal. Andhra Pradesh employs 32% of its fisher-women in fish curing, drying and net making and 27% in processing plant works.

Success Stories of Seven Fisher Women From Kerala, Karnataka, Tamil Nadu and Andhra Pradesh Based on Intervention of Simple Technologies

It is well known that poverty, hunger and malnutrition are comparatively more among coastal fisher folk. Coastal fisheries being common property resources, stake holders in the upper strata with better equipment and facilities are empowered to earn higher income which is further widening the gap between the rich and poor. The unequal distribution of income coupled with illiteracy and lower socio-economic status leads the fisher families into this deplorable situation.

The National Agricultural Technology Project entitled Studies on Fisherwomen in coastal ecosystem of Andhra Pradesh, Karnataka, Tamil Nadu and Kerala explored the socio-economic status of fisherwomen and found families wherein women are actively involved in one or other occupation have flourished and achieved all round development. Three such cases in the southern coast of Kerala, two in Karnataka, one from Andhra Pradesh and one from Tamil Nadu are highlighted below.

1. **Mrs. Thressia:** A successful clam processor cum-vendor at Thekkumbhagam in Kollam District in Kerala could earn an amount of Rs. 10000/- month from clam processing and vending. This income supplements the income of her husband from fishing activities. Her message to the society is if hard work and perseverance is there, women can reach to any level.
2. **Mrs. Amalorphavam:** An enterprising fish vendor at Poovar in Thiruvananthapuram District from Kerala is a member of Self Help Group of Poovar and commanding reasonably good respect among the neighborhood. Amalorphavam is a happy woman now and strongly suggest that woman in fishing villages can easily take up fish trade or dried fish trade as an occupation.
3. **Mrs. Bhageerathy:** Fishing cum-marketing as a family enterprise from Kerala states that women in fisheries sector can always play a key role to supplement the family income. They can always promote the habit of savings and this will help the family to tide over the lean season and also make appropriate productive investment. She feels that fish trade always form the easiest and alternative employment avenue for fisherwomen of coastal region.
4. **Smt. Banumati:** From fresh fish vending to ice plant ownership from Karnataka states that the high demand for fresh fish in Kerala State made her to expand her territory as far as Kasargod, Cannonore and Calicut. The demand and cost of ice was high. This made Banumati to think about starting an Ice factory. Though she was reluctant initially, with encouragement from her family members and bank, she established "Gajanana Ice and Cold Storage" with a capacity of 15 tones per day at Hoige Bazaar about 2 kms from Mangalore fish landing center. Smt. Banumati attributes her success to hard work and her will to cross all hurdles with a desire to earn more.
5. **Smt. Hemavathy Puthran:** From Karnataka stresses following the footsteps of her mother in dried fish marketing traditional processing of fish by her mother Sheshamma. Since then she is processing all types of fishes. Fish varieties mostly used by her are Mackerel, Sardine, Soles, Anchovies, Small size Shrimps, Silver belly and Lizard fish. Hemavathy feels happy. By following the footsteps of her mother she has achieved what she wanted and she is proud of her profession as she could give employment to five members.
6. **Smt. P. Roopavathy:** Kovalam fishing village, Kanchipuram from Tamil Nadu studied up to eighth standard and she had an opportunity to work as an enumerator for a research project of the institute. At that time, her talents were identified by the Project Leader who initiated the Survey. She was motivated to form a Self Help Group comprising women of similar interest. But the picture was not rosy and there were many objections to her. But she overcome the objections with the help of the awareness meetings organized by Dr. H M Kasim, CCPI, Chennai about the importance and advantages of the Self-Help Groups. Now, many women joined the SHG and Smt. Roopavathy became a trusted leader of that group and she is the Secretary of the Self Help Group. Thus a shy and introvert Smt. Roopavathy has transformed herself into a leader and organizer which not only helped to improve the socio-economic status of her family and also of other members of her village. Yet it is very much fitting here to quote her as one of the role model for the fisherwomen.
7. **Smt. Gapala Pentamma:** Mypadu of Uppada hamlet of Kakinada from Andhra Pradesh started a small net making unit in her hut by employing three fisherwomen at a wage rate of Rs.40 per day. Her interest, hard work and motivation by the Institutional Organizations saw her emerge as a successful entrepreneur from an average individual. She has some aspirations like diversifying her enterprise in value added fish products after getting trained in that field. She is also seeking financial help to attempt the new ventures.

The above fisherwomen attained training and awareness from the National Agricultural Technology Project, implemented in their places and enhanced their socio-economic status through various skill oriented training programs and continuous day-to-day discussions with the scientists.

Nutrition Education as a Tool to Improve the Nutritional Status of Tribal Women

Tribal's are free living population inhabitated in remote forest area and high altitude, many a time untouched by the civilian communities. They are known for their peculiar lifestyles and it is difficult to influence them. Andhra Pradesh is the seventh largest tribal populous state in India. Tribes are distributed in three principle territorial zones, namely North Eastern Zone, Central Zone and Southern Zone. They live in certain definite areas, with different dialects, cultural homogeneity, and unifying social organizations. Nutritional status of any community is influenced by interplay of various factors including beliefs, customs, food stuff availability in the region. This will in turn influence the physical growth and nutritional status of the community. This is all the more relevant in the context of tribals as they have more bondage with their traditional food practices and values.

Traditional food practices, poor sanitation, non utilization of available food resources, poverty illiteracy and poor hygienic condition have a detrimental effect on their nutritional status. Food taboos such as consumption of milk and milk products are taboo among most of the tribals of Andhra Pradesh. Milking of cows is a taboo among many tribal groups, hence, their foods are grossly deficient in animal protein, fats, and vital nutrients like calcium iron and vitamin. Prior to 1970, most of the nutritional studies among the tribal groups were limited to gathering of quantitative information on food intake for consecutive days, taking the household as the unit. Magico-relegious beliefs and food taboos tend to aggravate the nutritional disorders (Thomas, 1992).

Many studies on nutritional status of tribals show high incidence of malnutrition (Gopalan 1971; Ali 1992; Basu et al. 1990). Ali (1992) found ecological imbalances caused by rapid deforestation. This study attempted to assess the nutritional status of tribals in two different regions of Andhra Pradesh state through Gomez classification method. To calculate calorie intake, 24 hour recall method was adopted and compared with Indian Council of Medical Research's recommended dietary allowances. The combination of food scarcity, imbalanced diet, poor purchasing power, monotonous food habits and ignorance about locally available food values are major reasons for this widespread malnutrition. The monotonous food habits of tribals and poor absorption of nutrients is another reason for this malnutrition. On the basis of geo ethinic characteristics, the tribal areas of AP can be divided into the following five geographical regions:

Another study was conducted in the Gond-Kolam region, which includes the 33 scheduled tribes with a population of 41, 99,000 as per census, forming 6.3% of the total population of Andhra Pradesh. Nutrition and health status of tribals in Bhadragiri tribal block in the Vijaynagaram district and high altitude and tribal area zone in Chinthapalli (Visakhapatnam district) were selected for this study. Adults (men and women), boys and girls and children between 4-12 years of age in both the blocks were selected. Food intake, nutrient intake, anthrpomomatic measurements of children, nutritional grades as per the Gomez classification and Waterloo's classification clinical signs of malnutrition were carried out. Food and nutrient intake of tribal's in Bhadragiri block indicate expect millets, cereals and other vegetables the intake of all other foods in the dietaries were found to be considerably lower than the recommended allowances. The calorie intake of adults was more than the RDA due to higher intake of cereals and millets. Similar pattern was observed in boys and girls as well as in children. The cereal intake by the children was double the RDA irrespective of the age group. The intake of pulses and other vegetables were close to RDA. Pulse intake was deficient by 43 to 75%, consumption of all other foods were much below the recommended dietary allowances.

In anthropometric measurements of children belonging to high altitude and tribal area zone in Chinthapalli, 39 to 100% of boys and 33 to 58% of the girls in all age groups were found stunted as per the height for the age. When assessed according to weight for height, 6 to 15% among boys and 11 to 33% among girls were found wasted indicating severe malnutrition. In the Bhadragiri area the children were suffering with nutritional deficiencies in all age groups. A majority of children were suffering from protein energy malnutrition (PEM) and anemia, Vitamin A and B complex deficiencies were also found in some children. Night blindness anemia, angular stromatitis and xerosis of the skin were also seen.

Food and nutrient intake of tribals in Bhadragiri in Vijaynagaram district reveal the mean food and nutrient intake by tribal adults as well as children of 4-12 years. Expected millets and cereals intake of all other foods in the dietaries of tribal children were found to be considerably lower than the RDA. The tribal populations are recognized as socially and economically vulnerable. Their lifestyles and food habits are different from that of their rural neighbors. They depend on minor forest produce and manual labour for livelihood. They may not have adequate income. Their food consumption pattern is dependent on the vagaries of nature and varies from extreme deprivation (in the lean seasons) to high intakes (in the post-harvest period). Higher prevalence of under-nutrition in tribal population is due to:

- Poverty and consequent under-nutrition;
- Lack of awareness about, access to and utilization of the available nutrition supplementation programs;
- Social barriers preventing the utilization of available nutrition supplementation programs and services;
- Poor environmental sanitation and lack of safe drinking water, leading to increased morbidity from water-borne infections;
- Environmental conditions that favor vector-borne diseases;
- Lack of access to health care facilities resulting in increased severity of health problems.

Creating Awareness to Improve the Health Status of Tribal's of Chinthapalli Block

Health problems of the tribals are related to number of factors which include illiteracy, ignorance of the disease and its prevention, poverty, poor nutritional status, poor environmental sanitation and poor personal hygiene, and non-availability of safe drinking water which make people more vulnerable to infections (Vijaya Khader et. al,1996). Superstitions and beliefs add to the health problems and complicate the situation. Malnutrition leading to tuberculosis and goitre are major disease in tribals. Vomiting; diarrhoea and consequent dehydration are causes for death among infants and children. Skin diseases,especially scabies and heat boils, are common.

Nutrition Education as a Tool to Indicate the Importance of Food to Tribal Mother's Attitude Towards Lactation Performance

Tribal women are mostly involved in food preparation (25%), whereas men are involved in occupational activities. A majority (85%) of tribal women do not feel a necessity to take special care about nutrition because they were lactating (Vijaya Khader, et.al, 1996). A majority of mothers (66%) were aware of the reason for decrease in lactation performance. Only a small number of mothers (5%) knew that sickness and insufficient food (2%) played a role in decreasing the lactation performance. As nursing mothers, they do not receive any special attention from the family members regarding the additional intake of food. A positive change was observed in lactating mothers through nutrition education.

Rural Development for Food, Nutrition and Health Security

It is well known that the role of women in agriculture and allied areas is multifarious, enormous and crucial for food security, specifically for nutrition security. There is no field of operation where women are not involved. While the achievements on the development program for women are taking positive strides, the pitfalls due to low or no access to training and technology have always been impediments in their development. If women are to contribute as equal partners in development, there is every need to understand their roles as providers and conservations in all fields of their participation, seasoned with appropriate empowerment. Concerted efforts are lacking to reduce their drudgery for better time utilization, access to resources and decision making at all levels for socioeconomic development of family, community and society at large. Though this fact has been realized late in the millennium, it is necessary that such an environment be nurtured and nourished in this new millennium by addressing their needs, issued by all possible means. The developmental status of women should be well linked with the health, food and nutritional security, and economic empowerment. It should help women in upgrading their skills and equipping them for an effective participation in all economic fields.

Gender equality and women's empowerment are not alien concepts to us. Indeed, in ancient times, women in India had a status that was by no means inferior to that of men; on the contrary, in many matters they had an upper hand. Hindu scriptures say '*Janani Janmabhoomischa Swargadapi Gariyasi*' (The mother and motherland are better than heaven).

Women are handicapped by unequal access to political, social and economic resources. This in turn has resulted in low levels of female literacy, high levels of infant morality and poor nutritional record. The continually declining sex ratio is not only disturbing for demographic purposes but also because it reflects the status of the girl child. On its part government will soon unveil a national policy for empowerment of women. This was a commitment India made at the fourth international conference of women at Beijing in 1995 Let this year mark the beginning of a new era of equality and opportunity for women in India and all over the world.

Uma Maheswari and Vijaya Khader (2001b) studied the effect of Jawahar rojgar yojana (JRY) program during lean season on the nutritional status of women in landless labour families of drought prone areas. The study was conducted in eight villages of four interior mandals having low rainfall (500-750 mm) in Ananthapurum, a drought prone district of Andhra Pradesh. A household survey was conducted to screen the families having at least one women of child bearing age from the eight selected villages of the four mandals. A total of 120 families were selected for the study of which 60 families were JRY beneficiary families' where at least one member of the family was being employed under JRY scheme and 60 families were non-JRY beneficiary families. The study showed that the additional income gained by the landless labourer families during the lean season from JRY programme had beneficial effect on the nutritional status as assessed by the anthropometric measurements as well as clinical observations. The results indicated the past malnutrition status of the population in Ananthapur district because of the repeated and prolonged droughts (Uma Maheswari and Vijaya Khader, 2003). Two rounds of survey were conducted to understand the difference in coping mechanisms operating between peak and lean seasons. The study centered around the empirical examination of eight major groups of coping mechanisms comprising of land, livestock, economic, food procurement and production, food consumption and distribution, food storage, social and health based mechanisms adapted by the families. The various economic activities under taken by the women in the study area included agriculture, agriculture labour, basket making, beedee making, brick making, broom making, cattle rearing, firewood collection, flour mill, fodder collection, forest produce collection, goat / sheep rearing, laundering, mat weaving, non-agricultural labour, petty trade, pottery, poultry rearing, ring making, sericulture, tailoring, tamarind peeling, vegetable vending and weaving clothes, etc. Most often children,especially girls, were involved in home based trades like groundnut shelling, beedi making, tamarind peeling, etc. A few of the mechanisms were found to be beneficial and can be encouraged.

Every woman is an entrepreneur as she manages, organizes and assures responsibility for running her house. It has been increasingly realized that women possess entrepreneurial talent which can be harnessed to create employment opportunities. Rural women as entrepreneurs in mushroom cultivation revealed a woman can easily manage 4-10 beds depending on the space available, helping them to earn Rs.180 to Rs.450 per month (Vijaya Khader, 1994). The results of the studies revealed that spawn multiplication can be done by women as a co-operative venture and mushroom cultivation can be undertaken at household level as an income-generating activity.

The increase in the annual per capita income of the family increased slightly the nutritional status of pre-scholars. The results also reveal that no significant difference was observed between the body weight of children and income of the parents in all the age groups. In spite of having high purchasing power, lower educational status of the mothers and also low nutritional awareness, majority of the children are in Grade 1 degree malnutrition (Vijaya Khader and Kavitha, 1993).

Transfer of home level preservative techniques of selective fruits and vegetables to rural women in Guntur district showed a significant, negative correlation between age of the respondents and gain in knowledge (Vijaya Khader and Bharathi, 1994). There was a significant positive correlation of socio economic variables such as educational status, family income, and land holding on gain in knowledge. Vitamin A deficiency causes many health problems especially among children. A study was undertaken to screen the effect of supplementation of Red Palm Oil (RPO) obtained from the fruits of tree Leis guineensis Jac.The oil is rich in β-carotene, a precursor of Vitamin A (Vijaya Khader and Aruna, 2008). Operational feasibility of RPO supplementation to pre-school children in anganwadi centers of ICDS project showed supplementation of crude RPO to anganwadi children increased the attendance of children, increase in heights and weights of children. Decrease in grade 2 and Grade 3 malnutrition was observed in respect of sex.

Studies on nutritional awareness of mothers and child mortality rate in selected urban slum and rural areas of Guntur district (Vijaya Khader,1996) with a sample of 1200 pro- school children of one to five years in 3 divisions of Guntur revealed that majority of the selected children in Guntur and Narasaraopet divisions were fed immune rich first breast milk colostrums and introduced the weaning foods (rice gruel) at the age of 6-8 months. The child mortality rate was observed more in Narasaraopet division as compared to Tenali and Guntur divisions. Majority of the mothers possessed medium level of nutrition knowledge which is directly influenced by the economic status of the family. The study clearly indicated that the socio economic status and literacy rate has got influence on the nutritional awareness of the mother and nutritional status of pre school children in selected urban slums and rural area of Guntur District.

A study was carried in 4 villages of Rajendranagar mandal and Ranga Reddy district on vegetable venders, agarbathi labourers, shopkeepers, washers, fruit venders, tea and snack workers to see the impact of women's supplementary income on families' nutritional status (Vijaya Khader, 1999). The results revealedthat the supplementary income of women had a positive impact on socio-economic status of the family. This impact was felt on more food and nutrition intake of the family, due to the additional income of the women.

The dairy program in Kenya has a significant impact on the overall improvement of the family specific to improving production, consumption and marketed surplus of milk (Mary Khakoni Walingo and Vijaya Khader, 2000). Food and nutrient intake and nutritional status of women and preschool children from participant households improved. The prevalence of under-nutrition in pre school children in participant households was lower (1.7%) than that of children in non participant households (2.9%). Stunting was 8.7% and 21.4% in preschool children from participant and non- participant households, respectively. Less percent (6.7%) of women in participant households had body mass index less than 18.5, whereas, 7.3% of women from non-participant households fell below this cut-off point.

Participation for Livelihood Security

Almost all the foods meant for human consumption are perishable in nature. Food commodities start deterioration immediately after harvesting. A significant quantity of produce is lost each year due to improper post-harvest management procedures. Today we are facing with an enormous problem of feeding the population. The problem of un employment amongst the educated youth leads to unrest in the society, which is not conductive for a developing country like India. In developing countries, agriculture is the mainstay of economy. Hence, it is no surprise that agricultural industries and related activities can account for a considerable proportion of their output of the various types of activities that can be termed as agriculturally based and fruit and vegetables are among the most important. The advent of food preservation is probably as old as human race itself. The preservation and storage of foods, an important factor involved in the technology of food preservation and processing is one such area which needs to be taken up priority (Vijaya Khader and Vimala, 1999).

Ushering in the green revolution has led to spectacular increase in food-grain production. India can take legitimate pride that it has achieved food security. How ever in view of lack of adequate purchasing power for a segment of population this is still a dream which has to be fulfilled. The major emphasis now is on achieving both food and nutritional security. If purchasing power of the masses could be enhanced it would automatically lead to nutritional security. In this respect it is important to take advantage of science and technology for bringing economic prosperity to the masses. Since income generation is a key to food and nutritional security, all-our efforts need to be made for using and popularizing technologies that can lead to income generation. The major objective of food technology is to convert foods into consumable forms. In India, agro foods worth more than Rs.62,000/- crores are converted annually into processed foods. Raw foods have to be processed either using simple techniques or elaborate procedures before they could be marketed for consumption. In spite of the vast agro-based industry, only 12% of the raw material is being processed in our country as against 64% in U.S.A.

Currently, food processing and associated quality assurance programs are undergoing revolutionary changes because of possibility of global marketing of foods and establishment of WTO General Agreement on Tariffs and Trade (GATT) and Sanitary and Phytosanitary (SPS) Measures and the Agreement on Technical Barriers to Trade (TBT). It has been observed that food preservation units have come up everywhere, as they contribute proper utilization of foods and prevent wastage, meet the needs of the people in secluded and difficult areas, and ensure the supply of the protective foods in homes and hotels. Over one-half of our population is in the age group of 20-35 and are underutilized human capital in rural areas. Youth in rural India account for 296 million, compared with 131 million in urban India. The majority of this human resource remains under utilized. Our failures to create rural bio-resources based employment opportunities and develop appropriate skill in them continued to be the reason for mass exodus of young people from rural areas to urban areas.

Today food processing business globally is an entirely sophisticated, capital intensive, technology driven, and management rich enterprise which demands not only excellent expertise but also protecting intellectual property involving merging of knowledge and brain power. India has been the focus of food processing industry world over, as India itself is a market and secondly India is rich in agri resources. Value addition to agri-resources is the key factor for an economic viability of a food processing industry. This could also include extension of shelf life of agri-resource products. Some of the technologies developed by the Department of Foods and Nutrition, Acharya N.G.Ranga Agricultural University for improving the livelihood security of the common man are given in a book entitled Income Generating Viable Technologies for women (Vijaya Khader and Vimala, 1999). They include: Agro huller for millets and legumes; processing of sorghum – scope for diversification; geriatric foods; malted infant food; pushti; Cerefica-an infant food; low calorie, high fiber mize biscuits ; high fiber vermicelli; papaya; preservation techniques for storage of palmyrah fruit; value added products with watermelon rind and oyster mushroom cultivation. These technologies can be further classified as:

- **Entrepreneurship Technologies** (sorghum food enterprise, geriatric foods, malted infant foods, high fiber vermicelli, preservation of palmyra palm fruit, mushroom cultivation.)
- **Knowledge Empowerment Technologies** (multipurpose fresh fish vending and display table, low cost ice-cream freezer.)
- **Value Addition Technologies** (value addition to fruits, value addition to red palm oil, fruit powders, horse gram products and soya products.)

IMPACT OF RESEARCH/SUMMARY

Based on work carried out by Vijaya Khader, the Commissioner of Horticulture issued the unit cost for Oyster Mushrooms cultivation at Rs. 70,000 by the National Bank for Agriculture and Rural Development (NABARD) and implemented from 1st August 1994 onwards and many people have availed the benefit. 41 families have established mushroom cultivation in Guntur. Prakasham and Krishna Districts of Andhra Pradesh. 10 families have taken fruit and vegetable processing at village level; 3 families have adopted the technology of Dehulling jowar and preparing value added products; 10 self help groups have been organized at Karnataka and Kerala are mainly involved in various income generating activities. Mrs Laura Bush, the First Lady of USA had discussions with Mrs. Khader on 3rd March 2006 for 2 hours on food processing, income generating activities and gender issues. The Deccan Development Society

(DDS) NGO in Medak District, Andhra Pradesh continues to use the millet based recipes (alternative use of millets) in feeding programme in 8 villages for anganwadi children (3 to 5 years age).

Food security can only be achieved through broadly – based actions that address many factors determining people's ability to obtain the food they need. Agriculture, forestry and fisheries do not simply produce crops and commodities, they provide livelihoods and improve nutrition too. Their products create employment both directly, on the land and seas, and indirectly in processing and related industries. Economic development in rural areas increases household income. Globalization opened up opportunities for Traditional as well as novel foods in Global Markets. Food is culture, emotion, hospitality, prestige and power.

Science alone is not technology and technology is not innovation. Innovation is made up of three key elements: creativity in technology, creativity in product planning and creativity in marketing. Technology comes from employing and manipulating science into concepts, process and devices. As an out growth of science, technology fuels the industrial engine. India has recognized ever since independence that its national development will be driven by science and technology. There are very good reasons for developing technology: creating national wealth; improving the quality of life of the people, particularly those living in rural areas and enhancing national security.

Technological interventions are effective within a timeframe that depends on several external and internal factors. Experts are turning to appropriate technological interventions at each step of the value chain, from the seed production stage to farm production, harvesting, food processing, storage, handling and marketing. Developed countries have been able to master the use of technological interventions to a great extent and consequently do not face food security problems, developing countries are still struggling to fill the demand-supply gap. Innovation is central to feeding a world with a growing population and limited natural resources. In this spirit, Norman Borlaug tirelessly pursued transformative improvements to wheat, which helped spur the green revolution that saved many lives from starvation.

In a world that is becoming increasingly food-insecure, due to population growth, climate change, volatile food prices, unequal food access, and inefficient supply chains, what solutions exist to feed 9 billion people by the year 2050?

RECOMMENDATIONS / SUGGESTIONS

- Appropriate technologies to be used to reduce the food wastage.
- Encourage the scope for the growth of agro processing, agro industries and agri business.
- Technological and economic up gradation of farm operations.
- Particular attention to nutrition and food safety and processing to be paid for food security.
- Entrepreneurs to be developed for self employment.

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Chapter 6
Biotechnology and Wealth Creation From Plant With Healing Properties

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ABSTRACT

The relevance of traditional healing in genomic science pertain to the use of specific herbal remedies which are therapeutic for the management of endemic diseases in developing and the least developed nations. Besides the therapeutic resources of the healers were discussed and in nature of their therapeutic modality was characterized. The physical, mental and social psychological model of traditional healing was developed. It was recommended that genomics specifically true sequencing could be applied to identify the phytochemical agents which are present in many of the herbs which traditional healers use. Among those herbs, those that are lethal and toxic to patients should be expunged.

DEFINITION OF BIOTECHNOLOGY

Biotechnology has several definitions and depending on the topic of interest, biotechnology can be defined to illustrate some unique application of biotechnological methods. Adopting the technical application, biotechnology can be defined as" the use of biotechnical methods to modify the genetic material of living cells so they will produce new substances or perform new functions. The most widely used definition of biotechnology focuses on" biotechnology as the use of living organisms to make a product or run a process. This definition includes using bacteria to make yogurt, cheese, and vinegar as well as the use of plant or animal cross-breeding techniques to produce stock with enhanced qualities" The New Zealand Technology Curriculum (1995) defined:

Biotechnology, as the use of living systems, organisms, or parts of organisms to manipulate natural processes in order to develop products, systems, or environments to benefit people. These may be products,

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such as foods, pharmaceuticals, or compost; systems, such as waste management or water purification; or environments, such as hydroponics. Biotechnology also includes genetic or biomedical engineering.

We must reiterate, how genomic science, since 1990 has created major biotechnological revolution after the accomplishment of the human genome sequencing by 25th 2003 March. Reports from the National Institutes of Health and the United States Department of energy have further revealed how the biotechnological industries have more than tripled in size between 1992 and 2001. Besides, owing to the availability sophisticated technology in the G-8nations, biotechnological and genomic applications have created an upsurge in revenue which increased from 8billion to 27.6 billion. Only in 2001, there just 191,000 United States employees, and now more opportunities are expected in healthcare, microbial genomics for the sequestration of carbon and clean-up of the environment and food production.

In United States and other highly industrialized nations, young adults who hitherto had their training in business and marketing now appreciate the increasing needs for them to hone their skills in the physical and biological disciplines. They must have a working knowledge in biology, chemistry and physics and other life sciences and scientific research development to participate and become effective business experts in the age of genomic science. The bioscience career paths will continue to enjoy a steady progressive growth not only in the developed nations but also in the progressive developing nations unimpeded by social-cultural forces.

Regarding the burgeoning drug industries derived from genomics, the consulting Resource Corporation's newsletter for biotechnology professionals recently echoed their observation "We expect the growing family of new genomics, proteomics, and bioinformatics technologies to dominate the national market… development in therapeutics by greatly improving the efficiency and speed of the entire drug discovery, testing, and approval process. We must bear in mind that currently, the most affluent and economically solvent company worldwide, is the pharmaceutical company." The impact of biotechnological role in wealth creation will continue to occur in the flowing fields:

Molecular Medicine, Improvement in diagnosis of disease, Detect genetic predispositions to disease, Create drugs based on molecular information, Use gene therapy and control systems as drugs, Design "custom drugs" based on individual genetic, Profiles, Microbial Genomics, Rapidly detect and treat pathogens (disease-causing, microbes) in clinical practice, Develop new energy sources (biofuels), Monitor environments to detect pollutants, Protect citizenry from biological and chemical, Warfare, Clean up toxic waste safely and efficiently, Risk Assessment, Evaluate the health risks faced by individuals who may be exposed to radiation (including low levels, in industrial areas) and to cancer-causing chemical Bioarchaeology, Anthropology, Evolution, and Human Migration Study evolution through germline mutations in lineages, study migration of different population groups based on maternal genetic inheritance, study mutations on the Y chromosome to trace lineage and migration of males, compare breakpoints in the evolution of mutations with population ages and historical events, DNA identification, identify potential suspects whose DNA may match evidence left at crime scenes, exonerate people wrongly accused of crimes (US Dept. of Energy, 2014).

Identify crime, catastrophe, and other victims, establish paternity and other family relationships, identify endangered and protected species as, an aid to wildlife officials (e.g., to prosecute poachers), Detect bacteria and other organisms that could pollute air, water, soil, and food, match organ donors with recipients in transplant programs, determine pedigree for seed or livestock breeds, authenticate consumables such as caviar and wine, agriculture, livestock breeding, and Bioprocessing, grow disease-, insect-, and drought-resistant crops, optimize crops for bio-energy production, breed healthier, more productive, disease-resistant species, grow more nutritious produce, develop biopesticides, Incorporate edible vaccines into food products, develop new environmental cleanup uses for plants (www.ornlhgmis/publicat/primer).

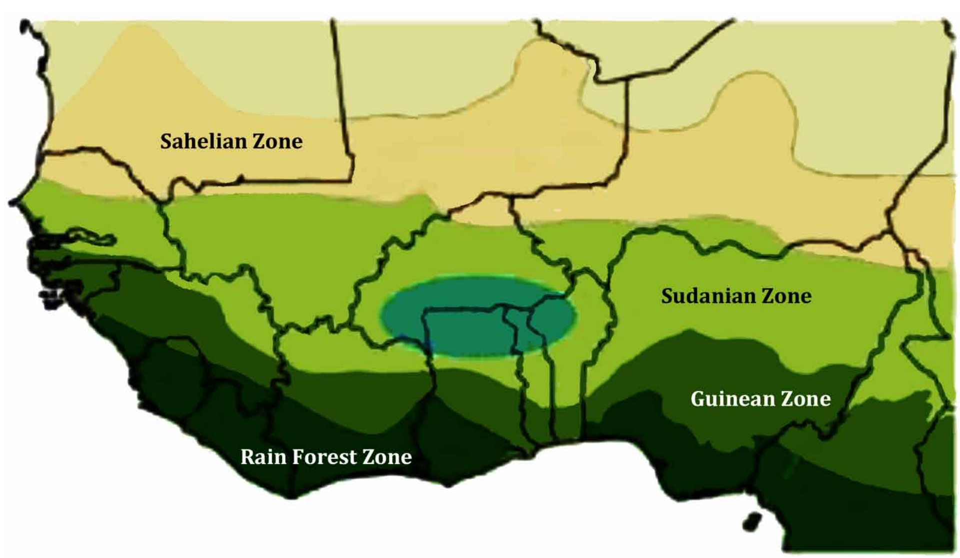
ECOLOGICAL BIOMES IN WEST AFRICA

Among the developing and the least-developing nations of the world, the many and varied ecological characteristics of these nations particularly those in Sub-Sahara African Nations have led to the proliferation of numerous plants with healing properties. Understanding biodiversity and biome phenomenon in West African geographical landscape is crucial in this age of genomic science. Applications of knowledge derived from genomics can further illuminate the relevance of genetic mapping of medicinal plants, food crops and vegetables with healing properties, which exist in the desert, grassland, tropical rain forest and the wetland biomes in West Africa. The tiny vestige of tropical rainforest constitutes a natural treasure trove of medicinal plants. These floras have not been comprehensively studied, characterized and genotyped in the wide expanse of West African biodiversity. With the inception of the genomic age, there are ample reasons to preserve bio-genetic diversity (Figure 1).

Bio-diversity includes the physical, biological make-up of an area, including the natural nidality, of species of plants and animals and the vegetation of an area. In the same vein, biomes can be defined as a wide expansion of vegetation and the assemblage of similar plants and animal species. In West Africa, the five main ecological biomes are the desert, grassland, tropical, rainforest and wetland biomes, which meander into the Atlantic Ocean.

The economic and medical value of plants are multifarious; their medical utility, their aesthetic value, recreational and intrinsic essence for many observances. Plants also have ecological benefits in enabling us to control carbon dioxide emission and the control of global warming. The imminent challenge is

Figure 1. Map of the Ecological Biomes in West Africa



the possibility of extinction of these endangered species over their natural range. With the innovative genomic technologies being developed rapidly in the industrialized nations, it seems plausible that more sophisticated techniques could yield several unknown bio-medical data about these florae with therapeutic benefits worldwide. Traditional healers rely on this rich ecological niche for utilizing the flora and fauna which have therapeutic benefits. In 1978, The World Health Organization (WHO) accorded recognition to traditional medical practitioners at its primary health care declaration at the Alma ATA conference in the former Soviet Union. In fact since 1976,WHO has stressed the importance of traditional medicine which was then defined as "the total of all the knowledge and practices whether explicable or not, used in diagnosis, prevention and elimination of physical, mental or social imbalance and relying exclusively on practical experience handed down from generation to generation whether verbally or in writing"(Lambo, 1956)

In many African nations, traditional medical practitioners rely on remedies derived from plants with healing properties. For example, in Ghana, Ivory Coast, Republic of Benin, Nigeria, and other West African, Central and East African nations, the population to health care ratio remains inadequate. Both groups of practitioners are usually overwhelmed by the broad spectrum of endemic diseases. To illustrate in Nigeria, there are 110 patients to everyone traditional healer and 15,740 patients to that of one medical doctor trained in the university. In Ghana, in the Kwahu district, there are 224 patients to traditional medical doctor compared to 21,000 patients to one university trained physician. In Swaziland, the ratio of patients to one traditional healer is 110 patients, compared to 10,000 patients to university-educated medical practitioner. In Tanzania the statistical ratio is 30,000 patients to one traditional healer and 40,000 patients to one university educated medical practitioner. In an effort to meet the Millennium Development Goals and combat increasing drug resistance and clinically tackle the problems of a broad spectrum of diseases in the developing nations, the World Health Organization has identified traditional healers as one of the important means to achieve comprehensive health care coverage of the world population (Lambo, 1956; Prince, 1960; Bannerman, 1981).

In the early part of the nineteenth century, traditional medical practitioners were not only professionally derided but economically marginalized. In genomic community, governments, pharmaceutical companies, researchers and international non-profits organizations now recognize the role of traditional medicine and its practitioners. Therefore, official government efforts are necessary to invest the requisite funds to study plants with healing properties. Scientists must identify the ecological biomes, which are conducive for the growth of these plants, so as to enrich the pharmacopeia of herbal healing in developing nations. At an alarming rate, massive deforestation of the tropical rain forest erodes the flora and fauna which traditional healers rely on and use as medicinal plants for the treatment of their patients. Research studies conducted by Ebomoyi (2011) have revealed numerous problems regarding the frequencies and abundance of plants with healing properties in many developing nations of the world.

There are the problems of industrialization, deforestation and prospecting for petrochemical products which have reduced the expanse of land hitherto covered by the tropical rain-forest in the African continent.

CAUSES OF DEFORESTATION

About 200 years ago, the tropical rain forest extended as a complex community covering the lowlands of humid tropics of central and South America, Africa, Southeast Asia and Indonesia. A sizeable portion of the evergreen raining forest still exists in Africa, Amazonia, Borneo and New Guinea. In West Africa, particularly Nigeria, the slash and burn agricultural practices which many farmers practice have done some demand to the various ecological biomes. However, desert encroachment and the development of new housing estates for the teeming population continue to create inordinate extinction of the large species of flora and fauna with healing properties. Industrialization and prospecting for petrochemical products are other man-made disasters that have created the extinction of plants with healing properties due to the destruction of wildlife, incessant logging, and the pollution of atmosphere, hydrosphere and lithosphere of the wetlands and the remaining tropical rainforest in Nigeria and other West African Nations. For agricultural purposes, the tropical rain forest has been intensively cultivated by planting bananas, cocoa, mangoes, bush mangoes, oil palm, coconut, cassava and timber. About five decades ago when there was rubber and timber boom in West Africa, vast expanse of the tropical rain forest were cleared for the cultivation of these cash-crops.

ECOLOGICAL IMPACT OF DEFORESTATION

Increased agricultural production, cattle ranching, industrialization, rural urban drift and the resources to defray the mounting debt burden in Africa have necessitated the unbridle ambition to harness the resources of the tropical African rain forest with resultant extinction of many medicinal plants. The ecological effects of deforestation are many and varied. Currently, the evergreen tropical rain forest with canopies of interlocking leaves and branches, which provide shelter for assorted varieties of living things are destroyed daily. The elimination of such protection is imminent. If the tropical rain forest is destroyed, the ominous prediction is that million species of therapeutic plants and the regional and global bio-diversity and the genetic heritage could be disrupted. In addition, the motives for deforestation of the tropical rain forest biome are multifarious. Peasant farmers utilize the forest trees as the principal source of firewood. Firewood is not only the principal source of energy for cooking, but also for warming sleeping rooms during the extremely cold month of November, December and January.

With over 250 million people worldwide making their livelihood directly by depending on tropical rain forest, peasants who are rubber tapers, wine tapers and oil palm producers, palm-kernel processors all make their living on the richness of the tropical rain forest. The global fear entertained by ecologists is the incalculable catastrophe which might plague humanity by the complete destruction of the tropical rain forest. As a result of the evergreen tropical rain forest with canopies of interlocking leaves and branches which provide shelter for assorted varieties of living things are being destroyed daily. The elimination of such protection is imminent. If the tropical rain forest is destroyed, million species of a major proportion of universal biological biodiversity and genetic heritage will be lost.

In the age of genomic science, the opportunity to study the therapeutic benefits of plants in West African has never been more crucial, because the healers who rely on these complex biodiversity do not have access to the relevant genomic technology to characterize the underlying mechanisms by which some of these herbal remedies and the combination of multiple plant species and animal parts are efficacious for specific diseases.

Summarized in Table1 are the plants with therapeutic benefits principally for the management of mental health dysfunctions. At Abeiye Village in Kwara State, Nigeria, the traditional healer had in storage over 90 percent of the plants in listed in the Table2. These herbs were stored hanging from the healers' kitchen for drying to avoid putrefaction. The healer confided in the investigator that in many instances,

Table 1. Medicinal plants with Mental Health Therapeutic Benefits

Plant Species	Therapeutic Applications
Rauwolfia serpentina	Mental health problems
Rauwolfia vomitoria	Mental health problems (bipolar disorders)
Solanum calycina	Mental health (tranquilizer)
Bryophillum pinnatum	Mental health (tranquilizer)
Commelina vogelii	Mental health (tranquilizer)
Chorophora excels	Mental health (tranquilizer)
Cola caricifolia	Mental health (tranquilizer)
Draceana fragrans	Mental health (tranquilizer)
Musa sapienium	Mental health (tranquilizer)
Garcinia kola heckle	Mental health (tranquilizer)
Newbuoldia laevis	Mental health (tranquilizer)

he would traveled to villages of Ogbomosho and Oshogbo in in the western region of Nigeria to collect these plants products since they grow only in many of the farms and forest of the neighboring states.

The younger patients at Abeiye, on drinking the herbal concoction from the admixture of Rauwolfia serpentine and Rauwolfia vomitoria, were observed to drool excessively. While our team advised the etiological reason for drooling could be due to excessive dosage, the healer countered our contention, and he remarked drooling is a key component of bipolar disorder.

However, the younger patients were observed to have more pronounced side-effects than the adult psychiatric patients. Those patients treated and adjudged to have been cured were usually cleansed and sacrificial observances were performed before their discharge to their significant others. The healer maintained that recidivism is rare in his psychiatric practice (Ebomoyi, 1986). A higher proportion of healers who specialized and treated cardiovascular diseases and cancers were males whereas the traditional birth attendants who manage maternal and child health-related diseases were principally elderly females. Male healers perceived cardiovascular diseases such as congestive heart disease, atria fibrillation and myocardial infarction as the health problems suffered principally by males. Regarding cancers, traditional healers rarely associated various cancers as dysfunctions which are common in both males and females. Breast cancers were usually managed by male healers. The emerging onset of childhood leukemia is usually most baffling to the healers. Periodically they were more prone to refer the child with leukemia to the university educated medical practitioners because of the invasive nature of the disease (Ebomoyi, 1986).

BIO-PROCESSING FOR MEDICINAL PLANTS

In West Africa, history is replete with the conservation efforts of many rural communities for sustainable development of their bio-diversity in medicinal plants (see Tables 3 and 4). Their reasons focused on the ready availability of these inexpensive plants. Also, traditional practices surrounding their use reflect local knowledge and wisdom, and the plants are relatively inexpensive. Besides, instructing the general

Table 2. Medicinal Plants with Therapeutic Benefits for Complex Diseases

Plant Species	Therapeutic Applications
Convallaria majalis	Heart tonic for high blood pressure
Digitalis purpurea	Management of congestive heart disease
Crataegus oxyacantha	Management of congestive heart disease
Carica papaya (seeds)	Management of high blood pressure
Hog plum	Management of high blood pressure
Annona senegalensis	Management of cancer
Poteriem spinosum	Management of cancer
Merdan lucida	Management of cancer
Spondias mombin	Management of ovarian and uterine cancer
Ageratum conyzoides	Management of childhood leukemia
Cybopogon citrates	Management of childhood leukemia
Xylopia aethiopica	Management of childhood leukemia
Xanthoxylum zanthoxyloides	Management of childhood leukemia
Catharanthus roseus	Management of childhood leukemia
Vernonia amydalina	Management of cancer and diabetes
Allium sativum	Management of blood cholesterol
Musa sapientum	Management of high blood pressure
Zingiber officinal	Management of stroke and myocardial infarction
Stachytarpheta jamaicensis	Management of high blood pressure
Physostigma vnenosum	Induces diarrhea diuretic
Crocodile gall**	Severe vomiting, induces diarrhea and death
Python gall	Severe vomiting induces diarrhea and death

community about these sacred cash-crops protect bio-diversity and inhibits their extinction by politicians who indiscriminately use technology to advance the concept of agricultural mechanization which occurs to the detriment of the ecological value of the flora and fauna in the areas. These medicinal plants are only able to grow and flourish in only selected biomes in Africa. Most of the African medicinal plants are not necessarily ubiquitous. Traditional medicinal practitioners have preserved traditional knowledge and practices of phyto-medicinal treatment for several years. In the age of genomic science, traditional healers have monumental role to play in identifying most of these plants with healing properties. Geneticists, and other scientists can assist in genotyping and finding out the essential active principles in these herbs and those with toxic properties could be expunged. With the professional application of biotechnological techniques genomics can be used to enhance medicinal plants This scientific process can be aggressively pursued by the commitment of governments and the generous funding of research centers to collaborate with traditional healers in the areas of bi-prospecting, training of the healers and the commercialization of medicinal plants by emphasizing sustainable development of their cash-crops.

Renowned African scientists, Soladoye. Chuwuma, Sulaiman et al (2014) have conducted ethnobotanical survey of plants used in the treatment of female infertility in the rain forest areas of South Western Nigeria. Even their interviewees remarked that many of these traditional herbal remedies were

Table 3. Medicinal Plants with Healing Effects for skin infections and STI and Asthma

Plant Species	Therapeutic Applications
Eleophorbia drupifera	Management of dracunculiasis
Hoslundia opposite mixed with Red kola nut	Management of dracunculiasis
Vitellaria paradoxa/Shea nut butter	Treatment of dracontiasis & skin infections
Spondiasmombin	Maternal and child care, contraceptive Management of ovarian and uterine cancer
Yohimbine combined with hug plum	Management of male impotence
Pistia stratiotes	Management of smallpox
Desmodium adscendens	Management of asthmatic attacks
Papilionacea thonningia	Management of asthma
Deinbolia pinnata	Management of asthma
Deinbolia Sapindaceae	Management of asthma
Fagara xanthozyloides	Anti-sickling agent
Carcina manni	Anti-microbial agent
Baphia nitida	Anti-microbial agent
Cinchoma succirubra	Antimicrobial agent
Oldenlandia affins	Management and to ease delivery of babies
Momordica foetida	Relaxes the smooth muscles
Ficus exasperates	Treatment of gonorrhea and other STI
Chasmathera dependents mixed with Buty-rospermum paradoxum	Treatment of fractures
Citrus lemon and leaves of ocimum gratissimum	Treatment of pile
Zanthoxylum zanthothoxyloides	Treatment of fever
Garlic(Allium sativum, Ginger, Zingiber Officinale and lemon	

found to be quite effective in the management and treatment of infertility among their patients who suffered from infertility.

ECOLOGICAL ADVANTAGES OF THE HERBAL PLANTS WITH HEALING PROPERTIES

The relatively stable ecological conditions in the tropical rain forest belt of South –Sahara Africa facilitate the proliferation and growth of numerous medicinal plants almost all-year round. Besides, traditional healers are able to either cultivate many of these plants from their farms or solicit assistance from seasoned healers about where they harvest such herbal remedies. Although the medicinal plants for the treatment of infertility were listed in Table 4, there are also those herbal resources for the management of complex diseases such as heart disease, high blood pressure and diabetes. The incipient stages of diabetes type 2 is managed by the traditional healer by using extracts from Bitter leaf (*Vernonia amygdalina*) with pure honey taken with two tablespoonful at least twice daily. Many patients are also treated with unripe

Table 4. Medicinal plants used in the treatment of female infertility in southwestern Nigeria. FHI = Forest Herbarium, Ibadan. EH = Elikaf Herbarium, Olabisi Onabanjo University, Ago-Iwoye. Parts used: bark (B), bulb (Bu), corm (C), fruit (F), leaf, (L), root (R), seed, (Se), stem (St)

Botanical Name	Family	Local Name (Yoruba)	Parts Used
Acacia nilotica (L.) Delile	Fabaceae	Booni	Se
Acanthus montanus (Nees) T.Anderson	Acanthaceae	Ahon ekun	L
Aedesia glabra (Klatt) O.Hoffm.	Asteraceae	Ope-kaua kaua	L
Aframomum melegueta K.Schum.	Zingiberaceae	Ataare	Se
Alchornea laxiflora (Benth.)Pax & K.Hoffm.	Euphorbiaceae	Ijun	B, F
Allium ascalonicum L.	Amaryllidaceae	Alubosa onisu	Bu
Alstonia boonei De Wild.	Apocynaceae	Ahun	F
Amaranthus spinosus L.	Amaranthaceae	Dagunro	L
Anacardium occidentale L.	Anacardiaceae	Kaju	L
Anthocleista djalonensis A.Chev.	Gentianaceae	Sapo	B
Antiaris toxicaria var. africana Scott-Elliot ex A.Chev.	Moraceae	Ooro	L
Aristolochia repens Mill.	Aristolochiaceae	Ako-igun	F
Calotropis procera (Aiton) Dryand.	Apocynaceae	Bomubomu	F
Capsicum annuum L.	Solanaceae	Atawewe	F
Cassia fistula L.	Fabaceae	Asunwon	L
Chasmanthera dependens Hochst.	Menispermaceae	Ag	
Cissampelos owariensis P.Beauv.ex DC.	Menispermaceae	Jokojee	L
Cissus populnea Guill. & Perr.	Vitaceae	Ogbole	R
Citrullus colocynthis (L.) Schrad.	Cucurbitaceae	Bara	F
Citrus aurantifolia (Christm.) Swingle	Rutaceae	Osanwewe	F
Corchorus olitorius L.	Malvaceae	Ewedu	L
Cucumeropsis mannii Naudin	Cucurbitaceae	Itogho	L
Curculigo pilosa (Schumach.& Thonn.) Engl.	Hypoxidaceae	Epakun	C
Cyathula achyranthoides (Kunth) Moq.	Amaranthaceae	Opapara/esupupa	L
Diospyros suaveolens Gürke	Ebenaceae	Esunsun	L
Elaeis guineensis Jacq.	Arecaceae	Oran ope	F (oil)
Euphorbia convolvuloides Hochst.ex Benth.	Euphorbiaceae	Emile	L
Ficus exasperata Vahl	Moraceae	Epin	L
Garcinia kola Heckel	Clusiaceae	Orogbo	Se
Glyphaea brevis (Spreng.)Monach.	Malvaceae	Atori	L
Gongronema latifolium Benth.	Apocynaceae	Madunmaro	R
Gossypium barbadense L.	Malvaceae	Owu akese	L
Hybanthus enneaspermus (L.) F.Muell.	Violaceae	Abiwere	L
Ipomoea pileata Roxb.	Convolvulaceae	Alukerese	L
Jatropha gossypifolia L.	Euphorbiaceae	Lapalapa	L
Khaya grandifoliola C.DC.	Meliaceae	Oganwo	B
Kigelia africana (Lam).Benth.	Bignoniaceae	Pandoro	B
Lagenaria breviflora (Benth.) Roberty	Cucurbitaceae	Tagiri	B
Lawsonia inermis L.	Lythraceae	Laali	L
Mangifera indica L.	Anacardiaceae	Mangoro	B
Markhamia tomentosa (Benth.) K.Schum. ex Engl.	Bignoniaceae	Oruru	L
Microdesmis puberula Hook.f.ex Planch.	Pandaceae	Aringo	L
Momordica charantia L.	Cucurbitaceae	Ejinrin	L
Morinda lucida Benth.	Rubiaceae	Oruwo	R
Mucuna pruriens (L.) DC.	Fabaceae	Esisi	L
Musa acuminata × balbisiana Colla	Musaceae	Ogede agbagba	F
Nymphaea lotus L.	Nymphaeaceae	Osibata	L
Ocimum gratissimum L.	Lamiaceae	Efinrin	L
Pergularia daemia (Forssk.)Chiov.	Apocynaceae	Kole-oro	L

continued on following page

Table 4. Continued

Botanical Name	Family	Local Name (Yoruba)	Parts Used
Physalis angulata L.	Solanaceae	Koropo	L
Piper guineense Schumach.& Thonn.	Piperaceae	Iyere	F
Plumbago zeylanica L.	Plumbaginaceae	Inabiri	R
Polygala arenaria Oliv.	Polygalaceae	Ose	F
Pseudocedrela kotschyi (Schweinf.)Harms.	Meliaceae	Akodinrin	L
Psidium guajava L.	Myrtaceae	Guafa	L
Raphia mambillensis Otedoh	Arecaceae	Alugbanko	F
Ricinus communis L.	Euphorbiaceae	Laa	F
Sarcocephalus latifolius (Sm.) E.A.Bruce	Rubiaceae	Egbesi	R
Secamone afzelii (Roem. & Schult.) K.Schum.	Apocynaceae	Ailu	L
Senna alata (L.) Roxb.	Fabaceae	Asunrin	L
Sesamum indicum L.	Pedaliaceae	Beni/eluru	L
Sida hyssopifolia C.Presl	Malvaceae	Isekotu	L
Sorghum bicolor (L.) Moench	Poaceae	Okababa	Pod
Sphenocentrum jollyanum Pierre	Menispermaceae	Akerejupon	B
Spondias mombin L.	Anacardiaceae	Iyeye	L
Stephania abyssinica (Quart.-Dill. & A.Rich.) Walp.	Menispermaceae	Gbejedi	L
Tacca leontopetaloides (L.) Kuntze	Dioscoraceae	Adosu	B
Telfairia occidentalis Hook.f.	Cucurbitaceae	Ugu	F, L
Terminalia avicennoides Guill. & Perr.	Combretaceae	Idi	B, St
Tetrapleura tetraptera (Schum. & Thonn.) Taub.	Fabaceae	Aidan	R, F
Tylophora sylvatica Decne.	Apocynaceae	Isigun	R
Uraria picta (Jacq.) DC.	Fabaceae	Alupayida	L
Uvaria afzelii G.F.Scott-Elliot	Annonaceae	Gbogbonse	R
Xylopia aethiopica (Dunal) A.Rich.	Annonaceae	Eru Alamo	B, L
Zingiber officinale Roscoe	Zingiberaceae	Atale funfun	F

Soladoye, et al (2014). - Ethnobotanical Survey of Plants Used in the Traditional healers

Pawpaw (Carica papaya) peeled and soaked in water for three days to extract the phytochemical nutrient before patients are asked to two tablespoon thrice daily for three days. The other traditional medicinal approach include guava (*Psidium guajava*)

Since typhoid fever is a common health problems in South-Sahara Africa, the recommended herbal treatment consist of ingestion of a paste of garlic (*Allium sativum*), and ginger (*Zingiber officienale*) boiled with lemon (*Citrus lemon*) which should be taken twice daily. If a patient suffers from ulcer, the healer who specializes in internal medicine will recommend or administer scrap bark of sugar cane (*Saccharum officinarium*) cut into pieces crushed and soak in water for three days. Patients are advised to drink a glass full of this solution three times a day.

POTENTIAL ACCOMPLISHMENT OF TRADITIONAL HEALERS IN THE AGE OF GENOMICS

In spite of the inertia in recognizing the role of the healers, within the national healthcare delivery establishment, they continue to maintain their lucrative professional business in the cosmopolitan and rural areas of the world. Numerous Western-trained medical personnel are reluctant to relocate to medically isolate rural areas where urban amenities are in short supply.

Traditional healers have a profound understanding of the dynamics of the culture within which traditional medicine is practiced. They exude copious knowledge of the ***material medica or the*** effectiveness of herbal drugs dispensed in their treatment of patients. Professor Adeoye Lambo, the former Deputy-Director of the World Health Organization had argued "Our medicine is not the medicine nor our religion the religion, and there is not one medicine but numerous and quite different medicine in the different parts of the world and in the past, present and future. Measuring everything by our everyday standards, we will never understand either the past or the future (Lambo, 1956)" Based on the World Health Organization (1978) Expert Committee, traditional medicine was defined as:

The sum total of all knowledge and practice, whether explicable or not, used in the diagnosis, prevention and elimination of physical, mental or social imbalance and relying exclusively on practical experience and observation handed down from generation to generation, whether verbally or in writing. Traditional medicine might also be considered as a solid amalgamation of dynamic medical know-how and ancestral experiences. Traditional African Medicine might also be considered to be the sum total of practices, measures ingredients and procedures of all kinds, whether material or not, which from time immemorial had enabled Africans to guard against disease, to alleviate his/her sufferings and cure himself or herself (WHO, 1978)

In order for the traditional healer to function effectively among genomic science workforce, the healer must have the expertise to identify plants that medicinal properties, the healer must have the ecological knowledge about suitable environment to facilitate the cultivation of herbarium. The healer must demonstrate knowledge about plant pharmacogenomics. This scientific term refers to providing the right dose to the right patient in specific amount based on the patients DNA so as not to cause life-threatening effects as we have discovered with many pharmaceutical products which are usually correctly prescribed to numerous patients worldwide by modern medical practice.

Dr. Barbara Starfield (2009), a distinguish professor in the Department of Health Policy, Management and Pediatrics, Johns Hopkins University, school of public health and medicine(Baltimore, MD), has augmented other etiological agents of death in United States to include: 7000deaths annually due to unnecessary surgery, 20,00 deaths recorded each year due to other hospitals errors, 80,000 death each year due to nosocomial infections in hospitals and 106,000 deaths that occur annually due to adverse effects to properly prescribed medications. Some of the etiological agents, if summed up and characterized as iatrogenic diseases can be ranked as third just below cancer (Starfield, 2009).

In the practice of medicinal herbal to treat many diseases, the prevalence of iatrogenic diseases is significantly reduced if the healer is efficiently trained and if the healer has been involved as a herbalist for many years. Although we agree that traditional healers have useful role to play in treatment of various health problems, mostly in developing and least developed nation, we must bear in mind that there are quacks among them who are dangerous to society. Official efforts must be made to reveal their unscrupulous practices that are very harmful to society.

WHO PARADIGM FOR TRADITIONAL MEDICINE IN PRIMARY HEALTH CARE

Infact, Dr Margaret Chen (2014) the Director-General of World Health Organization has endorsed the practice of traditional medicine in many progressive developing and least developing areas of the world:

Let me begin with the current reality, which on at least one level is quite straightforward. Traditional medicine is generally available, affordable, and commonly used in large parts of Africa, Asia, and Latin

America. For many millions of people, often living in rural areas of developing countries, herbal medicines, traditional treatments, and traditional practitioners are the main – sometimes the only – source of health care.

This is care that is close to homes, accessible, and affordable. In some systems of traditional medicine, such as traditional Chinese medicine and the Ayurveda system historically rooted in India, traditional practices are supported by wisdom and experience acquired over centuries.

In these contexts, where traditional medicine has strong historical and cultural roots, practitioners are usually well-known members of the community who command respect and are supported by public confidence in their abilities and remedies.

This is the reality, and this form of care unquestionably soothes, treats many ailments, reduces suffering, and relieves pain. This is the reality, but it is not the ideal.

When we see estimates that around 60% of young children in some African countries suffering from high fever, presumably caused by malaria, are treated at home with herbal remedies, we have a very serious problem. Malaria can kill within 24 hours. Modern drugs can greatly improve the prospects of survival.

During this year, WHO estimates that around 136 million women will give birth. Of these women, around 58 million will receive no medical assistance whatsoever during childbirth and the postpartum period, endangering their lives and that of their infants.

Again, we have a very serious problem. The consensus is now solid. The stubbornly high numbers of maternal deaths will not go down until more women have skilled attendants at birth and access to emergency obstetric care (Chen, 2014).

In an effort to balance her assessment of traditional medicine compared to Western-type scientific medicine the Direction General (2014) further remarked:

Recent studies conducted in North America and Europe indicate that these remedies tend to be used most in groups with higher incomes and higher levels of education. In many cases, the costs are not covered by medical insurance schemes. The use of these complementary and alternative therapies has become a multi-billion dollar industry that is expected to continue its rapid growth. This is not the poor man's alternative to conventional care. What does this trend represent? The reaction of the medical establishment is predictable and, I believe, largely legitimate. This trend has some dangers.

As I said, some systems of traditional medicine have histories dating back thousands of years. Over a comparatively short period of time, modern medicine has developed powerful methodologies for proving efficacy, ensuring quality, standardizing good manufacturing practices, testing for safety, and conducting post-marketing surveillance for adverse effects.

Many, but not all, traditional medicines have an inadequate evidence base when measured by these standards. Tests for quality and standards for production tend to be less rigorous and controlled. Products may escape the strict regulations set up to ensure drug safety. Practitioners may not be certified or licensed.

These concerns are legitimate, but we are still left with a central question: what explains the sharp rise in the use of complementary and alternative medicines? Again, we can turn to the medical establishment for some explanations. Some commentators in journals such as the British Medical Journal, The Lancet, and the New England Journal of Medicine interpret this trend as a biting criticism of high-technology, specialized medicine, despite all its well-documented merits.

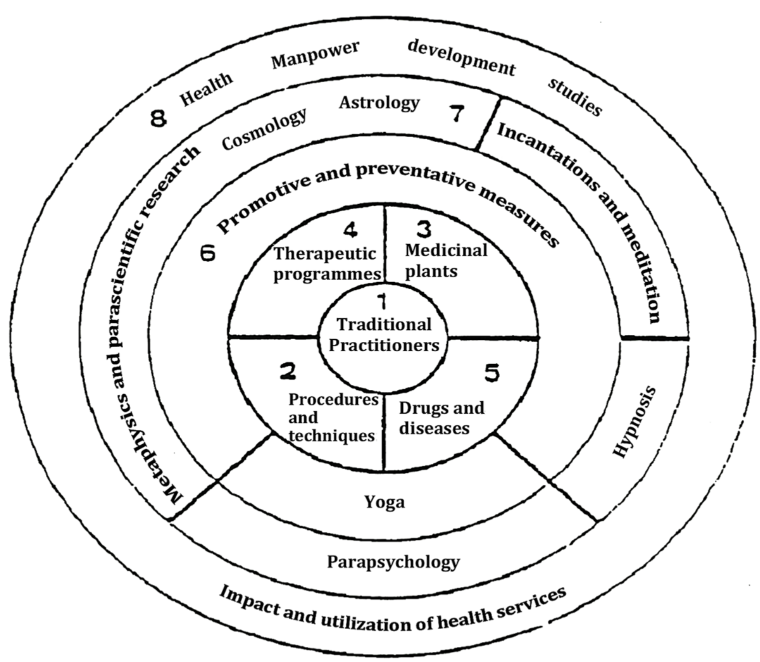
Medical care has become depersonalized, some would even say "hardhearted". In most affluent countries, the number of family physicians and primary care doctors continues to decline. The trend towards highly specialized care works against a sympathetic doctor-patient relationship. In too many cases, the patient is no longer treated as a person, but rather as an assembly line of body parts each to be managed, often with great expertise, by an appropriate specialist (Chen, 2014).

Figure 2 is the resume of research which was developed by the World Health Organization expert committee on traditional medicine to spell out how best to conduct research on the benefits of traditional healing worldwide (Figure 3).

W.H.O. PARADIGM FOR TRADITIONAL MEDICINE IN PRIMARY HEALTH CARE

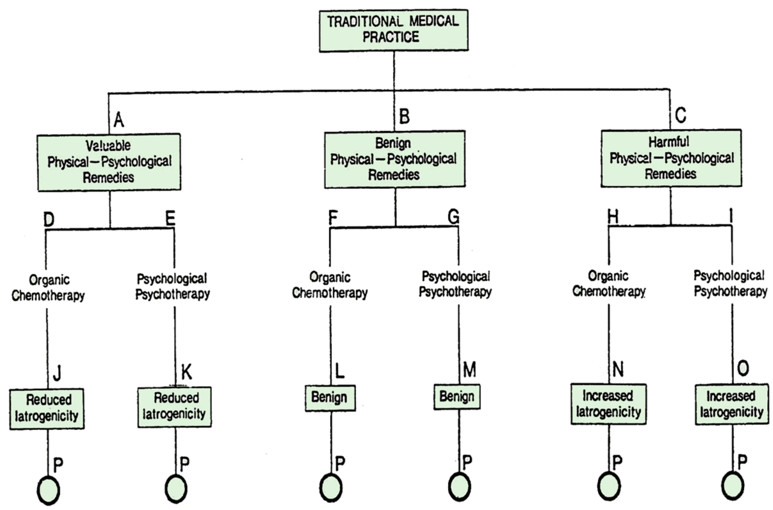
Basic rationales underlying the promotion and development of traditional medicine in the developing world are numerous. The rubric of traditional medicine which is generally practiced in the developing world involves methodology which conventional sciences delineate as metaphysical, magical or para-scientific. Philosophical paradox about traditional medicine pertains to the issue of efficacy, patronage and the World Health Organization now urged new efforts to support traditional medical practice because three-fourths of the earth's population are psychologically and culturally tried to indigenous health care. The currently available Western-type medicine cannot provide the badly needed health care services to people living in rural communities.

Figure 2. WHO Paradigm for Traditional Medicine in Primary Health Care
Source: WHO Technical Report 1978, p. 33



1. Research on traditional practitioners of all types
2. Research on traditional systems, procedures, techniques, technology, and fundamental principles
3. Medicinal plant research
4. Evaluation of therapeutic programs
5. Research on drugs and diseases
6. Research of promotive, educational, and preventative measures
7. Metaphysics and parascientific domains, cosmology and astrology, parapsychology, hypnosis, religious incantations and meditation
8. Manpower development research: impact and utilization of health services

Figure 3. The physical psychological model of traditional medical practice



For example, WHO records revealed that about two-thirds of the newly born infants of the world are delivered with the assistance of indigenous mid-wives who are now classified as traditional birth attendants. Even though traditional medical practice might appear unhygienic and inappropriate, the concerted research efforts of WHO expert committee have discerned that some practices involving the use of herbal components of traditional pharmacopeia have proven to be effective. Among the examples reported by one WHO expert committee, are prescriptions used in Ghana of a paste made from root bark as treatment for herpes zoster. Also in Mexico, it was found by a group of scientists that the application of spider webs as dressing to the umbilical cord is scientifically sound; because cob-webs have antibiotic qualities.

The Ghanaian Experience

The utilization of herbal products in traditional African medicine is probably more developed in Ghana than in any other West African country. Elderly herbalists in Ghana have been able to identify more than four hundred plants with healing properties. Within this decade a center for scientific research into plant medicine has been established in Ghana. Illustratively the plant combretum mucronatum was identified to be used as a worm expeller at a calculated dose of 0.3gm/kilogram. Plants for bronchial asthma were variously identified as Desmodium adscendens –Papilionaceae Thonningia sanguinea - Balanophoraceae and Deinbolia pinnata Sapindaceae (Ampofo, 1977).

Collaboration in traditional medicine in Ghana has given rise to the development of (herbal) clinical drug trials. As mentioned by Ampofo, director of the scientific research into plant medicine, in Ghana:

The leaves of Eleophorbia drupifera and Itilleria Latifolia, taken in combination with a palm oil soup preparation, acts as a filariacide in guinea-worm… Four traditional treatments of herpes zoster are particularly interesting. The local application of the flowers of Hoslundia opposita and red kola nut, chewed together and sprayed on the lesion twice a day, often heals it within a fortnight. The local application of quava leaves, ground into paste with Kaolin or white clay and piper guineense, twice a day heals the infection in about ten days.

Chinese Experience

Though the roots of Chinese medicine go back to the dawn of civilization, colonial invasion also brought in the practice of Western-type medical practice. But the practice of traditional medicine was never discouraged. The philosophical design of Yin and Yang permeates Chinese medical understanding.

The Chinese Nei Ching rest on two basic rational concepts of health and disease. The first concept pertains to the normal functioning of the body which depends on the equilibrium of Yin and Yang which are entities which underlie nature. Yin and Yang cannot exist singly since the existence of one necessitates the presence of the other, hence they are regarded as mutual affinities and mutual antipathies.

Five primordial substances which are germane to the practice of acupuncture are exemplified in metal, wood, fire, water and earth. These substances portray bewildering intricate connections and interconnections. These understandings provide the theoretical basis for the practice of acupuncture or needle therapy. Chinese traditional medicine was developed from this frame of reference.

WHO has unraveled the beneficial lessons to be learned from the Chinese experience. Though acupuncture has been practiced for many centuries, the application of modern scientific research to develop the nation's traditional medicine has now perfected the traditional approach for the treatment of a wide range of diseases. Specifically, recommends that research on traditional medicine should be focused on the possibility of promoting and developing traditional approaches in a given area mobilizing scientists locally and where necessary to seek international collaboration.

The World Health Organization has espoused several reasons for the promotion of traditional medicine. It is said to have several intrinsic values. Its potential medicine needs to be advanced for the broader use of mankind. Traditional medicine needs to be critically evaluated, recognized and developed in order to ameliorate its efficacy, safety, availability and wider application at reasonably low cost.(WHO, 1978)

Additionally, the indigenous people regard traditional medicine as their own cultural health care system. Therefore, it has several covert advantages over imported systems of medicine in any society because it constitutes part of the people's cultural heritage, and can be more useful in solving pertinent cultural health problems. Traditional medicine will not only contribute to scientific and universal medicine but also to its recognition, promotion and development.

The Nigerian Experience

Recently, Ekong reported in The UNESCO Courier that Fagara xanthoxyloides was used by traditional healers in their practice. The root of this plant is commonly used by traditional healers in treating sickle cell related diseases. As a result of the sporadic detection of invaluable herbal plants in the practice of traditional healing services, Ampofo has recommended.

To achieve any success in the field of research into traditional medicine, we should first acquire our knowledge from the traditional healer himself, try out this method clinically and then if successful subject them to scientific analysis. Many plant screening programs have not yielded any fruitful results because traditional healers have not been involved in these trials; but experience shows that with the advice of the good healers there is at least a 50/50 chance of success. (Ampofo, 1977).

Specifically the utilization of traditional medicine is designed to incorporate native health care approaches which are naturally acceptable to various member countries. The approach which has been emphasized for the Nigerian basic health care services by WHO pertains to research in the following areas:

- The socio-cultural basis of traditional medicine in research should be recognized.
- It was important to achieve collaboration between traditional medicine and modern medicine for expansion, efficiency and integration.
- The occult aspects of traditional medicine were not to be ignored; they were, however difficult to develop now, especially as such attributes could not be freely transferred.
- More research centers needed to be created, and a multidisciplinary approach was preferred.
- Research in traditional medicine should have as its goal the transfer of results to the traditional healers and the health profession in order to improve the efficiency of services and to eliminate harmful practices.
- Maintenance of traditional medicine drugs in their original forms of preparation, offer scientific validation, was very much to be encouraged.
- Three task forces were recommended at the national level for the collection of information, research and the application of information and research findings for the development of traditional medicine(WHO,1978)..

WHO Resume of Research

The World Health Organization expert committee on transitional medicine (1978) has developed the resume of research in this field. Figure 2 illustrates diagrammatically the various realms of traditional medicine which should be investigated internationally. The WHO endorses a holistic approach to medical practices.

Culturally, it is earlier for the indigenous people inhabiting rural areas to relate with the folk medical practical than patronize imported medical practice which necessitates red-tape, diagnostic procedures communication barriers and a distressing hospital setting. These situations exist in many societies owing to inadequate facilities and an acute shortage of physician-extended personnel.

To incorporate traditional medicine into the conventional Western-type health care at an international level, the World Health Organization has formulated all the dimensions of indigenous medical practices which will be integrated. From the WHO's review of literature, the aspects of research which will be given pertinent attention are the methodologies utilized in traditional medicine. Additionally, the pharmaceutical analysis of herbal plants will be carried out. Manpower development, community educational orientation, and the impact of metaphysical and para-scientific techniques will also be investigated.

The WHO (1978) has designed a very broad proposal; the practical issues at stake are (a) whether Western-type medical practitioners will cooperate with traditional healers, (b) what will constitute the categorical professional status of traditional healers? (c) Will there be a power struggle between these two practitioners? How do medical students and students in other academic disciplines perceive the integration of Western-type medicine into traditional African medicine? In Nigeria, and many other developing nations many of the above questions remain unsolved. But the National Institute for Medical Research continues to interest itself in traditional medicine, specifically in the application and integration of useful aspects of traditional medicine into modern medicine (Federal Government of Nigeria, Ministry. of Health, 1980). Today, African traditional healers are gradually being recognized and they are provided certification based on their areas of expertise and encouraged to reside in their various rural and peri-urban communities unanimated by law officers which were quite common in their yesteryears of medical practice.

ROLE OF TRADITIONAL HEALERS IN THE AGE OF GENOMIC SCIENCE

Based on the philosophical construct of the physical-psychological model of traditional medical practice, many traditional healers are knowledgeable of the very effective herbal preparation with have therapeutic benefits for patients in their rural ecological environment. In the same vein, they are also knowledgeable about those benign physical or organic remedies as sodium chloride(salt) or chalk However, there are harmful entities as sasswood *(Erthropbleum guinesse* for the detection of the so called witches by the healers, Calabar beans *(physorstigmavenenosum*) which can induced diarrhea and exhaustion if ingested in miscalculated proportions. Crocodile gall and python gall, which can cause severe vomiting and possible death and certain medicinal plants for the induction of abortion. In the age of genomic science and interdisciplinary team of modern genome epidemiologists, botanists, pharmacologists and other health professionals would be doing a great service by working with traditional healers to investigate the use of harmful herbal remedies and animal parts which are used by traditional healers in their medical practice.

In the twenty-first century in which DNA-based treatment is being used in pharmacogenomics, we must be cognizant of those health needs that are not met by traditional medical practices and are of the overtly harmful practices that are sometimes encountered by unsuspecting patients

Many traditional healers live in rural areas in many countries, with a lower frequency of their workforce in the urban-cosmopolitan settings worldwide. Health planners should encourage them to stay in those areas and find some means of rewarding them for their beneficial services. Finally, since many of them are knowledgeable of so many beneficial practices, concerted efforts must be invested in studying the knowledge possessed by these indigenous healers as further delay may result in their scientific knowledge being lost forever.

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Chapter 7
Millets as an Integral Part of Nutritional Diet in India

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ABSTRACT

Millets are small grained cereals belonging to the family Gramineae and they include major millets and minor millets. Millets are quite important from the point of food and nutritional security at regional and house hold level. In India's dry lands, they play a significant role in meeting food and fodder requirements of farming communities. Millets are found to have high nutritive value comparable and even superior to major cereals with respect to protein, energy, vitamins and minerals. They are also rich sources of phytochemicals and micronutrients. Since millet is gluten-free, it is an excellent option for the people who are suffering from atherosclerosis, diabetics and heart disease. In the face of increasing population and stagnant wheat and rice production, millets can be a promising alternative in solving the problem of food insecurity and malnutrition, because of their sustainability in adverse agro-climatic conditions. These crops have substantive potential in broadening the genetic diversity of the food basket and ensuring improved food and nutrition security.

INTRODUCTION

Millets are small grained cereals belonging to Gramineae family which include major millets like sorghum and pearl millet (which are tall growing and fairly drought tolerant) and minor millets with short slender culm and small grains possessing remarkable drought tolerance (ICRISAT and FAO, 1996). The term "millet' is often used loosely to refer to several types of small seeded annual grasses. Millets share a set of characteristics which make them unique amongst cereals. They belong to five genera, namely *Panicum*, *Setaria*, *Echinochola*, *Pennisetum, Paspalum*, and *Eleusine*. The genus *Pennisetum* includes about 140 species, some of which are domesticated and some grow in the wild. Most of the genera are widely distributed throughout the tropics and subtropics of the world (De Wet et al, 1984). Millets can

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be a valuable source of forage because of their rapid growth, high nutritive value and ability to survive stressful conditions such as drought. According to Hulse *et al*. (1980), the most important cultivated millet species are pearl millet *(Pennisetum typhoides),* also known as bulrush millet; proso millet (*Panicum miliaceum)*, also known as common millet; foxtail millet (*Setaria italica*); Japanese barnyard millet *(Echinochloa crus- galli*var *or E. colona*); finger millet (*Eleusine coracana*), also known as birds foot millet or African millet and kodo millet (*Paspalum scorbiculatum*). Other millets include little millet (*Panicum sumatrense*), tef millet (*Eargrostis tef*) and fonio millet *Digitaria exilis* and *D. iburua*) (Dogget, 1989). The vernacular names of millets in India are given in Table 1.

India is also the home for the species *Echinochola colona (Sawa)* under barnyard millet. Many indigenous communities in Asia preferred millets as their grain crop for shifting cultivation. The long history of minor millet cultivation and their spread to different regions of the world, which are notable for extremely harsh farming conditions, had generated considerable genetic variability in these crops. Kodo millet is very hardy and possesses the highest drought resistance with potential to offer a good yield in a growing period between 80-135 days. Barnyard millet could be said to be the second hardiest millet with the ability to give a modest yield in 50-100 days. Finger millet is more widely grown in Africa and Asia, differentiated in to five races and shows wide variability in appearance, adaptability, maturity period, yield and quality. Foxtail millet may be ranked fourth in yielding ability. The yield potential of little and proso millets are relatively lower with proso millet being hardier. Brief details of millet crops are given in Table 2.

HISTORY

NABARD (2007) summarized the history of millets as follows: From African highlands finger millet was taken to India about 3000 years ago and to Europe at the beginning of the Christian era. Later, the crop was widely distributed both in many African countries as well as in the Indian subcontinent. They have been a part of the human food system from time immemorial. Many types of millets have been found in Harrapa and Mohenjadaro archaeological sites. Africans were known to use millets in their myriad culinary courses. The leader of the Shang Dynasty in the 2nd millennium BC was known as Hou Chi, 'The ruler of Millet'. Indian vedic scriptures like Sathapatha Brahmana have ample references to millets. Kalidasa, in his legendary literary masterpiece 'Shakuntala', has sage Kanva pouring foxtail millet while bidding farewell to Shakuntala in Dushanta's court.

The oldest historical roots of millet are found in China, where it was considered a sacred crop. One of the earliest recorded writings dates from 2800 BC giving directions for growing and storing of the grain. During prehistoric times, people of Northern India were also cultivating millet. Millet's travel continued throughout the Middle East and Northern Africa where it became a staple food. It further became a typical food of the Sumerian diet in about 2500 BC. Millet was even mentioned in the Hebrew bible. The idyllic Hanging Gardens of Babylon were said to have included millet among their treasured plants. Through trading with Eritrea and Somalia circa 3000 BC, the early Egyptians learned from the Africans how to cultivate millet, which would grow well in the dry Sahara, where wheat and barley were unable to thrive. Millets made their way from China to the Black Sea region of Europe by 5000 BC. Romans and Gauls made porridge from it and in the middle ages millet was more extensively eaten than wheat. The interesting fact is that millet is also pointed out in the Bible as used to prepare bread during those days.

Genetic Resources

Even the limited millet genetic resources are getting eroded in a fast pace mainly due to neglect, among other reasons, resulting in replacement with more remunerative commercial or non-food crops (Balaravi e*t al*., 2010). Despite national efforts to collect minor millet germplasm from farmers, research to improve these crops has been negligible. Liberalization of the Indian seed sector in the 1990s favoured dry land cereals and legumes, with little impact on research and formal distribution channels for minor millets. Neglected and underutilized crop genetic resources are very vital for sustainable agriculture (Bhag Mal, 2007) and minor millets belong to this important group of crops (Dutta *et al*., 2007). Plant genetic resources play a critical role in enhancing adaptation and resilience of agricultural production systems (Jarvis *et al*., 2007). Currently, states of Andhra Pradesh, Karnataka, and Tamil Nadu lead in crop improvement research on minor millets. but the range of improved varieties is narrow. Private companies show little interest in developing new varieties, due to their lack of commercial importance and the limited scope for developing new hybrids. Minor millet with a higher yield potential have been recommended for cultivation in India are given in Table 3 and some of these varieties are mentioned in the publication by ICAR(2013)

Kolli Hills of Tamil Nadu, Koraput of Odisha and Dharvad in Karnataka have a genetically diverse pool of minor millet varieties being grown by the tribal farming communities for their own consumption without formal trade. Lack of attention of researchers, policy makers, donors, farmers and consumers is increasingly threatening the genetic diversity of minor millets. This is an irreversible loss to the humanity, particularly the poor who heavily depend on these crops for their food and nutritional security and income generation (Prabhakaran *et al.* 2012).

Very recently minor millets, especially finger millet has received better attention by research and development agencies in terms of agronomy and improved varieties. About 86 improved varieties of finger millet have been released during 1935-2008 with seed production system available for a few of these varieties. These crops are virtually free from insect-pests in the field, though they are affected by a few major diseases. Plant protection measures, which are seldom used by farmers, can contribute to productivity increase by minimizing the disease-induced yield losses. The Variation in Finger shape of *Eleusine coracana* is shown in Figure 1.

With regard to the conservation of the genetic resources of minor millets, the largest *ex situ* collection at international level is maintained by the Consultative Group on International Agricultural Research (CGIAR). These collections hold 46,231 accessions and 16.7% of them has been duplicated and deposited with the Global Crop Diversity Trust for safe storage at the Svalbard Gene Bank in Norway. The largest CGIAR collection is being held at ICRISAT (10,193 accessions). India holds the largest national collection at the National Bureau of Plant Genetic Resources (21,226 accessions) in New Delhi. A working collection of 13,296 accessions is being maintained by the All India Coordinated Small Millet Improvement Project at the University of Agricultural Sciences, Bangalore (Karnataka). Minor millet germplasm collections are also maintained at the N.I.Vavilov Research Institute of Plant Industry (VIR) in Russia and at CIRAD, France. Very scarce information is available with regard to *in situ*/on-farm conservation of minor millets. On-farm conservation is a dynamic process, because varieties managed by the farmers continue to evolve in response to natural and human selection leading to crop populations with better adaptive potential for the future (Brush, 2000).

Figure 1. Phenotypic variation in fingers of Eleusine coracana from Odisha region of India

ADVANTAGES OF MILLETS

Millets are versatile in that they perform well in regions with erratic rainfall or in low-quality arable land. They are highly nutritious, the grains have a good storage capacity, mature quickly and are less susceptible to pests and diseases. The extraordinary hardiness of many of these species and their ability to cope with adverse growing and climatic conditions offer great promise in the context of climate change. Though millets occupy relatively a lower position among food crops in Indian agriculture, they are quite important from the point of food security at regional and house hold level. Small millets can be grown even in poor soil and climatic conditions. They have short growing season and can be very well fitted into multiple cropping systems both under irrigated as well as dry farming conditions. They can provide nutritious grain and fodder in a short span of time. Small millets have a capacity for wide adaptation. They can withstand a certain degree of soil acidity and alkalinity, stress due to moisture and temperature and variation in soils from heavy to sandy infertile ones. It is important to enhance production and productivity of these crops to ensure food and nutritional security (Stanly *et al.*, 2013). The small seeds have a long shelf life and can be stored for a long period without insect damage, which makes them good reserves for famine-prone areas. Millets provide the cheapest source of calories in people's diet, but unfortunately the support for production and consumption of rice and wheat through public distribution system has resulted in neglect of various millets by a significant number of small rain fed farmers engaged in its cultivation. This has led to reduction in conservation, cultivation and consumption of these crops (Yenag *et al.*, 2011).

Nutritional Value of Millets

Nutritional quality of food is a key element in maintaining overall human health. An increasingly important determinant in food choice is the growing consumer concern about nutrition and health (Nehir and Simsek, 2012). Therefore, for solving the problem of deeprooted food insecurity and malnutrition, dietary quality should be taken into consideration (Singh and Raghuvanshi, 2012). In addition to their cultivating advantages, millets are found to have high nutritive value comparable to that of major cereals such as wheat and rice (Parameswaran and Sadasivam 1994). It has also been reported that millet proteins are good sources of essential amino acids- except lysine and threonine -but are relatively high in methionine. Millets are also rich sources of phytochemicals and micronutrients (Mal *et al*., 2010; Singh *et al*., 2012). The various types of millets and their food values are given in Tables 4 and 5.

However, millet seeds have a seed coat which gives a darker color, chewy texture and musky odour. These characteristics reduce the applicability of millet in the food industry. Millets are highly nutritious, non-glutinous and non-acid forming foods. Hence they are soothing and easy to digest. They are considered to be the least allergenic and most digestible grains available. Compared to rice (especially polished rice), millets release lesser percentage of glucose. Finger millet is the richest in calcium, about 10 times that of rice or wheat. Considering the nutrient richness of these grains they are now considered as 'nutri-cereals' and not as 'coarse cereals'.

Though millets are generally regarded as "coarse" grains, their potential for augmenting the grain supplies, as also to considerably bridge the protein gap is being increasingly realized. Millet, besides being a rich source of carbohydrates, is very easy to digest; it contains a high amount of lecithin and is excellent for strengthening the nervous system. Millets are rich in B vitamins, especially niacin, pyridoxine and folic acid, as well as the minerals calcium, iron, potassium, magnesium and zinc.

Finger millet carbohydrates comprise of free sugars (1-2%), starch (75-80%) and non-starchy polysaccharides consisting of cellulose and hemicellulose. It is a very good source of dietary fibre, micronutrients and polyphenols. Fermented finger millet extract suppresses growth of *Salmonella* sp. and *Escherichia coli*. It is reported to have many nutraceutical and functional properties. The extremely good storage property of finger millet and its processed foods could be attributed to its polyphenol content (Mathangi, *et al*., 2012).

The seed husk of millet is an excellent source of phytochemicals (polyphenols up to 3%) and dietary fibre (Palanisamy, Bruntha Devi *et al.*, 2011). Certain parts of the seed contain anti-nutritive compounds such as phytates (0.48%), polyphenols, tannins (0.61%), tripsin inhibitory factors and hydrochloric acid which require processing for the promotion of millets for nutritional and organoleptic acceptance (Jingju, 2007; Shobana, 2007; Bagdia *et al..*, 2011).

In general, cereal proteins including millets are limited in lysine and tryptophan content and vary with cultivars. However, most cereals contain the essential amino acids as well as vitamins and minerals (Devi *et al..*, 2011; FAO, 2009). Millets generally contain significant amounts of essential amino acids particularly the sulphur containing amino acids (methionine and cysteine); they are also higher in fat content than maize, rice and sorghum (Obilana and Manyasa, 2002; Mal *et al.*, 2010). Though millets are not the important part of daily diet of American and European people, now these countries have recognized its importance as an ingredient in multigrain and gluten-free cereal products. However, in many Asian and African countries millet is the staple food of the people in millet producing areas and they prepare various traditional foods and beverages, breads as well as infant and snack foods from it (Chandrasekara and Shahidi, 2011). Whilst a number of traditional foods are made in the domestic household, the lack of large-scale industrial utilization discourages the farmers from raising millet crops (Subramanian and Viswanathan, 2003). Therefore, many countries including India, China, USA etc. have now started research to develop process technology for nutritional improvement, to fully take advantage of the health benefits and to promote them as food on a larger scale. 21st century challenges like climate change, water scarcity, increasing world population, rising food prices and other socio economic impacts are expected to generate a great threat to agriculture and food security worldwide, especially for the poorest people who live in arid and sub-arid regions (Saleh *et al.*, 2013). Millets have relatively poor digestibility and low bio-availability of minerals due to the presence of inherent anti-nutritional factors. The difficulties in millet grain processing present a challenge but nutritional as well as health benefits and consumer demand for health foods provide opportunities in processing, development of suitable technology for newer products and process mechanization.

Millet grains are nutritionally comparable and even superior to major cereals with respect to protein, energy, vitamins and minerals (Sehgal and Kawatra, 2003). Millets are a rich source of minerals, nutraceuticals and higher dietary fibers when compared to rice or wheat and contains 9-14% protein and 70-80% carbohydrates (Hadimani and Malleshi, 1993). These are rich sources of phytochemicals and micronutrients (Singh *et al.*, 2012b). The quality of protein is mainly a function of its essential amino acids. Finger millet contains 44.7% essential amino acids of the total amino acids (FAO, 1991; Mbithi *et al.*, 2000). The characterization of the proteins of millet grains shows that prolamin fraction constitutes the major storage protein of the grain and lysine is the most limiting amino acid followed by cystine but millets are relatively high in methionine (Monteiro *et al.*, 1987; Sudharshana *et al.*, 1987; Kumar and Parmeswaran, 1999). The true digestibility and biological value of these millets range between 95.0 to 99.3 and 48.3 to 56.5 respectively (Geerwani and Eggum, 1989). Among the millets, pearl millet (*Bajra*) has the highest content of macronutrients and iron, zinc, Mg, P, folic acid and riboflavin. It is significantly rich in resistant starch and soluble and insoluble dietary fibres (Antony *et al.* 1996; Ragaee *et al.*, 2006). Finger millet seed coat is an edible material and contains good proportion of dietary fibre, minerals and phytochemicals. The seed coat matter (SCM) forms a by-product of millet milling, malting and decortication industries which can be profitably utilized as composite flour in biscuit preparation (Krishnan *et al.*, 2011). Finger millet is an extraordinary source of calcium. Kodo millet and little millet are also reported to have 37% to 38% of dietary fiber, which is the highest among them (Malleshi and Hadimani 1993; Antony *et al.*, 1996). Kodo millet has the highest free radical (DPPH) quenching activity followed by great millet (sorghum) and finger millet (Hegde and Chandra, 2005). The niacin content in pearl millet is higher than all other cereals. In addition, millets are gluten-free, easy to digest and are a great source of antioxidants and might have anti-carcinogenic properties (Dykes and Rooney, 2006). The lipid content is generally high (3–6%) for pearl millet - higher than that of sorghum and most other common cereals. About 75% of the fatty acids in pearl millet are unsaturated and linoleic acid is particularly high (46.3%). For this reason energy content of millet is greater than sorghum and nearly equal to that of brown rice. Finger and teff millet are good sources of dietary calcium and magnesium and iron content is significant.

Health Benefits of Millets

Millets are still the staple food for millions of poor people in Africa and Asia. Like many other cereals, millets are nutritious and high in carbohydrate energy content, making them useful components for dietary and nutritional balance in foods. Millets offer unique advantage for health being rich in micronutrients, particularly minerals and B vitamins as well as nutraceuticals. Combination of millets with other sources of protein would compensate the deficiency of certain amino acids such as lysine. Successful improvement of these attributes would be a crucial key to expand the spectrum of applications of millet grains (Issoufou Amadou *et al* 2013). If included in the daily diet, millets provide adequate nutrition and offer health benefits especially in the management of disorders like diabetes mellitus, obesity, hyperlipidemia, etc. (Veena, 2003).

Since millet is gluten-free, it is an excellent option for people suffering from celiac diseases often irritated by the gluten content of wheat and other more common cereal grains and also useful for people who are suffering from atherosclerosis and diabetic heart disease (Gélinas *et al*., 2008). Finger millet diets have been found to lower blood glucose and cholesterol. It has a potent therapeutic role as dietary supplement for the prevention of glycation induced complications, as in diabetes or aging. The grain is also rich in phytochemicals, including phytic acid, which is believed to lower cholesterol, and phytate, which is associated with reduced cancer risk (Coulibaly *et al.*, 2011). These health benefits have been partly attributed to the wide variety of potential chemo preventive substances, called phytochemicals, including antioxidants present in high amounts (Izadi *et al.*, 2012). Chandrasekara and Shahidi (2010) reported that non processed brown finger millet had the highest radical quenching activity than the processed one and postulated that tannins and phytic acid were responsible for the activity. Millet extract from the seed coat were reported to have shown high antibacterial and antifungal activity compared to whole flour extract due to high polyphenol content in seed coat (Viswanath *et al.*, 2009). It maintains cardiovascular health and helps to reduce acidity problems. Epidemiological evidence from research studies has shown that diets rich in plant foods are protective against several degenerative diseases such as cancer, cardiovascular ailments, diabetes, metabolic syndrome and Parkinson's disease (Manach *et al.,* 2005; Scalbert *et al.,* 2005; Chandrasekara and Shahidi 2012). In addition, there is strong epidemiological evidence that whole-grain cereals protect the body against age-related diseases such as diabetes, cardiovascular diseases and some cancers (Fardet *et al.* 2008).

The chemical reaction between the aldehyde group of reducing sugars and the amino group of proteins is a major factor responsible for the complications of diabetes and aging (Monnier 1990). Millet grains are rich in antioxidants and phenolics; it has been established that phytates, phenols, and tannins can contribute to antioxidant activity, important in health, aging, and metabolic syndrome (Bravo 1998). It has also been found that methanolic extracts from finger millet and kodo millet inhibited glycation and cross-linking of collagen (Hegde *et al.,* 2002). Therefore, there is potential usefulness of millets in the protection against aging (Issoufou Amadou *et. al* .2013).

Value Addition

All millets are cooked after dehulling and dehulled grain is milled into flour. Traditional way of hulling Finger millet is given in Figure 2. Italian millet is consumed as stiff porridge called sargatic or as roti. Proso millet flour is also used as a substitute for rice flour in various snack foods. Millet protein lacks gluten, hence it is unsuitable as the sole material for preparation of bakery products. Mudde from millet flour is prepared by steaming the dough and making it into balls. Millet flours are soaked overnight in cold water containing a little butter milk and the slurry after fermentation is used to prepare porridge. Millets and black gram mixed in the ratio of 3:1 are wet ground and fermented overnight which can be steamed to make idli or baked on hot pan to prepare dosa or wet pan cakes. Non-conventional foods like flakes and extruded products can be prepared from millets. Flakes are prepared by soaking pearl millets in water and then steamed under pressure for complete gelatination of the starch and dried to about 18% moisture. Then they are pressed to requisite thickness between heavy duty rollers and dried to prepare flakes which hydrate quickly when added to warm water or milk. Noodle like products can be prepared from millet flours. They form nutritionally balanced food which is used as supplementary or weaning foods.

Typical grain texture and hard seed coat of millets increases their keeping quality but makes them difficult to process as well as cook in convenient form. Absence of appropriate primary processing technologies to prepare ready-to-use or ready-to-cook products and also secondary as well as tertiary processing to prepare ready-to-eat value added products have been the major limiting factors for their diversified food uses (Malleshi, 2014). Par boiling improves the quality and is also used to prepare expanded grains. Millets are rarely used to produce starch for industrial uses. Their starches generally exhibit higher gelatinization temperature, higher water binding capacity and are slow in enzymatic hydrolysis than that of wheat and rice. Millets may also find use for formulating high fibre and diabetic foods.

In collaboration with agricultural universities in Bangalore and Dharwad as well as Bioversity International, M.S. Swaminathan Research Foundation (MSSRF) has been working with tribal farming families in the Indian states of Uttarakhand, Odisha, Tamil Nadu and Karnataka to increase production and to facilitate commercialization of little millet, finger millet and foxtail millet. Traditional milling and grinding using pestle and mortar and manual grinding stones take several hours. To reduce the drudgery of processing, simple mechanical pulverisers and dehulling units were introduced and women trained to operate and maintain them. Using the new machines, processing was reduced to ten minutes

Figure 2. Traditional method of dehusking finger millet

and consequently led to a revival of interest amongst the women for cultivating and consuming millets to a greater extent. Attempts were also made, along with rural women to add value and develop popular snack foods such as ragi powder, *murukku*, *laddu* etc. By training the women in maintaining quality, standardization, packaging and production, new millet-based recipes were developed for urban consumers and schools, which led to increased sales of millet based products. The new recipes were cost effective without being labour or time intensive, leaving the women with more time for carrying out other responsibilities. The new recipes were also promoted to combat nutritional deficiencies among school going children, as the snacks are higher in protein and vitamins than equivalent products made of rice or wheat. In another initiative, women who produced and packaged a finger millet-based, hot malt drink testified that it tasted similar to chocolate, with more nutrients. These opened opportunities to provide it for the benefit of both mothers and children creating a higher demand and increased profits. But much desires to be done to take these initiatives to a marketable proposition.

Cultivation: Indian Scenario

India is the largest producer of many kinds of millets and it remains a staple crop for numerous households. In India's dry lands, they play a significant role in meeting food and fodder requirements of farming communities. Millets are invariably grown in the semi-arid and mountainous regions of tropics and subtropics, where monsoon failure and drought are frequent, soil fertility is poor and land terrain is difficult. These regions are also hot spots of poverty and frequent starvation. Traditional agriculture in these regions has found more dependability on minor millets because of their extreme hardiness. Millets are grown in an area of 3.5 million hectares in India, their cultivation extending from sea level in coastal Andhra Pradesh up to an altitude of 8000 feet above sea level in hills of Uttaranchal and North-Eastern states (Table 6). They offer satisfactory yields from shallow and less fertile soils and in steep slopes of hillocks and mountainous terrains. Their yield varies widely from very low to modestly high across regions and years depending on the soil, management and weather. Millets have retained their primacy under these farming conditions to provide livelihood and food security to the poor people. Millets have been farmed at subsistence level with years of experience and traditional wisdom embedded in the varietal choice and farming systems. These systems are invariably structured on location specific multiple or intercropping systems to safeguard livelihood even under unforeseen weather. These farming systems and underlying economic compulsions have discouraged extensive use of fertilizers, herbicides or pesticides in minor millet farming. Farmers in each region have been innovative in developing many local cultivars, which are well adapted to their farming conditions. Millets have hardly received any attention from national or global food policy makers in research funding and improvement of these crops. Hence they continue to be grown largely under traditional practices using traditional cultivars under subsistence farming.

Millets, and particularly small millets, are in a crisis situation in India. The period between 1961 and 2009 saw a dramatic decrease in cultivated area under millets (80% for small millets, 46% for finger millet, 59% for sorghum and 23% for pearl millet); a 76% decrease in total production of small millets; a significant decrease in per capita availability of all millets (despite high productivity gains for some varieties); and a steep fall in overall millet consumption. Almost 50% area under millets has been diverted largely to soybean, maize, cotton, sugarcane and sunflower. A combination of factors like low remuneration compared to other food crops, lack of input subsidies and price incentives, subsidized supply of fine cereals through Public Distribution System (PDS), and change in consumer preference coupled with difficulty in processing, low shelf life of flour and low social status attached to millets, have led to shift from production of millets to other competing crops.

Constraints Limiting Productivity of Millets

Millets have traditionally played an important role in farming and food culture in many regions of the world, including Sub-Saharan Africa and South Asia (McDonough *et al.*, 2000) with India being the world's largest producer of these crops. Millets mature quickly, a valuable trait important for rain-fed farming, and require relatively few inputs compared to major cereals. They grow under a range of day lengths and in poor soil, making them an attractive crop for marginal farming environments. In addition to these agronomic advantages, millets can offer other benefits in ecological, nutritional, and socio-economic areas. Though overall production of millets in India has increased over the past few decades, from 7.7 million tons in 1961 to 10.7 million tons in 2012, the area dedicated to minor millets has fallen; finger millet declined from 2.3 million ha in 1951–1955 to 1.35 million ha in 2006–2010. Other minor millets declined even more precipitously, from 5.29 million ha to 0.97 million ha over the same period. Productivity of finger millet, in terms of yield per ha, doubled from 704 to 1471 kg ha^{-1} largely thanks to improved varieties more than making up for the decrease in area. According to Mal and Padulosi.,2013, the other minor millets recorded more modest gains in productivity, from 410 to 480 kg ha^{-1} and total production is less than a quarter of its 1950 value (2.177 MT in 1951–1955 *vs.* 0.467 MT in 2006–2010). The decline in minor millets in India can be attributed to many factors; agronomic, economic and social. The green revolution of the 1970s saw government promotion of rice and wheat pushing minor millets into even more marginal areas. Unfortunate consequence is that in those areas, millets have come to be regarded as crops of the poor, which they are, and thus to be avoided. Policymakers have contributed to this by keeping millets largely out of the scope of both official research and development and price support agreements. Continuing neglect hastens the loss of genetic diversity and traditional knowledge on the production, processing and use of millets. Production is inefficient as a result of lack of suitable higher yielding varieties, poor quality seeds and unimproved cultivation practices. Traditional processing methods considerably increase the daily drudgery of women who prepare millets. Coupled with unfavourable environmental policy, there is a lack of attractive recipes for adding value, lack of awareness of the nutritional value of millets, poorly organized integration with markets, and generally unfavourable environmental policy.

The major constraints can be summarized as follows:

1. Millets are grown on poor shallow and marginal soils under rain fed conditions. The soils on which these are gown have mostly low moisture retention capacity. Some of these are still grown in the hilly areas under shifting cultivation which is one of the most primitive ways of cultivation.
2. Shortage of improved seeds as there is no organized programme for production and supply of seeds with high yield potential. Seed is usually farm saved and of poor quality. Poverty and lack of food security also threaten the seed supply sometimes forcing farmers to eat their saved seed.
3. Seeds are often broadcast. This is a major bottle neck in taking inter-cultivation operation and effective weed control. Mixed cropping practices adopted by the farmers are often suited to sustenance agriculture and many of them are not remunerative.

4. Research has paid little attention to improve the genetic potential of the crop and the way it is cultivated and used. Even the known crop management practices are not able to be adopted by the farmers due to their socio-economic constraints ((Balakrishnan *et al.*, 2002, Stefano *et al.*, 2015).
5. Typical grain texture and hard seed coat of millets make them difficult to process as well as cook in convenient form. Absence of appropriate primary processing technologies to prepare ready-to-use or ready-to-cook (RTC) products and also secondary as well as tertiary processing to prepare ready-to-eat value added products make it difficult to exploit their diversified food uses (Malleshi, 2014) The grains are to be hulled, cleaned and often powdered before use. These are cumbersome tasks often carried out by women and in the absence of affordable small scale processing units, act as a deterrent factor in taking up millet cultivation.
6. There is no ready market for the disposal of surplus produce at a remunerative price. So also extension and development support are unsatisfactory.
7. More recently, farmers have turned to cash crops such as cassava, and even eucalyptus where promotional schemes are available, resulting in a decline in millet cultivation.
8. The yield gap in millets is largely due to existing poor cultivation technology that leaves ample scope for improvement.
9. Lack of awareness on the nutritive value and health benefits of millets.

FUTURE STRATEGY

1. **Strengthening Breeding Programmes:** Added research efforts are required in collection of traditional cultivars and their breeding to provide improved seeds with high yield potential and other desirable traits like drought tolerance. Development of varieties/ hybrids should better be taken up with active participation of farmers (participatory millet breeding) to take full advantage of local resources and indigenous knowledge. Conventional breeding as well as marker-assisted breeding for bio fortification and for incorporating other traits such as better root architecture.
2. **Seed Production:** Efficient seed production measures with public, private, NGO partnership and establishment of seed villages to make quality seeds available in sufficient quantity.
3. **Improved Agro Techniques:** Concurrent work is required to develop specific management practices to realize full potential of the newly evolved varieties. Strategies for zero tillage under rice fallows are required. Validation and refinement of indigenous technology under various farming situations will be rewarding.
4. **Processing Facilities:** Development of small scale processing units for de-husking and powdering of small millets coupled with proper packaging facilities.
5. **Value Addition:** Processing technologies to prepare ready-to-use or ready-to-cook products and also secondary as well as tertiary processing to prepare ready-to-eat value added products.
6. **Government Support:** Support to farmers in terms of subsidy and loan for various farm operations is required, considering the poor financial position of the millet farmers. Better procurement prices and insurance coverage to mitigate hardship of millet farmers in view of the serious yield loss under climate change.
7. **Inclusion of Millets in the PDS System:** This recommendation made by M.S. Swaminanthan and accepted by the Government of India has to be properly implemented.

8. **Post-Harvest Technology:** Research for better post-harvest management, especially for enhancing the shelf life of millets and prevention of wastage.
9. **Validation of Health Benefits:** Consortium-mode research may be pursued for validating the advantages of millets as health and functional foods.
10. **Marketing:** Markets and entrepreneurship development through modern and innovative approaches coupled with storage and marketing facilities at village level.
11. **Public Awareness:** Proper advertisement strategies are necessary to increase awareness on the nutritional advantages and health benefits of millets.

CONCLUSION

In the face of increasing population and stagnant wheat and rice production, millets can be a promising alternative in solving the problem of food insecurity and malnutrition, because of their sustainability in adverse agro-climatic conditions. These crops have substantive potential in broadening the genetic diversity of the food basket and ensuring improved food and nutrition security. Through millet consumption, we will be encouraging farmers in dry land areas to grow crops suited for these regions. This is a step towards introducing diversity in our diets, by using the local biodiversity.

These facts call for added attention to promote their cultivation and consumption. Enhancement of millet cultivation gives an interesting opportunity to bridge the yield gap in food production. According to one estimate, "increasing yields to 50% of the potential yield in all low-performing areas could increase annual production, which is enough to meet the basic caloric requirements of 850 million people". While annual yield increase (as a percentage of current yield) in staples like rice and wheat are below 1%, directing greater research attention to nutritious cereals like millets would be a strategic choice, because it would be more viable and would offer greater benefits in terms of lower water requirement and adaptation to climate change. This creates social impact in terms of greater self-reliance of local population as well as more resilience to food systems. There is further opportunity to provide better

Table 1. Vernacular names of millets

English	Alternate Names	Botanical	Hindi	Kannada	Tamil	Telugu	Malayalam	Marathi
Sorghum	Great Millet/ Milo/Chari	*Sorghum vulgare*	Jowar	Jola	Cholam	Jonnalu	Cholam	Jwari
Pearl Millet	Spiked Millet/ Bullrush	*Pennisetum typhoideum*	Bajra	Sajje	Kambu	Gantilu/ Sazzalu	Kambu	Bajri
Finger Millet	Rajika	*Eleusine coracana*	Mandua/ madua	Ragi	Kelvargu/ kezhvaragu	Ragulu	Muthari	Nachni
Barnyard Millet	Japanese Millet/ Sawank	*Echinochola frumantacea*	Jhangora/ Shama	Samai	Kuthiravaali	Odalu/ Bonta/ Chamula	–	Shamul
Foxtail Millet	Moha Millet/ Italian Millet	*Setarai italica*	Kangni	Navane/ PriyanguThene	Tenai	Korra/ Korralu	Thina	Rala
Kodo Millet	Pakodi/ Manakodra	*Paspalum scrobiculatum*	Kodra	Harka	Varagu	Arikelu	Varagu	Harik
Proso Millet	French Millet/ Common Millet	*Panicum miliaceum*	Barri	Baragu	Panivaragu	Varigulu/ Varagalu	Panivaragu	Vari
Little Millet	Goudli/Gondola	*Panicum miliare*	Kutki	Same	Samai	Sama	Chama	Sava

Table 2. Details of small millet crops

Crops	Particulars	
Barnyard Millet: *Echinochola colona* (L.) Link.	Origin	India
	Existential	Minuscule food, cattle fodder, cattle and poultry feed.
	Ecology	Adapted to temperate climate and grows well in tropics as well as on soils with fragile ecology
	Temperature	Tolerant to wide temperature range
	Altitude	Up to 2700 metres
	Rainfall	200-400 mm.
	Distribution	
	Global	Tansaniaand Malawi republic of Africa, India, Nepal, Japan, Korea and China.
	India	Andhra Pradesh, Gujarat, Madhya Pradesh, Maharashtra,Tamilnadu and Uttarakhand
Common(Proso) Millet: *Panicum milliaceum* L.	Origin	Central and Eastern Asia
	Existential	Minuscule food with medicinal properties being rich in Choline with traces of manganese, copper and zinc and minerals like calcium, phosphorous and iron. Used for hog feed, cattle fodder, bedding and starch for textiles.
	Soils	Marginal shallow lands with low humus
	Temperature	Tolerant to very wide temperature range
	Altitude	Up to 2700 metres
	Rainfall	200-400 mm.
	Pollination	Partly cross-pollinated
	Distribution	
	Global	Neolithic Europe, Volga region of Russia, Khazakhistan, Bangladesh, Srilanka, Nepal and China, North and West America, Kenya, Zimbabwe Ethiopia and India.
	India	Andhra Pradesh, Bihar, Gujarat, Karnataka, Maharashtra, Rajasthan and Tamilnadu
Foxtail Millet: *Setaria italica* Beauv.	Origin	Eastern Asia.
	Existential	Minuscule food rich in minerals, popped culinary and cattle fodder
	Ecology	Adapted to hot and dry climate. Grown in temperate regions to tropics
	Soils	Marginal shallow lands with no humus. Grown mostly as companion crop with cotton/pulses/ oilseeds
	Temperature	Tolerant to very wide temperature range
	Rainfall	200-400 mm
	Distribution	
	Global	Eurasia, Ethiopia, Zimbabwe, Japan, China, Nepal and India
	India	Andhra Pradesh, Gujarat, Maharashtra, Rajasthan and Tamilnadu
Kodo Millet: *Paspalum scrobiculatum* L.	Origin	India
	Existential	Minuscule food, cattle and cattle fodder
	Ecology	Koda millet can grow even where no other cereal grows. Adapted to very hot and dry climate.
	Soils	Marginal soil with no humus, hilly slopes/edges
	Distribution	
	Global	Uganda
	India	Andhra Pradesh, Gujarat, Karnataka,Maharashtra, Chhattisgarh, Madhya Pradesh and Tamilnadu
Little Millet: *Panicum sumatrense* Roth Ex. Roem & Schult	Origin	Arid Western and North America.
	Existential	Minuscule food, cattle fodder
	Ecology	A very hot and dry season crop grown on marginal lands and hilly slopes.
	Temperature	Tolerant to very wide temperature range.
	Rainfall	200-400 mm
	Altitude	Up to 2100 metres
	Distribution	
	Global	South East Asia, China and India
	India	Andhra Pradesh, Bihar, Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Odisha and Tamilnadu

continued on following page

Table 2. Continued

Crops	Particulars	
Finger Millet: *Eleusine coracana*	Origin	Ethiopian region of Africa
	Existential	Across the states in India. A famine crop in Ethiopia, staple food in the regions of perturbed ecology across the globe. Used for beverages, baby food, cattle fodder and for thatching
	Ecology	A warm season crop grown from sea level to 3000 metres (above msl.), C4 plant
	Soils	Grows well on well drained soils with steady supply of moisture
	Rainfall	500-2000 mm
	Temperature	Optimum 15-27^{0}C
	Distribution	
	Global	South East Asia, Africa, China and India
	India	Andhra Pradesh, Bihar, Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Odisha and Tamilnadu

Table 3. Some released varieties of millets in India

SL No.	Crop	Name of the Variety
1	Finger Millet	GPU 45, Chillika OEB 10, TANU 946, VL 315 & GPU 48, VL 149, PR 202, GPU 26 and CO 11 PES 176, PES 110, Pant Mandua 3, PRM 1, PRM 2,(Ranichouri) CO 10,CO 11,Paiyur 1, CO 12, TRY 1, CO 13 Indira Ragi -1(BR-7), Dapoli Safed-1
2	Foxtail millet	Meera (SR 16), Sri Lakshmi, Prathap kangni 1(SR 1), SR 51, PRK 1 & TANU 196 Pant Setaria - 4, PRK-1
3	Kodo millet	Jawahar kodo 48 (JK 48) & KK 2 GPUK 3 and JK 48 Indira Kodo-1(BK-1) CO 3, APK1,Vamban 1
4	Barnyard millet	VL Madira 181and VL 172 CO1
5	Little millet	Tarini (OLM 203), Kolab (OLM 36) & OLM 20 TNAU 63 CO 2, Paiyur1, CO 3, Paiyur2
6	Proso millet	GPUP 8 & GPUP 21 PRC - 1 BR 7 and K 1 CO 2,CO 3,CO 4

Table 4. Food value of millets compared to rice (%)

Name of Millet	Moisture	Protein	Carbohydrate	Fat	Fibre	Mineral	Calcium	Phosphorous	Calorific Value (100g)
Finger millet	13.0	8.0	72.0	1.3	3.0	2.70	0.3	0.3	332
Common millet	11.1	13.71	72.26	1.76	0.10	1.07	0.01	0.2	341
Foxtail millet	11.9	9.7	72.4	3.5	1.0	1.5	0.04	0.3	353
Little millet	11.1	13.4	72.3	1.8	0.10	1.1	0.02	0.3	360
Kodo millet	11.6	10.6	59.2	4.2	10.2	4.4	0.04	0.3	346
Tef	11.2	9.1	74.3	2.2	-	-	-	-	-
Japanese Barnyard millet	11.9	6.2	65.5	2.2	9.8	4.4	-	-	-
Hungry rice	6.0	8.7	81.0	1.1	1.1	2.1	-	-	-
Polished rice	13.2	7.5	76.7	1.0	0.3	1.6	0.01	0.17	348

Source: FAO 2001.

adapted and higher yielding materials both for grain and forage, but these will require added research efforts, development of niche markets and improvement in management techniques.

Millets are drought, temperature and pest tolerant and hence are grains for the future in an environment of climate change and global warming. Despite these attributes, these cops are loosing their pride of place both in terms of production and consumption, for a variety of reasons, including unfavourable

Table 5. Amino acid profiles of millet grains

Amino Acids (g/100g)	Foxtail Millet (Defatted Flour) (a)	Proso Millet (Dehulled Grain) (b)	Pearl Millet (True Prolamine) (c)	Finger Millet (Native Grain) (d)
Essential Amino Acids				
Isoleucine	4.59	4.1	5.1	4.3
Leucine	13.6	12.2	14.1	10.8
Lysine	1.59	1.5	0.5	2.2
Methionine	3.06	2.2	1	2.9
Phenylalanine	6.27	5.5	7.6	6
Threonine	3.68	3	3.3	4.3
Valine	5.81	5.4	4.2	6.3
Histidine	2.11	2.1	1.7	2.3
Tryptophan	NA	0.8	1.2	NA
Non-Essential Amino Acids				
Alanine	9.3	10.9	8.1	6.1
Arginine	3	3.2	0.9	3.4
Aspartic acid	7.71	6.2	6.2	5.7
Cystine	0.45	NA	0.8	NA
Glutamic acid	22	21.3	22.8	23.2
Glycine	2.91	2.1	0.7	3.3
Serine	4.56	6.3	5.4	5.3
Tyrosine	2.44	4	2.7	3.6
Pronile	5.54	7.3	8.2	9.9
*PER (b)	0.8	1.1	1.6	2

References: (a) Bagdia *et al.*. (2011); (b) Devi *et al.* (2011).
*Protein efficiency ratio (PER). NA: Not available.

Table 6. Trend in harvested area, production, and consumption of millets in India

Years	Harvested Area (in 0000' M. Ha)	Growth %	Production (in 0000' M. MT)	Growth %	Consumption (in 0000' M. MT)	Growth %
2001	12000	-7.87%	900	0.00%	900	0.00%
2002	9000	-25.00%	700	-22.22%	700	-22.22%
2003	13100	45.56%	900	28.57%	900	28.57%
2004	11000	-16.03%	800	-11.11%	800	-11.11%
2005	10500	-4.55%	900	12.50%	900	12.50%
2006	10300	-1.90%	900	0.00%	900	0.00%
2007	10800	4.85%	1000	11.11%	1000	11.11%
2008	10000	-7.41%	1000	0.00%	1000	0.00%
2009	10400	4.00%	700	-30.00%	700	-30.00%
2010	11150	7.21%	1200	71.43%	1200	71.43%
2011	10800	-3.14%	1500	25.00%	1500	25.00%
2012	8500	-21.30%	1200	-20.00%	1200	-20.00%

Source: Ministry of Agriculture, Govt. of India and United States Department of Agriculture.

policy initiatives. Though they have not enjoyed technological breakthroughs like the green revolution for rice and wheat, their productivity has increased. Confined to poor lands, productivity is affected resulting in a wide gap between potential productivity and productivity in farmers' fields. Scientific, technological and behavioural engineering involving convergence of efforts of agricultural scientists, food technologists, home scientists, policy makers, and media is needed to revitalise millets. Nutritional as well as health benefits and consumer demand for health foods provide opportunities in processing, development of suitable technology for newer products and process mechanization. This change in technology and consumer food preference would help in increasing the area under millets, maintaining ecological balance, ensuring food security, preventing malnutrition and increasing the scope for utilization of millet grains on an industrial scale.

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Chapter 8
Strategic Approaches to Food Security in Developing Countries

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ABSTRACT

As the world's population increases, the issue of food security presents a serious challenge. Currently, food security is reliant on a very narrow range of cultivated plant species and is also limited to traditional animal husbandry practices. The use of edible wild plants can be considered to support food security efforts. Such plants have shown to be more resilient compared to traditionally cultivated crops and also have superior nutritional attributes. The issue of protein food security can be addressed through production improvements for local or indigenous chickens, livestock production systems and wildlife to some extent. Food security in developing countries would increasingly become more dependent on widening the biodiversity from which food is selected and utilized and insects, like wild plants, provide another such opportunity. Contemporary reproductive technologies such as lactation induction, embryo transfer and artificial insemination among others can bolster food security efforts in developing countries. Improvements in forage species as well as processing technologies to improve nutritional value of low quality forages can improve overall animal nutrition. Irrespective of the concerns related to genetically modified organisms (GMOs), these sources of food could be beneficial globally. The formation of farmers' groups can be a strategic approach to food security in resource poor developing countries for the purposes of collective action and resource sharing. Sustainable food security requires the integration of several multi-dimensional approaches into a holistic management model to achieve the food security objectives in many developing nations.

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INTRODUCTION

Global food security objectives, amidst increases in the world's population and environmental changes, would require the implementation of multidimensional strategies to significantly improve the future sustainable production of food. According to Food and Agriculture Organization (FAO, 2009a), the world population is expected to be just over 9 billion by 2050 and most of this population increase is expected to occur in developing countries. While China (1.4 billion) and India (1.3 billion) remain the two largest countries of the world, representing 19 and 18 per cent of the world's population, respectively, Africa has been cited as the fastest growing major area (2.55% annually, from 2010-2015) and is expected to account for more than half of the global population increase between now and 2050 (United Nations, 2015). Africa is followed by Asia, Northern America, Latin America and the Caribbean and Oceania. It is therefore instructive that if population growth is to be concentrated in many of the underdeveloped and developing regions of the world then food production, sustainability and security become a major center piece in policy development for these regions. Rijsberman (2012) in a report related to the future of food indicated that agricultural production is unable to keep up with the global demand for food resulting from an increase in world population levels. The report further suggests that annually there are almost 80 million more mouths to feed. There have been estimates that food production would need to increase by 70% by 2050 (FAO, 2009b). It was recommended that this estimate can be reduced to 60% by drastically reducing huge losses and wastage of food and through the sustainable management of natural resources (Nwanze, Graziano da Silva, Cousin & Frison, 2012). The amount of food globally loss or wasted per year is predicted to be around 1.3 billion tons (Gustavsson, Cederberg, Sonesson, van Otterdijk & Meybeck, 2011). As a result of a myriad of biological, environmental and socio-economic factors, food losses in developing countries are considerably high and urgent intervention is required to address this occurrence.

The urbanization phenomenon has the potential to impact agricultural productivity in the rural regions of developing countries. The pressures of urbanization such as rural to urban migration and rural urbanization would see the removal and reduction of labour and land resources away from agricultural activities. The reality of a shrinking agricultural work force, resulting from employment preferences in other economic sectors, is further negatively impacting agricultural production. The shift of labour from low productivity agriculture sector to the more productive industrialized sectors has increased the level of income derived for Caribbean countries. Notwithstanding the need for industrial development, Lewis (1954) pointed out that "industrial and agrarian revolutions always go together and is the reason why economies in which agriculture is stagnant do not show industrial growth." The industrial development of the Caribbean and other developing countries should not occur with agricultural neglect. It is necessary for governments in the developing regions around the world to place focus on developing and employing sustainable agricultural polices to ensure national food security. Although, urbanization is seemingly a positive driver for economic growth and development within developing countries (Overman & Venables, 2005) there are noticeable effects on the availability, stability, safety and access to food as reported by Matuschke (2009). It should be noted that rapid urbanization may have a long term effect on the sustainable production of food as there would be extreme demands to intensify the agricultural productivity of rural areas beyond their capacity.

The national food security of any country can be improved by either accelerating food production or through the importation of food (Trueblood & Shapouri, 2001). Currently, the agricultural sectors in the Caribbean and many other developing countries have been underperforming resulting in unfulfilled national demands for food. The underperformance of the agricultural sector in such countries has been attributed to constraints on productivity resulting from small scale operations, limited public and private investment and natural disasters (Bourne, 2008). Vehemently outdated farming techniques, improper infrastructure and limited mechanization continue to keep the level of food production well behind the rate of population growth. As a direct result of food production inefficiencies, developing nations throughout the world have grown increasingly dependent on food imports over time (Walters & Keithley, 2012). The gap between domestic consumption and domestic production in the Caribbean is noticeably significant, with consumption being almost two, to four times greater than production (Mendoza & Machado, 2009). The reliance on food imports can have catastrophic consequences in the long run and as such much greater focus must be placed on accelerating food production and exploring alternative food sources within developing countries. It is essential for greater efforts to be directed to insisting, implementing and monitoring the adoption of standard best practices at the farm level if there are to be any significant improvements in the production of food within developing countries.

The unavoidable influence of climate change would undoubtedly exacerbate the challenges already impacting food security aspirations of many developed and developing countries. However, in contrast to the developed countries of the world, the vulnerability of the agricultural sector to climate change in many developing countries is substantially high because of restricted adaptation measures and limited resources (Mendelsohn & Dinar, 1999). There have already been noticeable changes in weather patterns which have impacted rain-fed dependent agriculture in Africa and many other countries in the tropics. Some of the predicted impacts of climate change according to FAO (2005) are increased crop water requirements, increased competition between weed and crops, spread of pests and nematodes and increased salinization of soils. Agricultural practitioners who are prone to climatic vulnerabilities must develop strategies to reduce the impact of climate change. These include and are not limited to the selection of new crop varieties, irrigation technique and management, crop diversification, mixed crop and livestock farming, changing planting and harvesting dates to correspond to the changing pattern of precipitation, soil and water conservation techniques (Juana, Kahaka & Okurut, 2013). There is no escape from the inevitable realities of climate change impacts to food production, however, developing nations must rise to the challenges of averting its undesirable influences to national food security objectives.

Food security in many developing countries requires a comprehensive examination of the many challenges which have been adversely affecting the sustainable production of food. Despite the fact that food security in on the political agendas of many developing nations, the realities of achieving sustainable food security is seemingly bleak. Agricultural practitioners in developing countries with the assistance of government and non-government support must recognize and adopt best practice standard approaches before food production intensification can be worthwhile. The approaches to food security are multidimensional ranging from improving farming techniques to treating the problematic challenges associated with climate change mitigation. The chapter examines several approaches to food security such as the utilization of underutilized indigenous or local plants for food, insects as a protein source, livestock and wildlife production in addition to contemporary approaches to improving livestock productivity. The role of farmers' groups to facilitate a coordinated and collective approach to improving agricultural productivity is also discussed. The strategic approaches discussed in this chapter could be integrated into a holistic model for food security management in developing nations.

UNDERUTILIZED PLANT SPECIES TO SUPPORT FOOD SECURITY

Farmers in the Caribbean and in many developing countries primarily cultivate non-indigenous or exotic vegetable crops many of which are from the brassicaceae (e.g. cabbage, cauliflower, broccoli, pak choi etc) and solanaceae (e.g. sweet pepper, tomatoes etc.) plant families. The availability of these commodities as a source of food, however, is much dependent on certified seed imports and/or on the importation of the commodity itself. In some instances, open-pollinated varieties and heirloom varieties are cultivated. Nevertheless most commercially grown produce are cultivated from imported hybrid seeds. The practice of cultivating such crops of imported origin is attributed to consumers' preferences and demand for high quality vegetable produce. Irrespective of the primary reliance on cultivation of crop plants, the consumption of edible wild plants as a source of food exists. According to Shanley and Luz (2003) billions of people in developing countries use wild plants as a source of food because of their low cost. Traditionally, a vast majority of edible wild plants contributed to the diet among the poor (Bharucha & Pretty 2010) especially those in rural communities. Today, many have now become forgotten or neglected. Petitioning the awareness of edible wild plants and their health benefits can stimulate consumption of this category of food irrespective of social class. Additionally, a unique feature of edible wilds plants is demonstrated by their characteristic resilience during periods of natural or man-made stresses, thus making them a potential source of an emergency food supply. Cultivated crop plants, in contrast to edible wild plants are prone to stresses which can have drastic adverse impacts to food security.

The Food and Agricultural Organization of the United Nations (FAO, 2009) maintains that around 30,000 plant species around the world are edible, but of these, only 7,000 are used as human food resources. The 23,000 plant species unused as human food is a reservoir of unexploited nutrition. In 1996, a FAO global plan of action was adopted for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture by approximately 150 countries. The plan identified improved conservation and use of neglected and underutilized species as one of its 20 main activities (FAO, 1996). Many of these unused food plants grow wildly in the natural landscape. Campton (2008) indicated that "wild" when applied to plants or plant species refers to those which grow spontaneously in self-maintaining populations in natural or semi-natural ecosystems existing independently of direct human action. Shava (2005) referred to Edible Wild Plants (EWPs) as both indigenous and naturalized exotic plants occurring in the natural environment. There must be caution against the dichotomization of wild versus cultivated food species, since many (if not most) wild species actually fall along a continuum, from wild species under various degrees and types of human management and intervention through to domestication (Bharucha & Pretty, 2010). Many cultivated plants species are in fact relatives of wild plants created through plant breeding and genetic manipulations. Meyer, DuVal and Jensen (2012) pointed to the origins of domesticated food crops as derived from a phylogenetically diverse assemblage of wild ancestors through artificial selection for different traits. In spite of this, it has been suggested that wild food plants are nutritionally superior to some of the cultivated ones (Burlingame, 2000). Edible Wild Plants have been reported to have high contents of photochemical such as phenolic compounds (including flavanoids, which has strong antioxidant properties and which have been implicated in the prevention of age related diseases such as cancer, arteriosclerosis and diabetes (Neudeck et al. 2012).

An inventory of the imported crop diversity and production quantities which contribute to the food supply of developing nations ought to be conducted in order to assess the extent to which these commodities contribute to food security. This would facilitate the formulation of alternative prescriptive strategic approaches aimed at buffering the impact of shortfalls from imported agricultural commodities;

either the commodity itself or the seed planting material. The reliance on imported staples such as rice (*Oryza sativa*) and Irish potatoes (*Solanum tuberosum*) in the Caribbean can be seamlessly substituted with the sustainable production of staple alternatives such as cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), yams (*Dioscorea alata*) and breadfruit (*Artocarpus altilis*). Similarly, the dependence on imported vegetables can be substituted for by using underutilized plant species and selected landrace varieties. The cultivation of underutilized crops would offer some protection against any issues related to the importation of food. The main challenge would be the acceptance of such categories of food by consumers. However, in the event of a food shortage, a source of edible food outweighs the custom of palatability preferences. It is noticeable that countries which are dependent on food imports are vulnerable to unstable global price shocks as well as food restriction polices from exporting countries. The recognition of underutilized and indigenous edible wild plants as a valuable source of nutrition may cushion the shortfalls resulting from a potential food crisis.

Although cultivated domesticated plants species to some degree have evolved from wild relatives, there is growing interest in the identification and development of new crops with the use of neglected and underutilized indigenous "wild" plants species. Undoubtedly, this category of plant species grow naturally in a multitude of ecosystems, and have been found to be valuable potential food sources. There exist an enormous biodiversity of plants which can be used as an easily accessible source of food. The identification of these edible wild plants in developing countries would require accessing the traditional ecological knowledge resource bank of rural communities. In some countries underutilized plants are under threat of extinction as a consequence of urbanization, natural habitat destruction, agricultural intensification, pesticide use and slash and burn agricultural practices. Concomitantly, cultural transformation and the lack of interest of the younger generation in rural communities have led to the loss of plant knowledge, both as a source of food and for medical uses. There is now a trend reversal from underutilized plants as a food source for the poor, to such plants being actively sought after among the affluent and middle class households because of its superior nutritional and medical value especially when compared to conventional crop plants.

It should be noted that some of these underutilized plant foods are considered weeds and are subjected to intense elimination pressure in the agricultural landscape with the use of pesticides and physical means. In Trinidad for example, *Amaranthus dubius* is a popular weed found in many cultivated fields. It is, however, a food source not only consumed in Trinidad but also consumed in other islands in the Caribbean and in many other developing nations in Africa and Asia. The management of *Amaranthus dubius* for food can range from completely unmanaged to intensive formal cultivation. Table 1 shows the comparative volumes of Amaranth traded at a local wholesale market in Trinidad, in relation to other leafy vegetables either imported or grown locally from imported seeds. Because of its low production costs, amaranth is one of the cheapest dark-green leafy vegetables in tropical markets and is often described as the poor man's vegetable (Varalakshmi, 2004). Although the price of *Amaranthus* in Table 2 is relatively close to the cost of pakchoi, the cost of production of pakchoi would be higher. *Amaranthus* which has been traditionally consumed, has been regaining its popularity as a promising food crop for production primarily due to its resistance to heat, drought, diseases and pests, and the high nutritional value of both its seeds and leaves (Wu *et a*l., 2000). Furthermore, it has a high content of essential micronutrients such as beta-carotene, iron, calcium, vitamin C and folic acid (Priya et al. 2007).

The strategy to make available and to incorporate indigenous food into the diet of a population would first require accurate botanical identification and inventory of the edible plant biodiversity which exist in and around farmlands and communities. It would also require a detailed agronomic evaluation of the

Table 1. Annual total volume of leafy vegetable traded for the period 2010-2014 at the Macoya wholesale market, Trinidad, West Indies

Leafy Vegetables	Unit	Annual Total Volume				
		2010	2011	2012	2013	2014
Lettuce (small)	Head	99,257	127,432	90,417	58,371	74,252
Lettuce (medium)	Head	190,700	252,372	175,225	119,750	127,305
Lettuce (Large)	Head	392,994	300,434	199,975	197,628	158,205
Patchoi	Bundle	372,195	267,491	172,939	139,235	143,855
Amaranthus spp (Spinach)	**Bundle**	**219,014**	**203,188**	**146,271**	**138,231**	**120,673**
Cabbage Imported - Green	Kg	608,867	558,217	578,930	528,121	646,185
Cabbage Local- Green	Kg	684,297	786,571	677,918	699,214	618,345
Cabbage Local - White	Kg	28,633	56,016	76,313	73,535	61,983
Cabbage Imported- Purple	Kg	70,088	75,411	88,725	68,487	95,256

Note: Data compiled from the National Agricultural Market Information System (NAMIS)

Table 2. Annual average wholesale prices for leafy vegetable for the period 2010-2014 at the Macoya wholesale market, Trinidad, West Indies

Leafy Vegetables	Unit	Annual Average-Wholesale Prices ($TT*)				
		2010	2011	2012	2013	2014
Lettuce (small)	Head	*3.24*	*3.28*	3.10	3.10	3.55
Lettuce (medium)	Head	*4.43*	*4.42*	4.21	4.26	4.86
Lettuce (Large)	Head	*5.47*	*5.56*	5.29	5.13	6.11
Patchoi	Bundle	*4.89*	*4.84*	4.91	5.49	5.68
Amaranthus spp (Spinach)	**Bundle**	***4.08***	***4.28***	**4.25**	**4.46**	**5.01**
Cabbage Imported- Green	Kg	*7.83*	*7.04*	6.65	7.41	8.01
Cabbage Local- Green	Kg	*8.01*	*7.68*	7.82	8.67	9.82
Cabbage (White)	Kg	*5.25*	*4.89*	4.95	5.35	6.04
Cabbage Imported- Purple	Kg	*10.76*	*9.72*	9.16	10.25	10.30

Note: Data compiled from the National Agricultural Market Information System (NAMIS)
* 6.02 TT equivalent to USD $1.00

"wild" plant to establish the formal cultivation techniques that would enable its successful cultivation as an agricultural crop. Furthermore, active promotion of the nutritional benefits associated with underutilized plants could encourage their utilization and conservation. Farmers who cultivate regular crops should be educated on the existence of wild indigenous plant which can be a source of food and should not entirely eliminate them. The preservation of indigenous plants around farmlands would ensure that they can be made easily available for a source of food in the event of a food crisis natural or otherwise. Moreover, the development and commercialization of underutilized plants can further be valuable to farmers as a low-input crop. Table 3 provides some essential requirements and actions required for the sustainable use of underutilized and indigenous wild plants as a potential source of food.

Table 3. Requiements for the sustainable use of underutilized plants as a source of food

Requirements for Sustainable Underutilized and Indigenous Wild Plant Consumption	Actions Required
1. Identification of underutilized or indigenous wild plants.	● Accessing traditional ecological knowledge from rural communities. ● Botanical classification and evaluation.
2. Nutritional and medical benefit profile.	● Accessing traditional medicinal uses. ● Nutrient analysis: - proteins, vitamins, minerals ● Nutraceutical determination.
3. Agronomic evaluation	Evaluation of determination of specific cultivation requirements.
4. Education	Farmers and public should be educated on the value and potential of these crops as food sources.
5. Research and development	● Research and development in the areas of menu development, palatability studies, preservation, storage and value chain development. ● Agronomic research ● Analysis of the value chains potential.

The cultivation or preservation of indigenous wild plants is not an attempt to downsize the production of conventional vegetables but to recognize the potential of wild plants in the agro-ecosystem. The development and commercialization of these under-utilized plants as a source of food is essential for sustainable food and nutrition security, particularly for the developing nations across the globe.

LIVESTOCK INTENSIFICATION FOR FOOD SECURITY

Animal production is mainly on a much smaller scale compared to crop cultivation in many developing nations. The lack of space and physical infrastructure along with the need to have costly specialized care inclusive of veterinary services has somewhat stymied farmer's interest in livestock production. Interestingly, in spite of this, the livestock sector is consuming a considerable portion of the world's crops which otherwise can be used as human food. It is essential that livestock production in developing countries not impact the availability of food derived from crop sources. More so, given that animal production is dependent on crop feed sources, it is ever more crucial that sustainable animal production systems are established and maintained to ensure the efficient production of livestock and livestock products. The sustainable development of food derived from livestock must take into consideration the key animal production factors which include animal breeding and genetics, reproduction, nutrition, animal health care and housing. Analytically linking each factor with the type of livestock and the physiological state of the livestock category would enable decisions for optimizing performance of the livestock production system. Additionally, improving the efficiencies in the production cycle of traditional livestock production will contribute directly to an increase in productivity of livestock products at the farm level.

Animal production systems may be broadly categorized as being either intensive or extensive. However, it must be noted that some systems show features of both categories and are hence categorized as semi-intensive. Intensification, as it relates to animal production, may be defined as the rearing of many animals in a single location in close proximity to each other. The intensive livestock production model is essentially a controlled oversight of every stage in the animal production system taking into account the animal production factors. The drastic increase in animal population densities associated with intensification usually results in problems associated with animals' requirements for nutrition and feeding, health and environmental management. In the Caribbean context because of the relatively small sizes of countries, livestock production enterprises are moving towards the adoption of intensive systems for production primarily because of competing interests for land use, praedial larceny, hilly topography and the need to control the environment for animal (Ramdwar, Maharaj & Siew, 2015). The management of livestock using intensive methods of production would ensure the achievement of performance target that will contribute significantly to food security.

Some examples of intensive systems used in the Caribbean region are:

1. Large tunnel ventilated houses for broiler production (with bird density of less than 0.09 m^2 per bird), which utilizes the deep litter system of production.
2. Open side naturally ventilated houses for broiler production using the deep litter system.
3. Slatted floor and deep litter systems for small ruminant (sheep and goats) production.
4. Feedlot systems for cattle and water buffalo production.
5. Intensive swine production facilities.

Local Chickens and Wildlife ("Bushmeat")

Developing countries normally import fertile eggs for commercial layer or broiler production. As a consequence of the importation of poultry for commercial production, the local or indigenous chickens (*Gallus domesticus*) are to some extent neglected especially with respect to the implementation of standard performance targets. These birds are normally not caged and are allowed to range freely and scavenge for food. The production of local chickens is characterized by a low input management system and consequently the productivity of this category of livestock is constrained. The specific constraints associated with the production of local chickens are related to poor housing, poor nutrition, poor reproductive performance, diseases, and predators. In order to increase the productivity of local chickens, there must be greater emphasis directed to improving the overall management of these birds. The overall management approaches directed to improving the productivity of local chickens would include:

- Protection for nesting and brooding sites
- Protection for chicks and adults from adverse weather and predators
- Protection from diseases
- Provision of adequate nutrition
- Genetic improvement and breeding management

Producing indigenous chickens in a more efficient manner would increase the number of eggs produced per bird and also increase the chances of survival of chicks produced per bird. Consequently, the potential number of offspring obtained per bird which can be reared for meat would increase. In essence, housing, nutrition, disease management and reproductive management are essential to fostering a sustainable operational management approach to improving the productive performance targets of local chickens in developing countries. It should be noted also that sustaining the performance improvements of commercial poultry production should be coupled with this additional focus to improving the productivity of local chickens. Increasing the production of local poultry would reduce the reliance on poultry importation and thereby contribute to the inclusion of sustainable local poultry production into the food security agenda of developing nations.

Along with indigenous chickens, there exists a biodiversity of wildlife (sometimes referred to as "bushmeat" or "wild meat") that has historically been used as a source of food. In some rural communities in developing countries "bushmeat" may comprise over 80% of the consumption of animal protein (Adu *et al*., 1999; Wilkie & Carpenter, 1999). In communities where wildlife is the main source of protein and where greater constraints exist for conventional livestock farming, wildlife farming can be a viable option. Wildlife farming is defined as the rearing of non-domesticated animals for the purpose of captive breeding (Nogueira & Nogueira-Filho, 2011). The farming of wildlife provides a sustainable approach to the conservation of wildlife biodiversity while simultaneously contributing directly and indirectly to food security. Meat from wildlife sources contributes indirectly to food security by providing income from sales or distribution to outside markets (Mainka & Trivedi 2002; de Merode *et al*., 2004). Brown-Uddenberg *et al*., (2004) identified several Neo-tropical species in Trinidad and Tobago with the potential for production in micro-livestock enterprises. They included the agouti (*Dasyprocta leporina / D. agouti*); spectacled caiman (*Caiman sclerops*); cocrico (*Ortalis ruficauda*) (this is one of the two national birds of Trinidad and Tobago); red brocket deer (*Mazama americana*); iguana (*Iguana iguana*); lappe/spotted paca (*Agouti paca / Cuniculus paca*); manicou/black eared opossum (*Didelphis marsupialis insularis*); tattoo/nine banded armadillo (*Dasypus novemcinctus*) and wild hog/quenk/collared peccary (*Tayassu tajacu / Pecari tajacu*). Wildlife farming has less negative impacts on the environment, as it reduces the pressure and dependence on wild animal populations (Garcia *et al.,* 2005; Roe 2008; Nogueira & Nogueira-Filho, 2011). Notwithstanding this, the constraints to wildlife farming far exceed the production systems for traditional livestock production systems. The main reasons for this are related to the limited technical knowledge available for the production of wildlife in captivity and lack of funding for the associated high cost of production. Arguably, hunting of wildlife is comparatively much cheaper than wildlife farming itself. In spite of the constraints to wildlife farming, its potential success is highly dependent on having a strong comprehension of the biology and behavioral characteristic of the wildlife being farmed. This is essential in order to map the physiological stages of the animal to the key animal production factors: housing, nutrition, reproduction and animal breeding and genetics. The physiological stage of any animal in production systems refers to the various stages in its growth and development during the production cycle, example oestrus, gestation, lactation, juvenile and maturity stages. Linking the various stages in the growth and developments of an animal in a production system with the specific animal production factors required for each stage would enable the realization of the production goals and performance objectives. This concept is not limited to wildlife farming but for animal production systems in general. The constraint for wildlife farming is the gap which exists between the wildlife species' various physiological stages and the respective requirements for each of the animal production factors. Researchers (Singh et al., 2014; Mollineau *et al*., 2006; Mollineau *et al*., 2007[a], 2007[b]) have published extensively on the production aspects of some neo-tropical wildlife in the Caribbean region. Although wildlife farming can be a source of reliable protein for communities in some developing countries it is somewhat inconceivable as a replacement to traditional domestic livestock production in a conventional sense. The introduction or expansion of traditional livestock is more suited for bolstering the sustainable production of food from animal sources rather than solely dependent on wildlife farming and hunting. Nonetheless, wildlife farming has a greater resilience to climate change impacts and provides significant economic opportunities for the rural poor. Additionally, the preservation and conservation of wildlife is essential to the food security aspirations of the developing world since the meat from wildlife is an acceptable protein source for human consumption. While many researchers have suggested the use of neo-tropical species for supporting food security from an animal protein perspective, the magnitude to which these species can be harvested remains a balancing act between overexploitation, conservation and consumption. Potential exist for domestication and production modeling for these species, however, domestication is a time consuming phenomenon and the need for immediate measures to bolster food security from already domesticated species remains pertinent.

Ramdwar, Maharaj and Siew (2015) suggested that world population growth along with several demographic factors inclusive of urbanization have influenced the demand for livestock food products tremendously. In addition to this, economic growth and a concomitant increase in individual incomes and by extension the standard of living; have also contributed to a shift in dietary choices and a subsequent increase in the demand for animal products. Some domesticated animal species that are presently reared on a large scale to provide food for human consumption are outlined in Table 4. A great degree of knowledge on the biology (nutrition, reproduction, genetics etc.) of these animals exist and relevant technologies are been constantly developed to improve their productivity as it relates to the sustained provision of affordable food for human consumption.

Contemporary Reproductive Technologies to Bolster Animal Production

There is growing demand for milk and milk based products, milk production and productivity of dairy animals have either remained constant or declined in many developing countries over the last two decades, resulting in a decrease in per capita milk production and therefore rendering these countries more food insecure (Ramgattie et al., 2014). In Trinidad and Tobago, for example, the Agricultural Services Department of Nestle Trinidad Limited suggested that milk intake declined from around 10 million kg

Table 4. Some of the major domesticated food animal species.

Common Name	Scientific Name	Major Food Produced
Cattle	*Bos taurus* (European Origin) *Bos indicus* (Asian Origin)	Meat (Beef) Milk
Sheep	*Ovis aries*	Meat (Lamb and Mutton) Milk
Goats	*Capra hircus*	Meat (Chevon) Milk
Chicken (fowl)	*Gallus domesticus*	Meat (Broilers) Eggs (Layers)
Pigs (Swine)	*Sus scrofa domestica*	Meat (Pork and Bacon)
Turkey	*Meleagris gallopavo*	Meat
Water Buffalo	*Bubalus bubalis*	Meat Milk
Rabbit	*Oryctolagus cuniculus*	Meat
Ducks	*Anas platyrhynchos* *Cairina moschata*	Meat Eggs
Tilapia	*Oreochromis spp.*	Fish
Atlantic Salmon	*Salmo salar*	Fish

in 1990 to 4 million kg in 2009, with the number of farmers also declining dramatically. The country therefore has to meet the demand for dairy products through importation of dry milk. One of the major reasons for farmers exiting the industry is their inability to turn a profit which directly hinges upon meeting biological efficiencies associated with the dairy animal. Meeting reproductive performance coefficients for parameters such as age at first parturition, calving interval, services per conception, heat detection rate and pregnancy rates are paramount to efficient production and therefore sustainability.

The typical dairy cow is expected to begin producing milk no later than 27 months old (age at first parturition), in many instances producers are unable to get these animals bred on time due to reasons like inadequate nutrition and poor heat detection. Once these animals begin to produce milk they are expected to go through a repeated cycle of a 10 month lactation and 2 month dry period (calving interval of 12 months) until their reproductive life has expired. This reproductively efficient cycle coupled with good nutrition, friendly environment (climatic and disease free) and superior genetics will maximize the productivity of each animal unit. Because producers seldom operate at the desired reproductive efficiency level, novel approaches have been developed to assist the farmer in meeting these targets and improve productivity.

Lactation Induction Used to Reduce Non-Productive Days

In a natural situation a dairy animal will commence producing milk at the point of parturition, this more or less suggests that establishment of pregnancy and the production of a neonate is necessary for milk production. The whole process of lactation is therefore dependent on the precise hormonal interaction that commences during pregnancy and continues throughout lactation. As indicated earlier, many dairy farmers suffer tremendous loses because they do not get their dairy cows to initiate lactation at 27 months neither do they get them rebred on time to allow for a calving each year. The end result is extended dry periods (periods of no milk production) or extended lactations (beyond 305 days) with lengthy periods of low milk production. Additionally, poor reproductive performance also denies the producer a calf that can be used to expand the herd, can be selected to improve the genetic composition of the herd, or can be sold to derive additional income (Ramgattie et al. 2014), the net result being reduced revenues and increased expenditures. Naturally, cows that are difficult to breed are culled and replaced, reported culling rates due to reproductive problems ranged from 47% (Allaire, Sterwerf & Ludwick, 1977) to 27% (Nahms, 1996). Generally, because management strategies aim to rebreed a dairy cows when it is in peak lactation under a negative energy balance, the highest milk producers are often the most difficult to rebreed and the farmer is at greatest risk of losing some of his best milking genetics based on reproductive failure. For these animal, lactation induction present a great salvage alternative as they can now be brought back into milk production without becoming pregnant and bearing a calf. Many lactation induction protocols have been evaluated with varying levels of success. Ramgattie et al. (2014) utilized a protocol involving the use of progesterone and estrogen treatment in combination for 7 days (day 1 to 7), quantities were based on the animals' body weight. This was preceded by an intramuscular injection of prostaglandin $F_{2\alpha}$ on days -10 and 0 of the protocol. On day eight, following the progesterone and estrogen treatment, another prostaglandin $F_{2\alpha}$ administration was made and this was followed by a combination of reserpine and dexamethasone from day 9 to 12 after which milking commenced. The authors reported a net profit of approximately US $342.00 per animal treated.

Use of Bovine Somatotropin to Increase Milk Production

Bovine Somatotropin (bST) is a growth hormone (protein) produced by the pituitary gland of cattle. It is used to increase milk production in dairy cows and was approved for commercial use in the U.S by the Food and Drug Administration (FDA) on November 5, 1993. Biotechnology (recombinant DNA technology) has allowed identification of the gene that codes for bST, this gene was inserted into a bacterium and this has led to large amounts of bST being produced under controlled conditions, purified and then made commercially available where cows can be treated with the hormone. The hormone is injected into the cows resulting in significant milk yields. Cows that are treated with bST have to be well fed in order to provide the necessary nutrients for the increased capacity for milk production. Major benefits of bST include better feed conversion efficiency and greater persistency in milk production (arresting of the rate of decline usually observed after peak production. Bauman (1989) suggested that best results are derived from treatment of cows entering mid lactation. Cows that have had more than one calf show a greater increase in milk production than do first lactation heifers (Peel et al., 1989).

Use of Estrus Synchronization and Timed Artificial Insemination Technology

In production of many of food animal species, efficiency in reproduction is greatly dependent on the ability of workers to identify animals in estrus (period of sexual receptivity, also referred to as heat) and present them for breeding. In dairy cattle production, Pregnancy Rate (PR) is a function of Conception Rate (CR) and Heat Detection Rate (HDR), given by (PR= CR*HDR). Poor heat detection rate or missed heat is detrimental to the sustainability of dairy production enterprises. Clunis and Sandy (2008) in a review of the reproductive performance of Eastern Caribbean Institute of Agriculture and Forestry (ECIAF) dairy herd, reported an overall heat detection rate to be 20%, this translated into a PR of 12%, given a 60% non-return rate for artificial insemination. This coincides with the 10% pregnancy rate in dairy cattle in Trinidad and Tobago reported by Hafez (1987). Estrus synchronization reduces the time spent detecting animals in heat while fixed timed artificial insemination protocols almost entirely eliminates the need for detecting estrus as these protocols dictate when the animals will ovulate thus dictating the precise time for insemination. This technology has proven very beneficial in improving pregnancy rates, and as a result the number of offspring produced, the daily quantity of milk produced and ultimately the profitability and sustainability of the enterprise.

Use of Artificial Insemination

In many developing countries one of the greatest hindrances to improving productivity and expanding the scale of production in the livestock industry is the availability of quality breeding stock. Hosein et al. (2013) identified several constraints to the development of the small ruminant industry in the Caribbean, at the top of this list was the unavailability of quality breeding stock. This seem to be a common problem across all livestock subsectors, for example, the average daily milk production per animal (10kg/cow) in the tropics is way below average figures reported for temperate regions (25kg/cow), as such, in a bid to introduce new genetic material, the Government of Trinidad and Tobago embarked on the importation of live dairy cattle to support the struggling dairy industry. The problem with this approach is that the imported animals struggle to adapt to the prevailing climatic, biological/disease and nutritional environment. Simply described, artificial insemination is the breeding of a receptive female without the presence of a male. This technology involves the collection, evaluation, extension and storage of semen that could be used at a later time. Some of the major benefits derived from use of this technology are:

- Rapid genetic improvement.
- Widespread use and availability of genetically superior sires (1 bull can breed 500,000 cows in a lifetime).
- After death semen can be used.
- Oldest frozen semen 40-45 years old.
- Rapid proof of sire (genetic evaluation).
- Progeny testing evaluates offspring for desired traits.
- With natural mating will only have hundreds of offspring.
- Availability of sires.
- Sires anywhere in the world can be used.

Use of Sperm Sexing Technology

Production of a male or female offspring may have significantly more economic benefit depending on the enterprise under consideration. In dairy operations the cow is the production unit and therefore the main income generator. Therefore, producing a male calf will have significantly less value than a female as the females are in high demand as replacements and breeding animals. Although bulls are needed, they are needed to a much lesser extent because the majority of dairy cows are artificially inseminated and with artificial insemination the bull to cow ratio is reduced as this technology allows for extension of semen, allowing more cows to be inseminated from a single ejaculate. On the other hand, in a beef production enterprise a bull calf is preferred as the steer is the unit that will earn revenue from beef sales. Each sperm will contain either X or Y chromosome, flow cytometry is used to separate X and Y bearing spermatozoa. The sperm is treated with a dye (DNA stain), because the X bearing sperm has more DNA, more dye is absorbed and therefore more-light is emitted when excited by a laser. The sperm will enter the flow cytometer chamber and pass in single file through a small nozzle where they will be separated in X, Y and dead sperm.

Super Ovulation and Embryo Transfer Technology

Super ovulation involves the stimulation, growth and development, and eventual ovulation of a large number of follicles within a donor animal. The process involves treating (injection) the female with gonadotropins to stimulate follicular growth and development followed by Gonadotropin Releasing Hormone (GnRH) treatment to stimulate ovulation of follicles. The unfertilized eggs can be collected (flushed from the reproductive tract) and fertilized *in vitro*, producing an embryo which can be later transferred into a recipient female. An alternative to this is to produce the embryos *in vivo* by artificially inseminating the females, then flushing the embryos from the reproductive tract of the donor female to be later implanted into a recipient female. The benefit of super ovulation and embryo transfer are:

- It allows rapid multiplication of genetically superior animals
- Allows widespread access to superior genetics through widespread availability of embryos

- It allows continued multiplication of animals with superior genetics which may not be able to carry another pregnancy due to injury.
- It allows use of animals of inferior genetics purely as surrogate for the multiplication of superior genetics

GENETICALLY MODIFIED ORGANISMS AND FOOD SECURITY

WHO (2014) defines genetically modified organisms (GMOs) as "organisms (i.e. plants, animals or microorganisms) in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination. The technology is often called 'modern biotechnology' or 'gene technology', sometimes also 'recombinant DNA technology' or 'genetic engineering'. It allows selected individual genes to be transferred from one organism into another, also between nonrelated species". Foods produced from or using GM organisms are often referred to as GM foods. In November 2015, a milestone for agricultural biotechnology was reached when the Food and Drug Administration (FDA) approved the first genetically modified animal for human consumption. Approval was granted for the commercial sale of a strain of salmon (AquAdvantage Salmon) who's DNA has been altered to make it grow faster. Bunge (2015) reported that "the modified Atlantic salmon was developed by Maynard, Mass.-based AquaBounty Technologies, a unit of Intrexon Corp., to grow to market weight twice as fast as wild or farmed versions of that species. It does so by incorporating a gene from a larger, Pacific Ocean species, the Chinook salmon, that helps boost the Atlantic salmon's growth-hormone production". Pollack (2015) reported that "it also contains a genetic switch from the ocean pout, an eel-like creature, this genetic switch keeps the transplanted gene continuously active, whereas the salmon's own growth hormone gene is active only parts of the year". Bunge (2015) also suggested that "AquaBounty reported that the modified fish require 20%-25% less feed to reach the same weight as conventional Atlantic salmon. The company pitches them as a more efficient means to meet growing demand for farmed fish and ease pressure on wild fisheries".

Notwithstanding the benefits and safety level reported by the FDA and producers of the GMO's, consumers are still very reluctant to widely accept these GM foods as common place on supermarket shelves and restaurants, in fact, many food brand distributors have refused to carry these products. Some of the major concerns with the use of GM foods are:

- Possibility of GMO's escaping from the production sites and mixing with the naturally occurring species, out-competing them, becoming preferred mates and putting the natural occurring species at risk of extinction.
- Possible allergenicity associated with the consumption of the GM food.
- Gene transfer from the GMO to naturally occurring organisms.
- Outcrossing
- Susceptibility of non-target species
- Stability of the gene in the medium to long term
- Possibility of the loss in biodiversity in the event of outcrossing
- Movement of resistant genes to other organisms.

The debate on the use of GM foods will continue for a long time, but this technology seems to hold significant potential for addressing food security issues worldwide.

ANIMAL NUTRITION AND ITS POTENTIAL TO IMPROVE FOOD SECURITY

Improved Forage Species

Scientifically meeting the animal nutrient needs remain a challenge in livestock production in the developing world. Given the increasing price of grain on the international market, forage based feeding systems still remain the economically feasible means of meeting the animal's nutrition. In many countries, the quality of the forage remains a major challenge to the improved productivity of ruminant animals. Utilization of improved forage species such as Mulato (*Brachiaria* hybrid CIAT 36061) and Mulato II (*Brachiaria* hybrid CIAT 36087) grass hybrids provides renewed hope for ruminant producers. These species are the result of more than 20 years of research by the International Center for Tropical Agriculture (CIAT) in Columbia. Mulato and Mulato II are *Brachiaria* hybrids of B. *brizantha*, B. *ruzinensis* and in the case of Mulato II, B. *decumbens*. The Mulato grass is highly suitable for use in Trinidad and Tobago seeing that its close relative tanner grass (*Brachiaria arrecta*) grows almost everywhere. Positive attributes of the Mulato grass when compared to tanner grass includes:

- Higher dry matter yield
- Higher leaf to stem ratio
- Higher nutritional value in terms of protein and energy
- Better resistance to pest and diseases
- Good recovery from fire damage
- Comparable tolerance to acid soils

Utilization of By-Products From Local Food Processing and Manufacturing Industry for Feeding Animals

Utilization of by products from processing provides a useful and viable alternative to imported grain for feeding ruminant animals. These could be used in combination to supplement the animals daily nutrient needs. The following represents a selection of commonly used byproducts in Trinidad and Tobago:

- Brewers grain – byproduct from beer production
- Coconut meal – by product from coconut oil production
- Dried citrus pulp – byproduct from citrus processing
- Wheat middling – by product from flour production
- Bakery rejects product e.g. cookies, bread etc.
- Fish meal
- Meat and bone meal
- Poultry offal meal

Utilization of Techniques to Improve the Nutritional Value of Low Quality Forages

The quality of forage material used is influenced by the forage specie, variety, stage of growth or regrowth, crop husbandry practices etc. It is without doubt that in the tropics poor quality forage is a commonplace in animal production because many producers do not pay particular emphasis to recommended forage production practices and the order of the day is to utilize forage where it is available. Technologies exist to assist the producer to enhance the feeding value of these otherwise useless fibrous material, these include:

- Mechanical treatment such as grinding to increase the surface area for rumen microbial action.
- Physical treatment such as temperature and pressure to help in improving digestibility.
- Chemical treatment such as treating with an alkali such as sodium hydroxide or ammonia to bread down resistant lingo-cellulose bonds.

Other Approaches to Improving Nutrient Availability and Utilization

- Improving the nutritional value of cereals – many are low in some of the essential amino acids such as lysine. The use of modern biotechnology is available to produce transgenic cereals with increased essential amino acid content.
- Removal of anti-nutritional factors in forages such as tannins, protease inhibitors, pectins etc. through the use of modern biotechnology.
- Use of enzymes as feed additives to improve digestibility – phytase is a commercial enzyme which is used to bread down phytate and make phosphorus more readily available to the animal.
- Forsberg et al (1986) have suggested the use of "transgenic to produce bacteria with enhanced cellulotic activity, capability to cleave lignohemicellulose complexes, reduced methane production capability decreased proteolytic and/or deaminase activities, increased capability for nitrogen "fixation" and increased ability for microbial production of specific amino acids."

INSECTS AS A SOURCE OF PROTEIN

The consumption of insects, entomophagy, is not novel since many people around the world particularly in Southeast Asia, Oceania, southern Africa, Central America and the northern part of South America have had insects as a component of their regular diet (van Huis et al. 2013). Insects are in fact consumed by at least two billion people in the world and more than 1900 insect species are currently used as food (FAO, 2013). The major group of commonly consumed insects are beetles (Coleoptera), however, other groups of edible insects include, Lepidoptera e.g. caterpillars, Hymenoptera e.g. bees, wasps, Orthoptera e.g. locust, crickets, grasshoppers, Hemiptera e.g. true bugs, cicadas, leafhoppers, plant hoppers, scale insects, Isoptera-termites, Odonata e.g. dragonfly and Diptera e.g. flies (Jansson & Berggren, 2015; Pal & Roy, 2014; FAO, 2013). Although insects are consumed by many people in some developing countries, it is still not widespread enough to have any significant impact on the global food security agenda.

The demands for food especially animal based protein would be increasingly difficult to supply by 2050. In developing countries alone meat consumption is growing at a rate of 5 percent per year (FAO, 2006). The dual pressures of population growth and urbanization would severely reduce the available resources to produce animal based protein. Furthermore the availability of food for human consumption at the global level is heavily impacted by the demands that livestock production places on land and water use (Charlton et al., 2015). Already, livestock production accounts for 70% of all agricultural lands (Steinfeld et al., 2006) and any further increase would not be sustainable. The influence of climate change and environmental effects would further erode the potential to increase animal production to meet the demands of a steadfastly growing world's population. It is imperative that alternative protein sources such as insects be evaluated for inclusion into the human food chain and for animal feed. The replacement of proteins derived from crops with nonconventional protein sources such as insects would redirect the cultivation of arable land solely for food production purposes.

Insects are underutilized as a valuable protein source. The proportion of protein per 100g of various insect species compares favourably with that from mammals, reptiles and fish (Glover and Sexton, 2015). Insects are generally low in cholesterol and fat (Srivastava, Babu & Pandey 2009) and for this reason it is advantageous when compared to the consumption of red meat. It has been reported by Rumpold and Schlüter (2013) that insects are comparable to beef, pork and chicken and contain more polyunsaturated fatty acids and have a higher content of minerals such as iron and zinc. Some insects contain more protein than meat (Johnson, 2010) and can be a better alternative to consuming animal derived proteins. Insects are extremely efficient at converting what they consume into consumable biomass. When compared to cattle the feed conversion efficiency of insects is twenty times higher (Durst & Shono, 2010). Additionally, insects can feed on a broad variety of materials including manure and they have a better feed conversion rate than most other animals, which reduces wastage and costs (Khusro, Andrew & Nicholas, 2012). It is a reality that the cultivation of insects as an alternative source of protein is more sustainable compared to livestock production, considering less land is required and low levels of greenhouse gasses are emitted in producing an even higher quality edible protein.

Western societies are psychologically, culturally and socioeconomically averse to the consumption of insects as a source of food. The taboo associated with insects as a source of food stems from the belief that insects are regarded as scornful pests. It is thus unlikely for the food neophobia associated with insect consumption in western civilization to dissipate, however, the taboo may be somewhat less if insects were used as a feed source for animals. It is expected that soy, maize and fish based ingredients for animal feed formulations would become limited and expensive in the future and as such insects can become a significant protein source for animal feed. There would, however, be a need to select and evaluate suitable insects based on nutritional profile, nutrient bioavailability and animal palatability before establishing sustainable mass production standards.

Although the potentiality of insects as an alternative source of food for humans and feed for animals exist to cope with the emerging problems of food security some major challenges exist. These challenges according to FAO/WUR[1] (2014) include:

- Further awareness raising among the general public to promote insects as healthy food for humans and feed for animals;
- Influencing policy makers to approve insect inclusive food and feed legislations;
- Further research efforts to provide and expand with validated data the available scientific evidence and benefits of using insects in the food and feed chains.

There are currently no international standards, for example, the Codex Alimentarius, governing the regulation of edible insects for human food and animal feed. The absence of such standards would further compound the unwillingness of western societies to include insects as a component of their diet. It is essential for any society to ensure that there are specific food safety guidelines for the consumption of any unconventional food. Hazard Analysis and Critical Control Point (HACCP), a system adopted by the Codex Alimentarius Commission, should be implemented to identify and procedurally regulate to avoid hazards (physical, chemical and microbiological) which may occur in the collection, production and processing of edible insects for food. Tapping into the traditional indigenous knowledge of societies where insects are consumed coupled with sound scientific research must be undertaken before the value of insects to global food security can be fully exploited.

Globally, a lot of emphasis is placed on the elimination of insects rather than exploring their potential for consumption as human food and animal feed. The nutritional value of insects as food and feed diversity has been somewhat overlooked. It would be essential for developing countries, particularly because of rapid population growth, to explore the opportunities for increasing the research, production, preservation and utilization of insects as food and feed. Food security in developing countries would increasingly become more dependent on widening the biodiversity from which food is selected and utilized and insects provides one such essential opportunity.

IMPORTANCE OF FARMERS' GROUPS IN ACHIEVING FOOD SECURITY

In the previous sections emphasis was placed on underutilized plants, local poultry, wildlife and traditional animal production. In this section, focus will be placed on farmers' groups and how they can impact the food security agenda of developing countries. A group is described as a collection of individuals among whom a set of interdependent relationships exist (Windapo & Afolayan, 2005). The terminology 'farmers' groups' and 'farmers' organizations' are commonly used interchangeably when referring to collective action among farmers. There is one distinction however, in that farmers' organizations are considered to be a more formal entity in the form of agricultural cooperatives and associations.

The formation of farmers' groups can be a strategic approach to food security in resource poor developing countries. The arrangement of farmers into groups can be within two interrelated categories namely geographic groups and commodity-specific groups. A geographic farmer's group is a local group within a community that seeks to address general agricultural production matters which are common to all farmers in a specific area. On the other hand, commodity specific groups extend beyond the local community and comprise members who are producers of a specific agricultural commodity. Commodity farmers' groups can be national entities e.g. National Poultry Production Farmer's Group or National Food Crop Farmers' Association.

The formation of farmers' groups enables farmers to come together for the purpose of collective action. Collective action arises when people come together because of constraints and to take joint action and decisions to accomplish an outcome (Sandler, 1992). Despite the potential benefits of farmers forming groups in the pursuit of common goals, there are numerous constraints which impact the longevity and performance of the group. Most of the issues facing farmers' groups are conflict oriented within the group and outside of it. The ideal farmers' group should be one which is democratically governed, has a self-help function and are self-sustaining and should serve the needs of the membership as well as the group as a whole. The purposeful organization of farmers into groups would promote the sustainable production of agricultural commodities. It can avert the issues of oversupply, since not all famers' groups would be engaging in the same type of production activity. Additionally, knowledge and resource sharing among farmers within a group secures the success of its membership and contributes to an increased food production output. Social networks throughout rural communities have been shown to play an indirect role in increasing agricultural productivity through knowledge sharing via networks (Liverpool and Winter-Nelson, 2010). Farmers' groups can provide farmers with many services that are critical to their success in accessing markets. According Stockbridge et al., (2003) these include:

- Marketing services (input supply, output marketing and processing, market information).
- Facilitation of collective production activities.
- Financial services (savings, loans and other forms of credit).
- Technology services (education, extension, research).
- Education services (business skills, health, and general).
- Welfare services, (health, safety nets).
- Policy advocacy.
- Managing common property resources (water, pasture, fisheries, forests).

There is an essential role for farmers' groups in driving the food security initiatives of developing countries. However, the propensity of farmers' groups to be successful is somewhat limited without government support. Government through its public agricultural extension services should encourage farmers to form groups and provide the necessary training to support the development of the groups. Given that individual farm visits are the predominant extension methods used in developing countries, the formation of farmers' groups can be a solution for the high farmer to extension officer ratio in many developing countries. As a consequence, many more farmers could have improved access to extension services, which would build their technical capacities and possibly improve their livelihoods. As such, many developing countries should hasten the formation and development of farmers' groups in a bid to organize their food production activities. Concomitantly, strengthening the technical capacity of extension officers in the areas of group dynamics and group development would improve the effectiveness and efficiency of the extension service in sustainable formation of farmers' groups.

CHAPTER SUMMARY

Food security aspirations of developing countries must adopt a multidimensional approach to ensure the availability of safe food. The first approach to food security would be to ensure that current food production levels are optimized in a sustainable manner. The optimization of current food production would require the implementation of improved farming techniques and the implementation of good agricultural practices. Beyond the optimization of current food production, there are opportunities to explore the use of unexploited or underutilized biodiversity as a food source for humans and for animals. There are many plant species which are either neglected or have not been explored as a source of human food. Developing countries in particular which are dependent on the importation of vegetable seeds or the vegetable commodity itself should attempt to identify local alternatives to augment food supplies. Food from animal sources must also take into consideration overall improvements in animal husbandry practices, improved management for local poultry, wildlife and wildlife farming and even insects. The implementation of contemporary reproductive technologies can improve the performance parameters for livestock enterprises and boost livestock overall productivity. Livestock nutrition is an important contributor to ensuring food security and must be factored into the overall approaches to improved animal husbandry practices. The use of alternative feed sources such as by-products from food processing as well as exploring the use of insects as a protein source for animals can contribute to a reduced reliance on imported feed. Humans and animals are both dependent on arable land for a source of food hence any food alternatives which can reduce this dependence can go a long way towards contributing to overall food security efforts. The coordination of food security efforts in developing countries must involve the agricultural extension officers. Given the high farmer to extension officer ratio in many developing countries, the population of farmers would be most effectively served if there were arranged into groups. The key concepts discussed within this chapter could be incorporated into an integrated food security management model in attempt to achieve some, if not full level of food security in developing countries.

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ENDNOTE

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Section 3

Food Engineering and Packaging

Chapter 9
Antimicrobial Edible Films and Coatings for Fruits and Vegetables

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ABSTRACT

Non-degradable packaging materials are doing much damage to the environment. So the interest has been developed in biodegradable films and coatings these days. Use of edible films and coatings is eco-friendly technology used for enhancing the shelf life of the fruits and vegetables. The use of antimicrobial compounds in edible coatings of proteins, starch, cellulose derivatives, chitosan, alginate, fruit puree, and egg albumin has been successfully added to the edible films and coatings. This chapter focuses on the development of edible films and coatings with antimicrobial activity, effect of these coatings on the target microorganisms, the influence of these antimicrobial agents on mechanical & barrier properties and application of antimicrobial edible coatings on the quality of fresh fruits and vegetables.

INTRODUCTION

The demand for minimally processed, easily prepared and ready-to-eat (RTE) 'fresh' food products, globalization of food trade, and distribution from centralized processing pose major challenges for food safety and quality. Recent food-borne microbial outbreaks are driving a search for innovative ways to inhibit microbial growth in the foods while maintaining quality, freshness and safety. One option is to use packaging to provide an increased margin of safety and quality. These packaging technologies could play a vital role in extending shelf-life of food(s) and reduce the risk from pathogens. Antimicrobial polymers may find use in other food contact applications as well (Rooney, 1995). It acts to reduce, inhibit or retard the growth of pathogen microorganisms in packed foods and packaging material (Vermeiren, *et al*. 1999).

Most food consumed comes directly from nature, some of them eaten directly after harvesting from the tree, vine or ground. With increased transportation distribution systems, storage needs and advent of ever larger supermarkets and warehouse stores, foods are not consumed just in the orchard, on the

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field, in the farmhouse, or close to processing facilities. It takes much time for a food product to reach the table of the consumer. During this whole process time-consuming steps are involved in handling, storage and transportation, the food product start to dehydrate, deteriorate and lose loose appearance, flavor and nutritional value. If no special care is provided, damage can occur within hours or days, even if this damage is not immediately visible. Today various modern methods, including combinations of these such as refrigeration, controlled atmosphere storage, and sterilization by both UV and gamma radiation are used to keep food safe. Nevertheless, for many kinds of food, coating with edible film continues to be one of the most cost effective ways to maintain their quality and safety.

Edible films and coatings made by use of agricultural commodities and wastes of food products have gained considerable attention in last few years. The biopolymers i.e. polysaccharides, proteins and their blends plays an important role as a carrier for different additives like antimicrobial, antioxidants, nutraceuticals and flavouring agents. Organic acids, chitosan, nisin and lactoperoxidase system and plant extracts & essential oils are the most commonly used antimicrobials. The main objectives of this chapter are to discuss the use of edible films and coatings, the applications and legislations concerning edible films and coatings. The information provided in this chapter helps to improve the design, development, applicability of edible films and coatings, their safety aspects that might be important while planning the future trends and better functionality of edible films as a preservation technique to enhance the shelf life of the food products.

BACKGROUND

Edible films and coatings like wax have been used for long time to prevent moisture loss and to stop the respiration process. These practices are still carried out in the present time. The association of edible fruits and vegetables are 50 years old. In 1967, edible films had very little use and were limited to wax layers only. A good business came out from this concept and by 1996, numbers grew to 600 companies. In twelfth century citrus fruits were preserved by placing them in box and pouring molten wax on them to preserve them for Emperor's table. Later in fifteenth century edible films made up of boiled soy milk were used in Japan for maintaining the food quality and appearance. In the nineteenth century, a US patent was used for preservation of various meat products by gelatin. But these days, many other methods and combination of these methods are used to keep the food safe. Use of edible films and coatings continues as one of the most cost effective method of food preservation.

HISTORY OF EDIBLE FILMS AND COATINGS

The use of wax coating of fruits by dipping is one of the old methods that became into vogue in the early 12th century (Krochta & Mulder-Johnston 1997). This was practiced in China, essentially to retard water transpiration loss in lemons and oranges. Application of lipid-based coatings to meats to prevent shrinkage has been a traditional practice since the sixteenth century, while later in the last century, meat and other foodstuffs were preserved by coating them with gelatin films. Yuba, a protein edible film obtained from the skin of boiled soymilk, was traditionally used in Asia to improve appearance and help preservation of foods since the fifteenth century. In the nineteenth century, sucrose solution was applied as an edible protective coating on nuts, almonds and hazelnuts to prevent their oxidation and rancidity during storage.

One of the most important advancements in edible film and coating technology since the 1930s involves use of an emulsion made of wax, oil and water. Such emulsions are applied to fruits to improve appearance (gloss and color) and to prevent softening and onset of mealiness. They are also used for delivery of fruits against fungicides, to control ripening, and retard moisture loss in fruit. A number of edible polysaccharide coatings including alginates, carrageenans, cellulose ethers, pectin and starch derivatives have been used to improve stored meat quality. Over the last forty years, a great number of studies have investigated formulation, application and characterization of edible films and coatings; evidence of such efforts can be found in both the scientific and patent literature (Debeaufort, *et al*. 1998).

DEFINITION

Edible films are defined as thin layers of material which can be eaten by the consumer and provide a barrier to moisture, oxygen and solute movement in the food. The material can be used as complete food coating or it can be disposed as a continuous layer between food components (Guilbert, 1986). A film or coating also provide surface sterility and prevent loss of other important components. Generally, its thickness is less than 0.3 mm. Items which are edible or are in contact with food should be generally recognized by qualified experts as being safe under conditions of its intended use, with amount applied in accordance with good manufacturing practices (GMPs). These food-safe materials must typically have approval of the Food and Drug Administration (FDA). Since it is impractical for FDA to have an all-inclusive list of every potential food ingredient, there are also other opportunities to acquire Generally Recognized as Safe (GRAS) status – i.e., manufacturers can petition for approval of an ingredient or food composite provided that this petition is supported by considerable studies. However, GRAS status does not guarantee complete product safety, especially for consumers who have food allergies or sensitivities, such as lactose intolerance (milk) and Celiac disease (wheat gluten).

COMPOSITION AND CLASSIFICATION OF EDIBLE FILMS AND COATINGS

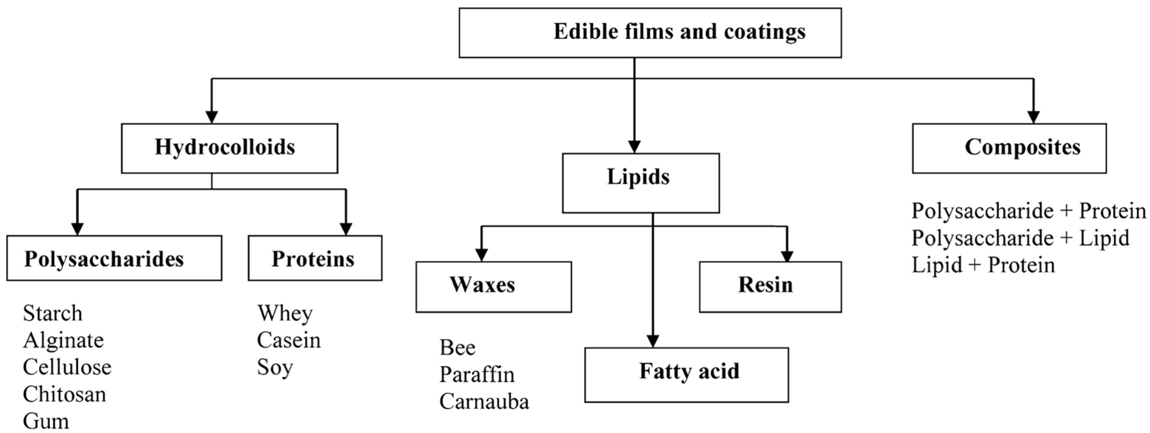
Edible films and coatings are composed of hydrocolloids, which consist of either proteins or hydrophobic compounds (e.g., lipids or waxes). Edible films may also be a mixture of hydrocolloids and hydrophobic compounds (composite films or coatings). Figure 1 illustrates the most common compounds used in edible films and coatings.

Prerequisites of Edible Films and Coatings

Ideal edible film should have the following characteristics:

- Contain no toxic, allergic and non-digestible components
- Provide structural stability and prevent mechanical damage during transportation, handling and display
- Have good adhesion to surface of food to be protected providing uniform coverage
- Control water migration both in and out of protected food to maintain desired moisture content

Figure 1. Classification of edible films and coatings applied in food according to their components



- Provide semi-permeability to maintain internal equilibrium of gases involved in aerobic and anaerobic respiration, thus retarding senescence
- Prevent loss or uptake of components that stabilize aroma, flavor, nutritional and organoleptic characteristics necessary for consumer acceptance while not adversely altering the taste or appearance
- Provide biochemical and microbial surface stability while protecting against contamination, pest infestation, microbe proliferation and other types of decay
- Film must retain flavor during the drying process to provide the whole range of desired notes during consumption
- The film has to protect flavor compounds from oxygen during storage; the flavor release must occur very slowly with water contact or with heating.
- Low cost of raw materials; and
- Simple technology for production

Advantages Microbial Films and Coatings

Advantages of edible coatings (Park, *et al.* 1994; Sothornvit & Krochta, 2000) include:

- Improves external appearance by giving additional shine to the fruit surface.
- Reduces weight loss and keep the fruit firm, so that its fresh look can be maintained.
- Reduces rate of respiration and ethylene production, thus delaying senescence.
- Prevents fruits and vegetables against chilling injuries and storage disorders.
- Act as barrier to free gas exchange.
- Provides a carrier for postharvest chemical treatments.
- Encapsulates aroma compounds, antioxidants, pigments, ions that stop browning reactions and Nutritional substances such as vitamins.
- Reduces the use of synthetic packaging material.
- In some countries, taxes levied on the shipment of packaging material can be saved by use of edible coatings and films.

ACTIONS OF MICROBIAL FILMS AND COATINGS

Fruits and vegetables continue to respire even after harvesting and use up all the oxygen within the produce, which is not replaced as quickly as by edible coating and produce carbon dioxide, which accumulates within the produce because it cannot escape as easily through coating.

Avoid Water Loss

A barrier is formed on the surface of fruits and/or vegetables by edible films/coatings, which decrease water vapor transmission rate. This barrier prevents texture decay, since water is essential for preservation of cell turgor (Garcia & Barret, 2002). Metabolic alterations that can cause accelerated rate of senescence due to water loss can also be avoided with their use. Ability of films and coatings to function as barriers to water vapor relies on external conditions, which include (1) temperature and relative humidity, (2) characteristics of commodity such as type of product, variety, maturity and water activity, and (3) characteristics of film such as composition, concentration of solids, viscosity, chemical structure, polymer morphology, degree of crosslinking, solvents used in casting the film, and type of plasticizer used (Olivas & Barbosa-Canovas 2005). In minimally-processed fruits, there is usually very high water activity present at the surface, making it difficult to develop a coating that delays water loss, since capacity of films to work as barriers to water vapor decreases as water activity increases in the commodity (or relative humidity of the environment) (Hagenmaier & Shaw 1990).

Enhance Texture

The action of pectic enzymes during storage causes dramatic loss of firmness in fruit tissues. The most common way of controlling softening phenomenon in fresh fruits is the use of treatments with calcium salts. Calcium ions interact with pectic polymers to form a cross linked network that increases mechanical strength, thus delaying senescence and controlling physiological disorders in fruits and vegetables. Texture enhancers can be into the formulation of edible coatings to minimize softening phenomena of produce. Hernandez-Munoz et al. (2006) observed that the addition of calcium gluconate to the chitosan (1%) coating formulation increased the firmness of strawberries during refrigerated storage.

Reduce Respiration

Respiration can be reduced by edible films or coatings and hence increase shelf life of a commodity. In selection of a coating, several considerations should be addressed to avoid extremely low oxygen concentration inside the commodity. Low oxygen concentration in the product could lead to anaerobic respiration, which can result in deterioration of product due to production of off-flavors and accelerated senescence (Kays & Paull 2004).

Decreased Ethylene Production

A well selected edible coating will produce a modified atmosphere inside the fruit, reducing levels of internal oxygen. If oxygen concentration inside the commodity drops below 8%, there will be a decrease in ethylene production (Kader, 1986) and the commodity's quality will be preserved longer.

Improve Colour

Color is one of the most important attributes of fruits and vegetables (Kays 1999). For some minimally-processed fruits and vegetables, browning is a big problem that can be controlled by use of films or coatings as carriers of anti-browning agents. The most common antioxidant used on fruits and vegetables is ascorbic acid; however other compounds have been successfully used such as cysteine, 4-hexylresorcinol, citric acid and calcium chloride (Olivas, *et al.* 2007). Baldwin et al. (1996) coated apple slices and potato cores with Nature Seal™ and found that ascorbic acid delayed browning more effectively when applied in edible coating than in aqueous solution. Depending on coating formulation, appearance of fruit can be affected positively or negatively by selected coating. For instance, candelilla wax gives a natural, non coated appearance to apples, whereas shellac or carnauba coating (when in contact with water) will give whitish color to apples (Bai, *et al.* 2003).

Preserve Flavor

Consumers may buy the commodity based on its appearance when first purchased, but if the flavor is not acceptable, they will avoid buying the product a second time. Flavor can be preserved or modified with edible films or coatings by two different means: (1) as a barrier to aroma volatiles, and (2) as a carrier of flavors. Baldwin, *et al*. (1999) found that a polysaccharide coating worked as a barrier to aroma volatiles on whole mango. Edible coatings can also modify internal atmosphere of the commodity, causing low oxygen and high carbon dioxide concentration. This is not beneficial to flavor, since it could lead to a decrease in production of characteristic flavor compounds (Fellman, *et al*. 2003). Some works have even suggested the possibility that edible coatings on cut fruits can supply fruits with volatile precursors (Olivas *et al*. 2003). Pear wedges coated with a methylcellulose-stearic acid formulation contained higher amounts of hexyl acetate throughout storage, probably due to synthesis in wounded tissue from the stearic acid contained in the coating (Olivas, *et al*. 2003). Higher production of hexanol was observed in apples coated with alginate-linoleic acid.

Minimization of Microbial Contamination

In case of minimally-processed fruits and vegetables, where natural protection (skin) has been eliminated, opportunity for microorganisms to invade and grow on the surface of the fruit is present. Incorporating antimicrobial compounds into edible films or coatings will preserve quality of fresh-cut fruits and vegetables. Since antimicrobials are needed just on the surface of the product, their application as part of a coating will help minimize antimicrobial usage. Retention of antimicrobial compounds on coated produce surface will depend on coating attributes (composition, hydrophilic characteristics and manufacturing procedure) and type (pH and water activity), as well as storage conditions (temperature and duration) (Cagri, *et al*. 2004). Antimicrobials most commonly used include potassium sorbate, sodium benzoate, sorbic acid, benzoic acid and propionic acid; other natural antimicrobials such as lemongrass, oregano oil and vanillin have also been used (Rojas-Grau, *et al*. 2007) .

Antimicrobial Food Additives

A wide variety of antimicrobials have been added to edible films and coatings to control microbiological growth and extend produce shelf-life. Antimicrobials used for the formulation of edible films and coatings must be classified as food-grade additives or compounds generally recognized as safe (GRAS) by the relevant regulations. International regulatory agencies are in charge of approving antimicrobials for the use on foods. In the European Union (EU), those compounds are regulated by the EU Framework Directive 89/107 (EU, 1989) and in the United States (US) by the part 21CFR172 enacted by the US Food and Drug Administration (US FDA 2009). Table 1 shows antimicrobial agents used on edible films and coatings and their code numbers for food additives approved by the EU (E-Code) or the regulation numbers established by the US FDA (RegNum).

ANTIMICROBIAL SYNTHETIC CHEMICAL AGENTS

Organic acids are the most common synthetic antimicrobial agents and include acetic, benzoic, citric, fumaric, lactic, malic, propionic, sorbic, succinic, and tartaric acid, among others. These acids typically inhibit the outgrowth of bacterial and fungal cells. Potassium sorbate and sodium benzoate are the two organic acid salts more widely used as antimicrobial food additives. Benzoic acid is also called phenylformic acid or benzene-carboxylic acid. The antimicrobial activity of benzoic acid and SB is related to pH, and the most effective are the undissociated forms. Therefore, the use of these preservatives has been limited to those products that are acid in nature (Chipley, 2005). Sorbic acid is a straight-chain unsaturated fatty acid. The carboxyl group of sorbic acid is highly reactive with calcium, sodium or potassium, and results in the formation of various salts and esters (Stopforth, *et al*. 2005b). PS, the most soluble form of sorbate is well known for its potent antifungal activity. Major mold species inhibited by PS belong to the genera *Alternaria, Penicillium*, and others. Propionic acid is a naturally-occurring monocarboxylic acid. Salts of the acid have a slight cheese like flavor. The antimicrobial activity of propionate salts is pH dependent, being also more effective at low pH because of the higher activity of the undissociated form. Propionic acid is primarily inhibitory to molds; however, some yeasts and bacteria have also been satisfactorily controlled (Doores, 2005).

Parabens are the alkyl esters of *para*-hydroxybenzoic acid. The alkyl chain length of parabens determines their water solubility. The shorter the alkyl chain length, the higher the water solubility of parabens. Parabens are inhibitory to either several gram-positive and gram-negative bacteria or molds, although fungi are generally more susceptible to parabens than bacteria (Davidson 2005). For both bacteria and fungi, the inhibitory activity generally increases as the alkyl chain length of parabens also increases. The optimum pH for effective antimicrobial activity of parabens is in the range 3.0–8.0.

NATURAL ANTIMICROBIAL AGENTS

Chitosan

Chitosan is a high-molecular-weight cationic polysaccharide composed of (1→4)-linked 2-acetamido-2-deoxy- β -D-glucopyranosyl and 2-amino- 2-deoxy- β-D-glucopyranosyl units (Sebti et al. 2005), and

Table 1. Antimicrobial compounds used on edible films and coatings

Food Preservatives			
Chemical Compounds	**E-Code[a]**	**Natural Compounds**	**E-Code/Reg.Num[b]**
Organic acids		*Polypeptides*	
Acetic		Lysozyme	E-1105
Benzoic	E-210	Peroxidase	____
Citric	E-330	Lactoperoxidase	____
Lactic	E-270	Lactoferrin	____
Malic	E-296	Nisin	E-234
Propionic	E-280	Natamycin	E-235
Tartaric	E-334		
Organic acid salts		*Plant extract esessential oils, spices*	
Sodium acetate	E-262(I)	Cinnamon	182.10
Sodium diacetate	E-262(II)	Capsicum	182.10
Sodium benzoate	E-211	Lemongrass	182.20
Sodium citrate	E-331(I)	Oregano	182.10
Sodium formate	E-237	Rosemary	182.20
Calcium formate	E-238	Garlic	184.1317
Sodium L-lactate	E-325	Vanilla	182.10
Sodium propionate	E-281	Carvacrol	172.515
Calcium propionate	E-282	Citral	182.60
Potassium sorbate	E-202	Cinnamaldehyde	182.60
Sodium L-tartrate	E-335(I)	Vanillin Grape seed extracts	182.60 ____
Parabens			
Methyl paraben	E-218		
Ethyl paraben	E-214		
Propyl paraben	E-216		
Sodium salt of methyl paraben	E-219		
Sodium salt of ethyl paraben	E-215		
Sodium salt of propyl paraben	E-217		
Mineral salts			
Sodium bicarbonate	E-500(I)		
Ammonium bicarbonate	E-237		
Sodium bicarbonate	E-500(II)		
Others			
$EDTA\text{-}CaNa_2$[c]	E-385		

Silvia, *et al.* (2011)

[a]E-Code = code number for food additives approved by the European Union.

[b]RegNum = Regulation number in Title 21 of the U.S. Code of Federal Regulations where the chemical appears.

cEDTA-CaNa2 = disodium calcium ethylenediaminetetraacetate.

produces transparent films. Chitosan is not water-soluble, so a coating solution comprised of weak organic acid (acetic acid) must be used. Chitosan has been shown to be a natural food preservative, though the antimicrobial mechanism involved is not well elucidated.

It is believed that positively charged chitosan molecules interact with negatively charged microbial cell membranes, causing change in microbial cell permeability that leads to leakage of cell constituents (No, *et al*. 2007). Chitosan films or coatings can increase shelf life and preserve quality of fruits and vegetables by decreasing respiration rates, inhibiting microbial development and delaying ripening. They have been used on fruits and vegetables with good results, showing antimicrobial activity against *Bacillus cereus, Brochothrix thermosphacta, Lactobacillus curvatus, Lactobacillus sakey, Listeria monocytogenes, Pediococcus acidilactici, Photobacterium phosphoreum, Pseudomona fluorescens, Candida lambica, Cryptococcus humiculus,* and *Botrytis cinerea* (Devlieghere, *et al.* 2004 ; Romanazzi, *et al.* 2002). Chitosan is considered ideal coating for fruits and vegetables, mainly because it can form a good film on the commodity's surface and can control microbial growth (Muzzarelli 1986; No, *et al*. 2007).

Nisin

Nisin is a small antimicrobial peptide produced by lactic acid bacteria; it inhibits gram positive bacteria such as *L. monocytogenes* and *Staphylococcus aureus* and gram negative bacteria, when the bacteria cell wall was previously weakened by a permeabilising agent such as EDTA or lysozime. Nisin is generally recognized as safe and is permitted for use in over 50 countries (Thomas & Delves- Broughtonmedia 2005; Ko, *et al*. (2001) found that nisin in whey protein films was more effective in reducing *Listeria* growth than in wheat gluten films, suggesting that antilisterial activity of nisin was enhanced in hydrophobic films. Also, a greater inhibitory activity against *Listeria* was verified under acidic conditions. The commented results demonstrated that nisin effectiveness is strongly dependent on system characteristics and environmental conditions.

Natamycin

Natamycin is a tetraene polyene macrolide. It is a natural antifungal agent produced by *Streptomyces natalensis*. Natamycin has no effect on bacteria, but it is active against nearly all molds and yeasts. Natamycin is usually applied as a surface treatment for hard cheese and dry or ripened sausages.

Lactoperoxidase

The lactoperoxidase system (LPS) is a natural antimicrobial present in milk and in mammalians saliva and tears. It presents a broad antimicrobial spectrum since it shows bactericidal effect on gram (−) bacteria, bacteriostatic effect on gram (+) bacteria, and antifungal activity (Naidu 2000). The LPS system consists of three components: LPS, thiocyanate, and hydrogen peroxide (H_2O_2). The enzyme catalyzes the oxidation of thiocyanate (SCN–) by the use of H_2O_2 and produces hypothiocyanite (OSCN–) and hypothiocyanous acid (HOSCN). These products inhibit microorganisms by the oxidation of sulphydryl (–SH) groups in their enzyme systems and proteins (Seifu, *et al*. 2005). From another point of view, the incorporation of the LPS to alginate films did not modify significantly the mechanical and barrier properties of evaluated films (Yener, *et al*. 2009). However, in a whey protein film, incorporation of LPS promoted a significant reduction in elastic modulus and in tensile strength when LPS concentration was equal to or higher than 0.15 g of LPS per gram of film (Min, *et al*. 2005).

Lactoferrin

Lactoferrin is an iron-binding, bioactive glycoprotein of the transferrin family that contributes to the control of iron in biological fluids. Lactoferrin inhibits microorganisms by binding iron and making it unavailable for microbial development (Stopforth, *et al*. 2005a).

Lysozyme

Lysozyme is an enzyme comprising 129 amino acids crosslinked by disulfide bonds (Cagri, *et al.* 2004). Lysozyme exhibits antimicrobial activity against vegetative cells of a wide variety of organisms, including numerous food borne pathogens and spoilage microorganisms. Gram-negative bacteria are generally less sensitive than Gram-positive bacteria to lysozyme, mainly as a result of protection of the cell wall by the outer membrane (Johnson and Larson 2005). The rate of cell catalysis by lysozyme depends upon the pH of the medium, showing a bell-shape with a maximum at pH 5.0 and inflections at pH 3.8 and 6.7 (Naidu 2003).

Plant and Herbs Essential Oils

Essential oils (EOs) are aromatic oily liquids obtained from individual or integrated plant material: flowers, buds, seeds, leaves, twigs, bark, herbs, wood, fruits, and roots (Burt 2004). EOs are commonly obtained by steam distillation of plants. Chemical composition of EOs is complex and strongly dependent on the part of the plant considered (e.g., seed vs. leaves), the moment of the harvest (before, during, or after flowering), the harvesting season and the geographical sources. Major components in EOs are phenolic substances, which are thought as the responsible of the antimicrobial properties, and many of them are classified as GRAS. However, it has been reported that other minor components have a critical influence in the antimicrobial and antioxidant activity, acting synergistically with other components (Zheng, *et al.* 2009). There is abundant scientific evidence in relation to the effectiveness of EOs fractions of many spices and herbs and their components as antimicrobial, antifungal, and antiviral compounds (Burt 2004; Valero & Francs 2006; Hoque, *et al.* 2006, Hoque, *et al.* 2008; Taniya, *et al.* 2016). Examples of such plants are cassia, clove, garlic, cinnamon, sage, oregano, pimento, thyme, rosemary, lemongrass, scutellaria, and forsythia suspense. The antimicrobial activity of the EOs can be attributed to their content of monoterpenes that, due to their lipophilic character, act by disrupting the integrity of microbial cytoplasmic membrane, which thus loses its high impermeability for protons and bigger ions. Lipophilic compounds accumulate in the lipid bilayer according to its specific partition coefficient, leading to disruption of the membrane structure (Zhang, *et al.* 2009). Then, membrane functions are compromised, not only as a barrier but also as a matrix for enzymes and as an energy transducer (Liolios, *et al.* 2009). Some disadvantages of EOs are their biological and chemical instability, reduced solubility in water and poor distribution to target sites.

ANTIMICROBIAL EDIBLE COMPOSITE COATINGS APPLIED TO FRUITS AND VEGETABLES

Antimicrobial edible films and coatings can potentially serve as active food packaging materials by altering permeability of a product to water vapor and oxygen, as well as by minimizing growth of surface contaminants during refrigerated storage, providing an alternative to post process pasteurization for inactivation of surface contaminants.

Some of the more commonly used preservatives and antimicrobials in edible films and coatings include benzoates, proprionates, sorbates, parabens, acidifying agents (e.g., acetic and lactic acids), curing agents (e.g., sodium chloride and sodium nitrite) bacteriocins, and natural preservatives (e.g., natural oils, lysozyme, liquid smoke) (Cagri, *et al.* 2004). Antifungal compounds, organic acids, potassium sorbate, or the bacteriocin, nisin, were reported to be more effective in reducing levels of food borne microorganisms when immobilized or incorporated into edible gels (i.e. starch, carrageenan, waxes, cellulose ethers, or alginate). Incorporation of essential oils has also been investigated in production of antimicrobial edible films and coatings. Although antimicrobial properties of essential oils have been recognized for centuries, there has been renewed interest in their use because of consumer demand for natural ingredients and additives. Table 2 summarizes relevant applications of an antimicrobial external edible films or coatings to prevent microbial spoilage.

EFFECT OF EDIBLE COATINGS ON SENSORY QUALITY

Thick coating on fruits and vegetables surface becomes an undesirable barrier between the external and internal atmosphere and restricts exchange of respiratory gases (CO_2 and O_2) (Cisneros-Zevallos & Krochta, 2003). This may result in anaerobic respiration, which produces much more carbon dioxide, acetaldehyde and ethanol. The acetaldehyde and ethanol result in fermentation and give off-flavor to the product, which are detrimental to the perceived quality. It is therefore necessary to adjust the thickness of the wax coat according to the variety and storage and marketing temperatures. Park, *et al.* (1994) reported that tomatoes coated with 2.6 mm zein film produced alcohol and off-flavors internally which is due to low oxygen and high carbon dioxide concentration. Smith, *et al.* (1987) summarized that use of coatings results disorders like core flush, flesh breakdown, accumulation of ethanol, and alcoholic off-flavors, which is due to modification of internal atmosphere. Edible coatings are usually consumed with the coated products. Therefore, the incorporation of compounds such as antimicrobials, antioxidants and nutraceuticals should not affect consumer acceptance. Some authors have indicated that the incorporation of antimicrobial agents into edible coatings could impart undesirable sensorial modifications in foods, especially when EOs are used (Burt 2004). Sometimes the incorporation of certain anti-browning agents into edible coatings can yield an unpleasant odor, particularly when high concentrations of sulfur-containing compounds such as N-acetylcysteine and glutathione are used as dipping agents (Richard, *et al*. 1992; Iyidogan & Bayindirli 2004; Rojas-Grau, *et al*. 2006). Not many studies have been reported on the sensory characteristics of coated fruits when nutraceutical ingredients are incorporated. The addition of nutraceutical compounds to edible coatings may impart bitter taste, astringent or off-flavor (Drewnowski & Gomez-Carneros 2000) that can lead to rejection of the product by consumers (Le Clair 2000).

Table 2. Application of antimicrobial edible films and coatings to improve the quality of fruits and vegetables

Hydrocolloid	Antimicrobial	Fruit/Vegetable	Effect	Reference
Starch/chitosan	Chitosan	Carrot slices	Inhibition of total viable count, lactic acid bacteria, psicrotrophic total coliforms and yeast and moldduring storage at 10 °C	Durango, *et al*. 2006
Cassava starch	Potassium sorbate	Pumpkin cylinders	Aerobic mesophiles, lactic acid bacteria, yeasts, and molds growth was prevented	Garcia, *et al*. 2008
Starch or MC/HPMC	Propolis extract	Fresh noodle	Total microorganism count was reduced during 4 weeks at 10 °C	Kim, *et al.* 2005
Alginate	Potassium sorbate	Potato cylinders	Initial microbial load was decrease during refrigerated storage at 5 °C	Mitrakas, *et al.* 2008
Chitosan Casein CMC	Chitosan	Butternut squash	Coating reduced the counts of mesophilic aerobic bacteria	Moreira *et al*.2009
Chitosan, carboxymethyl cellulose, and Casein	Natural plant extracts	Butternut	Coatings enriched with rosemary and olive oleoresins produced a slight antimicrobial effect against native microflora and Listeria monocytogenes	Ponce, *et al.* 2008
Alginate	Cinnamon, palmarosa, and lemongrass	Fresh-cut melon	Native flora growth and S. enteritidis population was reduced extending shelf life by more than 21 days	Raybaudi-Massilia, *et al.* 2008
Agar-agar	Chitosan and acetic acid	Garlic	Filamentous fungi and aerobic mesophilic were inhibited during 6 days storage, at 25 °C	Robson, *et al.* 2008
Chitosan	Chitosan	Carrots slices	Native microbial populations were maintained very low	Simoes, *et al*. 2009
Hydroxypropyl methylcellulose-lipid	Organic acid salts, parabens	Mandarins	Antifungal action of the coatings was fungistatic rather than fungicidal	Valencia-Chamorro, *et al.* 2009
Chitosan/cassava starch/ gelatin	Chitosan	Mango slices	Inhibition of Botryodiplodia theobromae was reduced on fruit surface was observed	Zhong and Xia 2008

EFFECT OF EDIBLE COATINGS ON NUTRITIONAL ASPECTS

Edible films and coatings can affect nutritional quality of fruits and vegetables. They can be used as carriers of nutrients. On the other hand, they can produce abiotic stress, which could modify metabolism of the commodity, affecting production of nutrients. Some works have determined effects of coatings on nutritional quality, and on phenolics and other phytochemicals. Han, *et al*. (2004) found higher amounts of vitamin E and calcium on strawberries coated with chitosan, containing calcium and vitamin E in the formulation, due to diffusion of these nutrients into the fruit. Romanazi, *et al*. (2002) observed an increase in phenylalanine ammonia–lyase activity, a key enzyme for synthesis of phenolic compounds, on grapes coated with chitosan. Edible coatings have also been used as carriers of probiotics. *Bacillus lactis* was maintained for 10 days on fresh-cut fruits under refrigeration, when applied on alginate- and gellan based edible coatings (Tapia, *et al*. 2007).

LEGISLATION RELATED TO EDIBLE FILMS AND COATINGS

Edible films supporting antimicrobials can be considered as an active film. Definitions stated in Regulation 1935/2004/ EC and in Regulation 450/2009/EC consider that "active materials and articles are intended to extend the shelf life or to maintain or improve the condition of packaged food". They are designed to deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food (Restuccia, *et al.* 2010). According to legislation and labeling in the USA, edible coatings and films are considered part of the food; as a consequence, their ingredients must comply with the Code of Federal Regulations and be declared on the label under the Federal Food, Drug, and Cosmetic Act (Franssen & Krochta 2003). The EU considers that an edible film is a special active part of the food and, seen from a legal point of view, it is to be regarded as a foodstuff, along with the food packed in the film, having to fulfill the general requirements for food (Fabec, *et al*. 2000). According to Rojas-Grau, *et al.* (2009), another important issue within regulatory status is the presence of allergens because many edible films and coatings are made with or can contain ingredients that could cause allergic reactions such as wheat protein (gluten) or peanut protein. Therefore, the presence of a known allergen on a film or coating on a food must be also clearly stated in the label.

CONCLUSION

Antimicrobial edible films and coatings are used for improving the shelf life of food products without impairing consumer acceptability. They are designed as a stress factor in order to prevent surface contamination and/or providing a gradual release of the active substance. The edible film formulation proposed must be adapted in order to ensure a content of the food that nisin accordance with maximum values allowed by food legislation of the country of application. Characteristics of edible films depend greatly on hydrocolloid used. Polysaccharides rend transparent and homogeneous edible films with moderate mechanical properties. However, the application of these films is limited by their water solubility and poor water vapor permeability. Protein based films could have impressive gas barrier properties and mechanical properties compared with those prepared from polysaccharides; however, the poor water vapor resistance limits their application. To solve this shortcoming, the blending with different biopolymers, the addition of hydrophobic materials such as oils or waxes or chemical and/or enzymatic modification of polymer can be performed. There is a trend to select the antimicrobials from natural sources and to use generally recognized as safe (GRAS) compounds so as to satisfy consumer demands for healthy foods free of chemical additives. The more commonly antimicrobials used are organic acids, the polysaccharide chitosan, some polypeptides as nisin, the system, and some plant extracts and its essential oils among others. It must be remarked that the release of the from a film or coating exerts a great influence on its effectiveness. As a consequence, the evaluation of the rate of release together with the evaluation of antimicrobial activity through the time will help to optimize the development of films and coatings for lengthening the shelf life of food products.

CHALLENGES AND FUTURE RESEARCH

Most work in this area has dealt with changes in quality due to application of coating. But very less work has been done to identify the relationship between the internal atmosphere caused by the coating and velocity of physiological ripening processes, such as respiration, tissue softening, metabolic reactions, production of metabolites and secondary compounds generated during storage.

To preserve quality of fruits by means of decreasing oxygen in the internal atmosphere, special care should be taken not to minimize oxygen concentration to a point where anaerobic respiration may occur. Thus, for each fruit, it is necessary to know the optimum oxygen concentration at which rate of consumption is minimized without promoting development of anaerobic respiration. Future research should be focused on the following aspects:

- Properties of coating solution: composition, concentration, viscosity and density
- Properties of film: mechanical, gas and vapor barrier properties
- Properties of coating: thickness, temperature, and atmospheric conditions
- Properties of the produce (fresh or minimally-processed): respiration rate, water activity, composition, etc.
- Variation in chemical and physical conditions (e.g., pH, temperature, time, etc.) could affect these properties.
- To understand possible changes to properties of a film when chemical and physical conditions are modified, simulating likely events a commodity could face during actual handling and storage.
- Study of metabolic reactions occurring within commodities and the extent to which they can be modified with coatings.
- Study of internal gas composition of coated commodities and relationships between internal atmosphere and velocity of physiological ripening processes, such as respiration, metabolic reactions and production of secondary compounds during storage.
- To study of impact of coatings on quality and shelf life of commodities, taking into account all possible conditions they could face during handling and storage.
- Determination of optimal methods of applying coatings most conducive to obtaining high quality product at lowest possible cost.
- Study of consumer acceptability of coatings.
- Study of impact of edible coatings on final cost of commodities.
- Studies should focus on commercial viability of edible film and coating technology for fruits and vegetables.

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Chapter 10
New Horizons of Nanotechnology in Agriculture and Food Processing Industry

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ABSTRACT

This chapter addresses the potential application of nanotechnology in various areas of agriculture and food processing sector. Nanotechnology is an exciting and fast developing field which aims to generate new materials and devices with wide range of applications. Nanotechnology is capable to solve the very complex set of engineering and scientific challenges in the agriculture and processing industry. Nanotechnology has great potential in providing novel and improved solutions to many challenges facing agriculture and food sector. Nanotechnology based products and its applications in agriculture include nano-fertilizers, nano-herbicides, nano-pesticides, recalcitrant contaminants from water, nano-scale carriers, nan-osensors, veterinary care, fisheries and food processing etc. Nanotechnology revolutionized the agriculture and food industry by innovation new techniques such as: precision farming techniques, more efficient and targeted use of inputs, disease detection and control, withstand environmental pressures and effective systems for processing and packaging.

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INTRODUCTION

Nanoscale science, engineering and technology embrace an exciting and broad scientific frontier which will have significant impact on nearly all aspects of the global economy, industry and people's life in the 21st century. Nanoscale science reveals the properties, processes and phenomena of matters at the nanometer (1 to approximately 100 nm) range. This technology renders precise capability to control and fabricate matters at this scale to provide novel and useful properties, thus leading to many new applications of nanoscale science and nanomaterials that can be used to address numerous technological issues.

Plant based agricultural production is the basis of broad agriculture systems providing food, feed, fibre and fuel through advancement in material sciences and biomass conversion technologies. While the demand for crop yield are rapidly increasing, the agriculture and natural resources such as land, water and soil fertility are finite. In agriculture and food science, a wide range of nanotechnology applications are being developed and commercialized with different goals ranging from improved food safety to reduced agricultural inputs, enhanced packaging, improved processing cum nutrition and the potential to promote sustainable agriculture and deliver better food globally (Gruere, 2012; Schnettler et al., 2013).

In agriculture, nanotechnology research and development have mostly focused on improving better input use, from water to nutrients, nano-pesticides, and nano-herbicides. Interesting applications include the use of nanoporous zeolites to slow the release and increased efficiency of fertilizers, nanosensors to measure soil quality and smart delivery mechanism for herbicides (Sastry et al., 2010).

Nanotechnology has the potential to improve food quality and safety significantly. It offers a wide range of opportunities for the development of innovative products and applications in food system. Nanotechnology and nanomaterials are a natural part of food processing and conventional foods, because the characteristic properties of many foods rely on nanometer sized components (Mir and Shah, 2014). Nanotechnology has been touted as the next revolution in many industries, including food processing and packaging. These applications are divided into several categories including food processing, nutraceutical delivery, packaging, and safety and sensing

BACKGROUND

Nanotechnology in Agriculture

Nanotechnology has the prospective to modernize the agricultural research and development with new tools for the molecular treatment of diseases with rapid detection and to enhancing the ability of plants to absorb nutrients etc. Smart sensors and smart delivery systems will help the agricultural industry, combat viruses and other crop pathogens. Nanotechnology also protects the environment indirectly through the use of alternative (renewable) energy supplies and filters or catalysts to reduce pollution and clean-up existing pollutants.

In the agricultural sector, nanotech research and development is likely to facilitate and frame the next stage of development of genetically modified crops, animal production inputs, chemical pesticides and precision farming techniques. While nano-chemical pesticides are already in use, other applications are still in their early stages and it may be many years before they are commercialized. These applications are largely intended to address some of the limitations and challenges facing large scale chemical and capital intensive farming systems.

Nanotechnology for Delivery of Agriculture Chemicals

Today use of chemicals such as pesticides, fungicides and herbicides are the fastest and cheapest way to control pests and diseases. Also biological control methods are very expensive currently. Uncontrolled use of pesticides has caused many problems such as adverse effects on human health, pollinating insects, domestic animals and its hazardous effect directly or indirectly on soil, water and ecosystem. Intelligent use of chemicals on the nano scale can be a suitable solution for this problem. These materials are used into the part of plant that was attacked by disease or pests. Also these carriers in nanoscale has self-regulation, this means that the medication on the required amount may only be delivered into plant tissue (Jha et al., 2011).

Many nanoscale carriers, including encapsulation and entrapment, polymers, surface ionic, weak bond attachments and other mechanisms are used to store, protect, deliver and release by control of intended payloads in crop production processes. One of the advantages of nanoscale delivery vehicles in agronomic applications is its improved stability of the payloads against degradation in the environment, thereby increasing its effectiveness while reducing the amount applied. This reduction helps address agricultural chemicals run-off and alleviate the environmental consequence (Baruah and Dutta, 2009).

The nanoscale delivery vehicles are designed to “anchor” to plant roots or the surrounding soil structures and organic matter if molecular or conformational affinity between the delivery nanoscale structure, targeted structures and matters in soil could be utilized. Controlled release mechanisms allow the active ingredients to be slowly taken up, hence avoiding temporal overdose, reducing the amount of agricultural chemicals used and minimizing the input and waste (Subramanian et al., 2014).

Nano-Fertilizers for Crop Nutrition

Fertilizer play pivotal role in the agriculture production up to 35 to 40% of the productivity. To enhance nutrient use efficiency and overcome the chronic problem of eutrophication, nanofertilizer might be a best alternative. Attempts have been made to synthesize nanofertilizer particularly for zinc in order to regulate the release of nutrients depending on the requirements of the crops and it is also reported that nanonutrients are more efficient than ordinary fertilizer. In the past few decades, use efficiencies of N, P and K fertilizers have remained constant as 30-35%, 18-20% and 35-40%, respectively, leaving a major portion of added fertilizers to accumulate in the soil or enter into aquatic system causing eutrophication. In order to address issues of low fertilizer use efficiency, imbalanced fertilization, multi-nutrient deficiencies and decline of soil organic matter, it is important to evolve a nano-based fertilizer formulation with multiple functions (Mousavi and Rezaei, 2011).

Significant increase in yields has been observed due to foliar application of nano particles as fertilizer. It was shown that 640 mg/ha foliar application (40 ppm concentration) of nanophosphorus gave 80 kg/ha P equivalent yield of clusterbean and pearl millet under arid environment. Currently, research is underway to develop nano-composites to supply all the required essential nutrients in suitable proportion through smart delivery system. Preliminary results suggest that balanced fertilization may be achieved through nanotechnology (Ghormade et al., 2011).

Indeed, the metabolic assimilation within the plant biomass of the metals e.g., micronutrients, applied as nano-formulations through soil-borne and foliar application or otherwise needs to be ascertained. Further, the nano-composites being contemplated to supply all the nutrients in right proportions through the “Smart” delivery systems also need to be examined closely. Currently, the nitrogen use efficiency is low due to the loss of 50-70% of the nitrogen supplied in conventional fertilizers. New nutrient delivery systems that exploit the porous nanoscale parts of plants could reduce nitrogen loss by increasing plant uptake. Fertilizers encapsulated in nanoparticles will increase the uptake of nutrients. In the next generation of nanofertilizers, the release of the nutrients can be triggered by an environmental condition or simply released at desired specific time (Gruere, 2012).

Zinc, magnesium and titanium are playing direct or indirect role in the photosynthesis process. In the rhizosphere, root exudation is a key process for carbon transfer into the soil and influencing the role of soil microbial communities in the decomposition of organic matter and in native nutrient cycling. Root exudates are the substances released by roots and may affect growth and activity of soil microorganisms in the rhizosphere. Root exudates act as a chemo-attractants to attract microbes towards root and have been shown to increase the mass and activity of soil microbes and fauna found in the rhizosphere. Nanotechnology is one of the most important tools in modern science yet only a few attempts have been made to apply these advances for increasing crop productivity. It is possible to develop microorganisms as bionano factories for synthesis of agriculturally important particles. These nanoparticles offer an excellent scope in developing efficient source of plant nutrients for enhancing biomass production through increased plant metabolic activities and utilization of native nutrients by promoting microbial activities (DeRosa et al., 2010).

Nano-Herbicide for Weed Control

Herbicides available in the market are designed to control or kill the above ground part of the weed plants. None of the herbicides inhibits activity of viable below ground plant parts like rhizomes or tubers which act as a source for new weeds in the ensuing season. Soil infested with weeds and weed seeds are likely to produce lower yield as compared to land dominated by weeds. Improvement in the efficacy of herbicides through the use of nanotechnology resulted in greater production of crops. The encapsulated nano-herbicides are relevant, keeping in view the need to design and produce a nano-herbicide that is protected under natural environment and acts only when there is a spell of rainfall, which truly mimics the rain-fed system. Developing a target specific herbicide molecule encapsulated with nanoparticle is aimed for specific receptor in the roots of target weeds which enter into root system and translocated to parts that inhibit glycolysis of food reserve in the root system. This will make the specific weed plant to starve for food and gets killed. Adjuvants for herbicide application are currently available that claim to include nanomaterials (Prasad et al., 2014).

Nano-Pesticide

Persistence of pesticides in the initial stage of crop growth helps in bringing down the pest population below the economic threshold level and to have an effective control for a longer period. Hence, the use of active ingredients in the applied surface remains one of the most cost-effective and versatile means of controlling insect pests. In order to protect the active ingredient from the adverse environmental conditions and to promote persistence, a nanotechnology approach, namely “nano-encapsulation” can be used to improve the insecticidal value. Nanoencapsulation comprises nano-sized particles of the active ingredients being sealed by a thin-walled sac or shell (protective coating). Nano-encapsulation of insecticides, fungicides or nematicides will help in producing a formulation which offers effective control of pests while preventing accumulation of residues in soil (Schnettler et al., 2013). In order to protect the active ingredient from degradation and to increase persistence, a nanotechnology approach of "controlled release of the active ingredient" are used to improve effectiveness of the formulation that may greatly decrease amount of pesticide input and associated environmental hazards. Nano-pesticides will reduce the rate of application because the quantity of product actually being effective is at least 10-15 times smaller than that applied with classical formulations, hence a much smaller than the normal amount could be required to have much better and prolonged management. Several pesticide manufacturers are developing pesticides encapsulated in nanoparticles. These pesticides may be time released or released upon the occurrence of an environmental trigger (e.g., temperature, humidity, light) (DeOliveira et al., 2014).

Plant diseases are major factors in limiting crop yield. The problem with the disease management lies with the detection of the exact stage of prevention. Most of the time appropriate plant protection chemicals are applied to the crop as a precautionary measure leading to avoidable environmental hazards, or else applications are made after the appearance of the disease symptoms, thereby causing some amount of crop losses. Among the different diseases, viral ones are the most difficult to control, as one has to stop the spread of the disease by the vectors. But once it starts showing its symptoms, pesticide application would not be of much use. Therefore, detection of the exact stage such as stage of viral DNA replication or the production of initial viral protein is the key for the success of control of viral diseases. Nano-based viral diagnostics including multiplexed diagnostic kits development have taken momentum in order to detect the exact strain of virus and the stage of application of some therapeutic to stop the disease (Sastry et al., 2010). Detection and utilization of biomarkers that accurately indicate disease stages, is also an emerging area of research in bio-nanotechnology. Measuring differential protein production in both healthy and diseased states leads to the identification of the development of several proteins during the infection cycle. Clay nanotubes (halloysite) have been developed as carriers of pesticides at low cost, for extended release and better contact with plants and they will reduce the amount of pesticides by 70-80%, thereby reducing the cost of pesticide with minimum impact on water streams (Bhattacharyya et al., 2010).

Precision Farming

Nanotechnology supports the application of information technologies applied to the management of commercial agriculture. Precision farming enabling technologies include satellite-positioning system, geographic information system and remote sensing devices. By connecting global positioning systems with satellite imaging of fields, farm managers could remotely detect crop pests or evidence of drought. Information about these conditions would trigger an automatic adjustment of pesticide applications or irrigation levels. Dispersed throughout field, a network of sensors would relay detailed data about crops and the soil. These sensors would need to have nanoscale sensitivity to monitor conditions such as the presence of plant viruses or the level of soil nutrients. Other forms of nanotechnology may directly alter agricultural practices. Nanoparticles or nanocapsules could provide a more efficient means to distribute pesticides and fertilizers, reducing the quantities of these chemicals introduced into the environment (Scott and Chen, 2013).

Nanotechnology in Agronomy

Precision agriculture is a new attitude in farm management. Nano-sensors help to farmers in maintaining farm with precise control and report timely needs of plants. Nano sensors and nano-based smart delivery systems could help in the efficient use of agricultural natural resources like water, nutrients and chemicals through precision farming. Through the use of nano materials and global positioning system with satellite imaging of fields, farm manager could remotely detect crop pests or evidence of stress such as drought. Once pest or drought is detected, there would be automatic adjustment of pesticide applications or irrigation levels. Nano sensors dispersed in the field can also detect the presence of plant viruses and the level of soil nutrients. Nano fertilizers will be absorbed by plants rapidly and completely. Nano encapsulated slow release fertilizers have also become a trend to save fertilizer consumption and to minimize environmental pollution. Super water adsorbents made by nanotechnology has an important role in storage and protecting water in arid and semiarid regions. Nanotechnology has many applications in the field of agricultural machinery such as: application in machines structure and agricultural tools to increase their resistance against wear and corrosion and ultraviolet rays; producing strong mechanical components with use of nano-coating and use of bio-sensors in smart machines for mechanical-chemical weed control; production nano-cover for bearings to reduce friction. The use of nanotechnology in production of alternative fuels and reduce environmental pollution. Nanotechnology has also shown its ability in modifying the genetic constitution of the crop plants thereby helping in further improvement of crop plants (Khot et al., 2012).

Biosensors to Detect Nutrients and Contaminants

Protection of the soil health and the environment requires the rapid, sensitive detection of pollutants and pathogens with molecular precision. Soil fertility evaluation is being carried out for the past sixty years with the same set of protocols which may be obsolete for the current production systems and in the context of precision farming approaches. Accurate sensors are needed for *in situ* detection, as miniaturized portable devices and as remote sensors for the real-time monitoring of large areas in the field. These instruments are able to reduce the time required for lengthy microbial testing and immunoassays. Application of these instruments include detection of contaminants in different bodies such as water supplies, raw food materials and food products.

Enzymes can act as a sensing element as these are very specific in attachment to certain biomolecules. Electronic nose is used to identify different types of odors; it uses a pattern of response across an array of gas sensors. It can identify the odorant, estimate the concentration of the odorant and find characteristic properties of the odor in the same way as might be perceived by the human nose. It mainly consists of gas sensors which are composed of nanoparticles e.g. ZnO nanowires. Their resistance changes with the passage of a certain gas and generates a change in electrical signal that forms the fingerprint pattern for gas detection (Baruah and Dutta, 2009).

Biosensors provide high performance capabilities for use in detecting contaminants in food or environmental media. They offer high specificity and sensitivity, rapid response, user-friendly operation and compact size at a low cost. While the direct enzyme inhibition sensors currently lack the analytical ability to discriminate between multiple toxic substances in a sample (such as simultaneous presence of heavy metal and pesticide), they may prove useful as a screening tool to determine when a sample contains one or more contaminants (Jha et al., 2011).

Nanotechnology in Seed Science

Seed is most important input determining productivity of any crop. Conventionally, seeds are tested for germination and distributed to farmers for sowing. In spite of the fact that seed testing is done in well-equipped laboratories, it is hardly reproduced in the field due to the inadequate moisture under rain-fed conditions. In India, more than 60% of the net area sown is rain-fed. Hence, it is quite appropriate to develop technologies for rain-fed agriculture. Nowadays research is going on metal oxide nano-particles and carbon nanotube to improve the germination of rain-fed crops. Literature reported the use of carbon nanotube for improving the germination of tomato seeds through better permeation of moisture. Carbon nanotubes serve as new pores for water permeation by penetration of seed coat and act as a passage to channelize the water from the substrate into the seeds. These processes facilitate germination which can be exploited in rainfed agricultural system (Jha et al., 2011).

Nanotech Sensors

Smart sensors, which are obtained by nanotechnology are the powerful tools for track detect and control with animal and plant pathogen. Detection of very small amounts of a chemical contaminant, virus or bacteria in agricultural and food systems is envisioned from the integration of chemical, physical and biological devices working together as an integrated sensor at the nano scale. The bio analytical nano sensors either use biology as a part of the sensor or are used for biological samples. At the University of Manitoba in Winnipeg, microelectronics and nanotechnology have been combined to create a tiny sensor that can help farmers in the early detection of grain spoilage during storage. The stand-alone sensor can detect parts per billion level of carbon dioxide and odour-causing chemicals to determine the level and cause of spoilage. "Each insect produces a specific chemical inside the grain bin. Similarly, if the grain is being infested with fungus, it produces different chemicals. The developed sensor has seven chips in it and will identify which insect or fungus is causing the spoilage." The sensor also measures changes in carbon dioxide to detect incipient and ongoing deterioration of stored grains. The central hub would automatically update a household computer, website or personal mobile device such as a cellphone so that a farmer could monitor the grain on a daily basis without having to visit the grain bin. By catching and treating spoilage before it becomes severe, additional benefits might include reduced chemical usage and better grain quality (Ghormade et al., 2011).

One of the major roles for nanotechnology enabled devices will be the increased use of autonomous sensors linked into a GPS system for real time monitoring. These nano sensors could be distributed throughout the field where they can monitor soil conditions and crop growth. Ultimately precision farming, with the help of smart sensors will allow enhanced productivity in agriculture by providing accurate information, thus helping farmers to make better decision.

Nano smart dust and gas sensors are used in determining the amount of pollutants and dust in the air. It is possible to evaluate the presence of pollutants in the environment by these nano sensors in few minutes (Baruah and Dutta, 2009).

Nanotechnology are developed and deployed for real time monitoring of the crop growth and field conditions including moisture level, soil fertility, temperature, crop nutrient status, insects, plant diseases, weeds, etc. Networks of wireless nanosensors positioned across cultivated fields provide essential data leading to best agronomic intelligence processes with the aim to minimize resource inputs and maximizing output and yield. Such information and signals include the optimal time for planting and harvesting crops and the time and level of water, fertilizers, pesticides, herbicides and other treatments that need to be administered given specific plant physiology, pathology and environmental conditions (Scott and Chen, 2013).

Biotechnological research has been focusing on improving plant resilience against various environmental stresses such as drought, salinity and diseases. Genomes of crop cultivars are currently being extensively studied. The advancement in nanotechnology enabled gene sequencing is expected to introduce rapid and cost effective capability within a decade, hence leading to more effective identification and utilization of plant gene trait resources (Sastry et al., 2012).

Nano-Fibers

Nanotechnology with use of biological, chemical and physical processes plays a role in recycling the residual materials of agricultural products to energy and industrial chemicals. For example, when cotton is processed into fabric or garment, some of the cellulose or the fibers are discarded as waste or used for low value products such as cotton balls, yarns and cotton batting. With the use of newly developed solvents and a technique called electro spinning, scientists produce 100 nanometer-diameter fibers that can be used as a fertilizer or pesticide absorbent. These high performance absorbents allow targeted application at desired time and location. Nanofibers are also used for encapsulating chemical pesticides, prevention of scattering of chemical pesticides in the environment, water and soil pollution. This technology increases the chemical pesticides durability and security applications. When the fibers are degraded through biological, chemical materials are released slowly in the soil. Porous nano-polymers have a very similar to the pollutants molecules and considered the most suitable means for separating organic pollutants of soil and water. Similar nano fiber-based fabrics are being used as a detection technology platform to capture and isolate pathogens. The nano fibers in this fabric are embedded with antibodies against specific pathogens. The fabric can be wiped across a surface and tested to determine whether the pathogens are present and perhaps indicating their presence by a change in colour (Khot et al., 2012).

Nano-Filtration

Due to increasing demand for freshwater in the world, developing new methods is essential for producing freshwater. The use of nano particles and nano-filtration provides possibility of refining and improving water with speed and accuracy. Also, nano-filter has a widespread application to eliminate microbial contaminants of water. In the new method for water desalination, hot salt water is passed on thin sheets of carbon nano tube membranes, that have nano-holes. Only the steam passes through these holes whereas, liquid, salts and other minerals remain in the membrane. Cold water containers are located in the other side of membrane and that steam is converted to liquid again with passing through it. The most important features of carbon nano-tubes include: smaller and denser holes; allowing high flow rate passing each hole. In the processing of dairy products are also used of nano-filters. Nano-filters, provides a selective passing particles. Also nano-filtration is used to detect metabolites quality control in food industry and pathogenic factors, and is a major change in food packaging and storage (Baruah and Dutta, 2009).

Nanotechnology in Pests and Plant Diseases Management

There are myriad of nano materials including polymeric nano particles, iron oxide nano particles and gold nano particles which can be easily synthesized and exploited as pesticide or drug delivery. The pharmacokinetic parameters of these nano particles may be altered according to size, shape and surface functionalization. Diseases are one of the major factors limiting crop productivity. The problem with the disease management lies with the detection of the exact stage of prevention. Most of the times pesticides are applied as a precautionary manner leading to the residual toxicity, environmental hazards and on the other hand application of pesticides after the appearance of disease leads to some amount of crop losses. Among the different diseases, the viral diseases are the most difficult to control, as one has to stop the spread of the disease by the vectors. But, once it starts showing its symptoms, pesticide application would not be of much use. Therefore, detection of exact stage such as stage of viral DNA replication or the production of initial viral protein is the key to the success of control of diseases particularly viral diseases. Nano-based viral diagnostics, including multiplexed diagnostic kit development have taken momentum in order to detect the exact strain of virus and stage of application of some therapeutics to stop the disease (Rai and Ingle, 2012). Detection and utilization of biomarkers that accurately indicate disease stages is also a new area of research. Measuring differential protein production in both healthy and diseased states leads to the identification of the development of several proteins during the infection cycle. These nano-based diagnostic kits not only increase the speed of detection but also increase the power of the detection. In the future, nano scale devices with novel properties could be used to make agricultural systems “smart”. For example, devices could be used to identify plant health issues before these become visible to the farmer. Such devices may be capable of responding to different situations by taking appropriate remedial action. If not, they will alert the farmer to the problem. In this way, smart devices will act as both a preventive and an early warning system. Such devices could be used to deliver chemicals in a controlled and targeted manner in the same way as nano medicine has implications for drug delivery in humans.

Nanotechnology helps to agricultural sciences and reduce environmental pollution by production pesticides by using the nano particles and nano capsules with the ability to control or delayed delivery, absorption and more effective and environmentally friendly; and production of nano-crystals to increase the efficiency of pesticides for application of pesticides with lower dose (DeOliveira et al., 2014).

The advancement in nanofabrication and characterization tools have enabled studies of physical, chemical and biological interactions between plant cell organelles and various disease causing pathogens, i.e., plant pathology. A better understanding of plant pathogenic mechanisms such as flagella motility and biofilm formation will lead to improved treatment strategies to control the diseases and protect production. For example, spatial and temporal studies of plant pathogenic xylem inhabiting bacteria have traditionally been conducted by monitoring changes in bacterial populations through destructive sampling techniques of tissues at various distances from inoculation sites. This approach seriously limits the information that can be obtained regarding colonization, biofilm development and subsequent movement and re-colonization at new areas, primarily because the same region or sample site cannot be followed temporally. Micro-fabricated xylem vessels with nano-size features have been shown very useful in gaining an appreciation of the mechanisms and kinetics of bacterial colonization in xylem vessels such that novel disease control strategies may be developed (Perez-de-Luque and Rubiales, 2009).

Nano-Scale Carriers

Nanoscale carriers are utilized for the efficient delivery of fertilizers, pesticides, herbicides, plant growth regulators, etc. The mechanisms involve efficient delivery, better storage and controlled release include encapsulation and entrapment, polymers and dendrimers, surface ionic and weak bond attachments among others. These help to improve stability against degradation in the environment and ultimately reduce the amount to be applied which reduces chemical runoff and alleviates environmental problems. These carriers can be designed in such a way that they can anchor plant roots to the surrounding soil constituents and organic matter. This can only be possible if we unravel the molecular and conformational mechanisms between the nanoscale delivery and targeted structures and soil fractions. Such advances will help in slowing the uptake of active ingredients, thereby reducing the amount of inputs to be used and also the waste produced (Bhattacharyya et al., 2010).

Smart Delivery Systems

Nanoscale devices are envisioned that would have the capability to detect and treat diseases, nutrient deficiencies or any other maladies in crops long before symptoms were visually exhibited. "Smart Delivery Systems" for agriculture can possess timely controlled, spatially targeted, self-regulated, remotely regulated, pre-programmed, or multi-functional characteristics to avoid biological barriers to successful targeting. Smart delivery systems can monitor the effect of delivery of nutrients or bioactive molecules or any pesticide molecules. This is widely used in health sector wherein nanoparticles are exploited to deliver required quantities of medicine to the place of need in human system. In the smart delivery system, a small sealed package carries the drug which opens up only when the desirable location or infection site of the human or animal system is reached (Morris, 2009).

Nanotechnologies for Water Quality and Conservation

Providing clean and abundant fresh water for human use and industry applications, including agricultural and farming uses, is one of the challenges facing by the world. It is estimated that "more than one billion people in the world lack access to clean water and the situation is getting worse. Agriculture requires considerable amount of fresh water and in turn often contributes substantially to pollution of groundwater through the use of pesticides, fertilizers and other agricultural chemicals. Effective technologies for remediation and purification will be needed to manage the volume of wastewater produced by farms on a continual basis and be cost effective for all.

Nanotechology, offers the potential of novel nanomaterials for the treatment of surface water, groundwater and wastewater contaminated by toxic metal ions, organic and inorganic solutes and microorganisms. Due to their unique activity towards recalcitrant contaminants, many nanomaterials are under research and development for use for water purification. To maintain public health, pathogens in water need to be identified rapidly and reliably. Unfortunately, traditional laboratory tests are time consuming. Water filtration are improved by the use of nanofiber membranes and the use of nanobiocides which appear promisingly effective (Subramanian et al., 2014).

Accessible water resources are often contaminated with pollutants largely due to various human activities. These contaminants include, but not limited to, water-borne pathogenic microorganisms (*Cryptosporidium*, *Coliform* bacteria, virus, etc.), various salts and metals (copper, lead, arsenic, etc.), run-off agricultural chemicals, and radioactive contaminants either naturally occurring or the result of oil and gas production as well as mining activities. For drinking water, sensory attributes (taste, smell, and turbidity) are also important quality indicators. Various nanoscale tools have been explored to address these challenges to improve water quality and safety (Baruah and Dutta, 2009).

Microbial Disinfection

In industrialized nations, chemical and physical based (chlorine dioxide, ozone and ultraviolet) microbial disinfection systems are commonly used. However, much of the world still does not have the industrial infrastructure necessary to support chemical-based disinfection of water. Hence, alternative technologies that require less intensive infrastructure and more cost effective approaches such as nanoscale oligodynamic metallic particles, may exhibit a toxic effect on living cells even in relatively low concentrations. Among the oligodynamic metallic nanoparticles, silver is considered the most promising nanomaterials with bactericidal and viricidal properties owing to its wide-range effectiveness, low toxicity, ease of use, its charge capacity, high surface to volume ratios, crystallographic structure and adaptability to various substrates. Its antimicrobial mechanism is due to the production of reactive oxygen species that cleaves DNA. Another nanoscale technological development for microbial disinfection is visible light photocatalysts of transition metal oxides made into nanoparticles, nanoporous fibers and nanoporous foams. Tubular nanostructures may be embedded into microbial cell wall to disrupt its structure integrity and result in leakage of intracellular compounds, and eventually cell death (Li et al., 2008).

Desalination

Given the limited fresh water supply both above or underground, it is likely that the desalination of sea water will become a major source of fresh water. Conventional desalination technology is reverse osmosis (RO) membranes which generally require large amounts of energy. A number of nanotechnologies have been attempted to develop low energy alternatives. Among them, three most promising technologies appear to be protein polymer biomimetic membranes, aligned-carbon nanotube membranes and thin film nanocomposite membranes. Some of the prototypes have demonstrated up to 100 times better water permeability with nearly perfect salt rejection than RO. Carbon nanotube membranes, owing to its extremely high water permeability than other materials of similar size have desalination efficiencies in the order of thousand times better than the current technology. Some of these membranes can also integrate other functionalities such as disinfection, de-odouring, de-fouling and self-cleaning (Baruah and Dutta, 2009).

Nanotechnology in Animal Sciences

Nanotechnology has the ability to provide appropriate solution for addressing the issues of food items, veterinary care and prescription medicine as well as vaccines for domesticated animals. Taking certain medications such as antibiotics, vaccines and probiotics are effective in treating the infections, nutrition and metabolic disorders, when used at the nano level. Medicines used at the nano level have multilateral properties to remove biological barriers for increased efficiency of the applied medicine. Appropriate timing for the release of drug and self-regulatory capabilities are the main advantages of the use of nanotechnology in the application of drugs (Kuzma, 2010; Singh and Nalwa, 2007).

The C-60 carbon particle is spherical molecule having nearly 1 nm diameter. It is non-toxic to the live cells and biocompatible in nature. It can be used as a carrier to deliver the water soluble peptides and drugs. The nanotechnology can help to understand certain drug behaviour in an animal body. The nano particles can penetrate the skin through minor abrasions can be used as sensor to detect the altered cell behaviour. The dendrimers are synthetic three dimensional macromolecules having a core particle surrounded by branches like a tree. They can be conjugated with the target molecule like drug as they are biocompatible and are easily cleared from blood through the kidney.

The nano-magnets can be used as drug delivery system specially to treat the cancerous growth without any harm to the surrounding tissues. Different types of proteins like albumin, gelatin, gliadin and legumin are used to prepare nanoparticle based drug delivery system. Inert nanobeads were used to neutralize the antigen causing osteoarthritis in racing horses. Use of nano based antibiotics in treatment of animal diseases requires less amount of antibiotics leaving less antibiotic residues. Nanoparticle based chromium supplementation has beneficial effects on growth performance and body composition and it increases tissue chromium concentration in the muscles. Iron deficiency is a common problem in animals especially during the early stage of life, gestation and parasitic infestation due to less bioavailability. The bioavailability can be increased with the supplementation of ferric phospholic nano-particles (Scott, 2007; Oberdorster, 2010).

Nanotechnology is used to produce the chicken/goat meat in the laboratory in large quantities maintaining the same nutritive value, taste, texture without any hazard (*vegetarian meat*). It can be eaten by the vegetarians also. It may solve the food scarcity problem, thereby eradicating the hunger. Use of nanotechnology in *designer egg* production is well-known. It can produce the eggs with low cholesterol, less yolk content, more nutrients and desired antibodies. In addition, nano-based sensors can help in early detection of egg-borne pathogens (Thornton, 2010).

Nanotechnologies in Animal Production and Animal Health

Agriculturally relevant animal production (livestock, poultry and aquaculture) provides society with highly nutritious foods (meat, fish, egg, milk and their processed products) which have been and will continue to be an important and integral part of human diets. There are a number of significant challenges in animal agricultural production, viz., production efficiency, animal health, feed nutritional efficiency, diseases including zoonoses, product quality and value, byproducts and waste and environmental footprints. Nanotechnologies offers an effective, sometimes novel solutions to these challenges.

Improving Feeding Efficiency and Nutrition of Animals

A critical element of sustainable agricultural production is the minimization of production input while maximizing output. One of the most significant input in animal production is feedstock. Low feeding efficiency results in high demand of feed, high discharge of waste, heavy environmental burden, high production cost and competing with other uses of the grains, biomass and other feed materials. Nanotechnology significantly improves the nutrient profiles and efficacy of minor nutrient delivery of feeds. Most animal feeds are not nutritionally optimal especially in developing countries. Adding supplemental nutrients is an effective approach to improve the efficiency of protein synthesis and the utilization of minor nutrients. The digestive aids such as cellulosic enzymes can facilitate better utilization of the energy in plant-based materials. Furthermore, minor nutrients and bioactives can help to improve overall health of animals so that an optimal physiological state can be achieved and maintained. A variety of nanoscale delivery systems have been investigated for food applications. They include micelles, liposomes, nano-emulsions, biopolymeric nanoparticles, protein-carbohydrate nanoscale complexes, solid nano lipid particles, dendrimers and others. These systems have shown collectively numerous advantages including better stability against environmental stresses and processing impacts, high absorption and bioavailability, better solubility and disperse-ability in aqueous based systems (food and feed) and controlled release kinetics. Self-assembled and thermodynamically stable structures require little energy in processing thereby helping to address issues related to sustainability (Sekhon, 2012).

Nanoscale delivery can be used to improve the nutritional profiles of feed and feeding efficiency. In addition, the nanoscale delivery systems can also be designed for veterinary drug delivery which protects the drug in gastrointestinal tract, and allows for release at the desired location and rate for optimal effect. These advantages help to improve the efficiency by which animals utilize nutrient resources, reduce material and financial burden of the producers and improve product quality and production yield. Similar to food applications, the design of an appropriate nanoscale delivery system will require a full consideration of the effectiveness of its intended uses while preventing any adverse effects or unintended consequences. The nanoscale particles should be subject to a rigorous risk assessment to ensure responsible and safe development and deployment in the products (Kreilgaard, 2002).

Minimizing Losses From Animal Diseases

Many animal diseases cause substantial losses in agricultural animal production. Some of the more significant diseases include bovine mastitis, tuberculosis, avian influenza, and porcine reproductive and respiratory syndrome. The World Health Organization estimates that animal diseases represent as much as 17% of animal production costs in the developed world and more than twice this figure in developing nations. Zoonotic diseases not only cause devastating economic losses to animal producers, but also impose serious threats to human health, e.g., Variant Creutzfeldt-Jakob disease. Detection and intervention are two important tools of an integrated animal disease management strategy that are critical to significantly reducing losses/threats from the disease and/or eradicating disease, or preventing disease introduction into the animal production (Morris, 2009).

Nanotechnology has the potential to enable revolutionary changes in this area and some specific technologies may be feasible in near future given the current state of research and development. Nanotechnology offers numerous advantages in detection and diagnostics including high specificity and sensitivity, simultaneous detection of multiple targets, rapid robust on-board signal processing, communication, automation, convenient to use and low cost. The uses of portable, implantable or wearable devices are particularly welcome in agricultural field applications. Early detection is imperative so that quick, simple and inexpensive treatment strategies can be taken to remedy the situation.

Nanotechnology based drugs and vaccines can be more effective in treating/preventing the diseases than current technologies thus reducing cost. Precise delivery and controlled release of nanotechnology enabled drugs leave little footprint in the animal waste and the environment which alleviate the increasing concern of antibiotic resistance and decrease health and environmental risks associated with the use of antibiotics. The targeted delivery and active nanoparticles may enable new drug administration's that are convenient, fast, non-intrusive to animals and cost effective (Chakravarthi and Balaji, 2010).

Animal Reproduction and Fertility

Animal reproduction remains a challenge for developing countries. Low fertility results in low production rate, increases in financial input and reduced efficiency of livestock operations. Several technological fronts have been explored in order to improve animal reproduction. Microfluidic technology has matured over the last two decades, and has been integrated into many nanoscale processing and monitoring technologies including food and water quality, animal health and environmental contaminations. The development of efficient microfluidic technology has enabled the automated production of large number of embryos in vitro, which has led to the rapid development of genetic improvement and selection of superior livestock for human food and fiber production. Nanoscale delivery vehicles are sought to substantially improve bioavailability and better control of release kinetics, reduce labor intensity and minimize waste and discharge to the environment. The technique also explored to monitor animal hormone level using implanted nanotechnology-enabled sensing device with wireless transmission capability, thus the information of optimal fertility period can become available in real time to assist the livestock operators for reproduction decision making (Kuzma, 2010).

Nanotechnology in Fisheries and Aquaculture

Nanotechnology has tremendous potential to revolutionize fisheries and aquaculture sector. Nanotechnology tools like nano-materials, nano-sensor, DNA nano-vaccines, gene delivery and smart drug delivery have the potential of solving many puzzles related to fisheries nutrition and health production, reproduction, prevention and treatment of disease. Nanotechnology helped fish processing industry for producing quality products by detecting bacteria in packaging, producing strong flavour, colour quality and safety (Rather et al., 2011).

Nanotechnology in Animal By-Products and Waste Management

Animal waste is a serious concern in the animal production industry. Stricter environmental policies will prevent irresponsible discharge of animal waste. The unpleasant odors that originate from intensive animal production facilities adversely affect air quality, and in turn, living conditions and the real estate value of the adjacent area. However, bioconversion of animal waste into energy and electricity can result in new revenue, renewable energy, high quality organic fertilizer and improved environmental quality while value added. Nanotechnology enabled catalysts will play a critical role in efficient and cost effective bioconversion and fuel cell for electricity production as well as enabling efficient energy storage which will greatly facilitate and benefit the development of distributed energy supplies especially in rural communities where infrastructure is lacking. Such an approach may result in the elimination of the need for system wide electricity grids, hence accelerate the rural development, improve productivity, living environment and will be especially beneficial to developing countries (Kuzma, 2010).

Nanotechnology in Food Industry

Nanotechnology has been touted as the next revolution in many industries including food processing industry. Food nanotechnology includes a range of potential applications, including alterations to the properties of foods, improvements to the delivery, quality, safety of food and the development of enhanced food packaging. Nanotechnology is expected to influence numerous areas of food science in ways that will benefit both the food industry and consumers. Nanosensors are being developed that can detect and signal the presence of spoilage microorganisms, and potentially even differentiate the presence of pathogenic from beneficial microorganisms. Nanotechnology is also being used to create healthier foods that can deliver nutrients and medication to different parts of the human body and can alleviate allergenic (Nazzaro et al., 2012; Sastry et al., 2012).

Advances in areas such as electronics, computing, data storage, communication and the growing use of integrated devices are likely to indirectly impact the food industry in the areas of food safety, authenticity and waste reduction. Many new consumer products containing nanoparticles have been launched to the market and are beginning to impact on the food associated industries. Nanotechnologies are set to impact on the food industry at all stages of production from primary production at farming level. The applications of nano-based technology in food Industry include nanoparticulate delivery systems (e.g. micelles, liposomes, nanoemulsion, biopolymeric nanoparticles and cubosomes), packaging, food safety and biosecurity (e.g. nanosensors), and nanotoxicity (Chen et al., 2006; Mir and Shah, 2014).

Nanoencapsulation

Nanoencapsulation is defined as a technology to pack substances in miniature making use of techniques such as nanocomposite, nanoemulsification and nanoestructuration and provides final product functionality that includes controlled release of the core. The protection of bioactive compounds, such as vitamins, antioxidants, proteins and lipids as well as carbohydrates may be achieved using this technique for the production of functional foods with enhanced functionality and stability. Scientists have developed a novel patented technology that has the ability to nanoencapsulate a multitude of bioactive and active ingredients in nutraceutical products (Sozer and Kokini, 2009).

These nanocapsules were found to break down and were absorbed as common foods after they have delivered their active ingredients. The recent innovation in encapsulation and controlled release technologies as well as a design principle of novel food delivery systems has been reported. Nanoencapsulation can make significant savings for formulators as it can reduce the amount of active ingredients needed. Researchers examined the encapsulation and controlled release of active food ingredients using nanotechnological approaches. Nanoencapsulation technologies have the potential to meet food industry challenges concerning the effective delivery of health functional ingredients and controlled release of flavor compounds (Sorrentino et al., 2007).

Nanocomposites in Food Packaging

It is always consumer's choice to demand fresh, safe and healthy food with longer shelf life and easy to handle packaging material. Conventional food packaging materials are difficult to degrade and cause serious waste problems as solid waste material. Although biomass based material has been deployed in food packaging but challenge is still there about their performance and cost effectiveness. Incorporation of nano-materials in packaging biopolymers like cellulose and its derivatives polyesters, plant oils and gelatins have proven to provide necessary mechanical strength, better reinforcement and barrier properties. Polymer nano-composites have shown tremendous potential as barrier against gases (e.g., O_2 and CO_2) and water vapours. Thermoplastic starch and clay nano-composite films have also been developed with remarkably fine dimensions and encouraging results. Nanocomposites such as nylon 6 have also been prepared to obtain lighter, stronger plastics with better heat resistance and barrier properties (Arora and Padua, 2010). Nano-clays and silicates like montmorillonite, hydrated alumina-silicate layered clay have been successfully used in food packaging. Along with better mechanical and barrier properties nano-clays have shown increased thermal degradation temperature and glass transition. Carbon nano-tubes like polyamide, polyvinyl alcohol, polypropylene are also being deployed in food packaging. An outstanding achievement is development of "electronic tongue" by Kraft foods. It is actually an array of nanosensors which change colour by the release of gases as the food spoils thus giving a clear indication whether the food is fresh or not. These nano-sensors are included in the food at the time of packaging nano barcodes and can also be used for monitoring and tracking of food. Scientists at Cornell University developed fluorescent based nano barcodes containing probes for detection of various farm pathogens. A site detector is used for pathogen detection even by non-trained individual. Same is the concept of "electronic nose" (E-nose), operating like human nose in detection of odour and concentration of odor-ant in food. It contains nano-particles of gas sensors mainly ZnO. The mechanism of action is based on resistant pattern of different gases as each gives different detection signals (Mir and Shah, 2014).

Nanocomposites can improve mechanical strength; reduce weight; increase heat resistance and improve barrier against oxygen, carbon dioxide, ultraviolet radiation, moisture, and volatiles of food package materials. Fine nanoparticulates (100 nm or less) are incorporated into plastics to improve the properties over those of conventional counterparts. Nanoscale inclusions consist of nanoclays, carbon nanoparticles, polymeric resins, nanoscale metals and oxides. Nanocomposites are characterized by extremely high surface-to-volume ratio, making them highly reactive in comparison to their macroscale counterparts and thus presenting fundamentally different properties (Sekhon, 2010).

Moreover, nanocomposites could also be characterized by an antimicrobial activity. Packaging containing nanosensors are coming to food stores to give information of enzymes produced in the breakdown of food molecules making them unsafe for human consumption. The technique could also be used to let air and other enzymes from the package, thus increasing shelf life as well as the reduction of man-made preservatives in our foods. Another important potential application of nanoparticles in food packaging is the degradation of ripening gas such as ethylene (Siegrist et al., 2007).

Natural biopolymer-based nanocomposite packaging has a huge potential for application in the food packaging industry. The preparation of natural biopolymer-based films, their nanocomposites and their potential use in packaging applications were reported in literature. Nanotechnology has the potential to influence the packaging sector by delaying oxidation and controlling moisture migration, microbial growth, respiration rates and volatile flavors and aromas. A methodology used to produce polymer nanocomposites with low-cost fibrous materials similar to expensive carbon nanotubes exhibiting optimized dispersion, interfacial bonding, attractive physical and other properties has been reported. Chitosan- based nanocomposite films especially silver-containing ones showed a promising range of antimicrobial activity. The nanoparticle created a stronger defense against oxygen, free radical and metal ions that cause lipid oxidation. Researchers are using silicate nanoparticles to provide a barrier to gasses or moisture in a plastic film used for packaging. This could reduce the possibly of food spoiling or drying out (Dudo et al., 2011).

Nanopackaging responds to environmental conditions and alerts a consumer to contamination and/or the presence of pathogens. The nanoparticles are dispersed throughout the plastic and are able to block oxygen, carbon dioxide and moisture from reaching fresh meats or other foods. The nanoclay also makes the plastic lighter, stronger and more heat resistant. Researchers have developed the intelligent packaging that will release a preservative if the food begins to spoil. This "release on command" preservative packaging operates by using a bio switch developed through nanotechnology. 'Smart' food packaging will warn when oxygen has got inside or if food is going off. Such packaging is already in use in brewing and dairy production and consists of nanofilters that can filter out micro-organisms and even viruses (Silvestre et al., 2011). Nano-capsules delivered chemicals in rapeseed cooking oil, will stop cholesterol entering the bloodstream. Nano packaging with self cleaning abilities or nanoscale filters will allow the removal of all bacteria from milk or water without boiling. In the area of nanolaminated coatings on the bioavailability of encapsulated lipids, bioactive lipophilic or fat-liking compounds could be incorporated into foods or beverages, which may increase the ingredient's stability, palatability, desirability and bioactivity. Advances in processes for producing nanostructured materials coupled with appropriate formulation strategies have enabled the production and stabilization of nanoparticles that have potential applications in the food and related industries (Duncan, 2011).

Nanoemulsions

Nanotechnology are used for the preparation of nanoemulsions which can prove beneficial for the food industry. The small droplet size gives nanoemulsions unique rheological and textural properties which render them transparent and pleasant to the touch and desirable in the food industry. Using nanoemulsions in food products can facilitate the use of less fat without a compromise in creaminess, thus offering the consumer a healthier option. Products of this type include low fat nanostructured mayonnaise, spreads and ice creams. As the size of the droplets in an emulsion is reduced, less likely the emulsion will break down and separate. In this way nanoemulsification may reduce the need for certain stabilisers in a product. Nanoemulsions look set to play a future role in revolutionising the production of spreads and mayonnaise, but this is very much still in development stages (Mir and Shah, 2014).

Nanoemulsions have been developed for use in the decontamination of food packaging equipment and in the packaging of food. Nanoemulsions have recently received a lot of attention from the food industry due to their high clarity. These enable the addition of nanoemulsified bioactives and flavours to a beverage without a change in product appearance. Nanoemulsions are effective against a variety of food pathogens including gram-negative bacteria. The nanoemulsions showed great promise for use in beverage and other applications. Various types of nanoemulsion including single-layer, double-layered and triple-layers nanoemulsions could be produced, depending on the polyelectrolytes, such as alginate and chitosan. Solid lipid nanoparticles are formed by controlled crystallization of food nanoemulsions and have been reported for delivery of bioactives such as lycopene and carotenoids. The major advantages of solid lipid nanoparticles include large-scale production without the use of organic solvents, high concentration of functional compounds in the system, long term stability and the ability to spray dried into powder form (Sanguansri and Augustin, 2006).

Nano Food Additives

The novel application of nanotechnology for food industry is the development of certain nano-structured (also termed as nano-textured) foodstuffs, such as spreads, mayonnaises, creams, yoghurts and ice creams. The nano-structuring of food materials has been claimed for new tastes, improved textures, consistency and stability of emulsions, compared to equivalent conventionally processed products. A typical product of this technology could be in the form of a low-fat nano-textured product that is as 'creamy' as the full-fat alternative and hence would offer a 'healthy' option to the consumer. Another area of application involves the use of nano-sized or nano-encapsulated food additives. This type of application is expected to exploit a much larger segment of the food sector, encompassing colours, preservatives, flavours and supplements (Jandt et al., 2006). The main advantage is said to be a better dispersability of water-insoluble additives in foodstuffs without the use of additional fat or surfactants and enhanced tastes and flavours due to enlarged surface area of nano-sized additives over conventional forms. A range of consumer products containing nano-sized additives is already available in the supplements, nutraceuticals and food sectors. These include minerals, antimicrobials, vitamins, antioxidants, etc. Virtually all of these products also claim enhanced absorption and bioavailability in the body compared to their conventional equivalents Nutraceutical are the functional components which provide the health benefits in addition to nutrition. Nanomaterials can be used as bioactives in functional foods. The prospect of the production of nutraceuticals at the nanoscale, which will have increased stability throughout the processing chain and will be of significant interest to food processors trying to maximise nutrient content and hence will ultimately benefit to consumers (Chaudhry et al., 2008; Schnettler et al., 2013).

Nano-encapsulation in the form of nanomicelles, liposomes or protein-based carrier systems has been used to develop delivery systems for additives and supplements in food and beverage products. A growing number of food and nutraceutical products based on nanocarrier technology are already available on the market. These include a number of food additives and supplements. Other products containing nano-antimicrobials and nano-antioxidants etc., are also commercially available (Chen et al., 2006). The concept of nanodelivery systems seems to have originated from research on targeted delivery of drugs and therapeutics. However, the use of similar technology in foodstuffs is interesting in the sense that whilst it can offer increased absorption, uptake and bioavailability. It also has the potential to alter tissue distribution of the substances in the body. For example, certain water-soluble compounds can be rendered fat dispersible through nanocarrier technology. Vice versa, fat-dispersible compounds can be rendered water dispersible. It is hoped that these nanocarriers are completely broken down and their contents are released in the gastrointestinal tract. As such, the encapsulated compounds will not be any different from their conventional equivalents. However, if a nanocarrier system is capable of delivering the encapsulated substance to the bloodstream, its absorption, tissue distribution and bioavailability may be drastically different from the conventional forms. This raises the concern that some nanocarriers may act as a 'Trojan Horse' and facilitate translocation of the encapsulated substances or other foreign materials to unintended parts of the body (Dreher, 2004).

CONCLUSION

Nanoscience as a powerful technology has the ability to create massive changes in agricultural and food processing industry. In agriculture industry, nanotechnology has phenomenal potential to facilitate and frame the next stage of farming techniques. It will increase agricultural potential to harvest higher yields in eco-friendly way even in challenging environment. Nanotechnology research and development facilitate and frame the next stage of development of genetically modified crops, animal production inputs, chemical pesticides and precision farming techniques. Nanotechnology is used for combating the plant diseases either by controlled delivery of functional molecules or as diagnostic tool for disease detection. Nanotechnology applications are being developed and commercialized with different goals, ranging from reduced agricultural inputs to improved food safety, enhanced packaging, improved processing, nutrition and the potential to promote sustainable agriculture and deliver better foods globally.

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KEY TERMS AND DEFINITIONS

Nanoencapsulation: The coating of various substances within another material at sizes on the nano scale.

Nanofertilizers: Molecular modified or synthesized with the help of nano-technology used to improve the fertility of soil for a better yield and increased crop quality.

Nanomaterials: Materials in which one of the dimensions of constituents objects is under is under 100 nm.

Nanosensor: A device for sensing radiation, forces, chemicals or biological agents, in which some portion of a device operates at the nonosacle.

Nanotechnology: Nanotechnology focuses on the characterization, fabrication, and manipulation of biological and non-biological structures smaller than 100 nm.

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Chapter 11

Nanoencapsulation of Food Ingredients

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ABSTRACT

Nanoencapsulation of food ingredients is one of the important applications of food nanotechnology. Nanoencapsulation is a technique used to produce nanocapsules from core materials packed within a wall material. Food manufacturers need to incorporate food ingredients with specific functional properties into food products. However, these ingredients may slowly degrade and lose their activity, or become hazardous due to various chemical reactions. They can also react with other components in the food system, which may lower their bioavailability, or change the color or taste of a product, allowing the food item to become prone to spoilage and deterioration. The protection of food ingredients against degradation and interaction with other food components may be done using the nanoencapsulation technique. It also, helps to enhance the bioavailability of food ingredients by protecting them during the digestive processes, improved uptake in the gastrointestinal tract and enhanced transport to the target sites. Nanosized materials provide a larger surface area for interaction with the biological substrates than microsized materials. Various techniques such as emulsification, coacervation, nanoprecipitation, solvent evaporation, spray drying and freeze drying are widely used techniques for nanoencapsulation of food ingredients.

INTRODUCTION

Nanotechnology has emerged as one of the most promising scientific fields of research in decades. It deals with the production, processing, and application of materials with sizes less than 1,000 nm. Particle size reduction to nanoscale range increases surface-to-volume ratio, which in turn increases their

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reactivity by many folds with change in mechanical, electrical, and optical properties (Ezhilarasi et al., 2013). These properties offer many unique and novel applications in various fields. Nanotechnology has been revolutionizing the entire food system from production to processing, storage, and development of innovative materials, products, and applications. The application of nanotechnology to the food sector could generate innovation in the macroscale characteristics of food, such as texture, taste, other sensory attributes, coloring strength, processability, and stability during shelf-life, leading to a great number of new products (Huang et al. 2010; McClements et al. 2009). Moreover, nanotechnology can also improve the water solubility, thermal stability, and oral bioavailability of bioactive compounds. At present, applications of nanotechnology in food industries are nanocomposites in food packaging material for controlling diffusion and microbial protection, nanobiosensors for detection of contamination and quality deterioration, and nanoencapsulation for controlled delivery of probiotics and bioactive compounds (Weiss et al., 2006; Ezhilarasi et al., 2013).

Nanoencapsulation technology is expanding rapidly with a number of potential applications in the areas of food and pharmaceutical industries (Mir & Shah, 2014). Nanoencapsualtion is a process by which nanoencapsules are produced by enclosing the core materials within the wall materials. Nanoparticle delivery systems are finding increasing application in the food, pharmaceutical, personal care, and other industries. Traditionally, food manufacturers have utilized delivery systems to encapsulate functional ingredients designed to improve food quality and safety, such as flavors, colors, antioxidants, enzymes, and antimicrobials. More recently there has been interest in the use of delivery systems to encapsulate bioactive components that have been shown to be beneficial to human health. This research has been stimulated by the food and beverage industries' interest in creating products specifically designed to promote human health and wellness, and to prevent chronic diseases, such as cardiovascular disease, diabetes, hypertension, obesity, osteoporosis, and cancer. The technical challenges involved in encapsulating these components into desirable commercial products has led to rapid developments in methods for encapsulating, protecting, and delivering functional food ingredients to improve food quality, safety and health. A well-designed delivery system can be used to overcome many of the technical challenges normally associated with incorporation of these active ingredients into commercial food and beverage products (McClements, 2014).

BACKGROUND

Food ingredients are added to food products serve specific functions like colors, flavors, antimicrobials, antioxidants, nutraceuticals (bioactive compounds), and preservatives. These ingredients have been used for centuries e.g., our ancestors used salt to preserve meats and fish, added herbs and spices to improve the flavor of foods, preserved fruit with sugar, and pickled cucumbers in a vinegar solution. Today, consumers demand and enjoy a food supply that is flavorful, nutritious, safe, convenient, colorful and affordable.

Incorporation of some of the food ingredients into food products is not always easy as there are many technological hindrances such as they are physically or chemically unstable, they are incompatible with the product matrix, or they lack the appropriate functional attributes. The functionality of active substances often is declined during processing and storage, and during passage to the gastrointestinal tract. These challenges can often be overcome by modifying the food ingredients before they are introduced into the final product (McClements, 2014). One of the strategies to modify the food ingredients is to incorporate the ingredients into some delivery system. A "delivery system" is a system designed to encapsulate, deliver and release one or more active components/food ingredients (McClements, 2014). Delivery systems can be designed to have a number of potential benefits to the food industry: incorporation of active ingredients into food matrices without negatively affecting quality characteristics such as appearance, texture, flavor, or stability; protection against chemical, physical, or biological degradation; off-flavor masking (such as bitterness or astringency); increasing the efficiency of active ingredients by delivering the active ingredients to particular sites-of-action; improvement of product storage and handling; extension of product shelf life. For example, a beverage cannot simply be formed by mixing flavor oil with water and other ingredients because the flavor oil is normally partly immiscible with water and would quickly separate. Instead, the flavor oil must first be converted into small particles (such as microemulsion, nanoemulsion or emulsion droplets) that remain stable within the final product (McClements, 2012).

Encapsulation is a process of trapping the active ingredients within the wall or coating material and encapsulation in nanometric delivery systems helps to protect the food ingredients from degradation and interaction with other food components. Also, nanometric size delivery systems can help to increase the bioavailability of food ingredients (bioactive compounds) by protecting them during the digestive processes, improve their uptake in the gastrointestinal tract and enhance transport to the target sites. The delivery systems of nanometric scale provide a larger surface area for interaction with the biological substrates than the corresponding micrometric size carriers. Moreover, an efficient design of the interfacial properties of the nanocapsules can improve the controlled release of the encapsulated compound to its target site, while avoiding any undesired instantaneous release (Luo et al., 2011).

FOOD INGREDIENTS

Food industries use a wide range of food ingredients to formulate different food products. These ingredients may be either obtained from natural sources or chemically synthesized. Chemically synthesized ingredients may be "nature-identical" (i.e., they have the same structure and reactivity as molecules found in nature) or they may be entirely new molecules that do not normally occur in nature. Food manufacturers need to consider which type of ingredients to be used for the manufacturing of particular food products because consumers often prefer natural rather than synthetic ingredients. Food ingredients from natural sources are generally regarded as safe and don't require extensive testing and regulatory procedures. While in case of any newly synthesized food ingredient, it has to undergo extensive testing and regulatory hurdles to ensure its safe use. This process consumes a lot of time and money. Thus, there is an increasing trend toward the use of more natural ingredients for the manufacture of various food and beverage products (McClements, 2014).

Generally, different food ingredients have different molecular, physicochemical, and biological properties. At the molecular level, they have different atomic composition, molecular weight, chemical formula, three-dimensional structure, flexibility, polarity, and their electrical charge. Molecular characteristics and the environmental conditions determine the physiochemical properties of food ingredients. Some of the most important physicochemical properties of food ingredients are their physical state (e.g., gas, liquid, solid), their phase behavior (e.g., boiling point, melting point, glass transition temperature), their solubility in particular solvents (such as oil, water, or alcohol), their surface activity, their rheology (e.g., viscosity, elastic modulus, yield stress), their optical properties (e.g., color or opacity), and their chemical stability under particular conditions (e.g., oxidation or hydrolysis). At the biological level, active ingredients can be characterized by their interactions with microorganisms, animals, or humans (e.g., antimicrobial activity, aroma, taste, digestibility, or bioactivity) (McClements, 2014). Some of the most important food ingredients that need to be encapsulated in foods and beverages are summarized in Table 1.

Colorants

Food colorants play a very important role in increasing the aesthetic appeal of food. Most food coloring agents are used to enhance the overall attractiveness of the food. A number of natural and synthetic agents are used to color foods. Although synthetic coloring agents continue to be used extensively because of their higher stability but due to safety concerns, there has been significant increased interest in the use of natural colorants. Natural colorants are very unstable and are often encapsulated to enhance their

Table 1. Food ingredients needed to be encapsulated before incorporation in food systems

Food Ingredient	Example	Advantages of Encapsulation
Colorants	Carotenoids Flavonoids Betalains	Easy incorporation into aqueous medium Help in storage and utilization Impede chemical degradation Increase efficacy
Flavors	Citrus oils Natural extracts	Easy incorporation into aqueous medium Help in storage and utilization Impede chemical degradation Control release profile
Antioxidants	Tocopherols Carotenoids Flavonoids Phenolics	Easy incorporation into aqueous medium Help in storage and utilization Impede chemical degradation Increase efficacy
Antimicrobials	Essential oils	Improve matrix compatibility Help in storage and utilization Impede chemical degradation Mask undesirable off-flavors Increase potency
Bioactive peptides	Milk peptides Meat peptides Plant peptides	Retard degradation in stomach Reduce bitterness and astringency Control release profile and bioactivity
Bioactive carbohydrates	Prebiotics Chitosan	Avoid adverse ingredient interactions Enhance product texture Control delivery in the gastrointestinal tract
Bioactive lipids	ω-3 fatty acids Conjugated linoleic acid	Allow incorporation in aqueous medium Improve ease of utilization Avoid chemical degradation (oxidation) Controlled delivery in GIT
Vitamins	Vitamins A, D, E Vitamin C	Allow incorporation in aqueous medium Improve ease of utilization Avoid chemical degradation
Minerals	Iron Calcium	Prevent undesirable oxidative reactions Check precipitation Increase bioavailability
Probiotics	Lactic acid bacteria	Enhance viability

storage stability, to prevent their chemical degradation, to improve their ease of handling and utilization (De Paz et al., 2012).

Flavors

Food flavors are used to alter and/or enhance the flavors of food products. Food flavors may be natural, nature identical or artificial. Food flavors differ in their chemical structure and include a wide range of active agents from non-volatile water-soluble substances such as salts, sugars, artificial sweeteners, vinegar and soy sauce that are perceived within the mouth, to volatile oil-soluble substances such as citrus oils that are perceived within the nose. Many food flavors used by the food industry are utilized in an encapsulated form. Food flavors are mainly encapsulated to prevent their degradation during storage, to inhibit chemical degradation, to enhance their handling and to improve their release profile (McClements, 2012).

Antioxidants

Antioxidants are substances used by food manufactures to prevent or inhibit lipid oxidation in foods. Antioxidants may be natural or synthetic in origin. On the basis of chemical structure, antioxidants may be hydrophilic, lipophilic or amphiphilic. The polarity of an antioxidant determines its location and environment within a food system (e.g., the aqueous, oil, or interfacial phase), which in turn will determine how effectively it can prevent oxidation by altering its proximity to the chemical reactants. Antioxidants are often encapsulated to improve their handling and use, to improve their compatibility with the food matrix, and to prevent chemical degradation (McClements, 2012). For example, β-carotene is sensitive to light and oxygen and can be encapsulated to inhibit its oxidation by limiting its exposure to light and oxygen (Ribeiro et al., 2008; Yuan et al., 2008).

Antimicrobials

Antimicrobials are the substances used by the food manufacturers to prevent or inhibit the growth of microorganisms, such as bacteria, molds and yeasts in various foods. Antimicrobials can be obtained from animal, plant, microbial, and mineral sources. Highly active Naturally occurring antimicrobials, with high activity, can be obtained from spices and herbs, or their essential oils, and include phenolic compounds and their subclasses such as terpenes, coumarins, flavonoids (Gaysinsky and Weiss, 2007; McClements, 2012).

Food antimicrobials may function through a variety of different mechanisms of action, including transition metal chelation, and membrane disruption. Antimicrobials vary widely in their polarities and may be hydrophilic (e.g., chitosan), lipophilic (e.g., essential oils) or amphiphilic (e.g., surfactants, proteins). Antimicrobials may be encapsulated to improve their compatibility with the food matrix, to enhance their efficacy, to improve release profile, to mask off-flavors, and/or to improve their storage stability, transportation and utilization. Four important nanoencapsulation systems for food antimicrobials are nanoemulsions, surfactant micelles, phospholipid liposomes, and solid lipid nanoparticles (Weiss et al., 2009). Also some emerging nanoencapsulation systems like double-layered nanocapsules, nanofibers and multi-assembled nanocapsule aggregates are being used for antimicrobial nanoencapsulation (McClements, 2012).

Bioactive Lipids

Lipids contain a wide group of chemically diverse compounds that are insoluble in water but soluble in organic solvents. A large number of different classes of molecules fall within this category, including acylglycerols, fatty acids, phospholipids, carotenoids, phytosterols and oil-soluble vitamins. Many lipids that have been shown to have specific health benefits beyond that normally associated with their established role in growth, development and other normal body functions e.g., ω-3 fatty acids, conjugated linoleic acid, carotenoids, and phytosterols. There are a number of potential challenges associated with incorporating these types of components into foods, including low water-solubility, high melting point, and chemical instability (McClements, 2012). Bioactive lipids may be encapsulated to improve their handling and use, to improve their compatibility with the food matrix, and to prevent chemical degradation.

Bioactive Proteins and Peptides

Besides providing energy and essential nutrients to the diet, many proteins and peptides also provide some additional benefits such as acting as growth factors, antihypertensive agents, antimicrobial agents, antioxidants, food intake modifiers, and immune regulatory factors. These components may be encapsulated to prevent them from degradation within the highly acidic environment within the stomach, so that these can reach the intended site of action in other regions of the GI (gastrointestinal) tract. Some bioactive peptides are bitter in taste and need to be encapsulated to prevent undesirable mouthfeel or off-flavors (McClements, 2012).

Bioactive Carbohydrates

Dietary fibers are one of the major class of bioactive carbohydrates that need to be delivered in foods. The main bioactive functions of dietary fibers are cholesterol reduction, blood glucose level modulation, prevention of certain cancers, prevention of constipation and prebiotic effects. At present a large proportion of the general population in developed countries does not consume the 25 to 30% of dietary fiber recommended per day for a healthy diet. Consequently, there is a need to increase the consumption of foods rich in dietary fibers in order to achieve these potential health benefits. One of the inherent problems with dietary fibers is that they often form highly viscous solutions. When added to foods they may adversely affect their textural properties of foods, and thus they may be encapsulated to ensure their delivery without affecting the textural properties (McClements, 2012).

Essential Minerals

Minerals are inorganic substances that may be added to foods as functional ingredients. They may be used for flavor enhancement, food preservation, texture modification, or essential nutrients (McClements, 2014). Some minerals can easily be incorporated into foods since they do not have any negative impacts of food quality and they have good bioavailability. However, a number of important minerals are unstable in foods, lead to precipitation, off-flavor production, promote lipid oxidation, or have low bioavailabilities, e.g. iron and calcium (McClements, 2012). In order to overcome these problems, those minerals need to be encapsulated.

Essential Vitamins

Vitamins are organic compounds that are important for proper functioning of biological processes. Since the body cannot manufacture vitamins they must be obtained naturally from foods or added to foods. Vitamins are classified as water soluble or fat soluble depending on their characteristics (Swanson & Evenson, 2001). The fat soluble vitamins are vitamins A, D, E, and K while as water soluble vitamins include vitamin A, C, and E. Vitamins are commonly added to food products to restore nutrients lost in processing or to enhance the overall nutritive value of the food. The addition of vitamin D to milk and of B vitamins to bread has been associated with the prevention of major nutritional deficiencies. Some vitamins such as vitamin A, C, and E are known for their antioxidant capacity because they help to scavenge free radicals from the body. Vitamins are sensitive to various factors like high temperature, pH and light and therefore they may need to be encapsulated to ensure their stability (McClements, 2012).

Probiotics

Probiotics are microorganisms introduced orally in the gastrointestinal tract (GIT) that are able to contribute positively to the activity of intestinal microflora and therefore, to the health of its host. Most probiotic bacteria belong to the group of lactic acid bacteria (LAB) and among them lactobacilli and bifidobacteria reportedly play a significant role in maintaining the intestinal ecosystem and in stimulating the immune system of the host.

There are a number of health benefits associated with the consumption of probiotic bacteria. They help in reduction of colon irritation, constipation, traveler's diarrhea, inhibition of the adhesion of pathogenic genera including *Escherichia, Clostridium, Salmonella* and *Campylobacter* to the intestinal lumen, synthesis of B vitamins, lowering of blood ammonia levels, cholesterol absorption and inhibition of tumor formation.

Probiotics have been incorporated into a range of dairy products, including yoghurts, soft-, semi-hard and hard cheeses, ice cream, milk powders and frozen dairy desserts. However, there are still several problems with respect to the low viability of probiotic bacteria in GIT and food environments. Probiotics of intestinal origin are difficult to propagate and high survival is important for both economic reasons and health effects. Consequently, there is a demand for new technologies such as encapsulation to enhance probiotic viability.

WALL MATERIALS USED FOR NANOENCAPSULATION

Nanoencapsulation of food ingredients (core materials) into wall (coating, shell) materials can be done by several methods. The selection of the nanoencapsulation process is based on the physical and chemical properties of core and wall materials and the intended use of food ingredients (Chen et al. 2006a, b). The nanoencapsulation techniques that are used to encapsulate food ingredients are given in Table 2. Sophisticated wall materials and technologies have been developed and an extremely wide variety of functionalities can be achieved through nanoencapsulation (Ezhilarasi et al., 2013). Many factors can be used to prompt the release of the encapsulated ingredient, such as pH change (enteric and anti-enteric coating), mechanical stress, temperature, enzymatic activity, time, osmotic force, etc. However, cost considerations are much more stringent in the food industry than in the pharmaceutical or cosmetic industries.

Nanoencapsulation is used to produce nanocapsules from food ingredients and wall materials. Generally, some precautions need to be taken while preparing the nanocapsules: the wall around the food ingredient should be proper so that leakage of the food ingredient does not occur. The selection of nanoencapsulation method and wall materials are interdependent and the appropriate method or coating material is selected based on the wall material or method to be used. Wall materials can be selected from a wide variety of natural or synthetic polymers, depending on the material to be coated and characteristics desired in the final nanocapsules. The composition of the wall material is the mainly responsible for the functional properties of the nanocapsule. An ideal wall material should exhibit the following characteristics:

1. Good rheological properties at high concentration and easy workability during encapsulation.
2. The ability to disperse or emulsify the active material and stabilize the emulsion produced.
3. Non-reactivity with the material to be encapsulated both during processing and on prolonged storage.
4. The ability to seal and hold the active material within its structure during processing or storage.
5. The ability to completely release the solvent or other materials used during the process of encapsulation under drying or other desolventization conditions.
6. The ability to provide maximum protection to the active material against environmental conditions (e.g., oxygen, heat, light, humidity).
7. Solubility in solvents acceptable in the food industry (e.g., water, ethanol).
8. Chemical nonreactivity with the active core materials.
9. Inexpensive, food-grade status.

NANOENCAPSULTION TECHNIQUES

Nanoencapsulation can be achieved through different techniques. Top-down and bottom-up are the two basic approaches used in nanoencapsulation technique to develop nanomaterials. Top-down approach uses precise tools for size reduction and shaping of structure for intended application of nanomaterials. Emulsification and emulsification–solvent evaporation techniques are categorized under top-down approach. Bottom-up approach involves the construction of materials by self-assembly and self-organization of molecules which were affected by factors like pH, temperature, concentration, and ionic strength. Methods used in the bottom-up approach are nanoprecipitation, inclusion complexation, coacervation and supercritical fluid technique. Both hydrophilic and lipophilic bioactive compounds can be encapsulated by employing these methods of nanoencapsulation. Nanoencapsulation techniques which are used usually for the encapsulation, of hydrophilic and lipophilic compounds, are emulsification, coacervation and supercritical fluid technique. However, for lipophilic compounds, nanoprecipitation, inclusion complexation, emulsification-solvent evaporation techniques are commonly used (Ezhilarasi et al., 2013).

Nanoencapsulation of various bioactive compounds by different techniques are presented in Table 2. Physicochemical properties like particle size, surface area, size distribution, shape, solubility, and encapsulation efficiency, and releasing mechanisms get affected by an encapsulation technique. Therefore, selection of an appropriate nanoencapsulation technique becomes important as it is based on the required size, nature of core material, physicochemical properties, and wall materials. Techniques employed for nanoencapsulation are more complex when compared to microencapsulation. This is attributed to

Table 2. Nanonoencapsulation techniques of various bioactive compounds

Nanoencapsulation Technique	Bioactive Compound	Wall Material	Particle Size
Emulsification	Salmon oil	OSA starch, chitosan, and lambda-carrageenan	160-207 nm
	Flax seed oil	Maltodextrin	135 nm
	Sunflower oil	Maltodextrin	40 nm
	D-Limonene	Maltodextrin	543-1292 nm
	β-Carotene	OSA starch, chitosan, and lambda-carrageenan	132-184 nm
Coacervation	Capsaicin	Gelatin, maltodextrin, tannins	100 nm
	Capsaicin	Gelatin, acacia, hydrolysable tannins	300-600 nm
	Curcumin	Maltodextrin	79-618 nm
	BSA	Chitosan, poly (ethyleneglycolran-propyleneglycol)	200-580 nm
Nanoprecipitation	β-carotene	poly (D,L-lactic acid) and poly (D,L-lactic-coglycolic acid);	80 nm
	Curcumin	poly (lactide-co-glycolide);	81 nm
	Curcumin	ethyl cellulose and methyl celluolose	117 and 218 nm
	Curcumin	chitosan cross-linked with tripolyphosphate	254-415 nm
	Phytosterol	poly (-methyl methacrylate) and polyvinyl alcohol	50-282 nm
	Quercetin	poly-D,L-lactide and polyvinyl alcohol	170 nm
	Coenzyme Q10	poly (-methyl methacrylate) and polyvinyl alcohol	40-260 nm
	α-Tocopherol	poly (-methyl methacrylate) and polyvinyl alcohol	90-120 nm
	β-carotene	poly (-methyl methacrylate) and polyvinyl alcohol	9-280 nm
	Astaxanthin	poly (-methyl methacrylate) and polyvinyl alcohol	115-163 nm
Freeze drying	Fish oil	β- cyclodextrin, polycaprolactone	183-714 nm
	Capsicum oleoresin	poly-ε-caprolactone and gelatin	152 nm
	Capsicum oleoresin	poly-ε-caprolactone	163-1984 nm
	α-Tocopherol	chitosan, zein;	200-800 nm
	Vitamin E	polyethylene glycol	164 nm
	Curcuminoids	polyethylene glycol	450 nm
	Catechin	chitosan and sodium tripolyphosphate	163 and 165 nm

the difficulty encountered in achieving the complex morphology of the core material and capsule, and releasing rate demands of nanoencapsulates. There are various techniques which have been developed and used for microencapsulation. However, emulsification, coacervation, inclusion complexation, emulsification–solvent evaporation, nanoprecipitation, and supercritical fluid technique are considered as nanoencapsulation techniques since they can produce capsules in the nanometer range (10–1,000 nm).

1. Emulsification Technique

Emulsification technique is generally used for the encapsulation of bioactive compounds in aqueous solutions by producing nanoemulsions. Nanoemulsions comprise of two immiscible liquids, of which one is being dispersed in the other, with droplet sizes ranging from 50 to 1,000 nm (Sanguansri & Augustin 2006). They are more suitable to encapsulate a high concentration of oil-soluble nutraceuticals or bioactive food supplements. Lipophilic active agents such as β-carotene, plant sterols, carotenoids, and dietary fats can be encapsulated and delivered by oil in water emulsion (o/w), while water in oil emulsion (w/o) was used to encapsulate water-soluble food active agents such as polyphenols (Zuidam & Shimoni 2010). Nanoencapsulation is accomplished through the drying of nanoemulsions using different drying techniques such as freeze drying or spray drying besides using nanoemulsions directly in liquid state. Nanoemulsions have high kinetic stability which is due to their extremely droplet sizes. This kind of stability, in nanoemulsions, is of paramount importance for the retention of surface oil content of the product (Jafari et al. 2008). Preparation of nanoemulsions requires a lot of energy input from mechanical devices as being non-equilibrium systems. High-energy emulsification methods like high shear stirring, high-speed or high-pressure homogenizers, ultrasonicator, and microfluidiser are generally used for the formation of nanoemulsions. These methods supply the available energy in the shortest time and possess the most homogeneous flow to produce the smallest droplet sizes. Microfluidisation uses very high pressure (up to 20,000 psi) to force the liquid through the interaction chamber, which consists of microchannels of a special configuration. The emulsion feeds through the microchannels into a collision chamber, leading to formation of fine nanoscale emulsion droplets. High-pressure homogenization is a technique in which a mixture is pushed with high pressure (100 to 2,000 bar) and high shear stress, which resulted in the disruption of particles down to the nanometer range. Homogenization may be performed either at elevated temperature (hot homogenization) or below room temperature (cold homogenization) (Ezhilarasi et al., 2013).

2. Coacervation

The coacervation process relies on the phase separation of coacervate particles and their subsequent deposition onto the surface of emulsified oil droplets or particles of an active ingredient. Further, a hydrocolloid shell can be cross-linked using an appropriate chemical or enzymatic cross-linker such as glutaraldehyde or transglutaminase, mainly to increase the robustness of the coacervate (Zuidam & Shimoni 2010). Coacervation can be simple or complex depending on the numbers of polymer type used. Simple coacervation involves only one type of polymer while complex coacervation involves two or more types of polymers. Interaction between polymers and nature of the complex formed are influenced by different factors such as the biopolymer type (molar mass, flexibility, and charge), pH, ionic strength, concentration, and the ratio of the biopolymers(Turgeon et al. 2007).Apart from the electrostatic interactions between biopolymers of opposite charges, hydrophobic interactions and hydrogen bonding can also contribute significantly to the complex formation. Coacervation is a distinctive and promising encapsulation technology because of the very high payloads achievable (up to 99 %) and the possibilities of controlled release based on mechanical stress, temperature, or sustained release (Gouin, 2004).

The nanocapsules were produced in the range of 100–600 nm using coacervation technique. The size of nanocapsules is also affected by a suitable drying technique like freeze drying and vacuum drying. Most commonly used wall materials used in coacervation are gelatin, chitosan and acacia gum. Moreover, the treatment of nanocapsules with tannins influenced their morphology (good dispersion and shape) and particle distribution. Crosslinking with glutaraldehyde for a particular time period had increased the melting point and thermal stability of the nanoencapsulates. The major problem associated with the use coacervated food ingredient is attributed due to use of glutaraldehyde for cross-linking. At present, enzymes have been developed for cross-linking. These enzymes can be better alternative for any chemical reagent for cross-linking.

3. Nanoprecipitation Technique

Nanoprecipitation is also known by the name of solvent displacement method. This technique presents numerous advantages, in that it is, rapid and easy to perform. The nanoparticle formation is instantaneous and the entire procedure is carried out in only one step. Nanoprecipitation technique involves the precipitation of polymer from an organic solution and the diffusion of the organic solvent in the aqueous medium (Galindo-Rodriguez et al., 2004). Nanocapsules as well as nanospheres are produced by solvent displacement method. polycaprolactone (PCL), poly (lactide) (PLA), and poly (lactide-co-glicolide) (PLGA), eudragit, poly (alkylcyanoacrylate) (PACA) are some commonly used biodegradable polymers in this method (Reis et al., 2006). Nanoprecipitation is considered to be an efficient method for the formation of nanocapsules of the size of 100 nm and below. The nanoencapsulates produced exhibit good stability, higher encapsulation efficiency, sustained release increased cellular uptake and bioavailability during in vivo studies. However, drying technique too has some impact on it only polymer based wall material can be used (PEG and PLGA). Selection of appropriate solvent and non-solvent phase is important, which may vary for each bioactive. The polymer and solvent used should be of food grade only. The usefulness of this simple technique is limited to water-miscible solvents, in which the diffusion rate is enough to produce spontaneous emulsification. This is an efficient method to nanoencapsulate lipophilic drugs because of the miscibility of the solvent with the aqueous phase (Ezhilarasi et al., 2013).

4. Emulsification–Solvent Evaporation Technique

Emulsification-solvent evaporation is an improved sort of solvent evaporation technique which includes emulsification of the polymer solution into an aqueous. Afterwards, the solvent is evaporated and the polymer precipitation remains as the nanoparticles. The size of the particles can be modified by adjusting the stir rate, type and the amount of dispersing substance, viscosity of the phases and temperature. High-speed homogenization and ultrasonication are applied in order to obtain a small particle size. Frequently used polymers are PLA, PLGA, ethyl cellulose, cellulose acetate phthalate, PCL, and poly (h-hydroxybutyrate). In order to produce a small particle size, often high-speed homogenization or ultrasonication may be employed (Zambaux et al., 1998).

Emulsification-solvent evaporation is an efficient technique for the formation of nanocapsules of the sizes of 100 nm and below. Nanocapsules produced by this method are found to be spherical having a high drug loading content and encapsulation efficiency of about 75–96 % with sustained release and increased absorption. The nanoemulsions prepared by this technique show good stability. However, the stability of nanoemulsions depends on the type of emulsification technique employed like microfluidisation, high-speed and high-pressure homogenization techniques. The size of the nanoemulsions droplets is largely determined by the emulsification methods used and other operating conditions. To produce good quality nanocapsules a suitable drying method is required. The main limitation identified in emulsification-solvent evaporation high energy input incurred on the homogenization while producing nanoemulsions. Most probably, it involves the application of a polymer-based wall material; only lipophilic core material can be encapsulated and the solvent to be utilized should be of food grade (Ezhilarasi et al., 2013).

5. Freeze Drying

Freeze drying is the most suitable technique for dehydration of all heat-sensitive materials. It is a multistage operation stabilizing materials through four main operations such as freezing, sublimation, desorption and finally storage (Mascarenhas, et al.,1997). Freeze-drying is a drying process for the long-term preservation of heat sensitive food and other biological materials based on the phenomena of sublimation (Ray et al., 2016). Freeze drying furnishes high quality products which are reconstituted easily. However, energy intensiveness, long processing time (more than 20 h), and open porous structure were the main drawbacks of freeze drying (Singh & Heldman, 2009). Generally, freeze drying is used to separate nanoparticles produced through other nanoencapsulation methods. Formation of pores due to ice sublimation process is the main problem associated with freeze drying. Therefore, this process exposes the active food ingredients due to the presence of pores on nanocapsules. Currently, freeze drying technique is a widely used technique to remove water from nanocapsules without changing their structure and shape. However, spray–freeze drying technique may be an effective alternative to conventional freeze drying technique in terms of reducing the pore size and drying time (Anandharamakrishnan et al., 2010).

Freeze drying plays a vital role in stabilizing nanocapsules by being an efficient drying technique. It is capable of retaining the size of particles in nanometric range (below 400 nm and exceptionally few near to 800 nm) improving the stability of active food ingredient against degradation. The process exhibits excellent encapsulation efficiency. Moreover, this technique is more suitable for the nanoencapsulation of heat-sensitive food materials and bioactive components. The characteristics of nanoparticles produced by freeze drying also depend on the emulsification technique employed or other encapsulation methods to reduce the droplets to nano form. Cryoprotectants like sucrose, trehalose, and mannitol prevent the aggregation of nanoparticles during freeze drying. Nanocapsule size was found to be affected by the freezing temperature. In most of the studies, polymers such as PCL and chitosan were used as a wall material (Ezhilarasi et al., 2013).

6. Spray Drying

Spray drying is the oldest and the most widely used encapsulation technique in the food industry sector. It is a flexible, continuous, but more important an economical operation. Encapsulation by spray drying appears to be an effective way for those compounds in the powder form because of its advantages. Excellent properties of the protection, stabilization, solubility and controlled release of the bioactive compounds can be obtained (Zuidam & Heinrich, 2009). Different types of encapsulating agents have been used for spray drying; these include polysaccharides (starches, maltodextrins, corn syrups and arabic gum), lipids (stearic acid, mono and diglycerides), and proteins (gelatin, casein, milk serum, soy and wheat) (Saenz et al., 2009). Spray drying is used for encapsulation of a huge number of food ingredients such as flavors, colors, vitamins, minerals, fats, and oils. Encapsulation prevents these ingredients from the surrounding environment and enhances their storage stability. Spray drying technique is reported to be considered as a suitable process for consolidating nanoparticles into macroscopic compacts and submicron spherical powders with nanometer-scale properties (Ezhilarasi et al., 2013).

Spray drying stabilizes the nanocapsules in an effective manner. It is more economical and fast when compared to freeze drying. It results in the production of uniformly spherical shaped particles which protect the encapsulated core material completely. Micron sized particles are produced on drying the nanoemulsions and nanosuspensions. Whilst the core materials encapsulated were in nano-size range. Nanoencapsulation by spray drying also depend upon the other encapsulation techniques like emulsification. Therefore, spray drying itself can't be considered a nanoencapsulation technique. Size and morphology of the particles are largely determined by varying process parameters and formulations. Hence, spray drying needs suitable modifications for drying of nanoemulsion and suspensions to retain their nanometer size (Ezhilarasi et al., 2013).

CONCLUSION

Nanoencapsulation of food ingredients is one of the important applications of food nanotechnology. Nanoencapsulation is a process by which small particles of core materials are packed within a wall material to form capsules. The development of new foods products requires technologies for incorporating health promoting ingredients into food without reducing their bioavailability or functionality. Nanoencapsulation cases, microencapsulation can provide the necessary protection for these compounds. Nanoencapsulation offer food processors a means to protect sensitive food components, ensure protection against nutritional loss, utilize sensitive ingredients, incorporate unusual or time-release mechanisms into the formulation, mask or preserve flavors/aromas and transform liquids into easy to handle solid ingredients. Various techniques of nanoencapsulation are gradually emerging and techniques such as emulsification, coacervation, nanoprecipitation, solvent evaporation, spray drying and freeze drying are widely used techniques in the nanoencapsulation process are enduring techniques for nanoencapsulation of food ingredients. Moreover, solvent evaporation and nanoprecipitation remains to be unique techniques for encapsulation of lipophilic bioactive compounds. Controlled release of food ingredients at the right place and the right time is a key functionality that can be provided by nanoencapsulation. Timely and targeted release improves the effectiveness of food additives, broadens the application range of food ingredients, and ensures optimal dosage, thereby improving the cost effectiveness for the food manufacturer.

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KEY TERMS AND DEFINITIONS

Antimicrobial: A substance used in foods to kill or inhibit the growth of microorganisms, such as bacteria, molds and yeasts.

Antioxidant: A substance that prevents or retards the oxidative processes in foods. They are used to retard rancidity of fats in stored foods. Natural antioxidants include vitamin E, ascorbic acid, plant phenolics while as synthetic antioxidants include propyl, octyl and dodecyl gallates butylated hydroxyanisole and butylated hydroxytoluene.

Bioactive Compounds: Bioactive compounds are essential and nonessential compounds (e.g., vitamins or polyphenols) that occur in nature, are part of the food chain, and can be shown to have an effect on human health. Bioactive compounds are also referred to as nutraceuticals.

Controlled Release: The process of releasing an encapsulated component with a specific concentration-time profile at the site of action. The release process may follow a number of different profiles, including burst release, sustained release, triggered release and targeted release.

Delivery System: The process of carrying an encapsulated component to the required site of action, which may be the surface of a bacteria, or the human mouth, nose, stomach, small intestine or colon. Once an active component has been encapsulated it usually has to be retained by the delivery system for a certain period under specific environmental conditions before it is released. A "delivery system" is a system designed to encapsulate, deliver and release one or more active components.

Encapsulation: The process of entrapping a specific component (core/active component) within some kind of matrix (wall/coating/encapsulant). The matrix may be made up of one or multiple components (such as proteins, polysaccharides, surfactants, lipids, water and/or minerals), and it may have either a simple (homogeneous) or complex (heterogeneous) structure depending on the materials and procedures used to fabricate it.

Nanoemulsions: Nano-emulsions consist of fine oil-in water dispersions, having droplets covering the size range of 100-600 nm. These emulsions are easily produced in large quantities by mixing a water-immiscible oil phase into an aqueous phase with a high-stress, mechanical extrusion process that is available worldwide.

Nanoencapsulation: Nanoencapsulation is the coating of various substances within another material at sizes on the nano scale.

Nanotechnology: Nanotechnology focuses on the characterization, fabrication, and manipulation of biological and non-biological structures smaller than 100 nm.

Nutraceuticals: Components/nutrients isolated or purified from foods which have health benefits besides their actual function of providing nutrition and are therefore used to prevent the occurrence of a disease or are used in its treatment.

Prebiotics: Non-digestible oligosaccharides that support the growth of colonies of certain bacteria in the colon. They include derivatives of fructose and galactose, and lead to the growth of bifidobacteria, so changing and possibly improving the colonic flora.

Probiotics: Preparations of microbial culture added to food or animal feed, claimed to be beneficial to health by restoring balance to the intestinal flora. Organisms commonly involved include species of *Bifidobacterium*, *Enterococcus faecium*, *Lactobacillus*, *Saccharomyces bulardii*.

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Chapter 12
Perspective Uses of Essential Oils in Functional Foods and Antimicrobial Packaging Material

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ABSTRACT

Functional foods are recently introduced to assure superior nutritional quality; contain biologically active compounds in defined amounts. These foods have to be effectively packaged and stored in order to prevent microbial spoilage and risk of food borne infections. Recently, food technologists and scientists are formulating the Essential Oil (EOs) containing functional foods. The antibacterial, antifungal, antioxidant and anti-carcinogenic properties of EOs have been proved by a number of researchers. Health conscious consumers prefer natural additives, hence these volatile oils due to their green image can be safely used as a replacement of synthetic preservatives. The shelf life of functional foods can be improved by antimicrobial packaging incorporating EOs and their derivatives in the edible films and coatings. EOs can be easily fabricated as microencapsules and nanoparticles, which increases their stability and solubility. Hence EOs are considered as the most usable additives in future functional foods.

INTRODUCTION

The 'food' has been traditionally defined as the nutritious substances required for the maintenance of life and growth. As the food consumption habits have been changed globally, so there is lot of concern on the health consequences. Especially in the developing countries nutritional status of an individual faces the challenges of ageing, globalization and urbanization (Kearney, 2010). As diet and health are closely related, nutritional deficiencies can result into number of diseases (Burkert, 2014; Levine & Labuza, 1990). In addition to the nutritional and sensory implications, the food items have also been proven to improve the psycho-physical well-being and associated with prevention of certain diseases (Menrad,

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2003). Hence in the present context, the food is not only intended to satisfy the hunger but it should also have additional nutritional and sensory properties, which can play an important role in physical and mental health of the consumers. Due to modernized life style, in urban regions a large portion of daily diet comprises of ready-to-eat and novel food types, which are highly prone to microbial spoilage and pose risk to the consumers. The traditional food items are replaced with the fast food due to their easy availability and quick processing (Ashakiran & Deepthi, 2012). There has been increasing interest in developing novel types of effective and non-toxic antimicrobial compounds to protect the food against contamination and the consumer against infection. Essential oils (EOs) due to their unique combinative properties of aroma, flavour and fragrance have been preferably used in food items since ancient times. This chapter offers an insight into exhaustive applications of EOs for development of future functional foods for the additional health benefits.

FUNCTIONAL FOODS

Newer food products such as nutraceuticals, medifoods and vitafoods; collectively termed as functional foods have now been designed and been included in the diet regimens of health conscious consumers (Azzurra & Paola, 2009). Functional foods are the foods and food components that provide allied health benefits in addition to the basic nutrition. It also includes conventional foods, fortified, enriched or enhanced foods and dietary supplements (Clydesdale, 2004). A plethora of these foods are available in the market; their consumption is not only required for the maintenance of health. In addition to the benefits to health, these foods have gained popularity because of their convenience (Frewer *et al.,* 2003).

The consumption of functional foods has enormously increased worldwide and is highly preferred over with the treatment of diseases (Castro *et al.,* 2005). Functional foods which contain probiotics and prebiotics can be used in the prevention and treatment of several diseases such as cardiovascular diseases, cancer, diabetes, hypertension (Alissa and Ferns, 2012) as well as infectious diseases (Singh & Bhatia, 2011).

Health benefits of these beneficial foods have been attributed to biologically active components which impart health benefits or desirable physiological effects (Hasler, 2002). These physiologically active compounds which are derived from plants are refereed as “phytochemicals” or in general also called botanicals (Rodriguez *et al*., 2006; Bloch, 2003; Bruulsema, 2000). Significant health potential of various phytochemicals such as carotenoids, phenolic compounds (flavonoids, phytoestrogens, phenolic acids), phytosterols and phytostanols, tocotrienols, organosulfur compounds (allium compounds and glucosinolates), and nondigestible carbohydrates (dietary fiber and prebiotics) have been already proved by clinical and experimental studies (Rodriguez *et al*., 2006). Research is also enduring on the beneficial effects of other phytochemicals such as glucosinolates, isothiocyanates (Dinkova-Kostova &d Kostov, 2012), terpenes, terpenoids, phytoestrogens and saponins (Dillard & German, 2000). The consumer acceptability of functional foods chiefly depends on their appearance and taste; hence should be incorporated with good flavouring agents.

ESSENTIAL OILS AS FOOD FLAVOURING AGENTS IN FUNCTIONAL FOODS

An EO is a concentrated hydrophobic liquid containing volatile aroma compounds derived from 'quinta-essentia' of plants (Cowan, 1999; Singh & Malik, 2008; Lee *et al*., 2004). According to ISO, EOs are defined as the products obtained from different parts of plants through distillation by steam distillation, hydro distillation and pressing the citrus fruit pericarp techniques (UNIDO & FAO, 2005). EOs are actually secondary metabolites present in special cells or groups of cells or in glandular hair in non-woody parts (stem, leaves, flowers and fruits) of aromatic plants (Pasqua *et al*., 2005). Chemically EOs are enriched in terpenes $[(C_5H_8)_n]$. Additionally may also contain terpenoids, phenylpropanes and specific compounds containing nitrogen and sulphur (Bassole & Juliani, 2012; Smadja, 2009; Dorman & Deans, 2000). EOs have been traditionally used for their pleasing aroma. These aromatic oils have a great usage in cosmetics, flavouring, folk medicine, perfumery and pharmaceuticals. EOs are known to soothe the body and soul, have physical and psychological healing effects and bring an euphoria to the body. The applications of EOs for therapeutic purposes is termed as 'aromatherapy', which was first introduced by Rene Maurice Gattefose (1937), and was later rediscovered by Dr. Jean Valnet (Singh & Maurya, 2005). In India, applications of EOs has been mentioned in the Vedic literature of India. The use of aromatics as flavours and fragrances has also been compiled in Ayurveda "Gandhshastra"(NIIR Board; Singh and Malik, 2008). Remarkable antibacterial, antifungal, antioxidant, anti-carcinogenic and biological properties of EOs have also been proved (Malik *et al*., 2015a; Malik *et al*., 2011; Malik & Singh, 2010).

The enormous application of flavours in food items is also supported by the fact that the global trade of flavouring products accounts to 7 billion US Dollars, out of which 16% is due to natural products and essential oils (Dubal *et al*. 2008). EOs or extracts from common culinary herbs and spices are also valued by Europe Union as the world's biggest importer (UNIDO & FAO, 2005). Flavour enhancement properties and medicinal properties of various culinary herbs and spices have been historically known. Some of the spices which are used in Indian cuisine are black pepper, chillies, cardamom, cinnamon, clove, curcuma, dried ginger, fennel, garlic and mustard seeds. Indian food is also seasoned and flavoured with herbs such as basil, coriander, dill, fenugreek, green onions, lemongrass, thyme, wintergreen etc. Not only Indian cuisines but in many other cuisines of different countries herbs and spices are also added (Kaefer & Milner, 2008; Tapsell *et al*., 2006). It is well recognized that the addition of dietary EOs improves the digestive processes which is the actual reason behind adding the herbs and spices in the food items. Due to aroma and culinary properties, EOs extracted from some of the carminative herbs are also used in bakery products, meat and fish dishes, icecream and alcoholic beverages (Kordsardouei *et al*., 2013; Sahib *et al*., 2012; Rather *et al*., 2012; Bajaj and Urooj, 2006; Diaaz-Maroto *et al.,* 2005; Badei *et al*. 2000).

The addition of EOs is not only anticipated for a pleasing aroma but these also improve the digestion; encourages the consumer to bite and chew. When ingested these oils stimulates production of saliva in mouth, enhances digestion of food in the intestine. The immune system may also get strengthened, as EOs also stimulates antibody production and toxin removal (Nam *et al*., 2008). Ingestion of EOs enhances the secretion of bile, mucus and digestive enzymes have been found to increase (Jang *et al*., 2007; Manzanilla *et al*., 2004; Platel, 2001). An essential oil derived from *Mentha longifolia* ssp. *Hymalaiensis,* rich in cis and trans-Piperitone Oxide and Piperitenone Oxide, has been formulated as candy, hard sugar, sugar-Free, toffee and hard-boiled candy. It provides a physical warming sensation when administered to the oral cavity; has been developed as a method for achieving a physical warming sensation (http://patents.justia.com/patent/20140010768). *Citrus sinensis* essential oil (orange sweet oil) is mostly used as flavouring agents of soft drinks, baked goods and confectioneries, soaps, other cleansing products and aerosols. Its health benefits includes anti-inflammatory, antidepressant, antispasmodic, antiseptic, aphrodisiac, carminative, diuretic, tonic, sedative and cholagoguitic activities. (Health Benefits n.d).

Tagetes EO (80 to 120 ppm) emulsified with propylene glycol has been added to a beverage made from the pulp of mango (variety totapuri) to achieve a distinct enhancement in fresh mango. A higher perception of beverage added with EO was judged by a trained sensory panel and it also scored better in consumer acceptability test[1].

In addition to flavour EOs also increase feed intake (Deyoe *et al.,*1962). Flavour and Extract Manufacturers Association (FEMA) Expert Panel has evaluated each EO on a case by case basis and have also applied their scientific judgment (Smith *et al*., 2005). FEMA has also laid the lower limit, upper limit and mean value of each EO to be used as a flavouring agent (FAO/WHO, 2009).

ANTIOXIDANT ACTIVITY OF ESSENTIAL OILS IN HUMAN BODY AND THEIR ROLE IN THE PREVENTION OF DISEASES

In the human body, cell death and tissue damage results due to exogenous chemical and endogenous metabolic processes which produce highly reactive free radicals (Saleh *et al*., 2010). Oxidative stress in humans results due to generation of active oxygen molecules which are an underlying cause of various inflammatory diseases such as cancer, cardiovascular diseases, atheroesclerosis, cataract, Alzheimer's and Parkinson's diseases (Parejo *et al*., 2002). In healthy individuals, the production of free radicals is balanced by the antioxidative defense system. Oxidative stress may also result in liver dysfunction disorders such as subclinical hepatitis without jaundice, inflammatory necrotic hepatitis, liver cirrhosis and hepatocellular carcinoma in which reactive oxygen species are generated (Zhu *et al*., 2012; Tanikawa & Torimura, 2006). These volatile oils as antioxidants may play an important role in prevention of brain dysfunction, cancer, cardiovascular diseases, disorders of immune system, heart diseases, type 2 diabetes, and neurodegenerative diseases (Maen & Cock, 2015; Opara *et al.,* 2014; Kamatou *et al*., 2010; Kaefer & Milner, 2008; Aruoma *et al*., 1998).

In addition to this, EOs as additives are effective in retarding the process of lipid peroxidation in oils and fatty foods. They also act by free radical scavenging, by termination of peroxides and also prevent lipid oxidation (Amorati *et al*., 2013; Miguel, 2010). Due to the hepatoprotective properties the consumption of *Rosmarinus officinalis* (Rosemary) EO has been recommended by European Medicines Agency (EMA) for treatment of certain clinical disorders such as dyspepsia and mild spasmodic disorders of the gastrointestinal tract. Its clinical application as an adjuvant in the relief of minor muscular and articular pain and use in minor peripheral circulatory disorders is also permitted (Raskovic *et al*., 2014). *Trachyspermum ammi* (Ajwain) EO has also been used for the treatment of digestive and inflammatory diseases also possess strong anti-oxidant properties (Kamaljeet *et al*., 2012). The principle active constituents of *T.ammi* EO which are phenols, mainly thymol (35-60%) are considered to be responsible for its free radical scavenging properties (Chatterjee *et al*., 2013).

EOs of some of the culinary herbs also possess antioxidant (Miguel, 2010; Tanabe *et al.,* 2002), antimicrobial (Thompson *et al*., 2013; Pittman *et al.,* 2011; O' Bryan *et al*., 2008; Škrinjar & Nemet, 2009), antithrombotic (Ballabeni *et al*., 2007; Ballabeni *et al*., 2004), anti-inflammatory (Miguel, 2010) and pharmacological properties (deSousa, 2011). Some EOs have a role in lowering the cholesterol; the hypocholestero-lemic effect of lemongrass oil is due to the inhibition of 3-hydroxy-3-methylglutarylcoenzyme A (HMG-CoA) reductase activity which is a key regulatory enzyme in the cholesterol synthesis process (Krishan & Narang, 2014; Elson 1989). EOs from coriander seed, lemon balm, peppermint, pine and tea tree oils have exhibited strong antibacterial activity, can be used in the formulations of herbal medicines against gastrointestinal disorders such as irritable bowel syndrome (Thompson *et al*., 2013).

EOs have also shown anti-cancerous properties. *Origanum dictamnus*(dittany) EO and its active component has shown anti-proliferative activity and cytotoxicity against HepG2cells (a human experimental model of hepatocellular carcinoma), can be applied as a promising chemopreventiveagent (Mitropoulo *et al*., 2015). However, the quantity of EOs and their components to be added in food and confectionery products at such as low concentrations which shouldn't alter the organoleptic qualities. EOs extracted from spices and herbs can also be used as flavouring agents in medicines, which excites reflux flow of saliva and many psycosomatic and psychological diseases which are associated with loss of appetite (Mohiuddin *et al*., 2012).

IMMUNOMODULATORY AND ANTI-INFLAMMATORY ACTIVITY OF EOs

Essential oils and their components have showed promising immunostimulant activity on both specific and non-specific immune mechanisms, proved by *in vitro* as well as *in vivo* animal studies. In an *in vivo* study, immunomodulatory effect of geranial, geranial acetate, gingerol, and eugenol oils was evaluated by studying humoral and cell-mediated immune responses using rats as the animal model. The essential oils were tested for hypersensitivity and hemagglutination reactions, using sheep red blood cells (SRBC) as the antigen; haemagglutinating antibody titre (HAT) and delayed type hypersensitivity (DTH) response were the test parameters studied after the oral ingestion. An increase was reported for both the parameters and the foot pad thickness response was also higher; indicated significant immunostimulant activity on both the specific and non-specific immune mechanisms (Farhath *et al*., 2012).

In another study, potentiation of antigen-specific T cell-mediated immunity and macrophage activity was observed for EO of Niaouli (Melaleuca quinquenervia). However, the humoral response was not enhanced (Nam *et al*., 2008). The immunomodulatory effect of garlic EO was explained due to its ability to enhance the production of interleukins, tumor necrosis factor (TNF-α), interferon (INF-γ). Garlic EO also increases phagocytosis of peritoneal macrophages, and secretary metabolism of macrophages. The antioxidant function and number of antigen presenting cells (APC) was also increased (Hanieh *et al*., 2010). Garlic EO in diets also improved antibody response against Newcastle disease virus, increased weight of spleen and bursa of Fabricious, and augmented hypersensitivity cutaneous basophilic response (Krishan & Narang, 2014; Rahimi *et al*., 2011).

Cinnamaldehyde, a major constituent of cinnamon EO inhibits the cyclo-oxygenase (COX-2) activity, which is responsible for its anti-inflammatory activity (Guo *et al*., 2005). Phenylpropanoids, active constituents of EOs has shown potent inflammatory activity by various mechanisms (Silveira *et al*., 2014). The traditional use of Phenethyl alcohol has been supported *in vitro* on the contraction of isolated tracheal smooth muscle in guinea pig, prevented histamine-induced bronchoconstriction, which indicates anti-asthmatic effect (Chi *et al*., 2009). The phenolic compounds of EOs possess suppress the metabolism of inflammatory prostaglandins such as TNF-α, IL-1β and IL-6; the precursors arachidonic acid and thromboxane A_2 (Silveira *et al*., 2014). *Nigella sativa* EO sold under the trade name, 'dNigellone' is advised orally to patients suffering from bronchial asthma. In clinical studies on the patients of allergic diseases, including allergic rhinitis, bronchial asthma, atopic eczema administration of dNigellone, decreased the IgE, and eosinophil count, endogenous cortisol in plasma and urine; can be effectively used as an adjuvant for the treatment of allergic diseases (Salem *et al*., 2005).

ESSENTIAL OILS AS PRESERVATIVES IN FOOD ITEMS

Packaging through the traditional methods is associated with loss of nutrients. The use of synthetic preservatives constitutes another approach for food preservation. Chemical preservatives such as calcium propionate, sodium nitrate, sodium nitrite, sulfites (sulfur dioxide, sodium bisulfite, potassium hydrogen sulfite) and disodium EDTA are usually added in the packaged food products to extend their shelf-life (Abdulmumeen *et al*., 2012; Noel *et al*., 1990). These chemicals are found to be associated with serious health problems like cancer, allergies, asthma, hyperactivity, and hormonal problems. Moreover, the addition of chemical food preservatives may result in adverse changes in organoleptic properties and loss of nutrients; may also be incompatible with some components of food items (Doyle, 2007; Rasooli, 2007). The consumers have a negative perception of synthetic food additives, which has spurred an interest for search of natural alternatives. Hence, the use of these synthetic preservatives for food items has to be restricted. The conception that EOs can substitute food preservatives has been supported by their antioxidant and antimicrobial properties. Incorporation of essential oils and their derivatives into food items and in packaging constitutes an option in 'Hurdle technology', which is a latest approach in food technology, also called combined Methods/processes or barrier technology. Different food items which can be preserved with EOs as preservatives include meat and meat products, sea foods, vegetables, cereals based products and dairy products (Perricone, 2005).

ANTIMICROBIAL PROPERTIES OF ESSENTIAL OILS

Antimicrobial potential of number of volatile oils has been well documented by various researchers. EOs of *Ocimum basilicum* (basil), *Cymbopogon flexosus* (lemongrass), *Pelargonium graveolens* (geranium), *Mentha arvensis* (mentha) have been shown to be highly effective against both bacterial (*Bacillus cereus*, *Salmonella enteritidis* and *Salmonella typhimurium)* and fungal (*Aspergillus flavus* and *Aspergillus niger*) pathogens associated with food borne infections. The lowest value of MIC was observed for basil and lemongrass oil for *Bacillus cereus* and *Salmonella enteritidis* respectively (Malik *et al*., 2008). A spice used in Turkish cuisine, *Satureja cuneifolia* has shown considerable antibacterial activity against *P.aeruginosa*, *B.cereus*, *Sarcina lutea*, *E. coli* and *S. aureus* (Kan *et al.,* 2006). Oregano spice which is used as flavouring in tea, salads and meat dishes, in the form of water extract or hydrosol, showed significant bactericidal effect against *E. coli* 0157: H7, *Listeria monocytogens* 4b, *S. aureus* and *Yersinia enterocolitica* (Gulmez *et al.*, 2006). High preservative potential for food and cosmetic industries were attributed to *Artemisia afra,* and *Rosmarinus offcinalis* essential oil which displayed high antimicrobial activity against 41 microbial strains causing food spoilage and/ or poisoning (Mangena & Muyima, 1999). The preservation of meat products was found to be improved by application of volatile oils in the study of Aureli *et al.* (1992), as shelf life was found to increase because of reduction of microbial load. 32 plant essential oils commonly used in food industry were tested against four strains of *L. monocytogenes* and one strain of *L. innocua* by paper disc diffusion and inhibition curve method. Five EOs, namely cinnamon, clove, origanum, prevents and thyme showed antibacterial activity even at lower concentration (1:50 v/v). Pimento oil showed most remarkable and rapid activity. In a minced pork meat food matrix, thyme oil reduced *L. monocytogenes* population by 100 fold over the first week of storage. The shelf life of seafoods can be increased by dipping them in solutions of garlic oil and its constituents; carvacrol and thymol. *Moraxella*, *Flavobacteruim* and *vibrioniaceae* were more sensitive to compounds whereas *Alcaligenes* strains were resistant. The "dipping" treatment followed by storage at low temperature extended the shelf life by reducing both the total microbial load by about 100 fold and the volatile bases nitrogen (VB-N). Antimicrobial activities of allspice, garlic and oregano essential oils were investigated against *Salmonella enterica* and *Listeria monocytogenes* in tomato puree film-forming solutions. The results indicated that the antimicrobial activities against the three pathogens were in the following order: oregano oil > allspice oil > garlic oil (Du *et al.*, 2009). EOs of *Lavandula angustifolia, Eucalyptus globulus* and *Satureja hortensis* inhibited *Salmonella enterica* at different concentrations added to whole liquid eggs stored at 7°C (Djenane *et al.*, 2013). Not only antibacterial but prominent antifungal activity of *Citrus lemon, Cymbopogon citrates, Lippia alba*, *Lippia microphbylla* and *Peumus boldus* EOs against mould strains (*Aspergillus flavus*, *A. niger*, *Fusarium* spp., *Penicillium* spp. and *Rhizopus* spp.) has been reported. The phytochemicals citral, eugenol and myrcene have also shown prominent antimould activity (deSouza *et al.,* 2005). *O. dictamnus* essentialoil and its main components namely, carvacrol, γ-terpinene, p-cymene and linalool were effective against *Staphylococcus aureus, Staphylococcus epidermidis, Escherichia coli, Listeria monocytogenes, Salmonella Enteritidis, Salmonella typhimurium, Saccharomyces cerevisiae*, and *Aspergillus niger* (Mitropoulo *et al*. 2015).

Some components of EOs derived from spices and condiments selectively inhibits pathogenic intestinal bacteria, hence may have a pharmacological role in balancing the microflora of intestine, can be added used as the probiotic alternative to the antibiotics. For example, Cinnamaldehyde and eugenol have broad spectrum activity against many pathogenic bacteria, fungi and viruses. These have also determined to be effective against *Helicobacter pylori,* the causative agent of peptic ulcers and gastric malignancy. *H. pylori* was significantly inhibited at 2µg/ml; were also active at low pH (Ali *et al*., 2005).

In an *in vivo* study, EO has been found to bind to the fimbriae of pathogenic bacteria and reduce the adherence of pathogens (for example, *E. coli* and *Cl. perfringens*) with intestinal wall (Jamroz *et al*., 2006). The inhibitory activity of some EOs can also be explained to the deregulation of virulence factors of certain pathogenic microorganisms. *Ocimum gratissimum* EO has shown remarkable antioxidant and inhibitory activity against *E. coli* protease, a virulence factor which plays a crucial role in numerous pathologic processes. Proteolytic enzymes are involved in arthritis, tumor invasion and metastasis, infections and a number of degenerative diseases (Adesegun, 2013). Some EOs have also exhibited anti-viral activity in experimental studies. *Nigella sativa* EO has shown a remarkable antiviral effect against murine cytomegalovirus infection. In addition, elevation of IFN-γ in serum for a prolonged time was also observed (Salem and Hussain, 2000). Wu *et al*. (2010) have advocated that the oral administration of a commercial essential oil blend, On Guard™ *(wild orange, clove, cinnamon, eucalyptus and rosemary EO) for protection against H1N1 influenza virus. The potential antiviral activity was observed as the virus was incubated with essential oil in Madin-Darby canine kidney (MDCK) cells. The antiviral effect was proposed to be due to inhibition of viral protein translation. In order to optomize their use as preservatives in food items the antimicrobial efficacy of a number of EOs their antimicrobial efficacy against microorganisms has been studied in different food models (Table 1).

Table 1. Studies on antimicrobial efficacy of EOs in food models

Food Items	Chemical Constituent/Essential Oil	Microorganisms Tested	References
Meat and Meat Products	Eugenol and coriander, clove, oregano, and thyme oils	wide range of microorganisms, including bacteria, yeasts and moulds	Speranza and Corbo (2010)
	Thyme oil	*L. monocytogenes*	Lemay *et al*., (2002); Singh *et al*. (2004)
Seafood Products	oregano oil	*Photobacterium phosphoreum*	Speranza and Corbo(2010)
	thymol	Total bacterial count	Del Nobile *et al*. (2009)
	oregano, thyme, basil, marjoram, lemongrass, ginger, and clove	Foodborne Pathogens and Spoilage Bacteria	Barbosa *et al*. (2009)
Vegetables and Fruits	Lemongrass and geraniol	*Salmonella enteritidis, Escherichia coli,* and *Listeria innocua*	Raybaudi-Massilia *et al*. (2006)
	cinnamon, palmarosa, and lemongrass	*Salmonella enteritidis, Escherichia coli*, and *Listeria innocua*	Raybaudi-Massilia *et al*. (2009)
	lemongrass, oregano oil, and vanillin	Total bacterial count	Rojas-Graü *et al*. (2007)
	Clove, eucalyptus, orange rind	*Aspergillus, Mucor* and *Rhizopus*	Lakshmi and Naidu, 2010
	Chiliadenus & Origanum	*Bacillus cereus*, *Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa*	Al-fawwaz and Alsohaili, 2015
Dairy Products	Terpineol	Total microbial count	Fisher and Phillips, 2008
	Chiliadenus & Origanum	*Bacillus cereus*, *Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa*	Al-fawwaz and Alsohaili, 2015
	Basil, Caraway, Coriander, Dill, lemonbalm	*Bacillus cereus, Escherichia coli, Lactobacillus delbrueckii*, *Listeria monocytogenes, Streptococcus thermophilus*	Mohamed *et al*., 2013
	Thyme	Total bacterial count, coliforms, enterococci	Dostálová *et al*., 2013
Cereal-Based Products	thymol		Del Nobile *et al*. (2009)
	lemon balm, garden sage, coriander, thyme, peppermint, cinnamon	*Fusarium, Aspergillus*, *Pichia, Saccharomyces* and *Hyphopichia*	Sulaman *et al*., 2013

MECHANISM OF ANTIMICROBIAL ACTION OF ESSENTIAL OILS

The antimicrobial activity of essential oils is related to the respective composition of the volatile oils, the structural configuration of the constituent components of the volatile oils and their functional groups. As EOs are a complex mixture of diverse constituents hence the antimicrobial action can't be explained due to a single molecule. Additionally, each microbial cell has different target sites. Cell wall, cell membrane, cell proteins and specific enzymes includes some of the target sites. Quorum sensing, cell division and production of micobial toxins can also be altered by EOs and their constituents (Table

2). The susceptibility of different microorganisms differs; the difference may also be observed between different strains. In addition, intrinsic and extrinsic conditions are also responsible for susceptibility and resistance of pathogens towards EOs (Singh and Malik, 2008).

Some active constituents have been associated with the antimicrobial activity (Prabuseenivasan *et al*., 2006). Terpenes, the backbone of EO structure have either low or nil antimicrobial activity (Hyldgard, 2012; Rao *et al*., 2010). The hydroxyl group was found to be important in the antibacterial activity and swarming inhibition of *P.mirabilis* (Malik *et al*., 2015b). Mostly alcohols, phenols and aldehydes are considered to be responsible for the cytotoxicity of essential oils (Bruni *et al.*, 2003). Alcohols are known to possess bactericidal rather than bacteriostatic activity against vegetative cells (Malik *et al*. 2015a). Phenolic compounds, such as thymol and carvacrol, cause structural and functional damages to the cytoplasmic membrane (Sikkema *et al*., 1995). Thymol causes the disruption of both outer- and inner membranes, interacts with membrane proteins and intracellular targets of microbial cell (Hyldgard, 2012). Eugenol inhibits various enzymes such as ATPase, histidine decarboxylase, amylase, and protease recovery is impaired (Gill & Holley, 2006).

The primary mode of action of yeast cells is proposed to be the inhibition of cell division. The other antifungal mechanisms include the disruption of membranes, mitochondrial enzymes and sterol biosynthesis (Hyldgard, 2012).

Pronounced antimicrobial activity is also explained due to higher number of unsaturated bonds in the structure of EO constituents. The presence of formate moiety in the structure appeared to increase the activity of parent compound. The formate group acts like a hetero atom which increases the antimicrobial activity because of presence of lone pairs of electrons (Malik *et al*. 2015b; Dorman and Deans, 2000). Several antimicrobial studies have shown that Gram- negative bacteria are usually less susceptible than Gram-positive bacteria. Lesser susceptibility can be explained due to the outer membrane of Gram- negative bacteria in which hydrophilic lipopolysaccharides (LPS), acts as a barrier toward macromolecules and hydrophobic compounds (Perricone, 2015; Trombetta *et al*., 2005). Among the Gram-positive bacteria, Lactic acid bacteria are observed to be the most resistant; can be attributed to ATP generation by substrate level phosphorylation (Perricone, 2015) (Table 2).

ESSENTIAL OILS IN MOOD FOODS AND BEVERAGES

The mechanism of physiological relaxation due to aroma is explained as the stimulation of the olfactory system and production of signals that project to the olfactory bulb, where smell images are produced. These images are then analyzed and are recognized by the brain (Buck, 2000). Hence EO containing functional foods can also be developed as ‘mood foods and beverages’, which may be designed to enhance mental performance, brain function and cognitive ability. Among the other substances such as chocolate, caffeine etc, EOs also bring about transient mood changes (Hammersley & Reid, 2009). EOs such as Lavender, Hiba and Vanilla have been tested and validiated experimentally for their anti-anxiety properties (Moss *et al*., 2008; Martin, 1996).

The olfactory impact of EOs of Lavender (*Lavandula angustifolia*) and Rosemary (*Rosmarinus officinalis*) on cognition and mood has been evaluated. Rosemary EO has shown significant enhancement of performance for overall quality of memory and secondary memory factors (Moss *et al*., 2003). Aroma of *Salvia officinalis* has resulted in significant enhancement effect in the quality of memory factor (Fu *et al*., 2013). Hence, their oral consumption may also prove to be beneficial in improving

Table 2. Different targets in a bacterial cell on which EO and their constituents act

Targets in Microbial Cell	Essential Oil/Chemical Component	Tested Microorganisms	References
ATP and ATPases	Eugenol & Carvacrol	*Escherichia coli, Listeria monocytogenes* and *Lactobacillus sakei*	Gill and Holley 2006;
	Oregano	*Listeria monocytogenes*	Caillet and Lacroix, 2006
	Cinnamaldehyde	*Escherichia coli, Listeria monocytogenes* and *Lactobacillus sakei*	Gill & Holley, 2006
	Cinnamaldehyde	*Bacillus cereus*	Kwon *et al.,* 2003
Cell wall	Oregano	*E. coli*	Gaunt *et al.,* 2005
	Eugenol or carvacrol	*E. coli, Listeria monocytogenes* and *Lactobacillus sakei*	Gill and Holley, 2006
Increase in permeability of Cell Membrane, cell lysis, leakage of cell contents	African basil	*E. coli, Klebsiella sp., L. innocua, L. monocytogenes,Proteus mirabilis, Pseudomonas aeruginosa, Salmonella enteritidis, Shigella flexneri, Staphylococcus aureus*	Nakamura et al.(1999), Cimanga et al.(2002), Nguefack et al.(2004)
	Bishop's weed (carom,ajwain)	Gram-positive strains Gram-negative strains	Paul (2011)
	Vanillin	*E. coli*	Fitzgerald *et al.,* 2004
	Carvacrol, Thymol, and trans-cinnamaldehyde	*E. coli* and *S. typhimurium*	Helander et al.,1998
	Carvacrol	*Bacillus cereus*	Ultee *et al.,* 2002
	Thymol and carvacrol, Oregano	*Pseudomonas aeruginosa* and *Staphylococcus aureus*	Lambert *et al.,* 2001
Inhibition of cell division	Cinnamaldehyde	*E. coli*	Domadia *et al.,* 2007
Inhibition of microbial toxin	Carvacrol	*B. cereus* (diarrheal toxin)	Ultee and Smid, 2001
	Oregano	*S. aureus (*enterotoxin)	De Souza *et al.,* 2010
Specific enzymes	Cinnamon	*Pseudomonas aeruginosa* and *Staphylococcus aureus*	Bouhdid *et al.,* 2010
Quorum sensing	Cinnamaldehyde	*Vibrio harveyi*	Niu et al.,2006; Gilbert,2006; Brackman *et al.,* 2008
	Clove oil	*Chromobacterium violaceum* and *Pseudomonas aeruginosa*.	Khan *et al.,* 2009
	Rose, geranium, lavender and rosemary, eucalyptus and citrus oils	*Chromobacterium violaceum* and *Escherichia coli*	Szabo *et al.,* 2010
ATP and ATPases	Eugenol & Carvacrol	*Escherichia coli, Listeria monocytogenes* and *Lactobacillus sakei*	Gill and Holley 2006;
	Oregano	*Listeria monocytogenes*	Caillet and Lacroix, 2006
	Cinnamaldehyde	*Escherichia coli, Listeria monocytogenes* and *Lactobacillus sakei*	Gill & Holley, 2006
	Cinnamaldehyde	*Bacillus cereus*	Kwon *et al.,* 2003
Cell wall	Oregano	*E. coli*	Gaunt *et al.,* 2005
	Eugenol or carvacrol	*E. coli, Listeria monocytogenes* and *Lactobacillus sakei*	Gill and Holley, 2006

continued on following page

Table 2. Continued

Targets in Microbial Cell	Essential Oil/Chemical Component	Tested Microorganisms	References
Increase in permeability of Cell Membrane, cell lysis, leakage of cell contents	African basil	*E. coli, Klebsiella sp., L. innocua, L. monocytogenes,Proteus mirabilis, Pseudomonas aeruginosa, Salmonella enteritidis, Shigella flexneri, Staphylococcus aureus*	Nakamura et al.(1999), Cimanga et al.(2002), Nguefack et al.(2004)
	Bishop's weed (carom,ajwain)	Gram-positive strains Gram-negative strains	Paul(2011)
	Vanillin	*E. coli*	Fitzgerald *et al.,* 2004
	Carvacrol, Thymol, and trans-cinnamaldehyde	*E. coli* and *S. typhimurium*	Helander et al.,1998
	Carvacrol	*Bacillus cereus*	Ultee *et al.,* 2002
	Thymol and carvacrol, Oregano	*Pseudomonas aeruginosa* and *Staphylococcus aureus*	Lambert *et al.,* 2001
Inhibition of cell division	Cinnamaldehyde	*E. coli*	Domadia *et al.,* 2007
Inhibition of microbial toxin	Carvacrol	*B. cereus* (diarrheal toxin)	Ultee and Smid, 2001
	Oregano	*S. aureus* (enterotoxin)	De Souza *et al.,* 2010
Specific enzymes	Cinnamon	*Pseudomonas aeruginosa* and *Staphylococcus aureus*	Bouhdid *et al.,* 2010
Quorum sensing	Cinnamaldehyde	*Vibrio harveyi*	Niu et al.,2006; Gilbert,2006; Brackman *et al.,* 2008
	Clove oil	*Chromobacterium violaceum* and *Pseudomonas aeruginosa*.	Khan *et al.,* 2009
	Rose, geranium, lavender and rosemary, eucalyptus and citrus oils	*Chromobacterium violaceum* and *Escherichia coli*	Szabo *et al.,* 2010

the physiological processes of human body. The effect of an experimental drink containing milk casein flavoured with eucalyptus oil has been found to be positive in physiological relaxation. Milk casein is an important ingredient in health assisting foods but has got a bitter taste hence has to be mixed with various flavours, most commonly used is grapefruit-orange flavor. Eucalyptus EO added with casein has shown a beneficial effect on stress control as salivary cortisol levels decreased in the human study subjects (Park *et al*., 2007). The oral consumption of *Salvia lavandulaefolia* EO (50µl) was proved to be a potent inhibitor of human acetylcholine sterase (AChE), lead to improved performance of secondary memory and attention tasks at 1h post dose in human participants (Kennedy *et al*., 2011).

Some EOs can be used as aphrodisiac, for example Nutmeg (*Myristica fragrans)* has been used to improve sexual function and enhances the sex drive, may be used as a safe and effective herbal remedy in treating sexual disorders. Eugenol, a constituent of number of EOs including has also been used as an aphrodisiac because of its vasolidatory and smooth muscle relaxant properties (Okonkwo & Ogu, 2014; Tajuddin *et al*., 2005; Tajuddin *et al*., 2003).

The consumption of peppermint EO (in the form of decaffeinated tea) has been observed to improve performance of individuals in a memory task and physiological measures. Peppermint intake produces calming effects, reduces both the heart rate and blood pressure, increases EEG activity (Fox *et al*., 2012).

Peppermint aroma causes an improvement in tasks related to attentional processes, virtual recognition memory, working memory, and visual-motor response. Ingestion of peppermint EO also improves athe-letic activity as it has significant effects on the spirometric measurements (FVC_1, PIF, and PEF), visual reaction time, audio reaction time, systolic blood pressure, diastolic blood pressure, heart rate, breath rate, grip force, vertical jump test, and long jump test (Meamarbashi,2014).

The fragrances of EOs and their main components affect the autonomic nerves, lipolysis and appetite in experimental animals. For example in study grapefruit oil and its major component, limonene enhanced the renal sympathetic activity (RSNA) and suppressed gastric vagal (parasympathetic) nervous activity (GVNA). The plasma glycerol concentration was increased while the appetite was decreased. Opposite effects on the autonomic nerves, the plasma glycerol concentration and appetite were observed with stimulation by the aroma of lavender oil and its major component, linalool (Shen *et al*., 2005a; Shen *et al*., 2005b).

The shelf life of unpasteurized fruit juices can be increased with the addition of EOs. Apple, pear,and melon juices when added with Lemongrass and geraniol, were found effective against *E. coli*, *Salmonella* sp., and *Listeria* spp. (Raybaudi-Massilia *et al*.,2006). Eucalyptus EO has been found to be a potent inhibitor of spoilage yeasts in mixed fruit juice (Tyagi *et al*., 2014).

To further enhance the health benefits EOs are also proposed to be used as additives in fermented drinks. EOs flavoured fermented milk products such as flavoured curd beverages or flavoured yogurt will not only provide protection against the gut pathogens, but will also curb the antibiotic resistant microorganisms and are also proposed to increase their shelf life. These beverages will function as both probiotic health product and preventive antimicrobial product against enteric pathogens (Hitoshi, 2012; Shipradeep *et al*., 2012). EOs are also deveolped in solid dosage forms as chewable tablets or orally disintegrating tablet consisting of eucalyptus oil, peppermint and clove essential oil releases essential oil in the oral cavity or in gastrointestinal cavity. These essential oils when ingested prior to bed will improve the quality of sleep. Sodium chloride added to it would further increase its antimicrobial activ-ity (US 20110150995 A1).

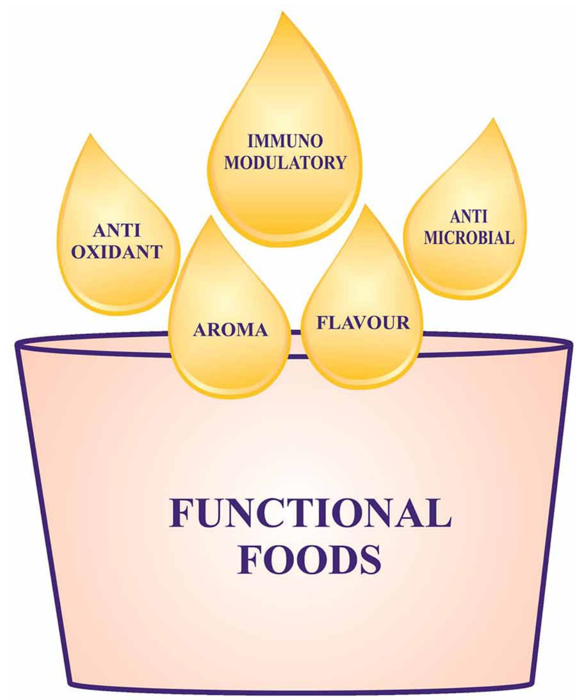
This extensive review depicts the remarkable antibacterial, antifungal, antioxidant, anti-carcinogenic and biological properties of EOs. Hence the unique combinative properties of essential oils will not only impart a pleasing aroma but will also enhance the health benefits of functional foods (Figure 1).

ESSENTIAL OILS IN EDIBLE FILMS AND PACKAGING

The use of edible films and coatings (EFC) is a new alternative to extend the shelf life of food items. Edible films and coatings are made from food-grade proteins and carbohydrates, are also compostable and biodegradable (Falguera *et al*., 2011; Debeaufort *et al*., 1998). These can also be consumed with the food product **;** functions as barriers to water vapour, oxygen, and carbon dioxide and may also carry substances to inhibit pathogenic and spoilage microorganisms (Miksusanti & Masril, 2013) . Natural antimicrobial agents can also be incorporated, leads to the development of antimicrobial edible films and coatings (AEFC) (Sánchez-González *et al*., 2011; Maftoonazad & Badii, 2009).

Since EOs are considered as Generally Regarded As Safe (GRAS) by US – FDA (Kim *et al.*, 1995), these could be added into the food packaging as antimicrobials. Their addition into food items not only enhances the flavour of packed food, but also inhibits the growth of microorganisms (Hosseinii *et al*., 2013; Maftoonazad & Badii, 2009).

Figure 1. Combinatorial properties of essential oils because of which they can be used as constituents in functional foods



The incorporation of EO is multifunctional, hence it is termed as "active or smart packaging". Packaging of EOs modifies the matrix of films improves water vapour barrier properties of protein-based films, increase the strength of the film and its resistance to stretching, the transparency, and probability of food spoilage are also reduced (Maftoonazad & Badii, 2009; Perez-Gago *et al*., 2006;). A starch edible film incorporated with Ginger EO showed best antibacterial and antioxidant activity at 3% EO concentration (Miksusanti & Masril, 2013).

Addition of EOs to edible films is an advanced approach for the preservation and extension of shelf life of meat products. Whey protein edible film incorporated with essential oils (cinnamon oil, clove oil, anise oil, turmeric oil, guava leaf oil, nutmeg oil and lime oil) in different concentration were found to be inhibitory against major molds (*Aspergillus flavus*, *Penicillium* sp.) and bacteria (*Staphylococcus aureus*) which are usually found on dried fish (*Decapterus maruadsi*) (Matan, 2012). Soy protein edible films incorporated with different concentration of oregano (OR) or thyme (TH) essential oils were found to be highly inhibitory for *Escherichia coli*, *E. coli* O157:H7 and *Staphylococcus aureus.* The inhibitory effects were also observed on fresh ground beef during refrigerated storage at 4 °C (Emiroglu *et al*., 2010).

In the past some essential oils have been reported as anti-quorum sensing in bacteria ((Szabo *et al.*, 2010); which inhibits the cell to cell communication, an important step in pathogenesis of virulent microorganisms. Oregano EO was formulation as a pectin edible film. Pectin-Oregano EO inhibited the quorum sensing not only in *Chromobacterium violaceum*, the model bacteria. But significant inhibitory results were also reported against *Escherichia coli* O157:H7, *Salmonella Choleraesuis*, *Staphylococcus aureus*, and *Listeria monocytogenes* (Alvarez *et al*., 2014).

Edible coatings enriched with EOs have also proved to be beneficial for fresh cut fruits/vegetables improves the antioxidant protection, prevents the browning reactions and hence the consequent quality loss in fruits and vegetables is managed without any adverse effect on their sensory acceptability (Espitia *et al*., 2014; Ponce *et al*. 2008; Rojas-Grau *et al*., 2006).

An edible film was constituted with apple puree solution (APEF) and incorporated with oregano, cinnamon, and lemongrass EOs; was investigated for mechanical, physical and bactericidal properties. Bactericidal activities of APFFS, expressed as BA50 values; defined as the percentage of antimicrobial that killed 50% of the bacteria under the test conditions. BA50 values ranged from 0.019% for oregano oil to 0.094% for cinnamon oil. The addition of EOs also decreased water vapor permeability and increased oxygen permeability of the film (Rojas-Grau *et al*., 2006). In another study, Thyme EO and apple skin polyphenols (ASP) were added to prepare açaí edible films, showed adequate physical-mechanical properties and antimicrobial activity against *Listeria monocytogenes* (Espitia *et al*., 2014). Moreover, the antioxidant activity of edible films prepared from biopolymers of several sources such as fish skin gelatin and chitosan incorporated with different EOs were also found to be higher (Perdones *et al*.,2011; Tongnuanchan *et al*.,2014).

Otoni *et al*. (2014) have developed coarse emulsions and nano-emulsions of different edible films with clove bud *(Syzgium aromaticum)* EO and oregano (*Origanum vulgare*) EOs and then edible film was prepared by adding methylcellulose. The resulting film had higher rigidity and flexibility for packing of bread slices. Even after the storage of 10 days, calcium propionate lost its effectiveness, whereas the edible films carrying EOs droplets delayed the growth of bread mold. The edible films fabricated for the preservation of fruits and vegetables are incorporated with EOs, which acts both as anti-oxidant as well as anti-browning agent. Hence the natural color of the fruits and vegetables are maintained and loss of their bioactive compounds is also minimized (Sitonio & Menegalli, 2014).

LIMITATIONS IN APPLICATIONS OF EOs AS FUNCTIONAL FOODS

This comprehensive review has revealed that EOs have enormous health benefits, however the information on their mode of action, as well as the exact supplementation level and their interaction with food ingredients for desired effects in literature is inadequate. As EOs are marked by an intense aroma, may cause a negative organoleptic impact upon addition in food items even at low concentrations. A threshold concentration has to be worked out which should be effective and also acceptable for the consumers. The variation in organoleptic properties of the final product due to the addition of EO can be managed by a mild temperature treatment. Additionally a mild thermal treatment also enhances the antimicrobial efficacy of the essential oil by influencing the vapour pressure of the molecules (Belleti *et al*., 2007; Gardini *et al*., 2001).

Sometimes it is speculated to increase the concentration of EOs to overcome the loss in effectiveness due to food matrix components; can only be applied to the spicy food items, in others it will result turn food non-palatable and consumers tend to avert due to strong odour (Lv *et al*., 2011). The low yield of EO indicates to these are highly concentrated and hence are not equivalent to the whole plant; should be preferably diluted before application (Balchin, 1996). As these compounds are photosensitive, light may degrade the active compound during storage and deteriorate optical properties like luminosity; hence measures should be taken to eliminate their photo-deterioration (Singh & Malik, 2008).

The interaction of EOs with food matrix is also a matter of concern, as these may interact with fat, protein and starch components, due to which efficacy is lost. High fat content of food reduces the action of EOs in meat products. High amount of fat and/or protein in foodstuffs protect the bacteria from the action of the EO as hydrophobicity of oil increases it dissolves more in the lipid phase of the food, due to which less is available to act on bacterial cells which are present in the aqueous phase (Mejlholm & Dalgaard, 2002). For example, mint oil has lower antibacterial effect on *Listeria monocytogenes* in high fat food (Tassou *et al*., 1996). The low water activity of food also reduces the action of EO on e target bacterial cell (Smith-Palmer *et al*., 2001). The physical structure of food item also determines the efficacy. Antimicrobial effect of EO in broth medium was determined to be higher as compared with the gel against *Salmonella typhimurium* (Speranza & Corbo, 2010).

The random and inappropriate use of EOs in food items may pose certain risks to human health due to mutational events, carcinogenic effects and genetic damages. A bioassay method has been developed for testing the toxicity of essential oils in which the hatching rate of the eggs and different stages in their life cycle has been used as a criterion for toxicity (Svoboda and Hampson, 1998). In animals EOs are administered by stomach tube and chronic feeding studies and their toxicological effects have been determined (Lee *et al*., 2004). Cytotoxicity and genotoxicity tests of these substances on different human cells are evaluated by trypan blue dye exclusion test, MTT assay, single cell gel electrophoresis and DNA diffusion assay; higher concentrations of EOs and their components have shown toxicity (Sinha, 2014). In order to elude the hypersensitivity concerns these have been tested for allergic contact dermatitis and photosensitization (Pednelar *et al*., 2013). Although these have been classified under GRAS by US-FDA; their incorporation in food items should be critically analyzed by the regulatory bodies of different countries so as to evaluate EOs and impose proper regulations for their usage (Sinha, 2014).

FUTURE PERSPECTIVES

As the bioactivity of EOs is altered by food components, pH, temperature and gaseous environments; hence, in order to ensure their safe and effective application, future studies regarding the mode of action of EOs, contraindications, synergistic effects are further required (Hyldgard, 2012). Development of edible films and packaging is an initiative in the preservation of food items. Experts from diverse fields such as nutrition, medical sciences immunology, chemistry, food technology and engineering have to come altogether for pragmatic production of edible films and coating.

EOs and their additive components as phytochemicals can be easily fabricated as microcapsules or nanoparticles, and then can be suitably added to the food items. Microencapsulation includes formation of a robust shell around the EO emulsion droplets, which will be effective for increasing their solubility and stability (Otoni *et al*., 2014; Maftoonazad & Badii, 2009). There should be a release system for EO from packaging or a fuming system inside the packaging to ensure maximum activity of their active compounds (Tongunacha *et al*., 2014).

The future of EOs containing functional foods depends on their practical efficacy in promoting human health. Their efficacy need to be confirmed by large investigating teams of researchers from different areas. Animal model and cell/tissue studies can authenticate the *in-vitro* studies, but the results need to be validated in humans. EOs and antibiotics when administered together have shown synergistic antimicrobial effects (Malik *et al*., 2011; Choi *et al*., 2009). Hence the application of combinations of antibiotics/preservatives/EO components and essential oils can be a futuristic approach in the food preservation (Boire *et al*., 2013).

CONCLUSION

EOs have been traditionally used as ingredients in food items because of their flavour and fragrance. Recently, the addition use of EOs is gaining momentum in dietary industry due to their unique amalgamating properties of aroma and flavour. Functional foods consisting of EOs and their active constituents are now being developed which serves the rationale of anti-oxidant and antimicrobial agent. EOs are associated with additional properties viz. anti-anxiety, mood alleviating, anti-inflammatory and immuno-modulatory, properties; which further enhances the market value of functional foods. Hence, functional foods formulated using EOs have versatile applications; if included in daily diet regimens will potentially reduce the disease burden. Hence these should essentially be included in the diet. Moreover, EOs are now being incorporated into edible films and coatings which constitutes a novel approach for food preservation.

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KEY TERMS AND DEFINITIONS

Aphrodisiac: A food, drink or other thing that stimulates sexual desire.

Carminative: An agent that prevents or relieves flatulence and in infants, may help in treatment of colic.

Cognitive Ability: The mental process of knowing, including aspects such as awareness, perception, reasoning and judgement.

Generally Recognized As Safe: A state label assigned by the FDA (US Food and Drug Administration) to a listing of substances not known to be hazardous to health.

Genotoxicity: Destructive effect on cell's DNA material, thereby causing cancer or mutation.

Immunomodulatory: Capability of modifying or regulating one or more immune functions.

Microencapsulation: The process of enclosing chemical substances in microcapsules.

Nanoparticle: A microscopic particle of matter that is measured on the nanoscale, usually that measures less than 100nanometers.

Phytochemical: A nonnutritive bioactive plant substance, such as flavonoid or carotenoid, considered to have a beneficial effect on human health.

ENDNOTE

[1] http://www.allindianpatents.com/patents/238344-a-process-and-formulation-for-the-preparation-of-enhanced-mango-flavor-beverage.

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Chapter 13
Accepting a New Nano-Tech-Based Technology in the Fruit Storage Industry:
A B2B Perspective From the Middle East

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ABSTRACT

Nanotechnology is increasingly being employed in the areas of food production and packaging. While there exists considerable research that analyses consumer trust and perception of nanotechnology use in the food sector, the B2B sector has widely been neglected. This research project analyzes the influence of perceived quality and psychological factors in adopting a new nano-based technology that increases storage life of fruits and vegetables. The research context is Iran and neighboring countries. The results show that customer acceptance of using nanotechnology is influenced by both quality dimensions (performance, features, reliability, conformance, durability, serviceability, aesthetics, perceived quality) and psychological dimensions such as perceived risk and trust. The research also reveals individual differences in accepting nano-technology, depending on the function held by the employee. The authors interpret the results from a culture perspective.

INTRODUCTION

Nanotechnologies are set to impact the food industry at all stages of production from primary production at farming level, due to advances in pesticide efficacy and delivery (novel formulations and better crop adherence), to processing where emulsion creation and encapsulation have progressed to the nanoscale (Neethirajan & Jayas, 2011). Concrete applications in this area include the development of improved tastes, color, flavor, texture and consistency of foodstuffs, increased absorption and bioavailability of

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nutrients and health supplements, new food packaging materials with improved mechanical, barrier and antimicrobial properties, and nano-sensors for traceability and monitoring the condition of food during transport and storage (2009, http://www.innoresearch.net).

Public perception is crucial to the realization of these technological advances. As contested by Cobb and Macoubrie already in 2004, trust plays an important part in public opinion about nanotechnology. Research in a consumer context has shown that individuals expose different perceptions with regards to the application of these high-tech products: Some believe the benefits of using nanotechnology products outweighs their risk and promote the use of nano-tech products. Other consumers remain more skeptical, partly because they lack familiarity with and knowledge of nanotechnology (Lee, Scheufele & Lewenstein, 2005; Currall, King, Lane, Madera & Turner, 2006). Overall, food-related applications in general are viewed less positively, or at least differently, to other areas of application (Cobb & Macoubrie, 2004). Research shows that this may vary between different cultural or regional contexts (Kahan, Braman, Slovic, Gastil & Cohen, 2008). For instance, the European public seems to be less optimistic about nanotechnology compared with consumers in the U.S. (Gaskell, Eyck, Jackson, Jonathan & Veltri, 2004). The public opinion in Europe compares the commercialization trajectory of emerging applications of nanotechnology frequently to that of genetic modification of foods (Mehta, 2004).

Approaching the development of novel food technologies through the analysis of psychological, social, political and historical issues is an essential element of commercialization. If consumers feel that they can control the consumption of associated products (and of course this requires more widespread industry acceptance of regulated labeling strategies, and international harmonization of labeling requirements), it is anticipated that consumer acceptance is likely to be higher compared to situations where applications are uncontained (in particular in terms of environmental release) and untraceable (Frewer Bergmann, Brennan, Lion, Meertens, Rowe, Siegrist, & Vereijken, 2011). While the focus on consumer perception of nano-technology products has been subject to a considerable number of studies, the B2B context has so far experienced a lack of interest. We aim to close this gap by looking at the effect of nano-technology perception on product acceptance in the B2B market.

This book chapter is structured as follows:

First, the use of nanotechnology in the food industry in general is discussed. Subsequently, the role of public perception in accepting the use of nanotechnology to improve food products is analyzed. Based on this discussion, we shift perspectives towards the B2B market and crystallize differences in dimensions that might impact the acceptance of nanotechnology amongst B2B customers. We derive a model that is tested in countries of the Middle East. We present our findings and couch the results into already existing literature, with the intention to provide some answers from a culture-related perspective. We conclude this article with implications for theory and practice.

THEORETICAL BACKGROUND

The Role of Nanotechnology in the Food Industry

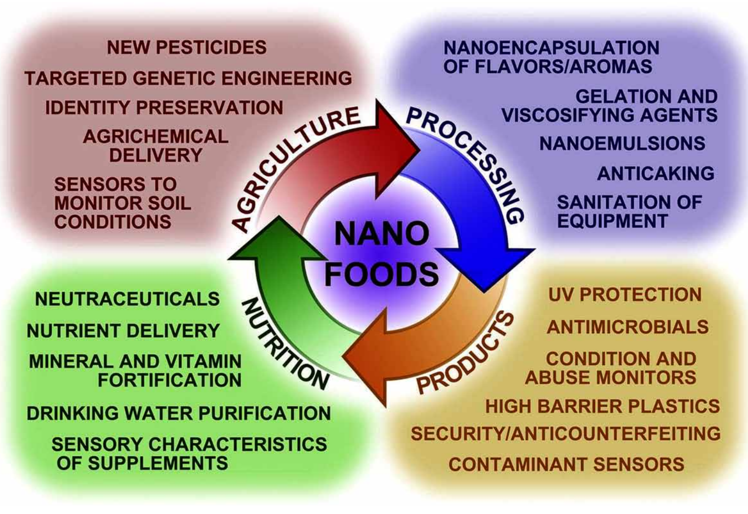
The food and beverage sector is a global multi trillion dollar industry. All major food companies are consistently looking for ways to improve production efficiency, food safety and food characteristics. Extensive research and development projects are ongoing with the ultimate goal of gaining competitive advantage and market share. For an industry where competition is intense and innovation is vital, nanotechnologies have emerged as a potential aid to advances in the production of improved quality food with functionalized properties. Advances in areas such as electronics, computing, data storage, communication and the growing use of integrated devices are likely to indirectly impact the food industry in the areas of food safety, authenticity and waste reduction (Cushen, Kerry, Morris, Cruz-Romero, & Cummins, 2012). Scientists and industry stakeholders have already identified potential uses of nanotechnology in virtually every segment of the food industry, from agriculture (e.g., pesticide, fertilizer or vaccine delivery; animal and plant pathogen detection; and targeted genetic engineering) to food processing (e.g., encapsulation of flavor or odor enhancers; food textural or quality improvement; new gelation or viscosifying agents) to food packaging (e.g., pathogen, gas or abuse sensors; anti-counterfeiting devices, UV-protection, and stronger, more impermeable polymer films) to nutrient supplements (e.g., nutraceuticals with higher stability and bioavailability) (Duncan, 2011). Figure 1 illustrates the applications of nanotechnology in food science, including the focus of this paper.

The Role of Public Perception in Accepting the Use of Nano-Technology for Food Products

Consumer confidence and public trust in nanotechnology are directly linked with having access to understandable information regarding the technology. Such information will allow people to understand what nanotechnology is, how it is applied and its implications for society. Involving citizens with science policymaking through an open debate and analysis of benefits and risks (both real and perceived) of nanotech have been highlighted as one way forward in regulating nanotech (www.euractiv.com, 2008).

Studies examining public perception of nanotechnology in the U.S. and in Europe show that public knowledge about nanotechnology is very limited (Cobb & Macoubrie, 2004; European Commission, 2001; Lee, Scheufele & Lewenstein, 2005). Even though the US public possesses little knowledge about nanotechnology, a majority is convinced that benefits outweigh the risks (Cobb & Macourbrie, 2004). In Europe, the public seems to be less optimistic about nanotechnology compared with the U.S. (Gaskell

Figure 1. Applications of nanotechnology in food science (in this paper we focus on the "product" quadrant" (Duncan, 2011, p.1)



et al., 2004). For instance, a study done by Siegrist, Stampfli & Kastenholz (2009) in a Swiss context shows that consumers are interested in products with additional health effects only when the effect is due to natural additives. Even though these studies provide insights about consumer behaviour, critics say that a major weakness of these studies is that the focus has mainly been on examining attitudes toward nanotechnology as an abstract concept as opposed to attitudes towards real products that have been treated by nanotechnology.

Public acceptance of food products which incorporate or utilize nanomaterials is predicated largely on how much trust the public has in the industry and the government to protect them from unknown hazards (Duncan, 2011). To that end, transparency regarding what companies do and why, is assumed to help leveraging public fears about consuming nano-food products. Unfortunately, a recently published editorial article in the journal Nature Nanotechnology recently asserted that "up to 400 companies around the world are researching possible applications of nanotechnology in food and food packaging and many of them do not want their customers to know this" (www.nature.com, 2010). Even more foreboding: in a report published in 2010, the United Kingdom House of Lords' Science and Technology Committee stated that "far from being transparent about its activities, the food industry was refusing to talk about its work in [nanotechnology] …This is exactly the type of behavior which may bring about the public reaction which [industry] is trying to avert" (www.publications.parliament.uk, 2010). Fact is, the use of nanotechnology may pose potential ecological and health risks as the nanoparticles can be inhaled, swallowed, absorbed through skin or injected into the body whereas the behavior of nanoparticles inside the body is not as yet known. In general, nanoparticles of 70 nm can enter the lungs while a 50 nm particle can enter cells and a 30 nm particle can pass through the blood/brain barrier. Not only can such tiny particles go undetected by the body's immune system, they also exhibit properties not found at the macro-scale (www.etcgroup.org, 2006).

Determinants That Influence the Degree to Which B2B Customers Accept New Nano-Technology

We contest that consumer's acceptance of using nanotechnology for food product improvement is an important driver for realizing the potential growth figures of the nano-tech industry (www.innoresearch.net, 2009, Macoubrie, 2006). Therefore there is reason to assume that also consumer perception and trust may have an impact on the degree to which B2B customers accept new nano-technology affecting food products (Dant & Brown, 2008). In a B2B context there are additional factors that influence new technology acceptance, such as quality management. Garvin (1987) defined quality management as an integrated approach to achieve and sustain high quality output, focusing on the maintenance and continuous improvement of processes and defect prevention at all levels and in all functions of the organization, in order to meet or exceed customer expectations. For our model to develop, we used Garvin's (1987) quality management framework which includes eight critical dimensions of quality: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. We therefore propose:

Hypothesis 1: Quality dimensions AND psychological dimensions impact the degree to which B2B customers accept the use of nanotechnology in the food science.

The perception to which these identified dimensions impact the acceptance of using nanotechnology might vary, depending on the function the person holds (Johnston & Lewin, 1996). In order to account for this fact and to receive in-depth managerially relevant insights, we propose:

Hypothesis 2: Perception of the dimensions that impact the acceptance of using nanotechnology varies, depending on the function of the employee.

Figure 2 illustrates the developed model for testing.

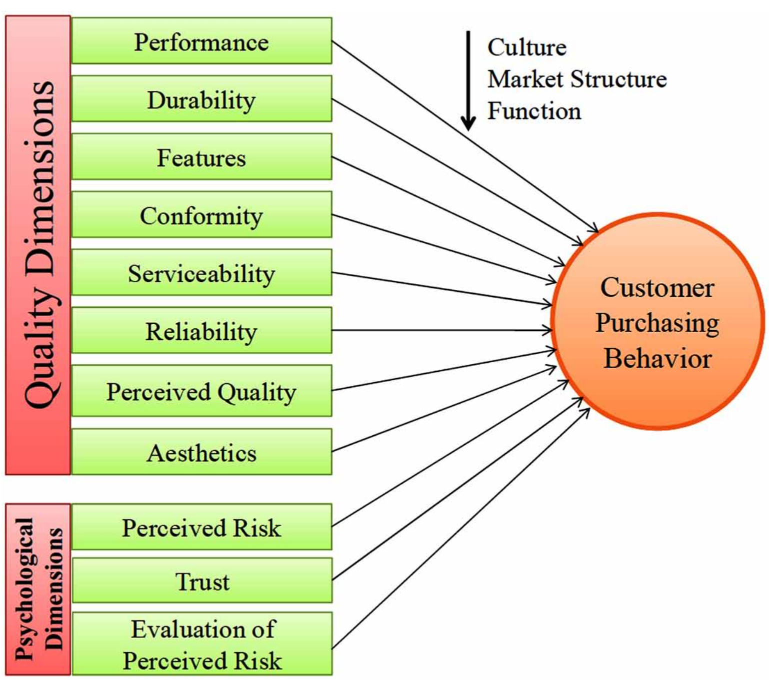
RESEARCH STUDY

The Research Setting

The company "Middle East Bio-Researchers Co. Ltd", located in Teheran / Iran, developed a nano-tech system for the fruit storage industry. The system increases the shelf-life of fruits during cold storage.

Iran is one of the top 10 fruit producing countries worldwide. Unfortunately, due to lack of post harvest technologies, more than 30% of fruits and vegetables (7.6 million tons) are spoiled in postharvest stage. Reduction of this spoilage rate to below 5% will increase profitability of the horticulture sector[1]. Since ethylene gas is one of the most important factors in fruit spoilage, Ethylene Nano-Absorbent technology has a critical effect to reduce fruit post harvest wastes. But would the company's B2B customers accept this new technology?

Figure 2. Developed model to test



The nanotechnology product which was evaluated in this research is the “Ethylene Nano-Absorbent System”. This nano-system includes two parts (Figure 3): A ventilation machine (Figure 3.a) and the nanotechnology part of the system is categorized in nano-Materials (Figure 3.b and c). The nano-materials consist of Ethylene oxidation materials such as potassium permanganate and zeolites (Figure 3.c). During the production process, an inoculation of zeolites by oxidative materials under specific pressure and temperature results in nano-materials. These nanomaterials form nanochannels which have the highest capacity of Ethylene Absorption (Figure 3.d).

In this research we have analyzed companies which are active in fruit supply chain. The fruits which are stored under “Ethylene Nano-Absorbent System” were transferred from orchards after harvest. After storage, the fruits are transferred to auctions or whole sale markets. Then they are transferred to fruit retails shops, supermarkets, hotels and restaurants for consumption. Cold store owners are dealing with fruit growers, whole sellers, importers and exporters. They follow a B2B business model. Figure 4 shows the fruit supply chain.

The sample consisted of 71 companies, of which 51 companies were located in Iran and 20 companies were distributed across UAE, Oman, Azerbaijan, Georgia, Armenia and Turkey. To allow identifying differences in perception, in each company, three people, including the owner, the sales manager and the quality manager, were asked to fill in the questionnaire.

The questionnaire was made up of 40 questions (see Annex 1). For each country, the questionnaire was translated into the spoken language – and back translated in order to ensure that the meaning of the words and terms used for this research were not significantly changed.

In order to avoid biases due to personal relations of the first author, an independent person was employed for distribution and collecting the questionnaires.

In total, 213 questionnaires were usable for data analysis.

Figure 3. Schematic overview of “Ethylene Nano-Absorbent System”

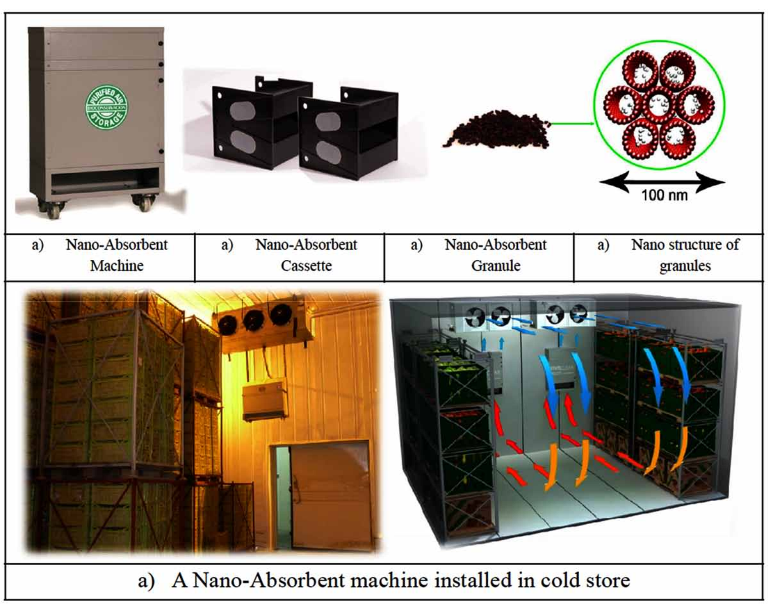
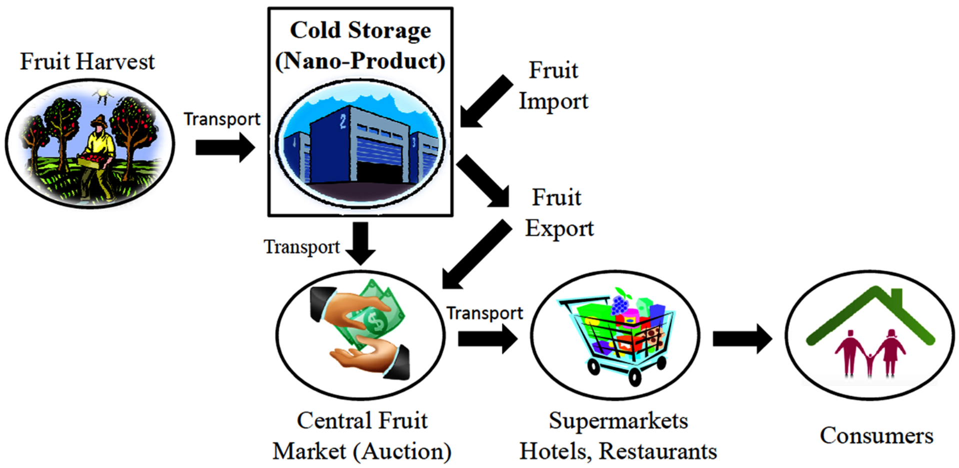


Figure 4. Supply chain of the fruits and vegetables -"Ethylene Nano-Absorbent System" is used in fruit cold stores



Results

The data were analyzed using SPSS software (Ver.17). We used Cronbach's alpha coefficient to analyze the consistency and reliability of the questionnaire. The "t"-test was applied for validating the developed hypothesis. For ranking the dimensions, an analysis of variance (ANOVA), "Duncan" and "Tukey" test were applied.

To check for internal validity, the variables of the research (performance, serviceability, reliability, perceived quality, aesthetics, conformity, features, durability, perceived risk, trust and public perception) and the effect of these dimensions on customers' acceptance of nanotechnology, descriptive statistics such as mean, standard deviation and variance were calculated. These data are summarized in Table 1.

The results of t-test showed that all of ten dimensions have an impact on the likelihood on accepting the use of nano-technology by B2B customers in the food industry (see Table 1).

Table 2 shows that the dimension "aesthetics" had the maximum effect on customer acceptance of nano-technology. This dimension had the maximum average and minimum distribution in comparison with other dimensions. On the other hand, the parameters *good shape*, *less sound* and *proportion with the dimension of rooms* are other items which are very important for the customers. Besides "aesthetics", the dimension "performance" has the maximum effect on the customer behavior of Nano-Product (average: 16.06).

The items "perceived quality, durability and serviceability" showed the minimum relevance for customer acceptance of a nanotechnology product (13.99, 14.44, 14.46 respectively).

The results also show that the items "Perceived Risk" and "Trust" with 75.63% and 75.16% respectively, plays an important, though moderate role in accepting the use of nano-technology.

- **Abbreviations:**
  - **PERF:** Performance,
  - **SERV:** Serviceability,
  - **RELI:** Reliability,

Table 1. T-test

	Test Value = 12					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Performance	19.573	212	.000	4.05634	3.6478	4.4648
Serviceability	10.211	212	.000	2.46479	1.9890	2.9406
Reliability	11.201	212	.000	2.51643	2.0736	2.9593
Perceived quality of "Nanotech Product"	8.797	212	.000	1.99061	1.5446	2.4366
Aesthetics	24.569	212	.000	4.22066	3.8820	4.5593
Conformity	27.117	212	.000	3.84507	3.5656	4.1246
Features	20.009	212	.000	3.11737	2.8103	3.4245
Durability	12.976	212	.000	2.44601	2.0744	2.8176
Perceived risk	15.680	212	.000	3.12676	2.7337	3.5198
Trust	16.886	212	.000	3.25352	2.8737	3.6333

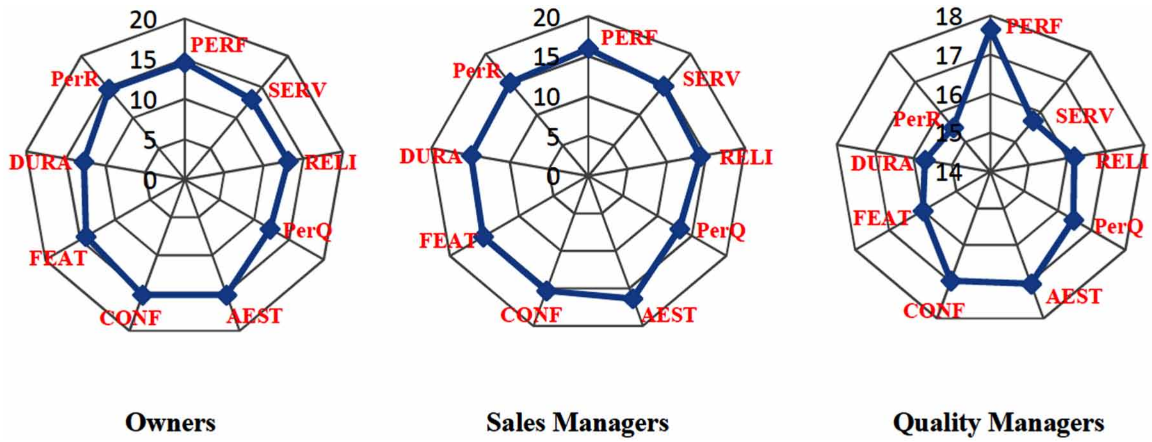
Table 2. Descriptive statistics

Total	PERF	SERV	RELI	Perc. Q	AEST	CONF	FEAT	DUR	Perc. R	T
Mean	16.0563	14.4648	14.5164	13.9906	16.2207	15.8451	15.1174	14.446	15.1268	15.2535
N	213	213	213	213	213	213	213	213	213	213
Std. Deviation	3.02453	3.52283	3.27886	3.30236	2.50719	2.06942	2.27379	2.75118	2.91028	2.81196
Std. Error of Mean	0.20724	0.24138	0.22466	0.22627	0.17179	0.14179	0.1558	0.18851	0.19941	0.19267
Minimum	6	5	5	5	8	12	9	6	7	8
Maximum	20	20	20	20	20	20	20	20	20	20
Variance	9.148	12.41	10.751	10.906	6.286	4.282	5.17	7.569	8.47	7.907
Sum	3420	3081	3092	2980	3455	3375	3220	3077	3222	3249

- **Perc. Q:** Perceived Quality,
- **AEST:** Aesthetics,
- **CONF:** Conformity,
- **FEAT:** Features,
- **DUR:** Durability,
- **Perc. R:** Perceived Risk,
- **T:** Trust

Figure 5 (and in greater detail Annex 2) shows the diversity of feature importance amongst the different people asked. Perception of quality managers in "Performance", "Perceived Quality", "Conformity" and reliability of the Nano-Product is higher amongst quality managers than amongst owners and sales

Figure 5. Difference in perception



managers within companies. On the other hand, owners and sales managers perceive less "risk" when using nano-technology compared to quality managers (see Annex 3: Multiple Comparisons within groups).

The variance within customers groups shows that the customers have different perspectives for the dimensions "Serviceability, Perceived quality and Reliability (12.41, 10.90, and 10.75 respectively." Variance for within customer group dimensions "Conformity and Features" were minimum (4.28 and 5.17 respectively). The results show that customers have a rather similar perception regarding conformity and features of accepting and, subsequently, using nanotechnology for improving the shelf-life of food.

DISCUSSION: AN INTERPRETATION FROM A CULTURE-RELATED PERSPECTIVE

An editorial article published in the journal Nature Nanotechnology asserted that ''up to 400 companies around the world are researching possible applications of nanotechnology in food and food packaging and many of them do not want their customers to know this'', (http://www.nature.com/nnano/journal/v4/n9/pdf/nnano.2009.244.pdf). Currently, there is no mandatory labelling for products containing synthetic nanoparticles. While one might assume that the public as well as other stakeholders have positive views about mandatory labelling, only little is known how such a label influences the risk and benefit perception of a product. Research carried out by Siegrist & Keller (2011) shows that in a consumer context, the research participants may infer that a label is a signal that there are risks associated with this technology. In fact, transparent labeling may cause unexpected reactions on behalf of the consumer (Druckman & Bolsen, 2011). For instance, at a public hearing the invited experts responded to the questions of a consumer group on the use of nanotechnology in food, cosmetics and textiles. Questions about the labeling of nanoproducts repeatedly triggered what was, in some cases, a heated debate. The participants demanded labeling in order to be able to decide for themselves whether they wished to purchase products manufactured using nanotechnology or not. Other important discussions points were the development of suitable analytical methods for the detection of nanoparticles, the disposal of nanoproducts and the provision of funds to carry out research into potential risks (www.lei.wur.nl, 2011; Druckman & Bolsen, 2011). Hence, there is still a big insecurity for managers as whether transparent communication of using nanotechnology in the food sector reduces or increases individual fear.

The results of our research provide indications that the use of nano-technology which does not directly impact the food product is associated with low perceived risk and that public trust towards the use of such nano-technology is rather high. This is different to findings from other researchers such as Kahan et al. (2008). We can identify two issues that provide room for explanation: 1. Culture-related reasons, and 2. the naturalness of the ingredient used in the nanotechnology.

1. Influence of Culture

First, there is reason to believe that this difference in nano-tech acceptance relates to the cultural region of this market. It seems that in Middle Eastern countries, people accept (maybe have to accept) more risk than European or U.S. citizens. Research done by Cobb et. al (2004) shows that a majority of Americans report low trust in business leaders within the nanotechnology industry to protect them from potential risks. Slightly more than 60% of respondents said they had ‘‘not much trust’’ in business leaders’ ability or willingness to minimize risks to humans. The amount of trust respondents have is not significantly related to knowledge about nanotechnology, but it is strongly associated with perceptions of specific potential risks and benefits. Less trust also results in more respondents claiming that risks will outweigh benefits (Cobb & Macoubrie, 2004).

Siegrist et al. (2007) report that cultural influences in different marketplaces will affect the acceptability of nanotechnology-driven products. For instance, a study reported that the Swiss public tends to be less receptive to the use of nanotechnologies in food than populations in China (Siegris et al., 2008). For instance, compared to Japan, USA, and Australia, the use of Active Food Packaging (AFP) in the European market is less receptive due to the more stringent European regulations in food packaging. This trend may also relate to the more conservative customer behaviors in Europe regarding innovations in food (Dainelli et al., 2008) than for example, in Middle Eastern countries.

Second, culture makes people and people do not leave their cultural identity at the company gate. The research was carried in a cultural region which is characterized by high power distance, leading to less integration amongst the different business functions processes (Malhotra et. al., 1994). In other words: While the technical manager may have a positive perception about nano-tech performance, he or she might find no reason to transfer this opinion to others (e.g. owner and sales manager). The high power distance effect leads to protecting his or her own turf (anecdotal note: “I am more important than the nano-system”).

2. Naturalness of the Ingredient Used in Nano-Technology

“Zeolite” is the main nanomaterial of the nano-tech based product researched in this research project. Zeolite is a mineral and natural product. When customers feel the naturalness of the product they trust nanotechnology more and perceive it as less risky to use it. In 2010, LEI Wageningen University & Research Center reported: ‘Naturalness’ plays an important role in customer perception: nanotechnology does not seem to pose a problem as long as it is used naturally (in the eyes of the customer). The obvious question is of course: what do customers consider to be natural? On the other hand, food safety in relation to nanotechnology applications does not yet appear to play a role in customer perception. However, if customers are given more information about both the risks and the actual application of nanotechnology in food production, they become more critical (Allianz, 2005). People are understandably sensitive about changes to the food they eat. In the past the introduction of novel technologies in the food sector has sometimes met with resistance or even hostility. The public's attitude toward food is influenced by a number of considerations including a fear of novel risks, the level of trust in the effectiveness of regulation, and other wider social and psychological factors (shaped by views on health, the environment and science). The development of nanotechnologies in the food sector may well elicit some of these concerns (www.publications.parliament.uk, 2010).

In this research the customers of the Nanotechnology products were more confident about the safety of the "Ethylene Nano-absorbent", as the nanotechnology product has no direct contact with the fruits and there is no perceived risk for contamination of fruits by nanomaterials. In cases where there is a direct impact of nanotechnology with the fruit products, individual perception and acceptance may change towards riskier and less trustworthy. This issue has been confirmed by research of Siegrist, et al. (2007). In this research, participants showed more interest to use nanotechnology packaging than nanofoods.

LIMITATIONS OF THE RESEARCH

First, there is a great bias towards male respondents: most participants (97%) were male and only 3% of the participants were female. In the countries investigated, the fruit supply chain is generally occupied by men.

Second, the fruit business is a seasonal business and therefore gaining access to relevant and potential interview partners outside of the season is very difficult. Therefore, in some cases alternative interview partners had to be found (which might influence the data validity) and the process of data collection extended its initial time plan.

Recommendation for Management

From the viewpoint of a seller of nano-tech systems or products we can make the following recommendations as regarding two relevant managerial questions:

How to Communicate Towards B2B Customers Located in Middle Eastern Regions?

The results of this research show that the asked B2B customers attach low perceived risk to the use of nanotechnology in order to increase the food life storage. Hence, we recommend to use these benefits as selling arguments and to transparently label the use of nanotechnology.

However, the project also shows that there are differences in perception regarding the acceptance of nanotechnology amongst the questioned employees. This lack of coherence can hinder the process of commercialization and marketing of novel technologies. Therefore, for sellers of nanotechnology products or systems we propose to actively engage with the customers and to gradually start a dialogue in order to better understand their needs – sometimes before new technological applications enter the market. This may lead to experiment with a whole spectrum of ways that are designed to involve different agents of the entire value chain: e.g. focus groups, demonstrations, consensus conferences, hybrid forums, etc.

How to Actively Integrating Feedback and Aligning Business Processes to Have a Better Ear Towards the Market?

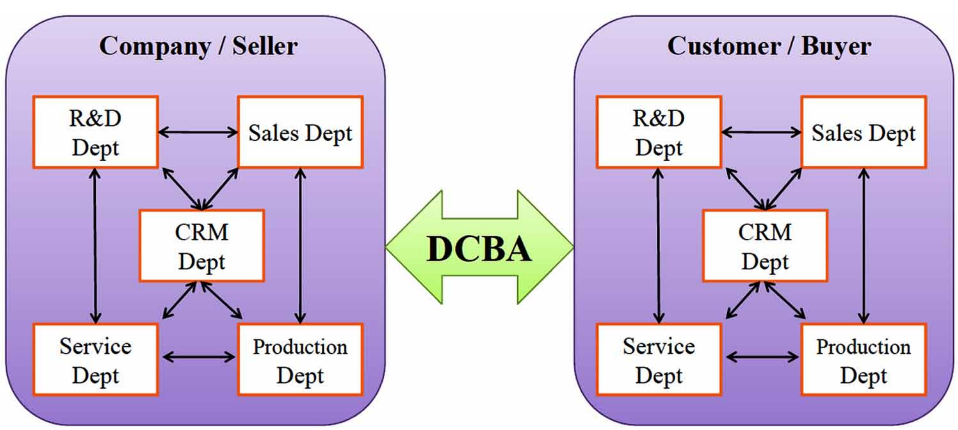
Despite these favorable conditions as regards to public trust in the researched countries of the Middle East, we warn to completely ignore the developing public attitude. In fact, public attitude toward Nanotechnology is at early stages. In the near future, nanotechnology may become increasingly important in the food sector. Consumer / customer acceptance of nanotechnology products and relating uncertainties and concerns about the use of nanotechnology will increase as public knowledge increases, as well as social, economical and political changes within the countries researched will happen. Therefore, for companies trying to sell nanotechnology products or systems we recommend to continuously re-engineer and adopt their production according to their customer / consumer needs. For this, we recommend to integrate and align different company departments (functions) and processes. Such an integrative system is more sensitive to feedbacks from customer, which can then source the re-engineering of underlying business processes like R&D, production, service or sales in order to better amplify the product quality (see Figure 6).

The implementation of such a “Dynamic Customer / Consumer Behavior Analysis (DCBA)” not only helps to leverage different attitudes towards nano-technology products or systems, but also allows responding at early marketing stages to critical voices against the use of nano-technology. This is in line what Siegrist, Stampfli and Kastenholz (2009) suggest in order to maximise customer / consumer quality perception.

FUTURE RESEARCH DIRECTIONS

The current study evaluates the effects of quality and psychological dimensions on the degree of B2B acceptance of nanotechnology in the food industry. Countries in which data was collected included mainly Iran and the surrounding countries. The research provide hints that key to quality management is maintaining a close relationship with the customer, in order to fully determine the customer’s needs, as well as to receive feedback on the extent to which those needs are being met. However, there might

Figure 6. Dynamic customer behavior analysis (DCBA) model



be a big impact of culture or other factors that relate more to the market structure that has an effect on customer integration efforts. Researching these links in these countries would provide knowledge in related areas to better manage despite cultural diversity and differences in markets.

Other potential research avenues open up if looked at this context from a macro economical perspective: an official statistic showed 31% of fruits are spoiled in post harvest stage in Iran. It means that 7.6 Million tons (out of 25 tones) of fruits and vegetables are wasted during handling from orchard to household refrigerators. By development of this Nano-system, the Iranian fruit exporters, producers and cold store owners will make benefits from advantages of this technology. By increasing shelf life and reducing post harvest wastes, the country efficiency of fruit production and export increases. Therefore, research in this area might contribute to the current discussion on the role of modern technologies on different social and political aspects of developing countries such as Iran (Ghazinoory & Ghazinouri 2009), which focuses strongly on the development of high nano-technolgy, nano-composite companies, and information availability (Ghazinoory & Farazkish 2011).

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KEY TERMS AND DEFINITIONS

B2B: Describes or involves business arrangements or trade between businesses, rather than between businesses and the general public.

Food Industry: The food industry is a complex, global collective of diverse businesses that supply much of the food energy consumed by the world population.

Middle-East: The Middle East is a region that roughly encompasses a majority of Western Asia (excluding the Caucasus) and Egypt.

Nanotechnology: Nanotechnology ("nanotech") is the manipulation of matter on an atomic, molecular, and supramolecular scale. Following the definition provided by the National Nanotechnology Initiative, nanotechnology is considered the manipulation of matter with at least one dimension sized from 1 to 100 nanometers.

Regional Culture: The total of the inherited ideas, beliefs, values, and knowledge, which constitute the shared bases of social action.

ENDNOTES

[1] Company internal data

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APPENDIX 1

Table 3. Questionnaire design & frequency distribution of answers

ID*	QN*	Questions/ Determinants	1	2	3	4	5
Performance	1	The performance of the "Nano-tech Product" matches my expectations.	2	16	18	96	81
	2	The higher performance of the "Nano-tech product" in fruit quality protection is due to the use of nanotechnology.	0	17	77	88	31
	3	This "Nano-tech product" absorbs Ethylene gas very fast.	2	19	49	76	67
	4	This "Nano-tech product" increases the shelf life of fruits.	0	6	18	71	118
Serviceability	5	I am exactly told of the "services needed" when using this nano-tech product.	0	9	47	89	68
	6	I can easily access the services offerings by the company.	9	23	45	82	54
	7	I am being promised that everything is done to prevent any errors of this "Nano-tech product".	2	19	88	81	23
	8	The company is flexible in offering discounts and payment terms.	29	51	42	29	62
Reliability	9	I rely that when I use this "Nano-tech product", no damage will occur to my fruits.	12	23	56	109	13
	10	The "Nano-tech Product" is more reliable than that of other competitors who do not use Nano-technology.	0	14	109	78	12
	11	My past experience with this product were so satisfying that I will continue buying this "Nano-tech product.	3	31	60	62	57
	12	By using this nano-tech product I am able to provide better services to our final fruit consumers.	4	11	27	92	79
Perceived quality of "Nanotech Product"	13	The value of the nano-tech product is much higher than its actual costs.	3	38	22	126	24
	14	The "Nano-tech product" in advertisements triggered my decision in buying the nano-tech product.	14	65	44	76	14
	15	I received enough training and technical supports.	1	5	54	102	51
	16	The low maintenance requirement of the nano-tech product is because of its nanotechnology properties.	18	37	57	49	52
Aesthetics	17	The non-tech product can be installed flexibly, depending on the sizes of the cold store rooms.	0	0	28	69	116
	18	The nano-tech product does not produce annoying sounds during application.	0	0	19	124	70
	19	The nano-tech system does not have any negative effects on other equipments during application.	0	2	48	95	68
	20	The abilities of the nano-tech product are appropriate with the visual appearance of the product.	11	24	69	64	45
Cnformity	21	The nano-tech product responds to the technical demands provided by the customers.	0	0	49	132	32
	22	The nano-tech product matches legal fruit quality standards.	0	0	41	136	36
	23	The nano-tech product matches legal health standards.	0	0	41	136	36
	24	The nano-tech product helps customer to achieve quality accreditation certificates.	0	0	40	139	34
Features	25	The motors of the "machine" do not produce high sound levels.	1	1	33	131	47
	26	The quality of fruits is satisfying for the market.	2	1	51	76	83
	27	Our clients are informed about the use of nanotechnology in our fruit cold storage.	7	56	102	21	27
	28	Electricity consumption of the "machine" is low.	0	9	46	105	53
Durability	29	Due to nanotechnology, the disposable part of this product (Nano-absorbent) has a longer active life.	1	3	81	107	21
	30	Durability and longevity of the "nano-tech product" (Nano-absorbent) is acceptable.	4	21	44	85	59
	31	The depreciation time of the disposable part of this "nano-tech product" (Nano-absorbent) is cost effective and affordable.	4	32	31	135	11
	32	Appearance of the "machine" had not a significant change.	8	64	29	54	58
Perceived risk	33	When using this "Nano-tech product", I have more peace of mind to keep the fruits at the best quality.	0	3	29	81	100
	34	I believe this "Nano-tech product" has no health risk for the users of this product and the final fruit consumers.	0	6	62	83	62
	35	I have no ambiguities in using nanotechnology products.	16	74	56	23	44
	36	I trust this "Nano-tech product" is safe.	6	7	71	59	70
Trust	37	I believe that the final consumers appreciate the transparent communication of the product features (based on nano-technology).	0	16	29	136	32
	38	As I am highly satisfied with the nano-tech product, I will purchase other products as well.	1	39	81	68	24
	39	I trust the company to provide good quality of nano-tech products and therefore I think about buying other nanotechnology products.	0	3	79	85	46
	40	I trust this company so much that I recommend others to buy Nanotechnology products.	0	0	41	84	88

ID* Independent Determinant, **QN*** Question Number

APPENDIX 2

Table 4. Analysis of variance between groups (dimensions) and within dimensions

		Sum of Squares	df	Mean Square	F	Sig.
Performance	Between Groups	341.606	2	170.803	22.450	.000
	Within Groups	1597.718	210	7.608		
	Total	1939.324	212			
Serviceability	Between Groups	268.423	2	134.211	11.930	.000
	Within Groups	2362.563	210	11.250		
	Total	2630.986	212			
Reliability	Between Groups	344.347	2	172.174	18.687	.000
	Within Groups	1934.845	210	9.214		
	Total	2279.192	212			
Perceived quality of "Nanotech Product"	Between Groups	683.559	2	341.779	44.076	.000
	Within Groups	1628.423	210	7.754		
	Total	2311.981	212			
Aesthetics	Between Groups	112.939	2	56.469	9.723	.000
	Within Groups	1219.690	210	5.808		
	Total	1332.629	212			
Conformity	Between Groups	135.239	2	67.620	18.379	.000
	Within Groups	772.648	210	3.679		
	Total	907.887	212			
Features	Between Groups	119.474	2	59.737	12.845	.000
	Within Groups	976.592	210	4.650		
	Total	1096.066	212			
Durability	Between Groups	335.615	2	167.808	27.769	.000
	Within Groups	1269.014	210	6.043		
	Total	1604.629	212			
Perceived risk	Between Groups	26.225	2	13.113	1.556	.213
	Within Groups	1769.352	210	8.425		
	Total	1795.577	212			
Trust and Public attitude	Between Groups	108.282	2	54.141	7.251	.001
	Within Groups	1568.028	210	7.467		
	Total	1676.310	212			

APPENDIX 3

Table 5. Multiple Comparisons within groups

Dependent Variable		(I) Responsible	(J) Responsible	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Performance	Tukey HSD	Owners	Sales Managers	-1.42254*	.46294	.007	-2.5153	-.3298
			Quality	-3.09859*	.46294	.000	-4.1913	-2.0058
		Sales Managers	Owners	1.42254*	.46294	.007	.3298	2.5153
			Quality	-1.67606*	.46294	.001	-2.7688	-.5833
		Quality	Owners	3.09859*	.46294	.000	2.0058	4.1913
			Sales Managers	1.67606*	.46294	.001	.5833	2.7688
Serviceability	Tukey HSD	Owners	Sales Managers	-1.71831*	.56295	.007	-3.0471	-.3895
			Quality	-2.71831*	.56295	.000	-4.0471	-1.3895
		Sales Managers	Owners	1.71831*	.56295	.007	.3895	3.0471
			Quality	-1.00000	.56295	.180	-2.3288	.3288
		Quality	Owners	2.71831*	.56295	.000	1.3895	4.0471
			Sales Managers	1.00000	.56295	.180	-.3288	2.3288
Reliability	Tukey HSD	Owners	Sales Managers	-1.16901	.50945	.059	-2.3715	.0335
			Quality	-3.08451*	.50945	.000	-4.2870	-1.8820
		Sales Managers	Owners	1.16901	.50945	.059	-.0335	2.3715
			Quality	-1.91549*	.50945	.001	-3.1180	-.7130
		Quality	Owners	3.08451*	.50945	.000	1.8820	4.2870
			Sales Managers	1.91549*	.50945	.001	.7130	3.1180
Perceived quality of “Nanotech Product”	Tukey HSD	Owners	Sales Managers	-.94366	.46737	.110	-2.0469	.1595
			Quality	-4.18310*	.46737	.000	-5.2863	-3.0799
		Sales Managers	Owners	.94366	.46737	.110	-.1595	2.0469
			Quality	-3.23944*	.46737	.000	-4.3426	-2.1362
		Quality	Owners	4.18310*	.46737	.000	3.0799	5.2863
			Sales Managers	3.23944*	.46737	.000	2.1362	4.3426
Aesthetics	Tukey HSD	Owners	Sales Managers	-1.04225*	.40448	.029	-1.9970	-.0875
			Quality	-1.77465*	.40448	.000	-2.7294	-.8199
		Sales Managers	Owners	1.04225*	.40448	.029	.0875	1.9970
			Quality	-.73239	.40448	.169	-1.6872	.2224
		Quality	Owners	1.77465*	.40448	.000	.8199	2.7294
			Sales Managers	.73239	.40448	.169	-.2224	1.6872

continued on following page

Table 5. Continued

Dependent Variable		(I) Responsible	(J) Responsible	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Conformity	Tukey HSD	Owners	Sales Managers	-.02817	.32193	.996	-.7881	.7317
			Quality	-1.70423*	.32193	.000	-2.4641	-.9443
		Sales Managers	Owners	.02817	.32193	.996	-.7317	.7881
			Quality	-1.67606*	.32193	.000	-2.4360	-.9161
		Quality	Owners	1.70423*	.32193	.000	.9443	2.4641
			Sales Managers	1.67606*	.32193	.000	.9161	2.4360
Features	Tukey HSD	Owners	Sales Managers	-1.01408*	.36194	.015	-1.8684	-.1598
			Quality	-1.83099*	.36194	.000	-2.6853	-.9767
		Sales Managers	Owners	1.01408*	.36194	.015	.1598	1.8684
			Quality	-.81690	.36194	.064	-1.6712	.0374
		Quality	Owners	1.83099*	.36194	.000	.9767	2.6853
			Sales Managers	.81690	.36194	.064	-.0374	1.6712
Durability	Tukey HSD	Owners	Sales Managers	-2.16901*	.41258	.000	-3.1429	-1.1951
			Quality	-2.97183*	.41258	.000	-3.9457	-1.9980
		Sales Managers	Owners	2.16901*	.41258	.000	1.1951	3.1429
			Quality	-.80282	.41258	.129	-1.7767	.1711
		Quality	Owners	2.97183*	.41258	.000	1.9980	3.9457
			Sales Managers	.80282	.41258	.129	-.1711	1.7767
Perceived risk	Tukey HSD	Owners	Sales Managers	-.60563	.48717	.429	-1.7556	.5443
			Quality	-.83099	.48717	.205	-1.9809	.3190
		Sales Managers	Owners	.60563	.48717	.429	-.5443	1.7556
			Quality	-.22535	.48717	.889	-1.3753	.9246
		Quality	Owners	.83099	.48717	.205	-.3190	1.9809
			Sales Managers	.22535	.48717	.889	-.9246	1.3753
Trust and Public attitude	Tukey HSD	Owners	Sales Managers	-.36620	.45862	.704	-1.4487	.7164
			Quality	-1.66197*	.45862	.001	-2.7445	-.5794
		Sales Managers	Owners	.36620	.45862	.704	-.7164	1.4487
			Quality	-1.29577*	.45862	.014	-2.3783	-.2132
		Quality	Owners	1.66197*	.45862	.001	.5794	2.7445
			Sales Managers	1.29577*	.45862	.014	.2132	2.3783

Section 4

Medicinal and Therapeutic Uses

Chapter 14
Herbal Benefits of Tea

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ABSTRACT

This chapter per the authors will introduce the reader to Complementary and Alternative Medicine (CAM) and shall discuss herbalism as a subset of CAM. Particular emphasis will be placed on herbal teas or rather infusions and decoctions used in disease therapy. This chapter will enumerate the different types of teas and shall use maps, graphs, and other tools to illustrate location, consumption, use and availability. Furthermore, the authors will highlight potential health benefits, recent studies (in vitro, in vivo) undertaken by research scientists to validate efficacy, and shall call for more research (clinical data management, clinical trials, etc.) and support for ongoing work in this area of expertise. The authors shall place a spotlight on the plant family, Asteraceae, and their herbal plants of interest, Artemisia annua and Brickellia cavanillesii. Extensive studies have been performed to determine the therapeutic potential of Brickellia cavanillesii plant at Ernest E. Smith laboratory, The Institute of Environmental and Human Health (TIEHH), Texas Tech University, Lubbock, USA.

INTRODUCTION

Complementary and Alternative Medicine (CAM)

The use of complementary and alternative medicine (CAM) in disease therapy dates back to prehistoric man, and has increased exponentially over time. Before the advent of modern science, early humans employed the use of alternative remedies as therapy for disease. Archeological records indicate that during the Stone Age, treatment of biologic disorders involved certain practices. The methods utilized involved a broad spectrum of approaches that is termed CAM by scientists today. Early civilizations embraced these practices as is evidenced in Persian, Greek, Egyptian and Chinese cultures amongst others. CAM continues to grow with concomitant recognition by scientific researchers and healthcare professionals around the globe. The motives for using CAM are variant and may include: to fight disease, to increase

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the body's ability to fight disease, to improve physical and emotional well-being, to counteract ill effect from disease, and as advised by healthcare professionals (Molassiotis, 2005). CAM, as the name connotes, is comprised of diverse medicinal and health care systems, practices, and products that are not typically considered to be a part of conventional medicine. Complementary medicine is used together with conventional medicine whereas alternative medicine is utilized in place of conventional medicine; CAM encapsulates traditional (conventional), alternative and integrative remedies. Treatment may be considered 'complementary' when non-orthodox methods are utilized simultaneously with conventional medicine. When non-orthodox methods are used in place of conventional medicine, it is considered 'alternative.' Approaches that utilize the systematic use of conventional and alternative treatment are termed 'integrative.' The National Center for Complementary and Alternative Medicine (NCCAM) classifies CAM into four distinct categories:

1. Whole medical systems;
2. Mind-body medicine;
3. Biologically based practices; and
4. Manipulative and body based practices (NCCIH, 2015).

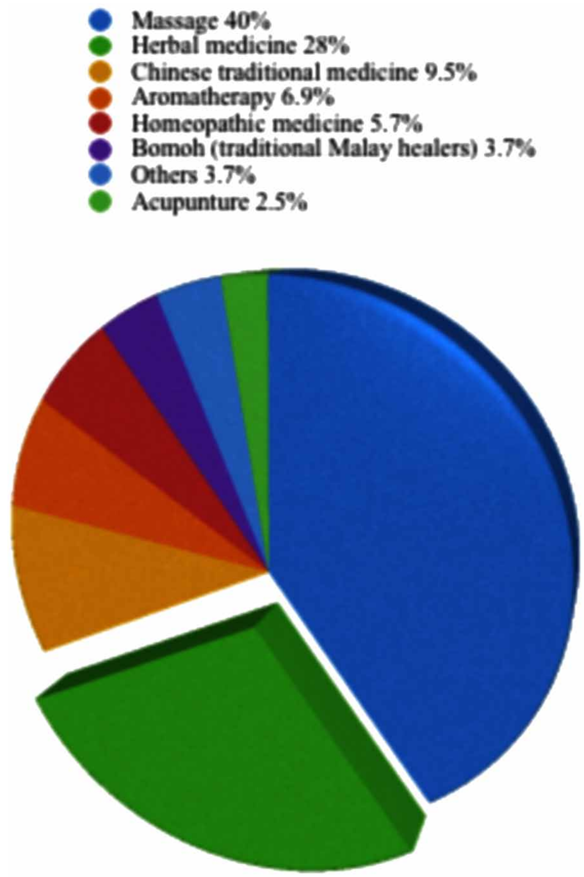
Whole medical systems are built upon complete systems of theory and practice which evolved earlier than and apart from the conventional medical approach used by western cultures. Mind-body medicine employs a variety of techniques designed to enhance the mind's capacity to affect body function and symptoms. Techniques such as meditation, prayer, mental healing and therapies that involve art, music and dance are usually applied by CAM practitioners. Biologically- based practices use substances found in nature such as herbs, foods and vitamin. Manipulative and body based practices involve the manipulation and/or movement of one or more parts of the body and includes chiropractic and osteopathic manipulation and massage therapy (NCCIH, 2015; Eshiet, 2010; Eshiet et al., 2014a, 2014b). This chapter focuses on biological-based practices as is demonstrated in the herbal benefits of tea (herbalism).

Herbalism

Herbalism also known as phytotherapy is an integral component of CAM, and is a veritable source of alternative medicine. The practice of herbalism dates back to primordial periods. Herbalism is a biologically-based practice whereby plants and plant extracts are used in traditional medicine. Plants synthesize many secondary metabolites which are useful for the maintenance of health in humans and other animals. Of these secondary metabolites, less than 10% (~ 12,000) have been isolated (Lai 2004; Tapsell 2006). Herbal plants have been used by all cultures throughout history. Records show that marshmallow root, hyacinth and yarrow were found placed around the bones of a Stone Age man in Iraq (Zand et al., 2003). Marshmallow is a demulcent herb which is soothing to inflamed or irritated mucous membranes such as sore throat. Hyacinth is a diuretic that facilitates the excretion of excess water from the body while yarrow is a renowned cold and fever remedy. Other records show that in 2735 B.C., Sheng Nong, a Chinese emperor, wrote an authoritative exposition that continues to find use today. In his exposition, Sheng Nong suggested the use of Ma Huang (ephedra) against respiratory distress. Ephinedrine, extracted from ephedra, is used extensively as a decongestant and can be found in its synthetic form, pseudoephinedrine, in many allergy, sinus, and cold relief medications manufactured by pharmaceutical companies (Zand et al., 2003). Texts from the ancient cultures of Mesopotamia, Egypt and India describe and illustrate the therapeutic properties of castor oil, linseed oil, white poppies and others. In 1649, one of the first manuals that the layperson could use for health care was written in Europe. It was authored by Nicholas Culpeper and titled "A Physical Directory." A few years later Culpeper wrote "The English Physician." Both manuals enjoyed remarkable respectability and are widely referred to and quoted (Herb Palace 2004). The first U.S. pharmacopeia was published in 1820. It included a compendium of herbal drugs: their properties, uses, dosages, and testing purity. This publication was revised periodically and by the year 1906 it had become the legal standard for medical compounds. However, as western medicine evolved from an art to a science in the nineteenth century, herbalism began to lose its popularity. As scientific methods were developed to extract and synthesize the active ingredients in plants, pharmaceutical laboratories became the producers of drugs. Consequently, in the industrialized parts of the world, herbalism as a customary approach to medicine suffered a significant decline. It is estimated that about 80% of the world population use herbal medicine as primary health care (WHO, 2003; Ekor, 2014). WHO observes that of 119 plant-derived pharmaceutical medicines, approximately 74% are used in modern medicine in ways that relate directly with their native usage. Of over 750,000 plants on earth, only a few have been scientifically studied. Modern pharmacology places emphasis on the active ingredients of herbal plants. Scientists perform research which focuses on identifying and isolating these active ingredients. Herbalism, on the other hand, considers the synergistic interaction of all the components of the whole plant for the treatment of acute and chronic conditions. Examples of herbalistic treatments include Aloe vera which is used traditionally in the healing of burns and wounds (Maenthaisong et al., 2007) and; cranberry (*Vaccinium oxycoccos*) used in treating urinary tract infections in women with recurrent symptoms (Jepson & Craig, 2008).

A study exploring the use of CAM in a subset of patients resident in Kuching, Sarawak, Malaysia may be indicative of the consistent popularity of herbalism as a component of CAM (Lee et al., 2004). This investigation revealed that herbal remedies may be the second mode of therapy after massage (Figure 1). A series of studies performed to determine CAM in the United States of America showed that in 1990 about 33.8% of Americans used alternative remedies which included oral supplements, chiropractic and acupuncture. This percentage rose to 42.1% in 1997. Fifteen million adults took CAM products and prescription drugs simultaneously; approximately 12.1% of patients took herbal supplements while 5.5% took megavitamins. A 2002 medication use in America report indicated that about 14% of the surveyed population used herbal remedies or supplements (Eisenberg et al., 1993; Eisenberg et al., 1998; Kaufman et al. 2002, Shane-McWhorter 2007). Unfortunately, many patients do not inform their physicians of their use of phytotherapies which may lead to potentially dangerous adverse interactions with pharmacotherapies. It cannot be overemphasized that healthcare professionals need to be better informed about herbal products that patients take singularly, or in combination with conventional medications. This invariably will afford clinicians ability to provide patients with excellent advice, and relevant complimentary information for safe administration and monitoring. There is a compelling need to comprehend the potential use, adverse effects, and drug-drug or drug-disease interactions triggered by herbal plants (Shane-McWhorter, 2007). Tea preparations are arguably the most prevalent form of administering herbal extracts. The benefits therein is the subject of this chapter.

Figure 1. Comparative use of complementary and alternative medicine (CAM) amongst Malaysians
Adapted from Lee et al, 2014.



TEA

All definitions agree that the word "tea" is used to refer to an aromatic beverage prepared by either pouring hot or boiling water over cured leaves of the *Camellia sinensis* plant, or from leaves and twigs of certain herbal plants.

Types of Tea

For the purpose of clarity, the authors shall divide tea into two distinct categories; a) conventional tea and; b) medicinal herbal tea.

Conventional Tea

Tea, otherwise known for present purposes as "conventional tea," is a riveting, soothing, gentle, relaxing, mild-mannered drink prepared from the leaves of one of three species – China bush, Assam bush, Java bush - of the plant, *Camellia sinensis* (Theaceae). *C. sinensis*, a sturdy evergreen shrub featuring dark, glossy-green, serrated leaves is originally native to Eastern Asia, an area between North Burma and Southwest China (latitude 29°N and longitude 98°E) (Heiss & Heiss, 2007; Martin, 2007). Flowers are yellowish white, diameter 0.98 – 1.87 inches (2.5 – 4 cm); with 7 to 8 petals. Leaves are 1.6 – 5.9 inches (4 – 15 cm) in length and 0.79 – 1.97 inches (2 – 5 cm) in breadth. Tea is largely consumed for its stimulating, refreshing and medicinal properties. Over time a multitude of methodologies have been developed to process tea for human consumption. Historical records show that tea leaves were steamed, pounded, and shaped into cake form during the Tang dynasty (618-907 AD). Loose-leaf tea was cultivated and enjoyed a surge in popularity during the Song dynasty (960-1279 AD). A technique that allowed tea leaves to remain green was developed during the Yuan (1279-1368 AD) and Ming (1368-1644 AD) dynasties. Unfermented tea leaves were initially pan-fried, and subsequently rolled and dried to interrupt the oxidation process which darkens the leaves. "Black dragon (Oolong) tea," where leaves are allowed to ferment partially (8-85%) before pan-frying, was developed in the 15th Century. Presently, western cultures have a preference for the fully oxidized black tea.

After water, tea is the most widely drunk beverage in the world (Figure 2; Macfarlane & Macfarlane, 2004; Lewis, 2012). *Camellia sinensis* is cultivated in over 30 countries of the world (~ 78% black, ~ 20% green, ~ 2% oolong) (Graham, 1992; Mukta & Ahmad, 2000). About 50 - 60 billion cups of tea is drunk respectively in the United Kingdom and the United States of America every year; in the United Kingdom a per capita intake of approximately 3.5 – 4 cups/person/day is consumed (Ashenef, 2014). Tea's rich, distinct taste characterized by a unique balance of flavor and aroma ranges from the fresh tasting, sweet, delicate green tea (Chinese), the aromatic, flavorful, bracing black tea (Indian), to the carefully tended, fresh, astringent tea (Java). Each tea preparation bears the singular stamp of the culture that produced it. Factors such as soil type, growing conditions, weather conditions, leaf style, pruning, timing of the pickings, skill and experience etc., combine with tradition, culture and terroir to produce the spectacular teas renown all over the world.

Medicinal Herbal Tea

The use of the word "tea" has been expanded to include infusions and decoctions prepared from the leaves and twigs of herbal plants believed to possess ameliorative or therapeutic properties. Medicinal herbal tea may be defined as a beverage prepared by infusion or decoction of herbal plant materials, and served either hot or cold, for the singular purpose of providing relief or healing to the consumer. The plant material used usually determines the mode of preparation. Infusions are made by steeping the plant material i.e. seeds, flowers and leaves in hot (boiling) water. Decoctions are made by gently simmering the plant material i.e. dried seeds, roots and barks in water.

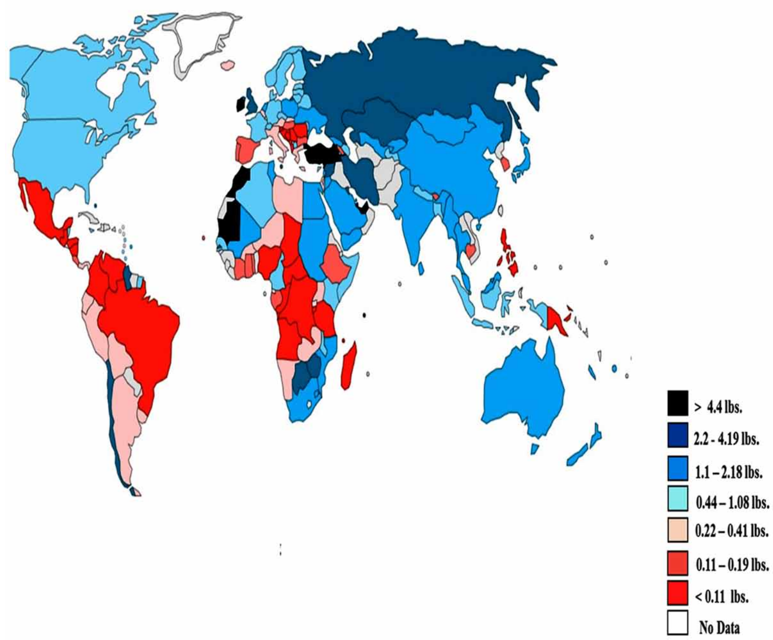
Generic recipe for preparing infusions:

1. Pour a quart of boiling water over 4 tablespoons of dried plant material (~8 tablespoons of fresh).
2. Cover and steep for 30 – 45 minutes.

Generic recipe for preparing decoctions:

1. Place 4 tablespoons of dried plant material (~8 tablespoons of fresh) in a pot of water (1 quart).
2. Slowly bring to a boil.
3. Cover and simmer for 30 – 45 minutes.

Figure 2. Annual per capita tea consumption of 2009
Adapted from Lewis, 2012.



4. Strain (Vinskofski, 2015).

Medicinal herbal tea, consumed largely for its beneficial and remediative properties, is believed to provide therapy for a plethora of health anomalies including the leading causes of mortality such as ischemic heart disease, stroke, chronic obstructive pulmonary disease (COPD), lower respiratory infections, lung cancer (plus trachea and bronchus cancers), HIV/AIDS, diarrhea, diabetes mellitus, and hypertension (Figure 3, WHO, 2014).

Potential Health Benefits

Health Benefits of Conventional Tea

Although tea lovers all over the world drink tea for its invigorating properties and distinctive, distinguished taste, mythology of many races, especially that of the Indochinese, suggest that *Camellia sinensis* may possess a number of remediative characteristics. Literature obtained from scientific investigations reveal that tea may have efficacy in disease therapy. Tea is believed to be rich in certain nutrients, particularly minerals. Volatile compounds, polyphenols, amino acids, proteins, glucides, and alkaloids also make up the complex chemistry of tea. Polyphenols, the most biologically active component of tea, is acclaimed for its anti-carcinogenic, anti-mutagenic and anti-oxidative attributes. Compounds such as fluoride, caffeine, chromium and manganese enable humans meet their daily dietary requirements (Reto et al. 2007). The major constituents of green tea are flavanols, or catechins of epigallocatechin gallate (EGCG), epigallocatechin (EGC), epicatechin gallate (ECG), and epicatechin (EC). The primary polyphenols in

Figure 3. The top ten causes of mortality
Adapted from WHO, 2014.

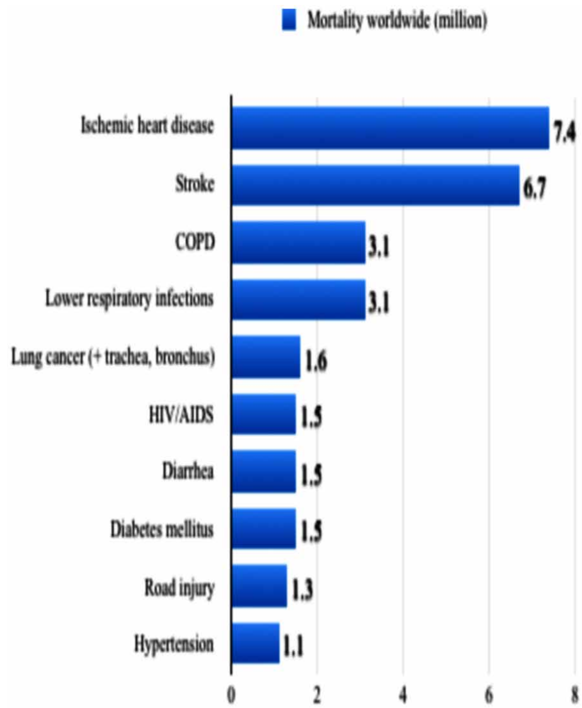
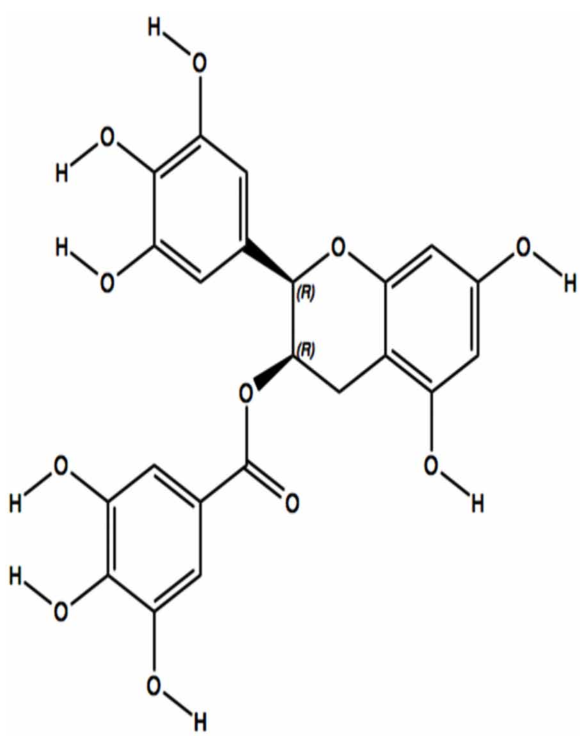


Figure 4. 2D structure of Epigallocatechin gallate (ECGC)



oolong and black tea are theaflavins (i.e. theaflavins, theaflavin 3-gallate,theaflavin 3'-gallate, theaflavin 3, 3'-gallate) and thearubigins (Figure 4-10) (Chan et al., 2011; NBCI, 2015a-f; Chemfaces, 2015). Tea contains the flavonols, quercetin, myricetin and kaempferol (Higdon, 2002; NBCI, 2015g-i, Figure 11-13).

However, an analysis of several studies performed to chemically characterize *Camellia sinensis* indicates that variability exists amongst tea plants grown in disparate locations. This may be due, in part, to localized environmental conditions and soil composition. Crude aqueous extracts taken from different parts of *Camellia sinensis* plant, cultivated in Iran, exhibited significant antiviral activity when exposed to human herpesvirus 1 (HSV-1) *in vitro* (Farahani, 2012). The plentiful content of flavonoids, saponins and terpenes in *Camellia sinensis* may be responsible for its use singly, or in combination, to treat various forms of arthritic and inflammatory disorders. A study performed to assess the anti-inflammatory activity of *Camellia sinensis* in rats implanted with cotton pellet granuloma showed a significant reduction ($P \leq 0.01$) in total leukocyte number, ESR and spleen weight. Inflammation is characterized by tumor, calor, rubor, and function laesia (Mishra, 2014). Experimentation conducted by Chan et al., supports the antioxidant and antibacterial activity of *Camellia sinensis*. Extracts and fractions of variations of *C. sinensis* inhibited the growth of *M. luteus*. *B. cereus*, and *S. aureus* disproportionately (Chan et al., 2011). Human observational studies show that consuming three (24 oz.) or more cups of tea everyday may lead to a reduction (~ 11%) in cardiovascular disease especially myocardial infarction and stroke. *In vivo* studies involving green and black tea is suspected to inhibit the incidence of prostrate, stomach, pancreas, mouth, bladder, skin, esophagus, lung, and colon cancer (Higdon 2002). Further investigations suggest that incorporating tea extracts in dental products i.e. chewing gum, mouthwash, dental floss and

Figure 5. 2D structure of Epigallocatechin (EGC)

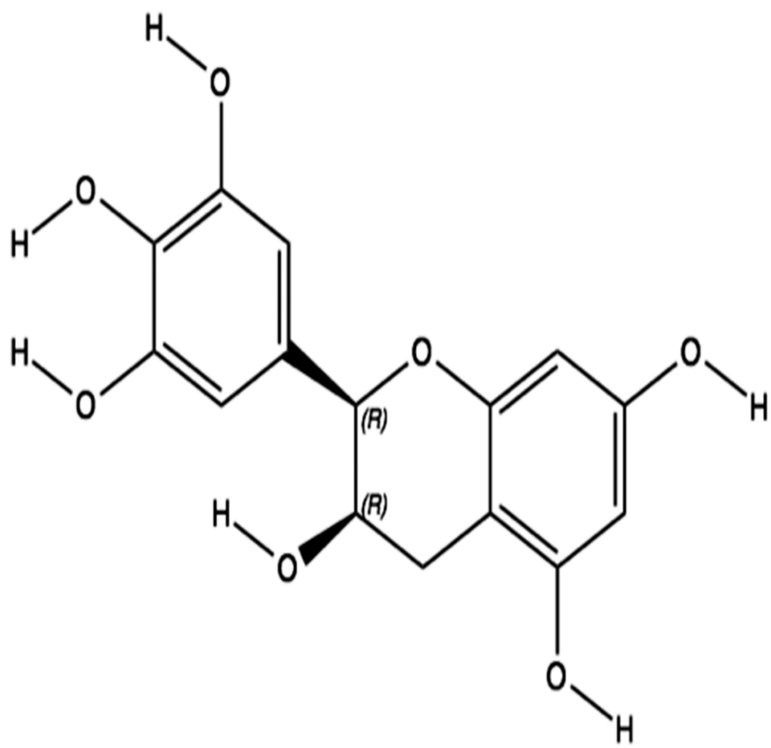


Figure 6. 2D structure of Epicatechin gallate (ECG)

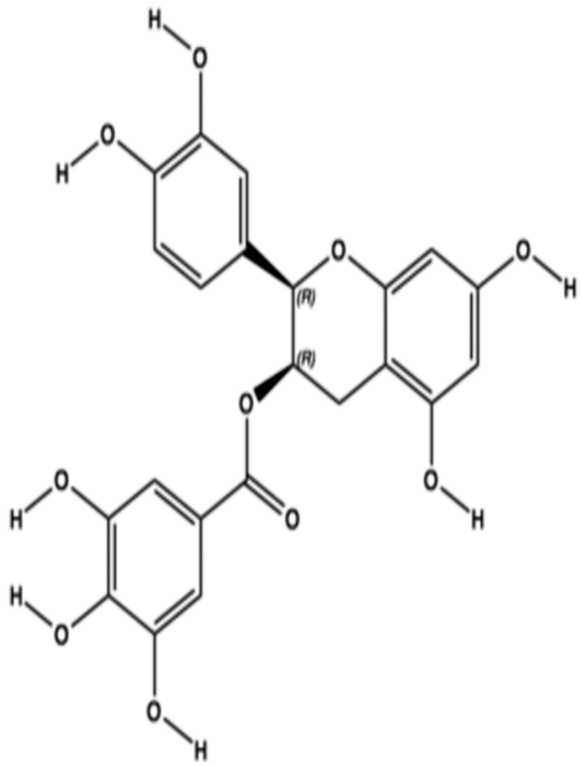


Figure 7. 2D structure of Epicatechin (EC)

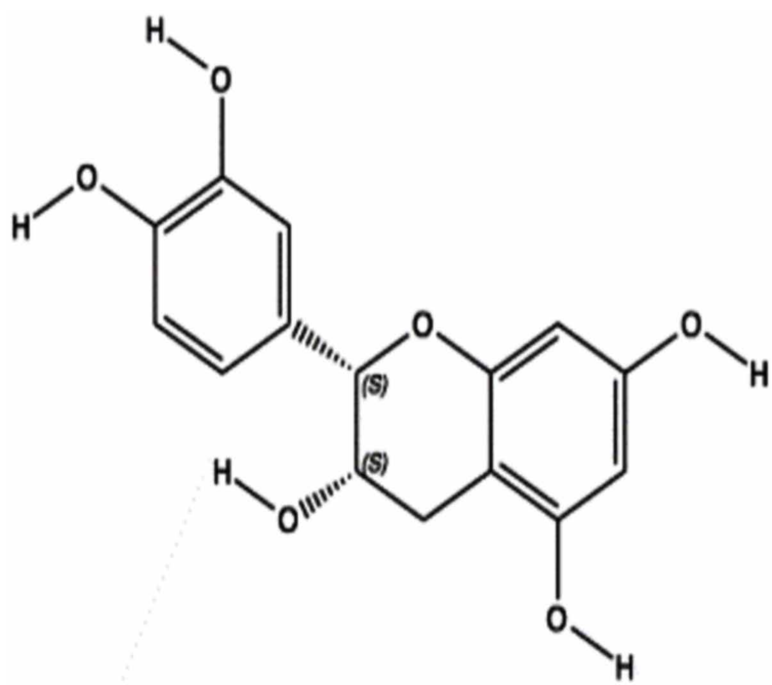


Figure 8. 2D structure of Theaflavin

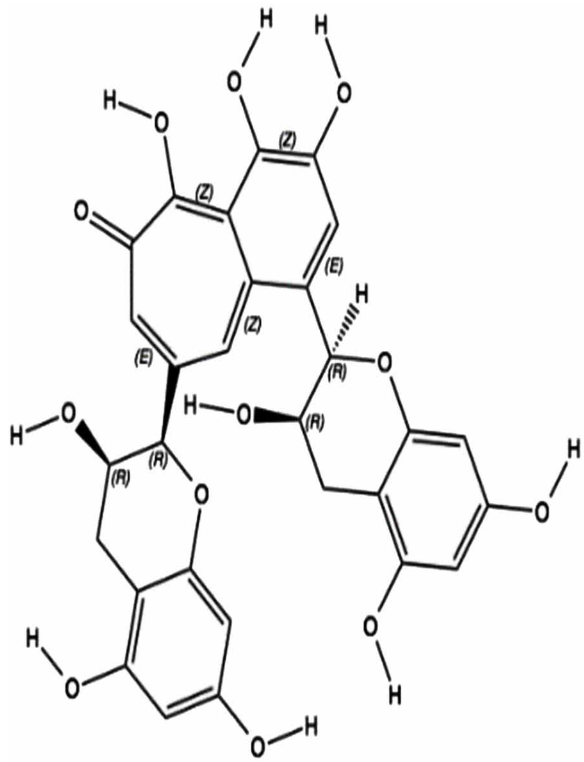


Figure 9. 2D structure of Theaflavin 3 gallate

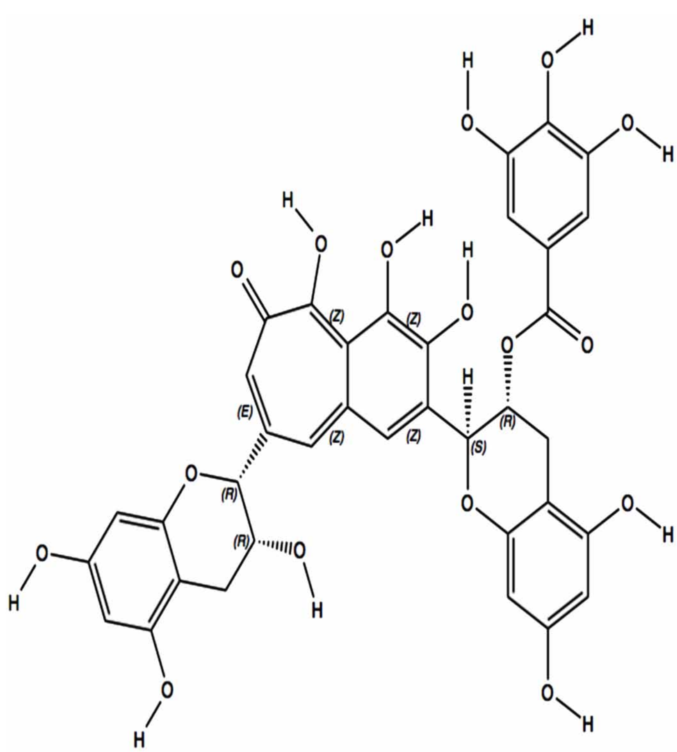
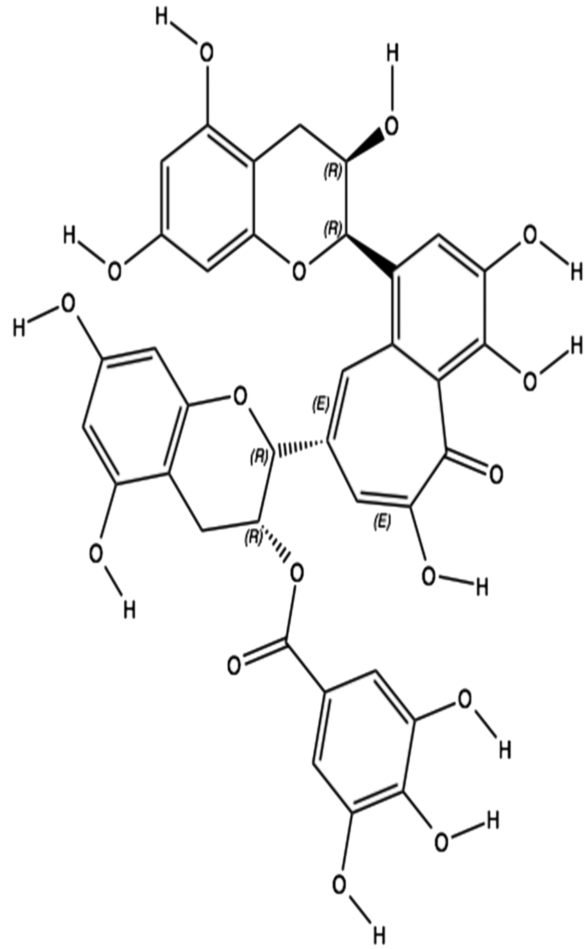


Figure 10. 2D structure of Theaflavin gallate



denitrification may inhibit the development of dental caries (Geonka, 2013). Other interesting laboratory investigations include a study that shows that the frequent drinking of hot tea lowered body mass index (BMI) and reduced mean waist circumference when compared with non-drinkers (men: 25 vs. 28 kg/m^2; women: 26 vs. 29 kg/m^2; both $p < 0.01$) after controlling for cofounders such as age, physical activity, total energy intake etc. (Vernarelli & Lambert, 2012).

Health Benefits of Medicinal Herbal Tea

As previously stated, medicinal herbal tea is a terminology used to describe infusions and decoctions of plants, not including *Camelia sinensis*, consumed primarily for their presumed therapeutic potential in the treatment of a myriad of physiological abnormalities. There are close to a million plants that exist globally. It can be argued that preparations from many of these plants have remediative capabilities. However, it would be daunting to discuss the properties of each plant in this discourse. While some herbal teas have been determined to have promise and are consumed widely, several are yet to undergo scientific determination. This discussion is therefore constrained to focus on plants that have piqued

Figure 11. 2D structure of Quercetin

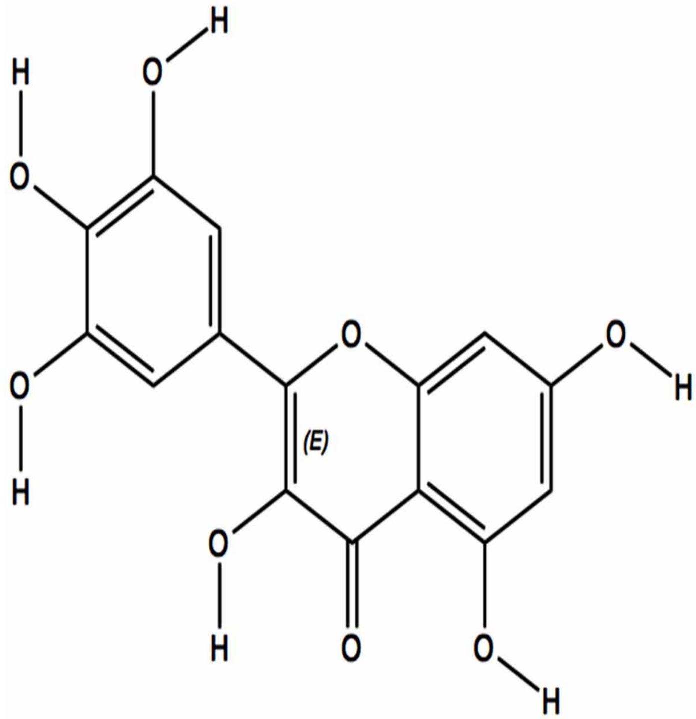


Figure 12. 2D structure of Myricetin

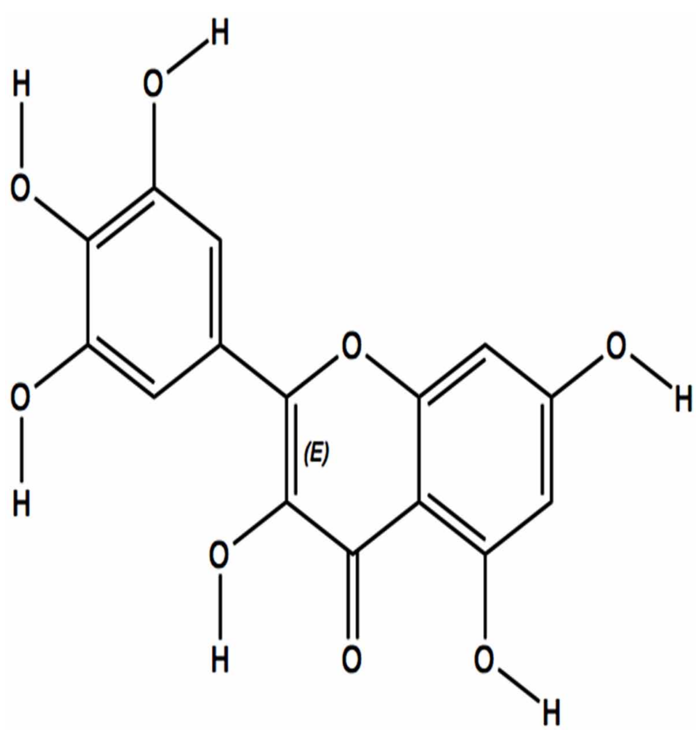
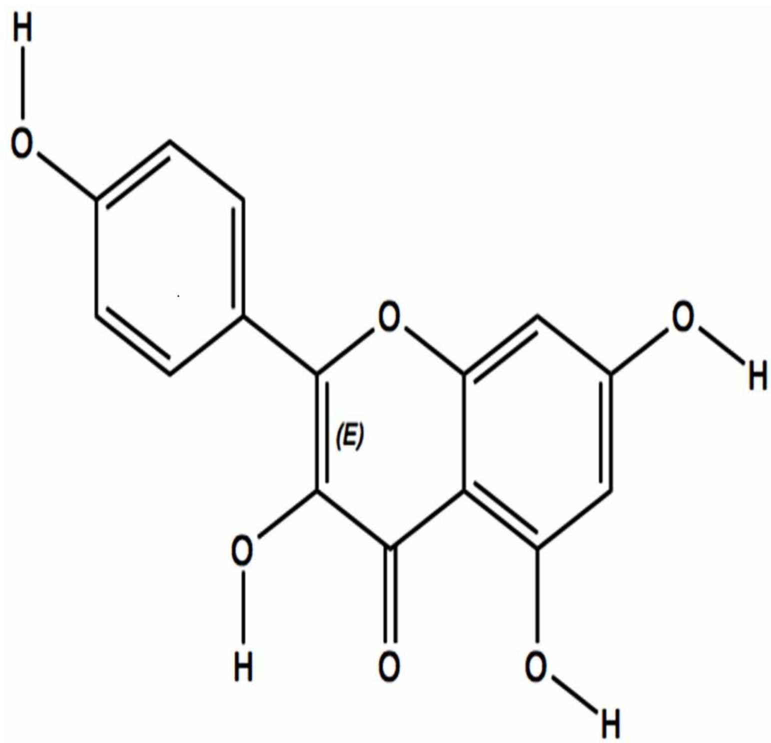


Figure 13. 2D structure of Kaemferol



academic curiosity and have demonstrated some benefit in disease treatment. Plants of primary interest in the present discussion are *Artemisia annua* (Asteraceae), and *Brickellia cavanillesii* (Asteraceae). Plants of the Asteraceae family have been strenuously investigated for their acclaimed medicinal properties. *A. annua*, consumed in the tropical developing countries of South Asia, Africa, and South America for its anti-malarial activity, has been the object of outstanding international recognition leading to the award of one-half of the 2015 Nobel Peace Prize in Medicine or Physiology to Tu Youyou ; *B. cavanillesii*, consumed extensively in neotropical Americas for its hypoglycemic properties, is a subject of vigorous exploratory, investigative research at Ernest Smith laboratory, The Institute of Environmental and Human Health (TIEHH), Texas Tech University, Lubbock, Texas, USA.

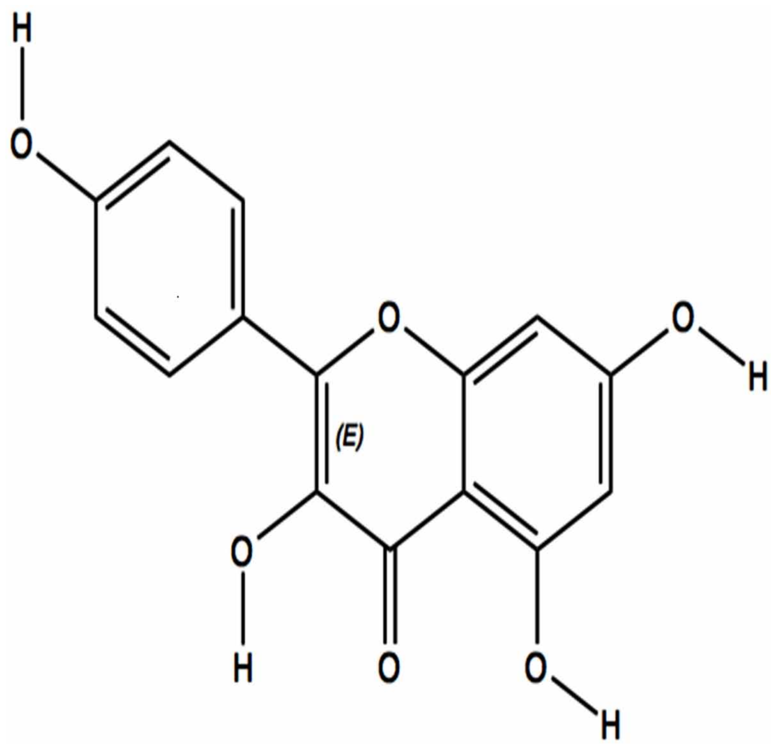
Artemisia Annua (Asteraceae)

Artemisia annua (English name: Sweet wormwood, Chinese wormwood, Sweet annua) is a weed, native to Asia, predominantly China, but now cultivated and naturalized in many countries of the world. *A. annua* is typically about 2 m tall with single stem, alternate branches. Leaves: fern-like, alternating, 2.5 – 5 cm in length, 1-3 cm in width, aromatic odor, deeply dissected. Flowers: tiny, bright yellow, core panicles with capitula 2 -3 mm across. Tea preparations are made using the dried aerial parts of the flowers which are usually collected before full bloom. (Ferreira & Jannick, 1996). The anti-pyretic (fever-reducing) properties of *A. annua* was recognized as early as the 4th century AD (Hsu, 2006). Studies performed show that *A. annua* contains sesquiterpene lactones, flavonoids and essential oils (Klayman et al. 1984). In 1971, Tu Youyou et al., isolated the sesquiterpene lactone compound Artemisinin (qinghaosu) ($C_{15}H_{22}O_5$, MW: 282.33218 g/mol, Figure 14), distilled from the dried leaves and flower clusters of *A. annua*. It is believed that Artemisinin may inhibit the malaria-triggering protozoal organisms in the genus Plasmodium. Artemisinin targets Plasmodium organisms that contain hemozoin, producing radicals that attack the parasite proteins, and ultimately eradicating the organisms. Presently, there are several derivatives of Artemisinin including Artesanate and Artemethen employed in malaria treatment. WHO recommends Artemisinin combination therapy (ACT) as the first-line treatment for uncomplicated malaria (WHO, 2015). Unfortunately, ACT's relatively high cost and inconsistent availability in areas plagued with malaria has led to a call by non-governmental organizations (NGOs) for the use of *A. annua* teas as an alternative therapy in communities where conventional medication is not readily obtained (Wilcox et al. 2011). Because the concentration of Artemisinin in infusions are considered inadequate, the medicinal value of tea preparations of *A. annua* in the treatment of malaria is debatable. However, studies involving clinical trials may suggest otherwise (Mueller et al. 2000; Mueller et al. 2004). Furthermore, in an extensive study ($\geq$ 3,000 patients), infusions of *A. annua* was found to be widely accepted, and well tolerated with few side effects; perhaps, better tolerated than quinine. Participants also had highly encouraging recovery rates (Wilcox et al. 2011).

Brickellia Cavanillesii (Asteraceae)

Brickellia cavanillesii (Asteraceae), is one of the more popular herbal plants consumed in Central America, Mexico, and the southwestern parts of the U.S.A. for the treatment of Type 2 diabetes mellitus (T2DM), stomach ulcers, gastritis, dyspepsia, and pain (Figure 15) . *B. cavanillesii* is a bitter tasting shrub known in many Latin American countries by its Spanish name "prodigiosa," "hamula," or "atanasia amarga" (Figure 16). Prior investigations indicate that *Brickellia cavanillesii* may possess anti-carcinogenic, antioxidative, antispasmodic, antihypertensive, and hypoglycemic abilities (Navarrete et al., 2011; Escandón-Rivera et al., 2012; Mata & Escandón, 2012; Vinas & Smith, 2013; Villarreal et al., 2014; Eshiet et al., 2014a, 2014b; Pérez-Vásquez et al, 2014a, 2014b). It is available commercially in herbal stores and is presently and commonly used by diabetics as a cheaper alternative to insulin. Extant literature states that the chemical composition of *B. cavanillesii* consists of Brickelin, resin, essential oil, fat, tannin, coloring material, gum, starch, chlorophyll, and mineral salts (HHS, 1997). Other characterization investigations reiterate that Brickellin, an O-methylated flavonol, is a major component of *B. cavanillesii*. Proton Nuclear Magnetic Resonance (^{1}HNMR), Carbon-13 Nuclear Magnetic Resonance (^{13}CNMR), and Electron Impact Mass Resonance (EIM) spectra were used to revise and confirm the structure of Brickellin ($C_{20}H_{20}O_9$), 2' 5-dihydroxy-3, 6, 7, 4', 5'-pentamethoxyflavone (Iinuma et al., 1985) (Figure 17). In another study performed on *Brickellia cavanillesii* (Rodriguez-Lopez et al. 2006) a natural product, 6-Acetyl-5-hydroxy-2, 2-dimethyl - 2H – chromene ($C_{13}H_{14}O_3$, MW: 218.252 g/mol, Figure 18) was isolated. Chromene was isolated by subjecting the methanolic extract of *Brickellia cavanillesii* to vacuum liquid chromatography (11 x 3 cm) over silica gel. Subsequently, elution was done with hexane to isolate chromene. Recrystallization from hexane CH_2Cl_2 (75:25) by slow evaporation produced yellow plates (m.p.376.6K) (Rodriguez-Lopez et al., 2006). Literature indicates that chromene is an intermediate in the synthesis of isoencecalin (Ahluwalia & Arora, 1981). Chromene has also been isolated from *Blepharispermun subsessile* (Kulkarni et al., 1987). Chromene belongs to the class of plant secondary metabolites called flavanoids (bioflavonoids) or vitamin P and citrin. Studies done on chromene show

Figure 14. 3D structure of Artemisinin



that it has anti-fungal activity against *Candida albicans* and *Cryptococcus neoformans*. (Agarwal et al., 2000). Bioassay-guided fractionation of active aerial extracts of *B. cavanillesii* resulted in the isolation of:

1. **Chromenes:** 6-acetyl-5-hydroxy-2,2-dimethyl- 2H-chromene and 6-hydroxyacetyl-5-hydroxy-2,2-dimethyl-2H-chromene;
2. **Sesquiterpene Lactone:** Caleins B and caleins C; and
3. **Flavonoids:** Acacetin, genkwanin, isorhamnetin, kaempferol, quercetin, and 3,5-di-O-caffeoylquinic acid (Escandón-Rivera et al., 2012).

High performance liquid chromatography with diode-array detection (HPLC-DAD) methods have also been utilized to confirm the presence of the chromenes: 6-acetyl-5-hydroxy-2, 2-dimethyl- 2H-chromene, and 6-hydroxyacetyl-5-hydroxy-2, 2-dimethyl-2H-chromene, in the infusion of *Brickellia cavanillesii* plant (Perez-Vasquez, 2014).

Quantitative analysis of a methanol extract of lyophilized *B. cavanillesii* using gas chromatography (GC) techniques: a) GC-flame ionization detector (GC-FID); b) GC-Mass spectrometry (GC-MS); c) Purge and Trap GC-MS (P & T GC-MS) resulted in the identification of twenty-one (21) bioactive compounds. The compounds were:

1. Cyclohexene, 6-ethenyl-6-methyl-1-(1-methylethyl)-3-(1-methylethylidene)-, (S)-;
2. Bicyclo (2.2.1) heptan-2-one, 1, 7, 7-trimethyl-(1S, 4S)-;

Figure 15. Distribution of Brickellia cavanillesii

Figure 16. Brickellia cavanillesii (Asteraceae) plant

Figure 17. Pentamethoxyflavone

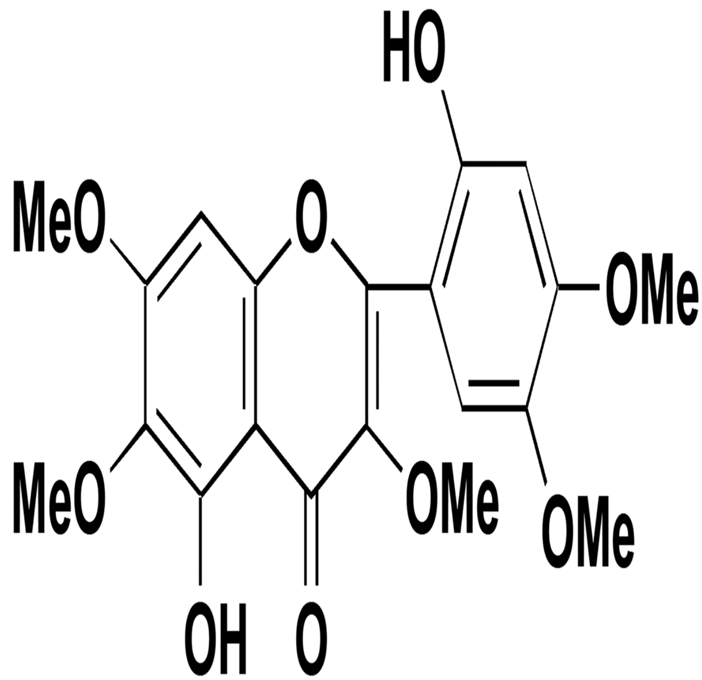
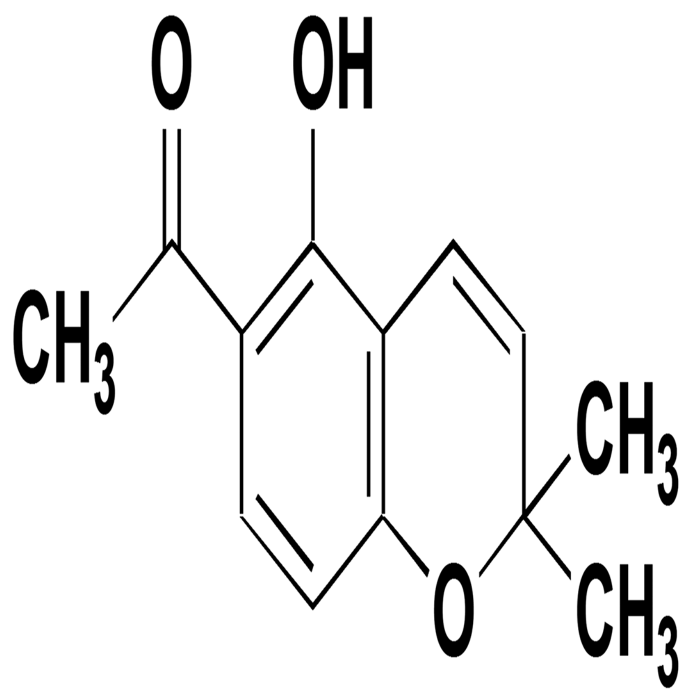


Figure 18. Acetyl-5 hydroxy+ 2-dimethyl-2H-chromene



3. Phenol, 2-methoxy-4-(1-propenyl)-;
4. Benzene, 1-(1, 5-dimethyl-4-hexenyl)-4-methyl-;
5. Naphthalene, 1, 2, 3, 5, 6, 8a-hexa- hydro4, 7-dimethyl-1-1-(1-methylethyl)-, (1S-cis)-;
6. Phenol, 2-methoxy-;
7. Benzaldehyde, 3-hydroxy-4-methoxy-;
8. 11, 13-Eicosadienoic acid, methyl ester;
9. 2-Furancarboxaldehyde, 5-methyl-;
10. Maltol;
11. Phenol;
12. Hydroquinone;
13. 1H-Indene, 1-ethylideneoctahydro-7a-methyl-, (1E, 3a.alpha, 7a.beta.);
14. 3-methyl butanal;
15. (D)-Limonene;
16. 1-methyl-4-(1-methyl ethyl) benzene;
17. Butanoic acid methyl ester;
18. 2-methyl propanal;
19. 2-butanone;
20. 2-pentanone; and
21. 2-methyl butanal (Figures 19-44) (Eshiet et al. 2010; Eshiet et al., 2014a, 2014b).

These compounds, terpenes, derivatives of terpenes, esters, ketones, aldehydes, and phenol-derived aromatic compounds are the primary constituents of the essential oils of many plants and flowers. Several research findings suggest that the identified compounds (**1**-**21**) have measurable medicinal value. Flavonoids have significant anti-inflammatory, antioxidant and antidiabetic attributes (Fawzy et al. 2008); essential oils possess anticancer, antiallergic, cardiovascular, anti-inflammatory and antimicrobial properties (Yamoto & Gaynor, 2001; Ruela de Sousa et al., 2007).

Exploratory *in vitro* toxicological/biological assays investigating therapeutic potential, proteomics and genomics indicate that there may be considerable biological benefit in the lyophilized extracts of *B. cavanillesii* (LBC) (Eshiet et al. 2010; Eshiet et al. 2014b) in the therapy of Type 2 diabetes mellitus (T2DM). Possible therapeutic effects of LBC were concentration dependent with and without fetal bovine serum (FBS). Western blot analysis of glucose facilitated transporter protein 2 (GLUT 2) expression of human carcinoma liver (HepG2) cells exposed to 0 mg/mL (control) and 0.2 mg/mL LBC for 2, 4, 6, and 24 h suggest that GLUT 2 was increased. Increase in GLUT 2 expression in the absence of FBS was statistically significant with time of exposure. Significant difference was observed for GLUT 2 expression between 6 and 24 h and also between 4 and 24 h at 0.2 mg/mL LBC. Gene expression analysis conducted attempted to elucidate a mechanism of action using apoptosis and GLUT 2 gene expression as biomarkers. Observed findings show that several antiapoptotic genes were significantly up-regulated whereas some apoptotic genes were significantly down-regulated. The most significant up-regulation was by BCL2L1; BCL2L1 is reputed to be an apoptosis inhibitor. Data acquired from the GLUT 2 gene expression study suggest that LBC may induce GLUT 2 gene expression and supports claims that *B. cavanillesii* exhibits antidiabetic activity (Eshiet 2010; Eshiet et al. 2014a, 2014b, 2015). Investigative *in vivo* assays demonstrated that dichloromethane-methanol extracts (10-300 mg/kg) obtained from the leaves of *Brickellia cavanillesii* triggered a dose-dependent reduction of ethanol-induced gastric lesions in rats (ED50 = 30 mg/kg); gastro-protective effect of *B. cavanillesii* was demonstrated to be the

Figure 19. Packet containing Brickellia cavanillesii leaves and twigs (front)

Figure 20. Packet containing Brickellia cavanillesii dried leaves and twigs (back)

Figure 21. Twigs of Brickellia cavanillesii (Asteraceae)

Figure 22. Powder of Brickellia cavanillesii (Asteraceae) dried leaves and twigs

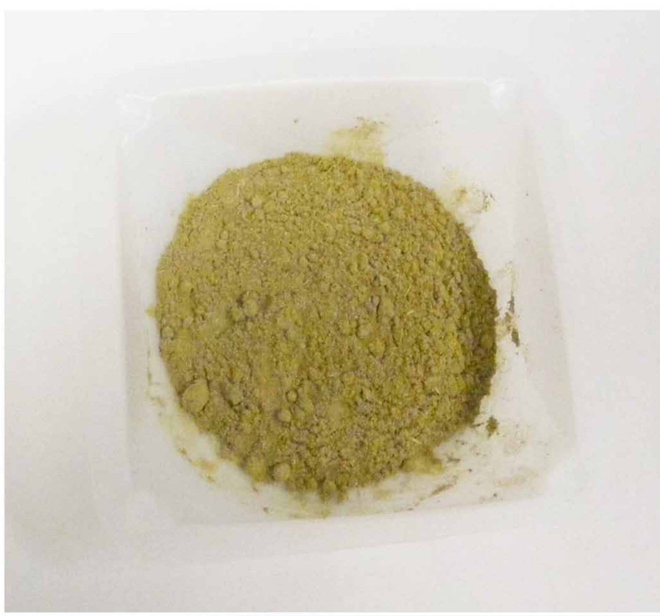


Figure 23. Lyophilized extracts of Brickellia cavanillesii (Asteraceae) dried leaves and twigs

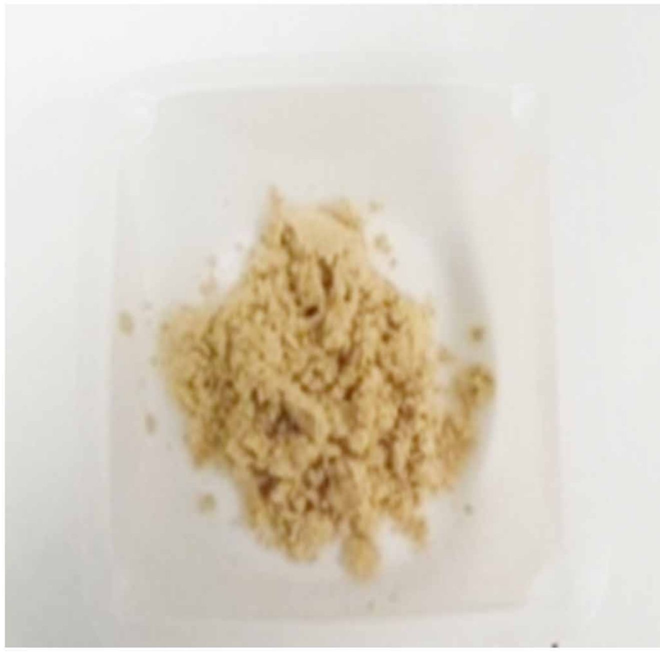
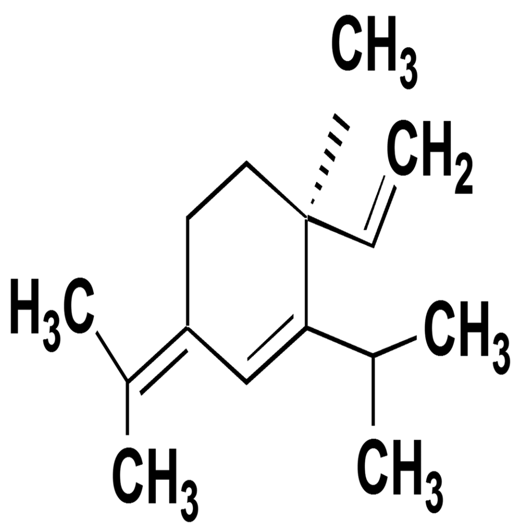


Figure 24. Cyclohexane, 6-ethenyl-6-methyl-1-(1-methylethyl)-3-(1-methylethylidene)-, (S)



same as that induced by carbenoxolene. Furthermore, aerial aqueous extracts of *Brickellia cavanillesii* reduced postprandial hyperglycemia in diabetic mice throughout the course of oral glucose and sucrose tolerance testing (Escandion-Rivera et al. 2012; Mata & Escandion, 2012; Perez-Vasquez et al., 2014).

Another herbal plant undergoing extensive experimentation is *Tecoma stans* (Bignoniaceae). *T. stans* is consumed for its presumed antidiabetic properties. Gas chromatographic characterization of methanol extracts of lyophilized *Tecoma stans* (LTS) support other characterization studies that show that *T. stans*

Figure 25. Bicyclo (2.2.1) heptan-2-one, 1, 7, 7-trimethyl-, (1S, 4S)

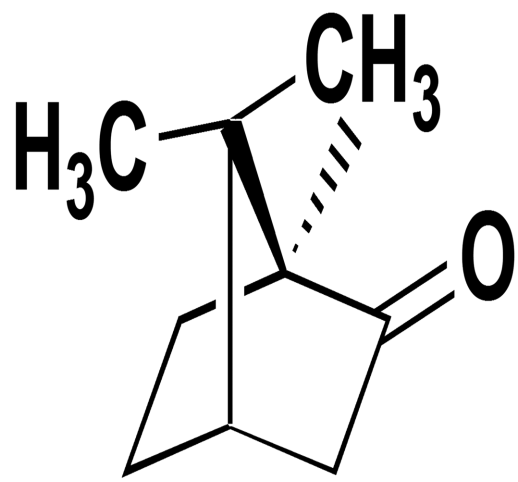
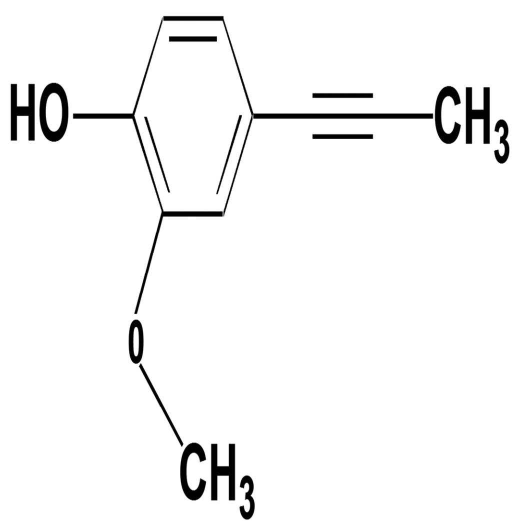


Figure 26. Phenol, 2-methoxy-4-(1-propenyl)-



contains two major compounds, Tecomine and Tecostamine, believed to be responsible for decreasing blood glucose levels (Zhu et al., 2008). Presently, complimentary and supplementary studies are being conducted, at Ernest E. Smith laboratory, The Institute of Environmental and Human Health (TIEHH), Texas Tech University, Lubbock USA, to isolate bioactive components of LBC and LTS using Liquid Chromatography Mass Spectroscopy (LCMS) methodologies; definitive, integrative *in vivo* and *in vitro* biological assays employing a broad spectrum of biomarkers are also being performed to elucidate mechanism of action. It is hoped that these studies will provide further clarity in determining the efficacy of LBC and LTS as therapeutic agents.

Figure 27. Benzene, 1 - (1, 5 - dimethyl -4- hexenyl) –methyl –

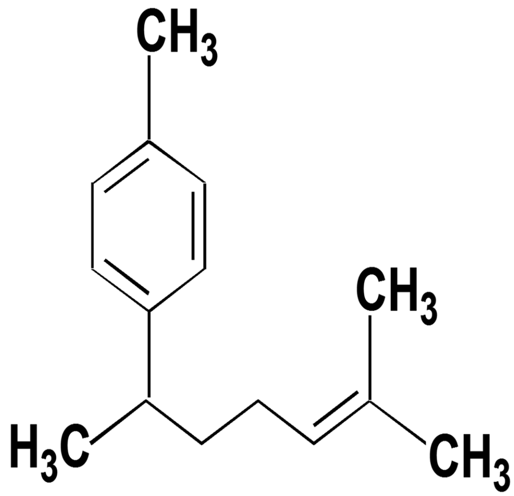
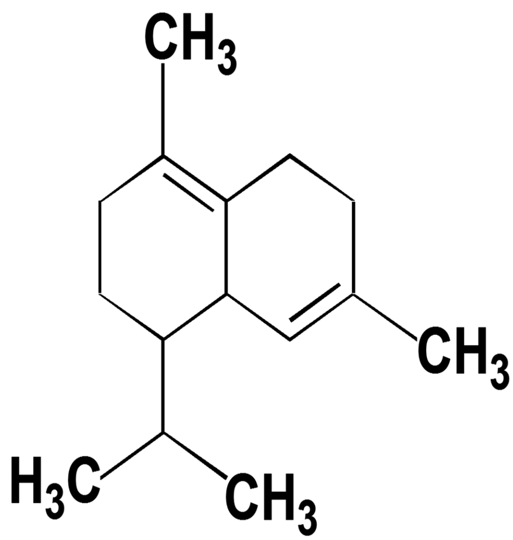


Figure 28. Naphthalene, 1, 2, 3, 5, 6, 8a-hexahydro-4, 7-dimethyl-1-(1-methylethyl)-, (IS-cis) –



CONCERNS

The growing trend of using tea preparations, and CAM to a larger extent, as ameliorative therapy has elicited a number of troubling concerns. Of particular interest are potential drug interactions and side effects. Herbal tea variability, contamination, standardization, and identification are a few other concerns generated by CAM usage. Complications arising from interactions between CAM remedies and prescribed medication are prevalent. Less than forty percent of patients are believed to share their usage of CAM products with their healthcare professional leading to improper diagnosis (Eisenberg et al. 1998; Shane-McWhorter, 2007). Patients taking CAM remedies have been known to experience serious side effects

Figure 29. Phenol, 2–methoxy –

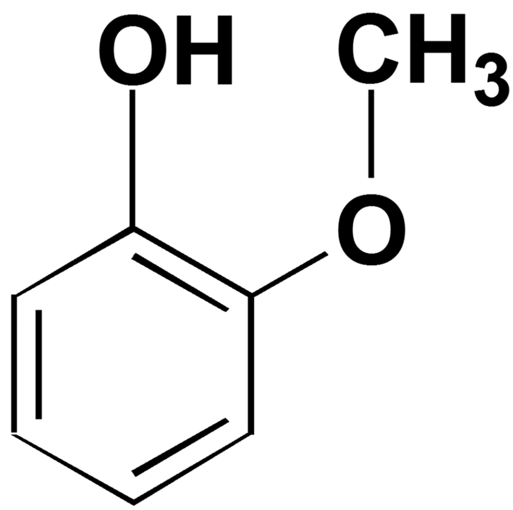
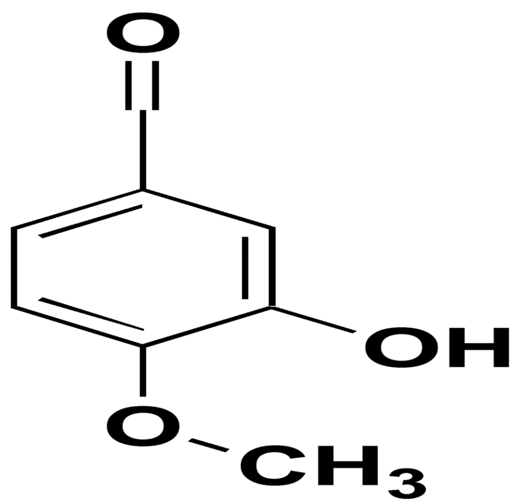


Figure 30. Benzaldehyde, 3-hydroxy-4-methoxy



(Shaw et al. 1997; Boullata & Nace, 2000). Unfortunately, the Food and Drug Administration (FDA) considers herbal plants and its supplements foods, not drugs. This puts this category of products outside the ambit of the strict testing, manufacturing, labeling standards and regulations that pharmaceutical drugs are typically subjected to. Although, many prescription drugs and over-the-counter medications are prepared from plants, these products are purified ingredients that are FDA regulated. Conversely, herbal plants, and its supplements, may contain entire plant materials that have not undergone FDA approved clinical trials to assure efficacy in the treatment or management of disorders (JHM, 2015). In 1999, the United States government initiated a program designed to determine the effectiveness of herbal plants,

Figure 31. 11, 13-Eicosadienoic acid, methyl ester

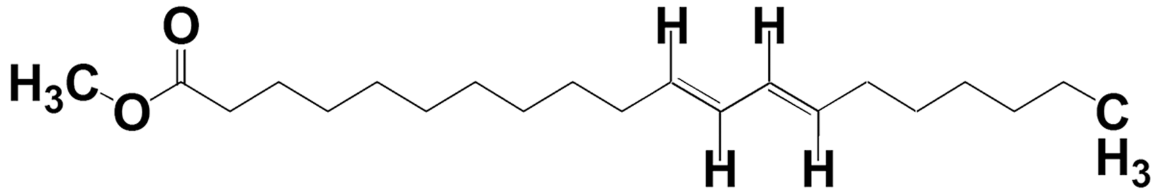


Figure 32. 2-Furancarboxaldehyde, 5-methyl –

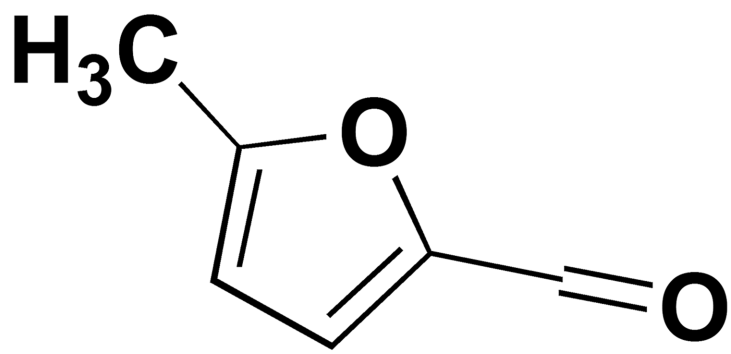
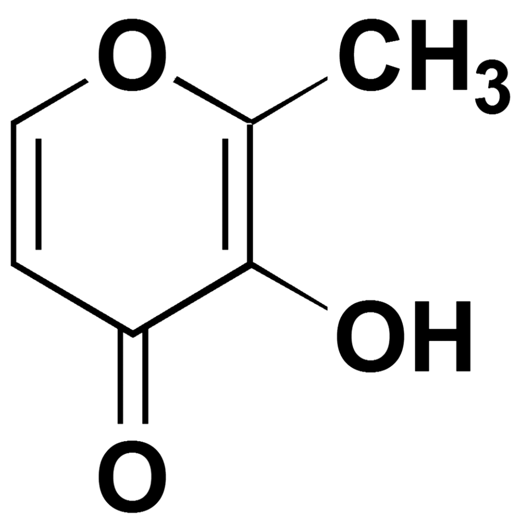


Figure 33. Maltol



and other CAM remedies, in disease therapy. In excess of $2.5 billion was expended on this exercise. Results obtained were at best inconclusive. Herbal derivatives involved in this investigation failed to show any significant difference with control (dummy pills). However, more studies are presently being conducted, and grants have been awarded towards studies further exploring the use of CAM treatments (Marchione, 2009).

Figure 34. Phenol

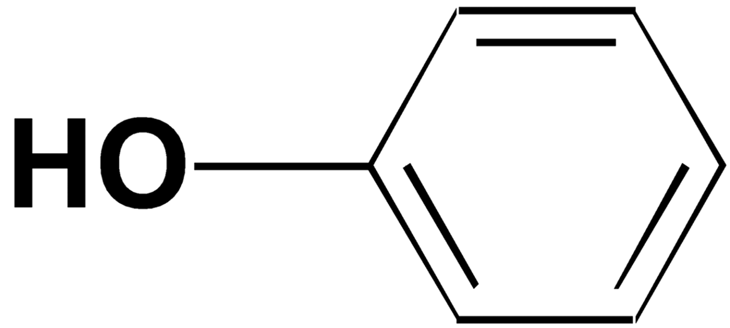


Figure 35. Hydroquinone

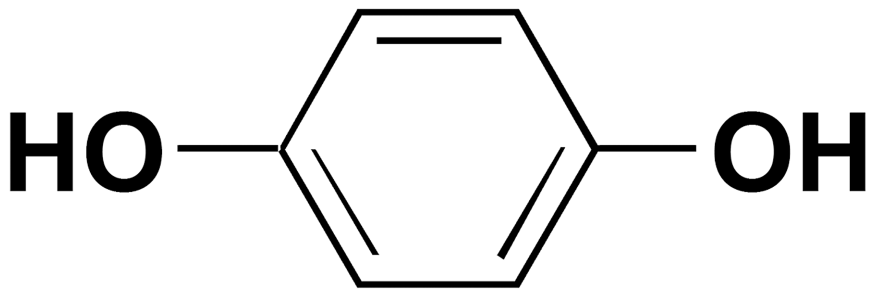
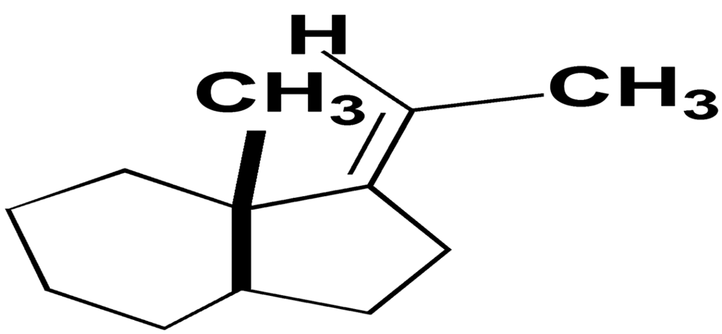


Figure 36. 1 H-Indene, 1-ethylideneoctahydro-7a-methyl-, (1E, 3a.alpha, 7a.beta.)



CONCLUSION

The efficacy, or otherwise, of plant extracts (~herbal teas) in disease therapy remains a primary concern to healthcare professionals and the international scientific community. Although an enormous number of plants used in disease therapy have been reported in literature and may in fact represent alternatives to developing new oral agents, valid ethnobotanical information about them is limited, doubtful and ambiguous (Martinez, 1954; Bailey & Day, 1989; Marles & Farnsworth, 1994; Aguilar et al. 1994). The result of our investigations leads us to suggest that concerted effort must be sustained in the pursuance of scientific investigation of traditional tea preparations as it may present valuable leads and potential for

Figure 37. 3-Methyl butanal

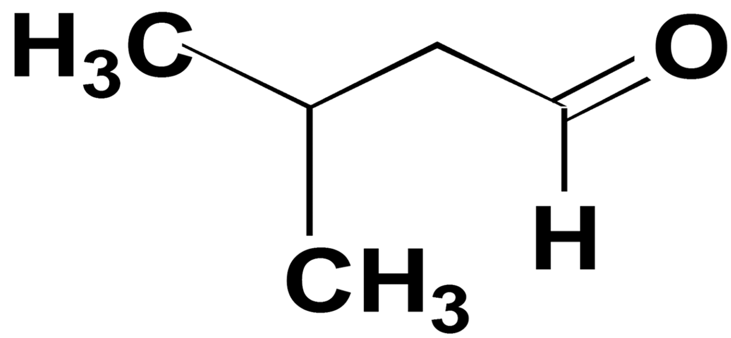


Figure 38. (D)-Limonene

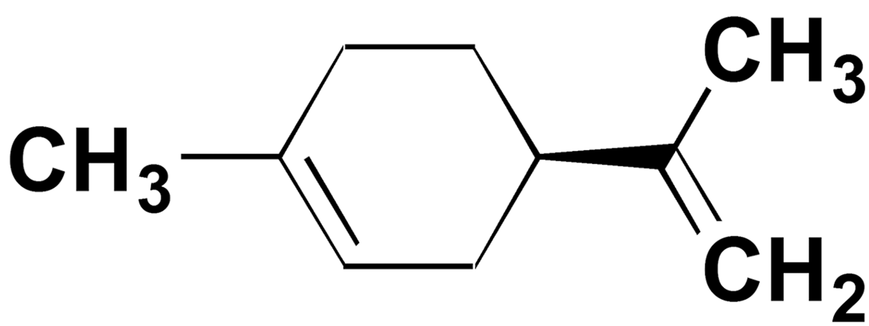


Figure 39. 1-Methyl-4-(1-methyl ethyl) benzene

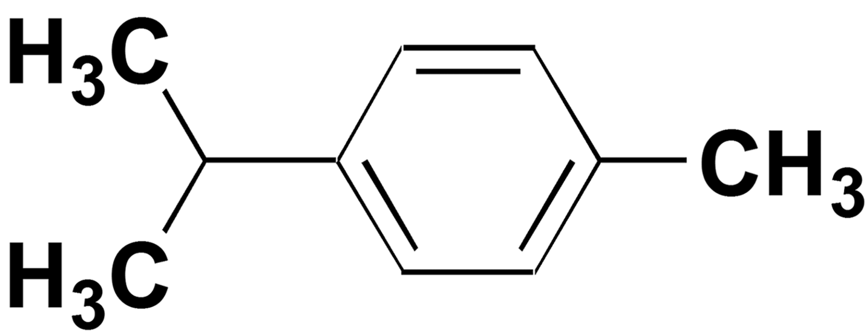


Figure 40. Butanoic acid methyl ester

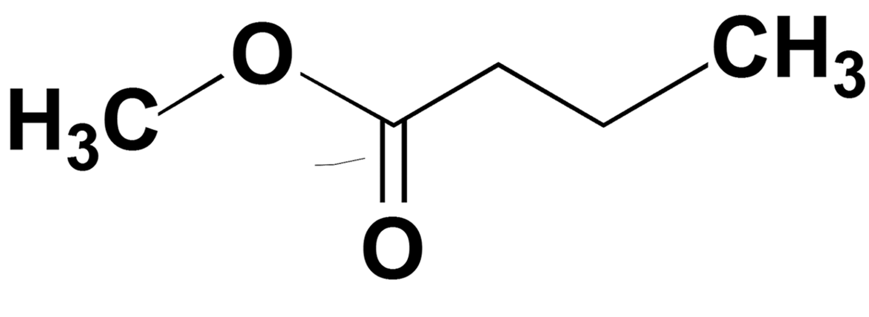


Figure 41. 2-Methyl propanal

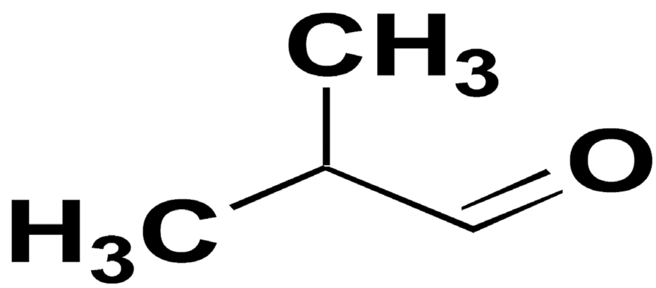


Figure 42. 2-Butanone

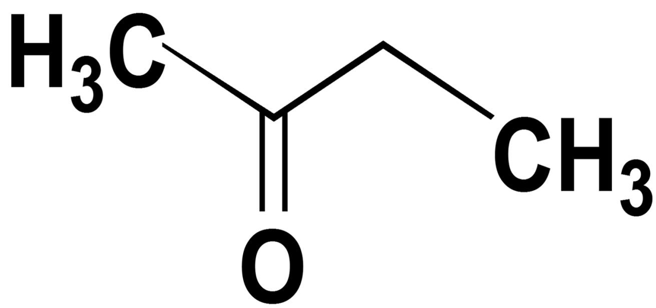


Figure 43. 2-Pentanone

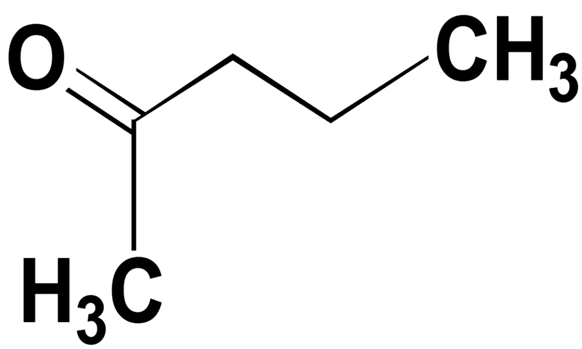
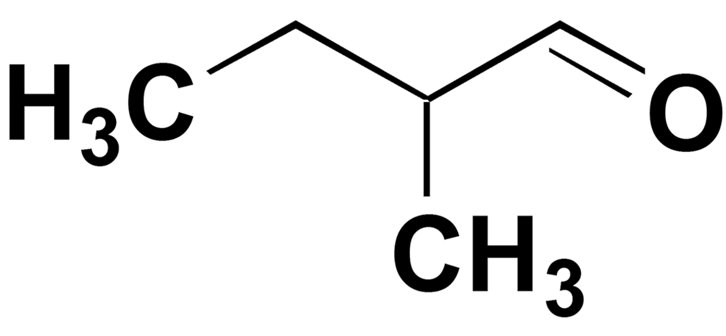


Figure 44. 2-Methyl butanal



the development of alternative drugs and therapeutic remedies. Tea preparations constitute a tremendous resource for alternative remedy especially at disease onset. Consequently, it is imperative that studies are undertaken to assure the quality, efficacy, and safety of plants. The lyophilization of plant extracts typically ensures durability and standardization. These are critical ingredients necessary in determining the dosage of therapeutic agents. Performing experimental procedures utilizing lyophilized plant extracts may perhaps provide data sets that are truly measurable and reproducible.

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Chapter 15
New Herbal Approaches for the Treatment of Diabetic Kidney Diseases and Its Therapeutic Implications

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ABSTRACT

Diabetic Kidney Diseases (DKD) is a very serious complication of diabetes. There is recent steep rise in the prevalence of metabolic syndrome and DKD worldwide. Factors responsible for intraglomerular hypertension include activation of various vasoactive systems, polyol pathway, oxidative stress, inflammation and protein kinase C. Sodium-Dependent Glucose Co-Transporter (SGLT-2) inhibitors, DPP-IV (Dipeptidyl peptidase-4) inhibitors are being develop to manage the hyperglycemia and oxidative stress induced inflammatory cascade. Herbal drugs have gained increasing popularity; are complex mixtures of polyphenols and phytochemicals from any raw or processed part of a plant, including leaves. Herbal drugs in this modern era are preferred due to its lesser side effects. Various preparations are presently used for ameliorating the effect of DKD. Since, medicinal plants have been reported to affect various metabolic receptors, enzymes and signaling cascade. Above book chapter explains the involvement of different phytochemicals in biological pathway associated with the kidney damage.

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INTRODUCTION

Diabetes is a metabolic syndrome which now becomes a growing epidemic in most of the developed and developing countries. Diabetes is of two types; Type 1 diabetes i.e. if individual's body is not able to make enough insulin. It usually starts when the person is a child or young, but it can happen to anyone. It is treated by taking daily insulin shots or using an insulin pump and by following a restricted diet plan with care. About 5-10% of cases of the diabetes are Type 1. Type 2 diabetes; body makes some insulin but cannot use it properly. It is partially preventable and is typically brought on by poor diet and lack of exercise. Heredity may be one of the reasons; but it usually starts when the person is above the age of 40, but it can happen earlier also. It is treated with exercise, weight loss and meal planning. People with Type 2 diabetes generally requires insulin, but oral medications are given (called hypoglycemics) are prescribed if diet and exercise alone do not control the disease. Type 2 is the most common type of diabetes.

Diabetic kidney diseases (DKDs) are one of the serious and common complications of diabetes and part of the chronic kidney diseases (Tripathi & Yadav, 2013). Presently modern medicine is using diabetic kidney diseases (DKD) instead of diabetic nephropathy for which cure has not been yet found. Much research has been conducted in both basic sciences and clinical therapeutics, enhancing our understanding of the pathophysiology of diabetic nephropathy and expanded horizon of the potential therapies available. A better understanding of the pathogenesis of DKDs is therefore necessary to develop more effective therapies.

EPIDEMIOLOGY

The recent steep rise in the prevalence of metabolic syndrome and of Type 2 diabetes worldwide is extremely pronounced in Asian nations and is particularly dramatically increasing in India. This gave India the dubious distinction of the "diabetes capital of the world". In urban Indians, the overt nephropathy and microalbuminuria was found to be 2.2 and 26.9%, respectively (Ritz & Zeng, 2011). Diabetic kidney diseases are the most common causes of chronic kidney failure and end-stage kidney diseases in the United States (Mehdi & Toto, 2009).

Factors responsible for intraglomerular hypertension include activation of various vasoactive systems, such as endothelial systems and the RAAS. Polyol pathway, oxidative stress, inflammation and PKC pathways which are involved in making it a syndrome; with serious complications. These changes results to high secretion of fibrotic cytokines such as transforming growth factor β resulting to furtherance of haemodynamic changes (Sharma & Sharma,2013). The earliest clinical evidence of nephropathy is an increase in microalbuminuria (defined as >30 mg/day) into the macroalbuminuria range (>300 mg/day) (Toth-Manikowski &Atta, 2015). Renal function is compromised even prior to the onset of initial damage to the kidney. There occurs several oxidation and reduction changes that appears early and continue as chronic damage progresses, highlighting the complexities of the disease. Besides the classical anti-diabetic drugs such as sulfonyl urea, begonides, α- glucosidase inhibitors, PPAR-γ agonists (Peroxisome proliferator activated receptor), Sodium dependent glucose co-transport (SGLT-2) inhibitors, aldose reductase inhibitors, DPP-IV (Dipeptidyl peptidase-4) inhibitors etc are being developed to manage hyper-glycemia (Pathak and Bridgeman, 2010).

Increasing evidence from both experimental and clinical studies suggests that there is a close relationship between hyperglycemia and oxidative stress induced inflammatory cascade. People with diabetes are at higher risk of vascular, peripheral and cardiovascular diseases. Evidence of kidney damages are albuminuria, proteinuria, haematuria, decrease in creatinine clearance and structural abnormalities found on the kidney imaging tests. AGEs cause thickening of extracellular matrix, decrease in function of glomerulus. An estimated GFR < 45 mL/min/ 1.73 m^2 is associated with higher risks of renal, cardiovascular and other clinical manifestations irrespective of the age. Herbal drugs in this modern era are preferred due to its lesser side effects. But new herbal multitargeted molecular therapeutics is required. Various herbal and medicinal plant preparations are presently used for ameliorating the effect of chronic renal damage. There are lists of pharmacological tools and their mechanistic action which are implied in the effective treatment of DKD. Ancient Ayurvedic systems, Chinese herbal medicines, folklore treatments around the various corners of the world are being investigated in newer dimensions for better prospects. Examples include Chiahuang-Yishen formula for chronic kidney diseases including diabetic nephropathy.

RISK FACTORS IN DKDs

Not all the diabetics develop kidney disease but those who develop it, their progression is very variable with time factor. The major lifestyle risk factors include high blood pressure, glycemia and dyslipidemia while less extreme risk factors are age, race and genetic makeup. Creatinine is widely used biomarker for kidney function; it is inaccurate at detecting mild renal impairment and levels differ with muscle mass and protein intake. DKDs are likely to develop in patients with a family history (Macisaac, Ekinci, & Jerums, 2014). Few racial groups are at higher risk such as Afro-Americans, Mexicans (Young, Maynard, Boyko, 1991).A meta-analysis of diabetic studies identified 24 genetic variants in 16 genes which are linked to DKD. These include a variety of genes; ACE, ALR2, APOC1, APOE, EPO, CARS, CPVL/ CHN2, FRMD3, UNC13B and GREM1. In another study of subgroup of Type 2 of diabetic Asians, ELMOI, CCR5 and CNDP1are also important finding relevantto the study (Mooyart et al., 2011).Other meta-analyses implicated polymorphic genes of ADIPOQ, PAI-1, TGF-β, PPAR-γ etc in the growth of DKD. The inherent polymorphism varies with different groups of wide ethnicity (Sun et al., 2014).

STAGES IN DIABETIC KIDNEY DISEASES

Approximately 25% to 40% of patients with Diabetes Mellitus (DM) ultimately develop DKD, which progresses through five stages.

Stage 1 – Hyperfiltration (Glomerular Hypertrophy): (Very early diabetes). Increased demand of filtration on kidneys is indicated by an above normal Glomerular Filtration Rate (GFR).

Stage 2 – Hyperfiltration (Mesangial Expansion / Basement Membrane Thickening): GFR remains in elevated level or returned to the normal but glomerular damage has progressed to significant microalbuminuria. Patients excrete more than 30 mg of albumin in the urine over a 24 hrs period. Excessive micro or macroalbuminuria will finally leads to End-Stage Renal Disease (ESRD). All diabetics should be screened for microalbuminuria on a routine or yearly basis.

Stage 3 – Microalbuminuria (Mesangial Sclerosis, Dipstickpositive Diabetes): Glomerular damage has progressed to clinical albuminuria. Urine is "dipstick positive," containing more than 300 mg of albumin in a 24-hour period. Hypertension i.e. high blood pressure typically develops during stage 3.

Stage 4 – Overt-Proteinuria Hypertension (Progressive Sclerosis): Late-stage diabetes Glomerular deterioration showed a continuous rise with increasing amounts of protein albumin and kidneys' filtering process begun to decline steadily; Blood Urea Nitrogen (BUN) and Creatinine (Cr) has begun to increase. The Glomerular Filtration Rate (GFR) decreases about 10% annually. Almost all the patients developed hypertension at stage 4.

Stage 5 – ESRD (Fibrosis/Sclerosis): GFR has fallen to approximately 10 milliliters per minute (<10 mL/min) and renal replacement therapy (i.e., hemodialysis, peritoneal dialysis, kidney transplantation) is required.

PATHOLOGY AND PATHOPHYSIOLOGY OF DIABETIC KIDNEY DISEASES

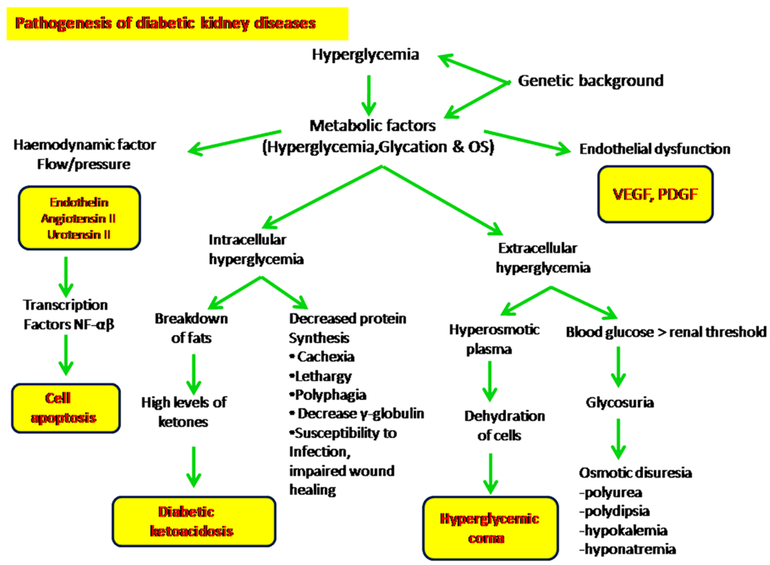
DKDs are characterized by various structural and functional changes in the human physiology. In glomeruli, there is mesangial expansion, thickening of the basement membrane and characteristically nodular glomerulosclerosis (Kimmelstiel-Wilson nodules). In early stages of DKD, tubular hypertrophy is present but eventually interstitial fibrosis with tubular atrophy develops, along with hyalinosis. In advanced cases, there is an infiltration of macrophages and T-lymphocytes in the interstitial spaces. Ultrastructurally, there is podocyte loss and reduced endothelial cell fenestration (Weil et al., 2012). Pathogenesis in DKD patients with several linked physiological connections are given in Figure 1.

HEMODYNAMIC PATHWAY

It includes an imbalance in an afferent and an efferent arteriolar resistance resulting in the increased glomerular hydrostatic pressure and excess hyperfiltration. Activation of renin-angiotensin system (RAS) increases angiotensin II levels, leading to an efferent arteriolar vasoconstriction. It causes production of proinflammatory and profibrotic molecules through multiple cellular mechanisms. High angiotensin converting enzyme (ACE) levels are associated with greater albuminuria and kidney damage in diabetic mice and humans (Wong et al.,2007). Increased levels of endothelin-1 and urotensin II also contribute to vasoconstriction of the vessels. Various dysregulation of nitric oxide and nitric oxide synthase has been described in DKD. Nitric oxide mediates endothelium-dependent vasodilatation. Nitric oxide in cells is formed from L-arginine by endothelial nitric oxide synthase. In an experiment it was shown that diabetic endothelial nitric oxide synthase knockout mice develop more severe glomerular lesions and proteinuria compared to wild-type mice (Kosugi et al., 2010).

ACEIs (Angiotensin converting Enzyme Inhibitors) and ARBs (Angiotensin II receptor blocker) have a long track record in reducing the rate of the creatinine, albuminuria and progression to DKD, ESRD and death (Bakris, S3-10, 2008). ET-1 (a powerful vasoconstrictor) has various physiologic functions in the kidney that mimic RAS including vasoconstriction and hence playing a role in hypertension, endothelial dysfunction, inflammation and fibrosis (Toth- Manikowski & Atta, 2005). Increased ET-1 expression activates a signaling cascade which leads to mesangial hypertrophy and proliferation as well

Figure 1. There are various pathways which are involved to commemorate the cellular effects in the body and their after-effects



as extracellular matrix (ECM) thickening. It is also thought to activate receptors that directly increase glomerular permeability, hence leading to the worsening albuminuria and progression of DKD.

METABOLIC PATHWAY

Oxidative stress and generation of reactive oxygen species (ROS) damages DNA and protein or function as signaling amplifiers to activate cellular stress pathways such as PKC, MAPK etc (Trachootham, Lu, Ogaswara, Rivera-Del Valle & Huang, 2008). Polyol pathway activation, aldose reductase converting excess glucose to sorbitol and its subsequent conversion to fructose by enzyme sorbitol dehydrogenase contributes to oxidative stress by increasing the NADH/NAD$^+$ ratio (Figure 2). A recently described novel mechanism of insult to cells also involves endogenous fructose production with activation of enzyme fructokinase in the proximal tubules of the organ kidney. The formation of advanced glycation end-products (AGE) by nonenzymatic binding of glucose to proteins, lipids and nucleic acids leads to alteration of protein structure and function, oxidative stress; and expression of proinflammatory cytokines and growth factors (Singh, Bali, Singh & Jaggi, 2014).

THE POLYOL PATHWAY

The polyol pathway is upregulated as a result of increased continous and persistent hyperglycemic condition. The reduction of glucose to sorbitol results in decreased intracellular NADPH levels, an important cofactor involved in regenerating the antioxidant ie reduced glutathione (GSH). A decreased level of GSH contributes to increased intracellular oxidative stress which in turn causes increased cell stress and apoptosis (Circu & Aw, 2012) and then oxidation of sorbitol to fructose sugar produces increased intracellular NADH: NAD^+ ratio which further inhibits the process of glycolysis. The increased NADH:NAD^+ ratio also increases the formation of methylglyoxal and second messenger ie diacylglycerol, precursors of the AGEs and PKC pathways (Brownlee M, 2001). Finally, the end products of the polyol pathway, fructose has been emerged as a potentially nephrotoxic. In an experimentally developed diabetic murine model, the endogenously produced fructose through polyol pathway led to increase in proteinuria, decline in GFR and increased glomerular capsule & proximal tubular injury when compared to mice with lower levels of endogenous fructose. Making the matter more worse, these mice expressed more superoxide levels and the inflammatory cytokines like NF-κB (2013, Forbes &Cooper).

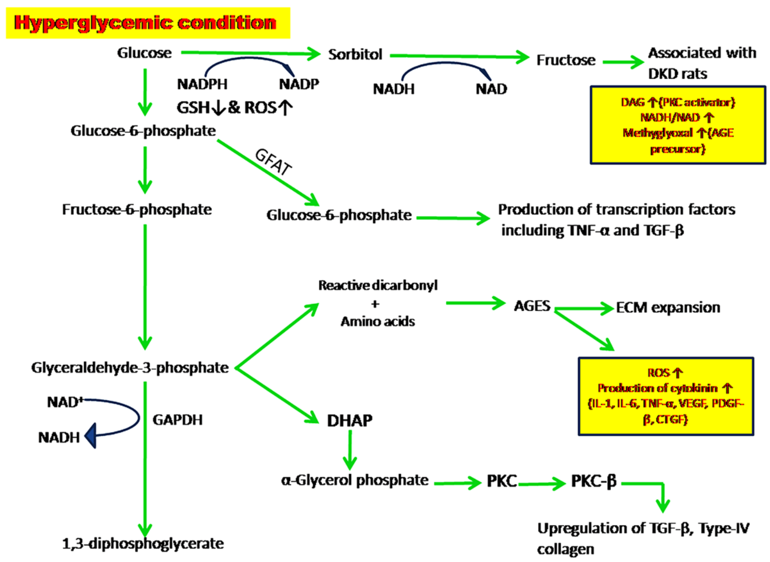
HEXOSAMINE PATHWAY

The hexosamine pathway originates from the third step of the glycolysis, fructose-6-phosphate, is converted to glucosamine-6-phosphate by the enzyme glutamine: fructose-6-phosphate amidotransferase (GFAT) Figure 2. Glucosamine-6-phosphate is then used as a substrate to increase transcription of inflammatory cytokines tumor necrosis factor-(TNF-α) and transforming growth factor-β1 (TGF-β1) (Liu, Kelm, Straunch, 2009). Increased TGF-β1 levels are responsible for promoting renal cell hypertrophy and increase in the components of the mesangial matrix. These are the two most important pathological hallmarks of the DKD (Chen et al., 2001) whereas TNF-α is an important inflammatory cytokine (Liu, Kelm, Straunch, 2009).

ADVANCED GLYCATION END PRODUCTS (AGEs)

AGEs products are the outcome of irreversible glycation of proteins that occurs in the presence of intracellular hyperglycemic condition (Lim, 2014; Brownlee, 2001; Sheetz, 2002). Increase in the uptake of glucose to the proximal tubular cells via sodium glucose co-transporter 2 (SGLT2) stimulates free radical generation and RAGE expression; thereby aggravating the AGE induced apoptosis in this cell type. AGEs work through three mechanisms to induce final damages and are primarily responsible for the production of AGE precursors. In the first step, there is intracellular protein modification in the kidney cells; oxidation of glucose to form glyoxal and then breakdown of Amadori products; finally aberrant glycolysis which shunts glyceraldehydes-3-phospahate to make methylglyoxal (Verspohl, 2012). In the second step, its abnormal behaviour with other matrix components and with the receptors of the matrix proteins for e.g. integrins on cell surface. In the final third step, binding of AGE receptors generates ROS and NF-kB activated gene expression. When AGEs are formed, they damage renal cells by modifying or impairing the function of both intracellular and extracellular proteins (Sheetz & King, 2002). AGEs modifies both matrix proteins; laminin and Type IV collagen and increases the permeability of the glomerular basement membrane (Forbes, Cooper, Oldfield & Thomas, 2003) leading to increased excretion of protein in the urine. They also cause rise in the expression of fibronectin and collagen Types I and IV which leads to the increased density and expansion of the extracellular matrix in the kidney (Huang, 2001; Sakurai, 2003). AGEs bind themselves to various proinflammatory receptors which activate the downstream production of cytokines (IL-18, IL-1, IL-6, TNF-α, TGF-β1, VEGF, platelet-derived growth factor- β (PDGF-β), connective tissue growth factor (CTGF), generation of excess ROS (Alicic,

Figure 2. Glycolysis pathway as affected by hyperglycemic condition leading to accumulation of ECM and generation of free radicles



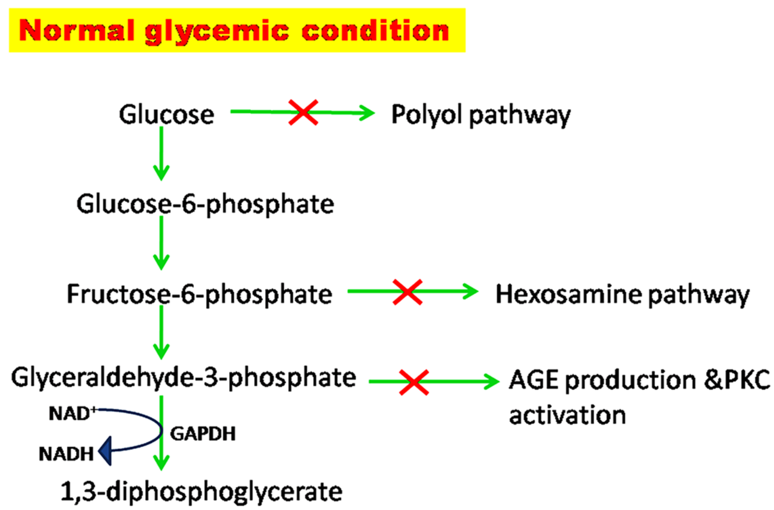
2014; Tan,2008). VEGF is required for endothelial cell survival, podocytes integrity and overall health of the mesangial cells whereas CTGF is a profibrotic agent; both have been implicated in DKD (Tufro & Veron, 2012; Mason, 2009).

THE PKC PATHWAY

Protein kinase has 12 isoforms. Nine PKCs are activated by DAG which is formed by excess production of glyceraldehydes-3-phosphate. High cellular glycemic index drives the conversion of glyceraldehyde-3-phosphate into dihydroxyacetone phosphate (DHAP) and finally diacylglycerol (DAG) which is a co-factor for activation of PKC (Noh & King, 2007). PKC pathway stems from the fourth step in glycolysis as shown in Figure 3.

In the presence of hyperglycemic state, DAG is chronically upregulated and gives its contribution to sustained activation of PKC (Craven, Davidson & DeRubertis, 1990). Protein kinase C contributes to DKD; it increases the prostaglandin E_2activity levels and nitric oxide (Bank & Aynedjian, 1993). This change further leads to vasodilation of the afferent arteriole and augmentation of angiotensin II's actions on the efferent arteriole (Ruan & Arendshorst, 1996; Nagahama, 2000). These complex actions combining together contribute to glomerular hyperfiltration (Noh &King, 2007). In the final stages of DKD, there is a progressive deficiency in level of nitric oxide which has been associated with severerity of proteinuria, decreasing renal function and high blood pressure. PKC mediates excess production of VEGF which is again linked to intra-renal blood flow abnormality and capillary permeability and is thought to play a role in the development of microalbuminuria (Menne et al., 2004). The activation of PKC increases CTGF and TGF-β levels in the tissue as well as the production of fibronectins and type IV collagen and opens gate to GBM thickening and ECM build up (Noh &King, 2007).

Figure 3. Different pathways activated when there is hyperglycemic condition



GROWTH FACTORS AND CYTOKINES

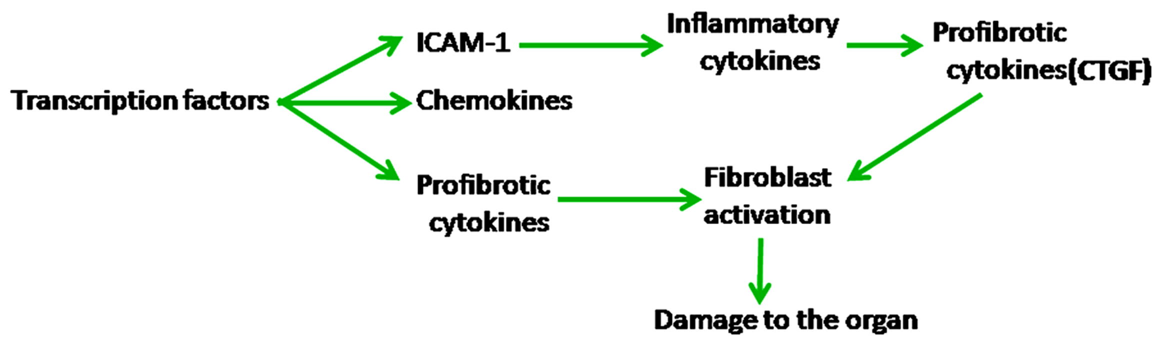
Activation of TGF-β and its relating cytokines like CTGF induces ECM formation and fibrosis. In most of the kidney biopsies, glomerular expression of TGF-β1 and CTGF were higher in diabetics as compared to controls and correlated with albuminuria and proteinuria. PDGF expression is also downregulated in DKD, which influences chemotaxis, vascular tonicity and aggregation of the platelets. VEGF is very crucial in the angiogenesis process but it also mediate vasodilatation and leukocyte trafficking in DKD.

CELL SIGNALING AND TRANSCRIPTION FACTORS

Increased renal gene transcription of PKC-β showed a strong relationship with glycemic control (Langham et al., 2008). There are various different groups of transcription factors which get involved during the changes and lead to the organ damage as shown in Figure 4.

PKC activation has wide ranging effects, including the action of angiotensin II, dysregulation of nitric oxide, endothelial dysfunction and activation of MAPK and NF-κB (Noh & King, 2007). MAPKs are cell signaling intracellular kinases involved in various cellular responses. They form a chain of cascade in number of nuclear transcription factors, including NF-κB, which finally regulates gene expression of other cytokines, chemokines and adhesion molecules in the cell. The p38-α isoform activation in p38 MAPK pathway is strongly associated with renal inflammation and DKD (Sakai, 2005; Adhikary, 2004). It may be mentioned to be an important role for toll-like receptors (TLR 2, TLR 4) and B7-1 costimulatory signaling in modulating inflammation and injuries (Fiorina, 2014; Mudaliar, 2013). Transcription factors bind to the promoter regions of genes and modulate transcription of mRNA. The factor NF-κB had been widely acknowledged in case of DKD. Activation of NF-κB factor in the renal biopsies correlates with severity of proteinuria and glycemic control index (Schmid et al., 2006).

Figure 4. Involvement of transcription factors in the metabolic pathways



ROLE OF INFLAMMATION

There is recruitment and activation of innate immune cells with extensive elaboration of proinflammatory cytokines in DKD (Lim & Tesch, 2012). Macrophages and T-lymphocytes of the immune system are active in early diabetic glomeruli while their interstitial infiltration generally develops in later stages. However, the absence of lymphocytes did not prevent fibrosis and declining renal function in experimental DKD (Lim et al., 2010). Strategies involving compromise on the part of renal leukocyte recruitment, its proliferation and activation have demonstrated that macrophages mediate in DKD (Chow, 2007; Lim, 2009). Recently attention is being focused on the subset of regulatory T-cells (T_{reg}) type, which may play a protective role in DKD. T_{reg} cell numbers are increased in experimentally induced diabetic mice (Lim, 2010; Xu, 2009). They have also demonstrated an anti-inflammatory function, which further reduces the metabolic abnormalities and insulin resistance in a mouse model of Type 2 diabetes (Ilan et al., 2010). In case of humans, renal macrophage accumulation was associated with the severity of glomerulosclerosis.

The main proinflammatory cytokines which are implicated in DKD are ICAM-1, IL-1, IL-6, IL-18, TNF-α, MCP-1 etc. These cytokines are increased in diabetic patients and showed correlation with albuminuria and glomerular pathology (Lim & Tesch, 2010). The inflammatory pathways are a consequence of a chronically activated innate immune system and a low-grade inflammatory state with diabetes (Eller, 2011; Xu, 2009). NF-κB is an important transcription factor which regulates the expression of multiple genes related to apoptosis, inflammation, immunity, chemo-attractant protein-1and localizes to glomerular, interstitial and tubular epithelial cells in human kidney. Hyperglycemic conditions manifold increases the expression of expression of NF-κB (Holman, 2008; Perkovic, 2013). The NF-κB activation in DKD correlates with proteinuria and interstitial cell infiltration (Ilan, 2010; Perkovic, 2013). Proteinuria again known to further stimulate NF-κB and contributes to persistent proteinuria in a cyclic fashion. The Janus kinase/signal transducers and activators of transcription (JAK/STAT) signaling pathway (Duckworth et al., 2009) are activated by reactive oxygen species induced by hyperglycemic states and is associated with hypertrophy of mesangial cells. It was demonstrated that JAK-2 mRNA levels are inversely correlated with estimated glomerular filtration rate (eGFR) in patients with diabetic kidney diseases (Gerstein et al., 2008). Some inflammatory cytokines such as TNF-α and interleukins (eg IL-1, IL-6 and IL-18) are expressed in higher and in greater proportions in kidneys of diabetics as compared to non-diabetic controls. In an experimental induced diabetic rat models, rise in the expression of TNF-α and IL-6 was also associated with increased kidney weight and urine albumin excretion

(Ismail-Beigi et al., 2010). SerumIL-18 and TNF-α levels are positively correlated with the degree of proteinuria in the diabetic patients (Ohga, 2007; Zhang, 2008. At cellular level, these cytokines increases the permeability of vascular endothelial cells, causes glomerular hypertrophy, GBM thickening, induces apoptosis of endothelial cells and directly leads to the toxicity in renal cells (Kodera, 2014; Mori, 2014; Fujita, 2014; Cherney 2014).

ALTERNATIVE PATHWAYS OF DKD

Autophagy is a highly conserved protective mechanism which allows cells to maintain homeostasis during cell starvation or oxidative stress (Tarnov et al., 2004). It involves the intracellular degradation of cytotoxic proteins and organelles by lysosomes whenever a cell is experiencing stress (de Galan et al., 2009). There was decreased autophagic activity which has been clearly explained in both metabolic disorders such as obesity and diabetes (Hayat, M.A., 2014). Renal podocytes are known to have a high basal level of autophagy (Brenner et al., 2001). In vi*tro stud*ies of podocytes exposed to high glucose conditions demonstrated defective autophagy which resulted in podocyte injury. Another evolutionary conserved mechanism is linked to the sodium-glucose transporter-2 (SGLT-2) in the proximal tubule. It is a very low-affinity and high-capacity transporter and is responsible for >90% of glucose reabsorption in the proximal tubules (Barnett, 2004; Lv, 2012). Experimentally knockout animalwithSGLT-2 gene loses approximately 60% of their filtered glucose into the urine. In hyperglycemia, there is upregulation of SLGT-2 expression which is believed to be the evolutionary benefit as it allows for glucose reabsorption and hence energy conservation for both the body and brain.

HISTOPATHOLOGICAL CHANGES IN CHRONIC KIDNEY DISEASES

Clinical manifestations of the diabetic kidney diseases are strongly related to the structural changes, especially with the degree of mesangial expansion in both Type 1 and Type 2 diabetes; and several important structural and functional changes are involved. Kidney is a part of the urinary system which is responsible for the excretion of the body's waste products and maintaining the proper balance of water and electrolytes. The functional unit of kidney is nephron, comprising of renal corpuscles and renal tubules. The Bowman's capsule and glomerulus filters the blood components selectively. The filteration in glomerulus is collectively performed by endothelial cells, intact glomerular basement membrane (GBM) and visceral epithelium that is podocytes. These three components working together prevent the passage of negatively charged molecules larger than albumin (about 3.6 nm) through this barrier. Albumin acts as an osmotic balancer of the blood.

GBM plays a very crucial role in both structural support and functional operation of the glomerulus. GBM is mainly comprises of integrins proteins such as laminin and collagen type-IV. The width of the GBM is double the thickness of the human basement membranes and is found in the range of 300-350 nm. At initial stages, glomerular volume goes high upto 70% and filtration surface area is increased by 80% as compared with the glomeruli of non-diabetic patients. One of the early physiological changes in diabetic patients are the occurrence of glomerular hyperfiltration accompanied by hypertrophied glomerulus. The first detectable and measurable change is GBM thickening, which can be detected as early as 1.5 to 2.5 years after the onset of the diabetes. Thickening in the tubular basement membrane (TBM) is closely parallels that of GBM thickening.

Mesangial expansion, predominant due to an increase in mesangial matrix, an advent rise in the matrix component of the mesangium can be detected as early as 8-9 years after diabetes onset. These structural and functional changes do not develop at the same rate in all the patients. Whenever, there is renal insufficiency, there would be marked mesangial expansion and GBM thickening. Mesangial expansion and diabetic glomerulosclerosis can be associated with nodular lesions consisting of marked areas of formed large, round, fibrillar mesangial zones i.e. nodule and compression of the associated glomerular capillaries (Kimmelstiel-Wilson nodules) (Figure 1). Both GBM and TBM thickenings are consequences of ECM accumulation with increased deposition of the type-IV and type-VI collagen, laminins and fibronectins (Berkholtz et al.,2006) due to their excess production, declined degradation or both.

The glomerular filtration barrier is composed of fenestrated endothelium, GBM, podocytes and slit diaphragms. Disintegration and insult to anyone or more elements of this filtration complex leads to proteinuria (Bianchi et al., 2006). Podocyte detachment from GBM, apoptosis, necrosis or loss of adhesive power plays a central role in the pathogenesis of albuminuria. In most of the renal glomerular disorders, proteinuria is finally associated with foot processes effacement. Numerous Glomerular disorders, collapsing glomerulopathy, lupus nephritis, chronic renal impairment and DKD have injured podocytes. A chronic hyperglycemic condition is necessary for DKD lesions and renal functional disturbances to develop.

It is essential to evaluate renal tissue using appropriate standards for renal biopsy for diagnosis. Staining is done by H & E (hematoxylin andeosin), Periodic acid- Schiff's (PAS), Periodic acid methenamine silver and Mason trichome for light microscopy. Kidney biopsy sections should contain at least 10 glomeruli per slide excluding incomplete glomeruli along the edge. In immunofluorescence technique different antibodies are used for eg IgA, IgM, IgG, CDs (Cluster of differentiation), C3, C1q and light chains to rule out non diabetic kidney diseases (Wesseling & Crowe, 2013). Electron microscopy must be accompanied for an accurate diagnosis of DKD. A patient should carry a clinical diagnosis of DKD with supportive information. DKD can lead to any nephritic disease.

DKD classification on criteria of glomerular damage:

CLASS I: THICKENING OF THE GLOMERULAR BASEMENT MEMBRANE OR PREDIABETIC LESIONS

The mechanisms involved in the development of diabetic lesions or thickening of basement membrane are not properly understood; but many of them are implicated by hyperglycemia. The microangiopathy leads to thickening of the GBM but also the expansion of the mesangial matrix and thickening of the tubular basement membrane. GBM thickening is a first prominent change change in Type 1 and Type 2; and increases with time duration of the disease.GBM thickening results fromaccumulations of proteins (types IV and VI collagen, laminins etc), their decreased degradation or both.

CLASS II: MESANGIAL EXPANSION, MILD (iia) OR SEVERE (iib)

Mesangial expansion is defined as an increase in extracellular material in the mesangium such that the width of the interspaces exceeds two mesangial cell nuclei in at least two lobules of the glomerulus. Generally the difference between mild and severe form of mesangial expansion is based the expanded mesangial area is smaller or larger than the mean area of capillary lumen. Expansion of cellular and matrix components in the mesangium is a hallmark of Type 1 and Type2 diabetes. Mesangium expansion restricts and distorts glomerular capillaries and diminishes the capillary filtration surface.

CLASS III: NODULAR SCLEROSIS (KIMMMELSTEIL-WILSON LESIONS)

Kimmelstiel-Wilson lesions appear in both Type 1 and Type 2 diabetes as lobular, round to oval mesangial lesions with hyaline acellular core which is rounded peripherally by sparse, crescent-shaped mesangial nuclei. While developing nodular sclerotic lesions in initial stages of DKD; two important processes take place: lytic changes in the mesangial area called mesangiolysis and detachment of the endothelial cells from GBM. Kimmelstiel-Wilson lesions are found in combination with mesangial expansion. The occurrence of Kimmelstiel-Wilson lesions is widely considered transition from an early or moderately advanced stage to a progressively higher advanced stage of the disease.

CLASS IV: ADVANCED DIABETIC GLOMERULOSCLEROSIS

Class IV implies advanced DKD and designates more than 50% of global glomerulosclerosis in which there is clinical or pathologic evidence that the sclerosis is attributable to DKD. Glomerulosclerosis is the end point of multifactorial mechanisms that lead to excessive accumulation of ECM in the mesangial space, which through various stages of mesangial expansion leads to the development of Kimmelstiel-Wilson lesions finally resulting in glomerulosclerosis. The presence of mononuclear cells in the interstitium is a widely recognized finding in DKD. Mesangiolysis is defined as disintegration of mesangium with the resultant balooned appearance of a glomerular tuft while the dilated lumens of simple tufts are filled with many red blood cells. Mesangiolysis was mostly observed in end stages regardless of acute or chronic disease.

THE FILTRATION BARRIER: A MULTICOMPONENT APPARATUS

Each capillary of a GBM is lined by fenestrated endothelium and covered by visceral epithelial cells or podocytes. The podocyte slit diaphragm is the final barrier in the GFB to filtration of macromolecules. It possesses interdigitating foot processes (primary, secondary and tertiary) which are separated by filtration slits/pores and is a specialized intercellular junction spanning the filtration slit. Filtration of blood components occurs via the endothelial fenestrae, across the basement membrane and through the filtration slits into collecting duct to form final urine. The glomerular filtration barrier (GFB) acting as a molecular sieve; is permeable to water, small solutes in plasma and maintains charge selectivity for proteins and larger molecules (Jarad & Miner, 2009). Importantly, when microalbuminuria like protein excretions are detectable then glomerular filtration rate (GFR) has passed through the state of hyperfiltration. Alterations in the components of filtration barrier play a part in the development of DKD and other pathological conditions. Chronic hyperglycaemic condition induces the morphological alteration in podocyte expression pattern, podocyte-integrin expression, altered and decreased MMP-2 & MMP-3 expression; finally rise in expression of tissue inhibitor of metalloproteinase (TIMP). Other factors contributing to renal matrix accumulation include VEGF, PDGF which are highly expressed in mesangial and visceral epithelial cells.

ENDOCRINOLOGICAL SIGNIFICANCE

DKD have characteristics that distinguish it from other forms of the chronic kidney diseases. Patients are generally anemic in DKD than in non-diabetic CKD. Erythropoiesis and proteinuria inhibitors, with losses of iron-carrying proteins, have been variably implied in the cause of CKD. Progressive fibrosis of the kidney precludes the increase of endogenous erythropoietin production in response to increasing levels of hypoxia sensed by the organ. DKD patients become highly vulnerable to the anemia when inflammation with proteinuria or both are diagnosed clinically. This is an important risk multiplier for diabetics with high prevalence rates of heart failure.

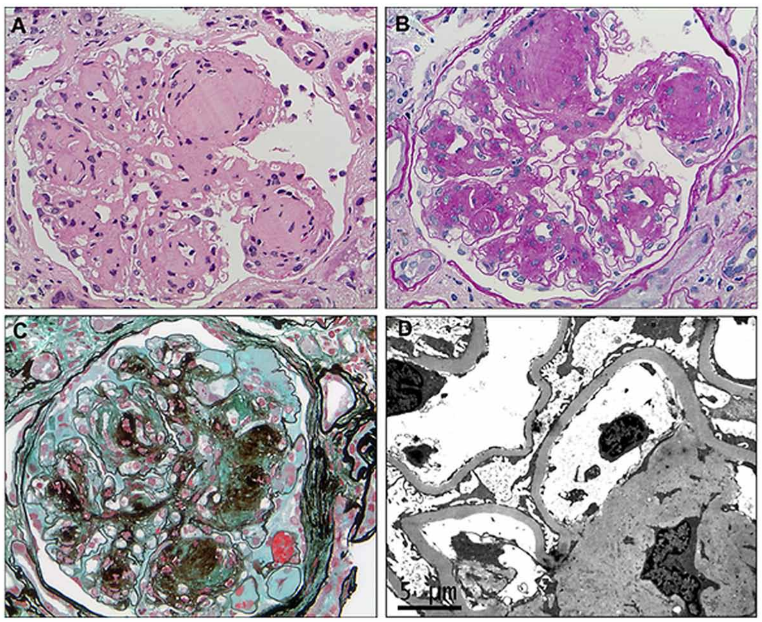
Endocrinologists have supported the confounding of glycemic control in the presence of renal impairment. When gluconeogenesis and glycogenolysis cell processes are impaired, with onset of insulin resistance; diabetic individuals are more susceptible to hypoglycemia. Hyperglycemia from insulin resistance promoting volume depletion strongly activates the sympathetic nervous system and brings about diabetic ketoacidosis. Continuous activation of renin-angiotensin-aldosterone system (RAAS) from ongoing sympathetic nervous system stimulation further aggravates proteinuria and renal fibrosis (Remuzzi et al., 2005).

Another endocrinological aspect which is more apparent in DKD is adynamic bone disease (ABD). This form of mineral and bone disorder is characterized by a marked decrement in bone turnover in the absence of osteoid accumulation. ABD occurs more frequently; this low-volume bone disorder is associated with lower parathyroid hormone levels, increase in fracture risk and calcified cardiovascularity. The pathophysiology of ABD in diabetics remains very mysterious. Improper absorption of calcium and phosphorus in bone makes them to migrate to vascular sites causing coronary and peripheral arterial diseases. Expansion in mesangiun caused by increased matrix secretion and cell enlargement is the initial change seen in light microscopy, while electron microscopy showed a thickened basement membrane and podocyte effacement Figure 5.

TREATMENT MODALITIES IN MODERN MEDICINE

There are different classes of compounds which are presently in use for the treatment of diabetic kidney disease. Orally given hypoglycemic drugs presently prepared in pharmaceutical world shown in Table 1 and novel agents used in treatment of diabetes related complications in Table 2.

Figure 5. (A) Light microscopy with hematoxylin & Eosin staining revealing extensive mesangial expansion without any marked increase in cellularity. A Kimmelstiel-Wilson (KW) lesion is shown here and refers to the nodular glomerulosclerosis that can be seen in late disease but is not as common as diffuse diabetic glomerulosclerosis. (B) KW lesions are spherical and eosinophilic with a central hypocellular or acellular area. Mesangial expansion and KW lesions are both due to increased extracellular matrix production. (C) Electron microscopy shows a thickened basement membrane and (D) podocyte foot process effacement. (Source: Lim A K H, 2014)



DRUGS MECHANISM OF ACTION

- **Sulphonylurea:** Sulphonylurea is an antidiabetic drug with stimulating effect on pancreas β-cells to secrete insulin. They induce channel closure by binding to the SUR subunit of ATP-sensitive potassium (K_{ATP}) ion channel.
- **Biguanides:** Biguanides has the ability to inhibit Gluconeogenesis; inhibitory effect which in turn is correlated well with its ability to inhibit pyruvate oxidation.
- **Meglitinide Analogues:** Meglitinide analogues belong to a new family of insulin secretagogues that acts synergistically with long-acting insulin (NPH insulin at bedtime), metformin and thiazolidinediones (pioglitazone and rosiglitazone). It acts by inhibiting the action of ATP-sensitive potassium ion channels of the β-cell membrane via binding to a receptor which is distinct from that of the sulphonylureas (SUR1/KIR 6.2).
- **Thiazolidindiones:** It improves insulin sensitivity through the mechanism involving activation of γ isoform of the peroxisome proliferator-activated receptor (PPAR-γ), a nuclear receptor.
- **α-Glucosidase Inhibitors:** Acarbose, Miglitol, Voglibose are some of the examples of α- glucosidase inhibitor which helps in delaying the absorption of carbohydrates from the small bowel which leads to the lower effect on postprandial blood glucose and insulin levels.

Table 1. Orally given hypoglycemic drugs

Class of Compounds	First Generation	Second Generation	Adverse Effects
1. Sulphonyl ureas	Tolbutamide, Chlopropamide	Gilbenclamide, Glipizide, Gliclazide, Glimeperide	Hypoglycemia, non specific side effects (nausea, vomiting, diarrhea, headache, weight gain.
2. Biguanides	Phenformin, Metformin		Lactic acidosis, Abdominal pain, anorexia, mild diarrhea, Vit B_{12} deficiency
3. Meglitinide analogues	Repaglinide, Nateglinide		Dizziness, joint pain, flu like symptoms, nausea.
4. Thiazolidindiones	Rosiglitazone, Pioglitazone		Nausea, dizziness.
5.α-Glucosidase inhibitors	Acarbose, Miglitol		Produce flatulence, loose stools

MARKERS OF THE CHRONIC DIABETIC RENAL FAILURE

There is dire need of biomarkers for the early detection of chronic kidney diseases, since it has multifactorial complexicities. In present scenario, proteinuria is the most important and widely used marker for the clinical detection of chronic kidney diseases. Low-grade albuminuria is a lesser predictor of disease progression than macroalbuminuria (Perkins et al., 2007). Therefore, there is keen interest in scientific world for finding biomarkers to detect DKD earlier and identify risk of progression while urine micro RNA profiling studies are fairly preliminary (Argyropoulos, 2013; Di-Stefano, 2013). The most promising

Table 2. Summary of novel agents in diabetes related diseases

Category	Mechanism of Action	Drugs
1. AGE inhibitors	Blocks AGE formation, enhances breakdown, or breaks crosslinks.	Aminoguanidine Pyridoxamine Alegebrium
2. Aldose reductase	Reduces sorbitol formation by the polyol pathway.	EpalrestatPonalrestat Tolrestat
3. Antifibrosis	Reduces TGF-β signaling and TNF-α levels but the exact mechanism needs to be discovered.	Pirfenidone
4. Antioxidative stress	Activation of nuclear transcription factor Nrf2.	Bardoxolone
5. Direct renin inhibitors	Blocks the conversion of angiotensinogen to angiotensin.	Aliskiren
6. Endothelin inhibitors	Predominantly blocks Predominantly blocks endothelin receptor on vascular endothelium.	Atrasentan, Avosentan
7. Glycosaminoglycans	Reduces heparan sulphate degradation in GBM and has anti-inflammatory actions.	Sulodexide
8. Vasopeptidase inhibitors	Blocks ACE and neutral endopeptidase while Palosuran blocks urotensin II receptor.	Palosuran Omapatrilat Ilepatril
9. PKC inhibitors	Blocks PKC-β intracellular signaling.	Ruboxistaurin
10. Phosphodiesterase inhibitors	Increases cellular cAMP with broad effects. Cilostazol blocks PDE3, pentoxifylline is nonspecific and also blocks the adenosine receptor.	Cilostazol Pentoxifylline

biomarker currently is serum TNF-α receptor level which predicts the progression of CKD and ESRD, both in Type 1 and Type 2 diabetics. Markers are listed in Table 3.

Markers with their short description are given in the following sections.

HS-CRP (HIGH SENSITIVITY CRP) AND CRP (C - REACTIVE PROTEIN)

Both tests measure the same protein in the blood. CRP is a protein that increases in the blood with inflammation. CRP structure is annular ring shaped, pentameric protein found in the plasma; rises during inflammation. It is synthesized by the liver in response to factors released by macrophages and adipocytes; a member of the pentraxin family of proteins. Its physiological role is to bind to lysophosphatidylcholine expressed on the surface of dead or dying cells in order to activate complement system via the C1Q complex. Hs-CRP test is for healthy people to determine the risk of cardiovascular diseases. It measures the CRP in the range from 0.5 to 10 mg/L. Hs-CRP is a useful test for determining risk of CVD, heart attacks, strokes and that hs-CRP can play a role in the evaluation process before a person develops these health problems. High levels of hs-CRP in healthy individuals is found to be a predictive of an increased risk of future heart attack, stroke, sudden cardiac death or peripheral arterial diseases even when cholesterol levels is in normal range.

IL-18 (INTERLEUKIN-18)

Interleukin-18 (also known as interferon-gamma inducing factor) is a protein which is encoded by the *IL18* gene in humans and is an important proinflammatory cytokine. It belongs to cytokine of IL-1 superfamily which is produced by macrophages, dendritic cells, monocytes, neutrophils and epithelial cells of the organs. It works by binding to the interleukin-18 receptor and together with IL-12 induces cell-mediated immunity following an infection with microbial products like lipopolysaccharide (LPS). After stimulation with IL-18, natural killer (NK) cells and certain T cells release an important cytokine called interferon-γ (IFN-γ) or type II interferon that plays an important role in activating the macrophages or other cells. IL-12 has been shown to inhibit IL-4 dependent IgE and IgG1 production and enhances IgG2a production in B cells. IL-18 binding protein (IL18BP) can specifically interact with this cytokine and thus negatively regulate its biological activity. It also induces severe inflammatory reactions, suggesting its role in inflammatory disorders. The action of IL-18 on basophils and mast cells causes complex physiological reactions including allergic reactions. IL-18 activity is inhibited by IL-18BP protein found in serum.

TIMP-β 1(TISSUE INHIBITOR OF METALLOPROTEINASES-β 1)

Tissue inhibitor of metalloproteinases 1 (TIMP-1) is a matrix metalloproteinase (MMP)-independent regulator of growth and apoptosis in various cell types. They are widely distributed in the animal kingdom and the human genome contains four paralogous genes encoding different forms like TIMPs-1 to TIMP-4. RNA interference of TIMP-1 has revealed that endogenous TIMP-1 suppresses the proliferation, metabolic activity and osteogenic differentiating capacity of human mesenchymal stem cells (hMSCs).

TIMPs are independent of metalloproteinases; these include effects on the cell growth & differentiation, cell movement, angiogenesis, apoptosis, synaptic plasticity etc. ECM composition variations are crucial for repair, morphogenesis, tissue remodeling, embryonic development etc. ECM catabolism activities are performed by proteases like matrix metalloproteinases (MMPs), which includes collagenases, gelatinases, matrilysins, stromelysins, membrane-type MMPs and ADAMTS (a disintegrin and metalloproteinase with thrombospondin domains) metalloproteinases. TIMPs are endogenous inhibitors of these metalloproteinases and are consequently important regulators of ECM formation, remodeling of the tissue and other cellular responses.

PTX3 (PENTRAXIN-3)

Pentraxin-related protein PTX3 also known as TNF-inducible gene 14 protein (TSG-14) is a protein; in humans is encoded by the *PTX3* gene. It is a member of the pentraxin superfamily. It is rapidly produced and released by different cell types, particularly involved are mononuclear phagocytes, dendritic cells (DCs), fibroblasts and endothelial cells in response to primary inflammatory signals [e.g., toll-like receptor (TLR) engagement, TNF-α, IL-1β].PTX3 binds with high affinity to the complement component C1q, the extracellular matrix component, TNF-α induced protein 6 (TNFAIP6; also called TNF-stimulated gene 6, TSG-6) and few selected microorganisms, including *Aspergillus fumigates* and *Pseudomonas* species. PTX3 activates the classical pathway of complement activation and accelerates the pathogen recognition by macrophages and dendritic cells. Its synthesis is stimulated by endothelial cells, macrophages, myeloid cells, dendritic cells by cytokines and endotoxins such as bacterial products, interleukin-1 etc.

TGF-β1 (TRANSFORMING GROWTH FACTOR-β1)

TGF-β1 is a polypeptide member of the transforming growth factor beta superfamily of cytokines. It is a secreted protein which performs many cellular processes like controlling of cell growth, cell proliferation, cell differentiation and cell death.TGF-β1 is encoded by *TGFB1* gene in humans. It acts synergistically with TGFA in inducing transformation and also acts as a negative autocrine growth factor. Dysregulation of TGF-β activation and defective signaling results in apoptosis. Many cells synthesize TGF-β and all of them have specific receptors that are TGF-β1, TGF-β2 and TGF-β3; all function through the same receptor signaling pathways. TGF-β1 with a molecular mass of 25 KDa has a potential role in wound healing. It plays an important role in controlling the immune system and shows different activities on different types of cell or cells at different stages of the development. TGF-β1 is secreted by many immune or leucocyte cells. Increased expression of transforming growth factor-β1 (TGF-β1) in glomerular mesangial cells augments extracellular matrix accumulation and hypertrophy during the progression of DKD.

TBARS (THIOBARBITURIC REACTIVE SUBSTANCES) AND MDA (MALONDIALDEHYDE)

Thiobarbituric acid reactive substances are formed as a byproduct of lipid peroxidation assayed by TBARS assay method. Reactive oxygen species have extremely short half-lives, so they are difficult to measure directly. Instead, the formed end products of damage produced by oxidative stress are measured e.g TBARS. Since the TBAR assay measures the end-point oxidative damage, it is very useful to determine the overall impact of oxidative stress-inducing while MDA is a low-molecular-weight end product formed via the decomposition of certain primary and secondary lipid peroxidation. However, only certain lipid peroxidation products generate MDA and it is neither the sole end product of fatty acid peroxide formation and decomposition, nor a complete substance generated exclusively through lipid peroxidation. Use of MDA analysis in studies of lipid peroxidation require caution, discretion and (especially in biological systems) correlative data from other indices of fatty peroxide formation and decomposition.

PROTEIN CARBONYL

Oxidative stress is an imbalance towards the pro-oxidant side of the pro-oxidant/antioxidant homeostasis found in several human diseases. These diseases include in which high levels of protein carbonyl (CO) groups have been observed including rheumatoid arthritis, diabetes, chronic renal failure, sepsis and respiratory distress syndrome. The usage of protein CO groups as biomarkers of oxidative stress has advantages in comparison to the measurement of other oxidation products because of the relative early formation and the relative stability of carbonylated proteins. Detection of protein assays containing CO groups involves derivatisation of the carbonyl group with 2, 4-dinitrophenylhydrazine (DNPH), which leads to the formation of stable product named dinitrophenyl (DNP) hydrazone. Their detection can be determined through various means such as spectrophotometric assay, enzyme- linked immunosorbent assay (ELISA) and one-dimensional or two-dimensional electrophoresis followed by Western blot. ROS leading to protein oxidation include radical species such as superoxide ($O_2^{\cdot -}$), hydroxyl ($OH^{\cdot}$), peroxyl ($RO_2^{\cdot}$), alkoxyl ($RO^{\cdot}$), hydro-peroxyl ($HO_2^{\cdot}$) and non-radical species such as hydrogen peroxide (H_2O_2), hypo-chlorous acid (HOCl), ozone (O_3), singlet oxygen ($^1O_2$) and peroxynitrite ($ONOO^-$). Carbonyl (CO) groups (aldehydes and ketones) are produced on protein side chains (especially Arg, Lys, Pro and Thr) on oxidation. These moieties are chemically stable which is useful for both their detection and storage. Protein carbonyl assays give the advantage of using no special or expensive equipment; they can be performed in any normally equipped biochemistry laboratory.

AGEs (ADVANCED GLYCATION END PRODUCTS)

AGEs are the risk factor in the development of many degenerative diseases (for eg diabetes, atherosclerosis, chronic renal failure, Alzheimer's disease etc). AGEs are formed both outside and inside of the body. Specifically, it start from the glycation reaction; addition of a carbohydrate to a protein without the involvement of an enzyme. Glycation, makes cell stiffer, unfit for the cellular function and premature aging. The mechanism by which AGEs induce damage is through a process called cross-linking that causes intracellular damage and apoptosis. They can form photosensitizers in crystalline lens, causes cataract development in later stages. Proteins inside the cells are usually glycated through their lysine residues. Histones found in the nucleus are richest in lysine and therefore form the glycated protein N (6)-Carboxymethyllysine (CML). AGEs receptors are found on many cells which include endothelial cells, smooth muscles cells of the immune system from tissue such as lung, liver and kidney. Receptor, when binding to AGEs, contributes to age- and diabetes-related chronic inflammatory diseases such as myocardial infarction, nephropathy, retinopathy, atherosclerosis, asthama, periodontitis, neuropathy etc.

URINARY 8-HYDROXY GUANOSINE 4 HYDROXY NONENAL

It is widely agreed that, increased generation of ROS cause toxic effects by oxidative damage of macromolecules, such as proteins, lipids and DNA. Reaction of ROS with purine and pyrimidine bases of DNA will generate several products; 8-OHdG is one of the major product of nucleotide oxidation ie oxidized derivative of deoxyguanosine. Concentrations of 8-oxo-dG within a cell are a measurement of oxidative stress.

ANTIOXIDANT ENZYMES (SUPEROXIDE DISMUTASE, CATALASE AND GLUTATHIONE PEROXIDASE)

Reactive oxygen species (ROS) are well recognized for playing a dual role as both deleterious and beneficial species. Cells generate ROS normally by regulated enzymes, such as nitric oxide synthase etc. Beneficial effects of ROS usually occur at moderate or low concentrations involving physiological cellular responses, in defense against pathological agents, in the function of cellular signaling pathways and in an induction of a mitogenic response. In contrast, overproduction of ROS [arising either from mitochondrial electron transport chain or excessive stimulation of NAD(P)H] results in oxidative stress to the cell or tissue. When antioxidant capacity exceeds the normal production inside cells, it gives rise to oxidative stress which causes damage to essential macromolecules resulting in abnormal gene expression, disturbance in receptor activity, apoptosis, immunity deviations, mutagenesis and protein or lipofuscin deposition. Antioxidant enzymes catalyze the decomposition of reactive oxygen species. Three unique antioxidant enzymes, SOD, glutathione peroxidase (GPx) and CAT help in combating oxidative stress. SOD is a group of metalloenzymes whose function is to protect cells from the toxic effects of endogenously generated superoxide radicals. GPx is a selenocysteine-dependent enzyme that protects against oxidative injury and they are the most important hydrogen peroxide (H_2O_2)-removing enzymes in all mammalian cells. CAT is an essential enzyme in the decomposition of intracellular H_2O_2. It promotes the breakdown of H_2O_2 into water and oxygen without producing free radicals. CAT is located in peroxisomes; found essentially in all aerobic cells. Catalase is an unusual enzyme although hydrogen peroxide is its only substrate still it follows ping-pong mechanism.

ADMA (ASSYMETRIC DIMETHYLARGININE)

ADMA is a naturally occurring chemical found in the plasma. It is a metabolic byproduct of continuous post translational protein modification processes in the cytoplasm of all human cells. It is closely related to the structure of L-arginine; a conditional essential amino acid. ADMA interferes with L-arginine in the production of nitric oxide, a key component involved in normal endothelial cell function, produced by dendritic cells as a defensive mechanism, endothelial homeostasis and cardiovascular health. This reaction is catalyzed by an enzyme called S-adenosylmethionine protein N-methyltransferases (protein methylases I & II) and methyl groups are transferred to create ADMA; which is derived from the methyl group donor S-adenosylmethionine. S-adenosylmethionine is an important intermediate in the metabolism of homocysteine. After synthesis it migrates into the extracellular space then to the plasma and can be measured by using high-performance liquid chromatography. ADMA concentrations are substantially elevated by native or oxidized LDL cholesterol. The elimination of ADMA occurs through urine excretion and metabolism by the enzyme dimethylarginine dimethylaminohydrolase (DDAH). Polyphenol antioxidants also play role in down-regulating homocysteine. ADMA's role has been linked with elevated levels of homocysteine. Whilst approaches at modifying the latter one with oral supplements of folic acid were strongly suggested. Endothelial layer or endothelium plays very crucial role in maintaining the structure and vascular tone. NO is major vasoactive substances, its low level is associated with impaired endothelial function. ADMA levels are increased in people with chronic renal and heart failure, atherosclerosis, hypertension, hypercholesteromia and diabetes mellitus. It is associated with three-fold increased risk of future mortality in patients undergoing hemodialysis.

PROTEIN REDUCED THIOLS

Oxidation and reduction of cysteine residues is emerging as an important post-translational control of protein function. The cysteine side chain is considered the most potent nucleophile of all amino-acid side chains under physiological conditions. This reactivity is due to the presence of a thiol functional group. Thiol is a sulfur analogue of alcohol, the smaller difference in electronegativity between the sulfur atom and the hydrogen atom makes the S-H bond less polarized than the O-H bond, leading to a diminished propensity to form hydrogen bonds. They are more acidic in comparison to alcohols, and this property can be explained by the weakness of the sulphur hydrogen bond. This gives information about the antioxidant status of the cellular processes.

β-TRACE PROTEIN (BTP)

BTP also known as prostaglandin D_2 synthase is a low-molecular weight glycoprotein (MW 25.2 kDa) was initially isolated from cerebrospinal fluid and served as a marker of cerebrospinal fluid leakage. The half-life of BTP is approximately 1.2 hr and it is easily filtered through the glomerular basement membrane with minimal non-renal elimination owing to its low MW and absence of protein binding. BTP serum levels increases progressively with the reduction in GFR. Low-molecular weight proteins in serum are better markers for detecting reduced GFR than the conventional measurement of serum creatinine. Recently, it has been identified as potential marker for renal function. β-Trace protein is synthesized mainly in the central nervous system by glial cells and the choroid plexus and forms one of the principal constituents of the cerebrospinal fluid. It catalyzes the reaction from prostaglandin H_2 to prostaglandin D_2, which plays a central role in nociception, temperature and sleep regulation pattern.

CYSTATIN C (CYSTATIN 3)

Cystatin C (γ-trace, post γ-globulin or neuroendocrine basic polypeptide)is a protein encoded by CST3 gene; mainly used as a biomarker for kidney function. In humans, all cells with a nucleus produce Cystatin C as a chain of 120 amino acids. It is a potent inhibitor of lysosomal enzymes and probably one of the most important extracellular inhibitors of cysteine proteases. Glomerular filtration rate (GFR), a marker of kidney health, is best measured by injecting compounds such as inulin, radioisotopes such as ^{51}chromium-EDTA, ^{125}I-iothalamate, ^{99m}Tc-DTPA or radiocontrast agents such as isohexol, but these techniques are mostly complicated, costly, time -consuming and have potential side-effects. Cystatin C has a low molecular weight with 13.3 KDa and is removed from the bloodstream by glomerular filtration in the kidneys. If kidney function and glomerular filtration rate decline, its blood level rises. Cystatin C levels are less dependent on age, sex, race and muscle mass as compared to creatinine. It has been suggested that Cystatin C might predict the risk of developing chronic kidney disease, thereby signaling a state of 'preclinical' kidney dysfunction.

PODOCIN

Podocin is a protein component of the filtration slits of podocytes. Glomerular endothelial cells, the glomerular basement membrane and the filtration slits function as the filtration barrier of the kidney glomerulus. Podocin is a new member of the stomatin family which consists of hairpin-like integral membrane proteins with intracellular $NH_{(2)}$ and COOH- terminus. Glomerular podocytes express podocin but its subcellular distribution and interaction with other proteins are unknown. Podocin localizes to the podocyte foot process membrane at the insertion site of the slit diaphragm and accumulates in an oligomeric form lipid rafts. It mediates the recruitment of nephrin into specialized microdomains of the plasma membrane and important for the function of the glomerular filter. It has been shown that nephrin and podocin are associated with detergent-resistant membranes at the filtration slit that represent special types of lipid rafts. Several studies have shown that deletion of the raft-associated protein tyrosine kinase results in a severe proteinuria in mice. Lipid rafts consist of dynamic assemblies of cholesterol and sphingolipids in the exoplasmic face of the lipid bilayer of the plasma membrane.

NEPHRIN

Nephrin is an Ig-like transmembrane protein necessary for the proper functioning of the renal filtration barrier which consists of fenestrated endothelial cells, glomerular basement membrane and podocytes of the epithelial cells. It is a structural component of the slit diaphragm and essential for maintaining glomerular permeability. A defect in the nephrin gene, NPHS1is associated with congenital nephrotic syndrome of the Finnish type and causes massive amounts of protein to be leaked into the urine. This protein is also required for cardiovascular development. One of the important protein ie CD2-associated protein (CD2AP) is necessary for normal glomerular permeability; a putative nephrin adapter molecule. Podocytes form a tight web like structure on top of GBM with their interdigitating foot processes joined by a slit diaphragm and disruption of nephrin/podocin is a final common pathway leading to foot processes effacement in the proteinuric diseases.

PODOCALYXIN

Podocalyxin, a sialoglycoprotein, is the major constituent of the glycocalyx of podocytes in the glomerulus (Bowman's capsule). It is a member of the CD_{34} family of transmembrane sialomucins. It coats the secondary foot processes of the podocytes. It is negatively charged and functions to keep adjacent foot processes separated; keeping the urinary filtration barrier open. It has a role in the opening of vascular lumens and regulation of vascular permeability. Podocalyxin is upregulated in a number of cancers and is frequently associated with poor prognosis. Sialylated, O-glycosylated glycoforms of podocalyxin expressed by colon carcinoma cells possess L-selectin and E-selectin binding activity and may be pivotal to the metastatic spread of colon carcinoma cells. At the cellular level podocalyxin has shown to regulate the size and topology of apical cell domains and act as a potent inducer of microvillus formation.

NGAL (NEUTROPHIL GELATINASE ASSOCIATED LIPOCALIN)/ LIPOCALIN-2 (LCN2)/ ONCOGENE 24p3

It is a protein that in humans is encoded by the *LCN2* gene (Kjeldsen et al., 1993). NGAL is involved in innate immunity by sequestrating iron that in turn limits bacterial growth. It is expressed in neutrophils and in low levels in the kidney, prostate and epithelia of the respiratory and alimentary tracts. NGAL is used as a biomarker of kidney injury. The binding of NGAL to bacterial siderophores is very important in the innate immune response to bacterial infection. Upon encountering invading bacteria the toll-like receptors on immune cells stimulate the synthesis and secretion of NGAL. Secreted NGAL then limits bacterial growth by sequestering iron-containing siderophores (Flo et al., 2004, Schmidt et al., 2007).

NGAL also functions as a growth factor. In the case of acute kidney injury (AKI), NGAL is secreted in high levels into the blood and urine within 2 hours of injury. NGAL is protease resistant and small; hence the protein is easily excreted and detected in the urine. NGAL can also be used as an early diagnosis for procedures such as chronic kidney disease, contrast induced nephropathy and kidney transplants (Goldstein, 2011). Serum creatinine is a marker of kidney function, whereas NGAL is a marker of kidney injury. Individuals positive for NGAL tend to have higher incidence of going renal replacement therapy. Renal expression of NGAL increases in the kidneys after injury for a variety of reasons. It is possible to measure NGAL in serum or urine in the range of 25 to 5,000 ng/mL by current laboratory tests. Low levels for NGAL have been considered to be 20 ng/mL, medium levels 200 ng/mL and high levels 1200 ng/mL (Lippy et al., 2012).

KIM-1(KIDNEY INJURY MOLECULE-1)

Kidney Injury Molecule-1 (KIM-1) is a type 1 transmembrane protein, with an immunoglobulin and mucin domain, whose expression is markedly up-regulated in the proximal tubule in the post-ischemic rat kidney. KIM-1 is not detectable in the normal human and rodent kidney but is increased in expression more than any other protein in the injured kidney and is localized predominantly to the apical membrane of the surviving proximal epithelial cells (Ichimura et al. 2008).

NAG (N-ACETYL β-GLUCOSAMINIDASE)

The urinary excretion of enzymes, in particular N-acetyl-β-D-glucosaminidase (NAGase), is considered a relatively simple, cheap, fast and non-invasive method in the detection of renal tubular function under various conditions. NAGase is an enzyme in lysosome which is contained abundantly in the renal tubular epithelia and is related to the degradation of mucopolysaccharides and glycoproteins. The determination of urinary NAGase provides a very sensitive and reliable indicator of renal damage, such as injury or dysfunction due to diabetes mellitus, nephrotic syndrome, inflammation, vesicoureteral reflux, urinary tract infection, hypercalciuria, urolithiasis, nephrocalcinosis, perinatal asphyxia, hypoxia, hypertension, heavy metals poisoning, and treatment with aminoglycosides, valproate or other nephrotoxic drugs.

L-FABT (LIVER TYPE FATTY ACIDS BINDING PROTEIN)

Liver-type fatty acid binding protein (L-FABP) is found in the cytoplasm of human proximal tubular cells. L-FABP binds fatty acids and transports them to mitochondria or peroxisomes where the fatty acids are β-oxidized, and participates in intracellular fatty acid homeostasis (Veerkamp et al., 1993). Moreover, L-FABP has a high affinity for and capacity to bind long-chain fatty acid oxidation products and thus is an effective endogenous antioxidant (Wang et al., 2005). FABP1 encodes the fatty acid-binding protein found in liver. Fatty acid binding proteins are a family of small, highly conserved, cytoplasmic proteins that bind long-chain fatty acids and other hydrophobic ligands. It is thought that FABPs roles include fatty acid uptake, transport, and metabolism.

We need better biomarkers that can identify the early diagnosis of diabetic nephropathy progression. Transcriptome analysis of human diabetic kidney diseases reveals the importance of biomarkers for the screening of the disease (Woroniecka et al., 2011).

HERBAL APPROACHES TO DIABETIC KIDNEY DISEASES

Herbal medicine is also known as botanical medicine, herbology, herblore, phytotherapy, medical herbalism. Sometimes it is extended to include certain animal parts, minerals, shells, fungal and bee products.

All plants produce different chemical compounds in their normal cellular metabolic activity. One is primary metabolites required for cellular function and other is secondary metabolites for special function that is not required for basic function. They are produced in very small quantities. Coloured pigments harvest light, minimizing radiation loss and attract pollinators. Many common weeds such as dandelion, chiraita, chickweed have important medicinal properties. Secondary metabolite gives specific property to the plant characteristics. They may act as poison to repel predators or pheromones to attract pollinators. Phytoalexins secretion helps in fighting fungal and bacterial attacks to plants. Allelochemicals inhibit the growth of rival plants by competing for soil, water and light. The synthetic biochemical pathways of plants are up and/ down-regulated in response to the long term weather conditions, herbivores, pollinators etc. Chemical profile of the plant varies according to the changing conditions overtime.

Plants synthesize variety of phytochemicals, some are commercially very important like rubber. But most of the compounds are derivatives of following biochemical motifs.

Table 3. Biomarkers for determining chronic kidney damage

Pathophysiology	Markers	Importance
1. Inflammation	Hs-CRP & CRP	Cardiac risk markers, they help to determine a person's risk of developing cardiovascular diseases.
	IL-18	Proinflammatory cytokine predictor of nephropathy and cardiovascular diseases in diabetes Type 2.
	TIMP-β 1	Glycoprotein which inhibits metalloproteinases (MMPs).
	PTX3	Deficiency increases the risk of DKD.
2. Fibrosis	TGF-β1	(TGF-β) is a key regulator of extracellular matrix protein synthesis and is secreted as latent complexes.
3. Oxidative stress	TBARS,MDA	Free radical generation, Cell membrane damage indicator.
	Protein carbonyl	Cell protein damage indicator.
	AGEs	Leads to thickening of extracellular matrix.
	Urinary 8-hydroxydeoxy guanosine 4 hydroxy nonenal	Oxidative stress derived DNA damage marker.
	Antioxidant enzymes (SOD, CAT, GPx)	Free radical generation.
	ADMA	Interferes with L-arginine in the production of NO which is involved in normal endothelial function. Indicator of progression of Type 1 diabetic nephropathy and microalbuminuria.
	Protein reduced thiols	Outcomes of free radical generation.
4. Kidney function	β-Trace protein	Potent inhibitor of platelet aggregation and involved in smooth muscle contraction, indicator of GFR.
	Cystatin C	It is an important extracellular inhibitor of cysteine proteinases.
5. Glomerular injury	Podocin	It is a component of slit diaphragms of podocytes which function as filtration barrier of the kidney glomerulus.
	Nephrin	It is a component of slit diaphragms of podocytes forming filtration barrier.
	Podocalyxin	It is the major constituent of the glycocalyx of podocytes, negatively charged and keeps adjacent foot processes separated, by keeping urinary filtration barrier open.
6. Tubulo-interstitial injury	NGAL	Early marker released in high amount to combat insult caused by kidney injury (Innate immunity).
	KIM-1	It is a membrane protein with extracellular immunoglobulin and mucin domains which maintains the integrity of epithelial cells.
	NAG	Predicts both micro and macro – albuminuria in Type 1 diabetic.
	L-FABT	Correlated with degree of urinary protein excretion.

- **Alkaloids:** They contains one or more nitrogen heterocyclic ring as an integral part of their structure. They produce striking physiological properties. Some alkaloids stimulate the central nervous system while others cause paralysis; some act as pain relievers, others as local anesthetics. Most alkaloids are toxic. Examples are nicotine, quinine, strychnine (*Nux vomica*). Strychnine present in single fruit of *Nux vomica* is enough to kill twenty humans. But in lower doses, it is used as medicine.

- **Polyphenols:** These are organic compounds containing multiple phenolic structural units. The number and characteristics of these phenolic groups give unique biological and therapeutic properties to the plant. Examples are ellagic acid, tannic acid. Tannins are bitter polyphenolic compound.
- **Flavonoids:** They comprise of large group of secondary metabolites with two phenyl rings and heterocyclic rings. Two important examples are quercetin and kaemferol. They are important pigments for plant colouration and attract pollinators. They function as radical scavengers and posses metal-chelating properties.
- **Terpenes:** These are unsaturated compound joined together by isoprene units. Terpenes containing oxygen or other functional groups are called as terpenoids; they can be linear (eg β-carotene) or cyclic (eg menthol). They are responsible for imparting particular aroma to the plant species. They find use in perfumes, essential oils and medicines. They are building blocks for phytol tail of chlorophyll, cytokinins, steroids etc. Common spices which contain terpenes are clove, ginger, cinnamon.
- **Saponins:** They are the group of organic compounds that form persistent froth when shaken with water even in dilute solution. They cause hemolysis of the red blood cells: they are used as surfactant and emulsifying agent; their small part is absorbed when taken orally but they enhance the absorption of other drugs. They improve liver function, physical and mental performance, immune function and metabolism; also has adaptogenic effect. Glycosides: They are plant molecules in which sugar is bound to the anomeric functional group via glycosidic bond. Glycosides can be linked by O- (O-glycoside), N- (N-glycosamine), S-(thioglycoside), C- glycosides. Disaccharides are glycosides. Many plants store chemicals in the form of inactive glycosides. Example is sinigrin, salicin, oleandrin.

These secondary metabolites further usually refined to produce drugs.

Phytochemical screening of various extracts used in the treatment revealed the presence of tannins; flavonoids and phenolic compounds in most of the herbals applied in the research (see Table 4).

ROUTES OF HERBAL DRUG ADMINISTRATION

Herbs can be administered in various forms, these include the following:

- **Decoctions:** It is a long-term boiled extract of roots, rhizomes, stems or bark.
- **Extracts:** These include liquid extracts, dry extracts and nebusilates. Liquid extracts are low percentage ethanolic liquids than tinctures. They are usually made by vacuum distilling tinctures. Dry extracts are plant material extracts which are evaporated into a dry mass. They can be further refined to a capsule or tablet. Nebulisates are dry extracts prepared by freeze drying.
- **Herbal Wines and Elixirs:** These are alcoholic extract of herbs; usually with an ethanolic percentage of 12-38%. Herbal wine is a maceration of herbs in wine while an elixir is a maceration of herbs in spirits (e.g., vodka, grappa, etc).
- **Inhalation:** As in aromatherapy it is used as a mood changing treatment to fight sinus infection or cough or to cleanse the skin on a deeper level (steam not direct inhalation).

Table 4. Herbals applied for the treatment of diabetic kidney diseases

Recent Herbal Developments	Mechanism of Action	References
1. Coenzyme Q10	Stabilizes the imbalance of antioxidant enzymes.	Maheshwari, Balaraman, Sen &Seth, 2014.
2. *Averrhoe carambola*	Decreases AGEs in the extracellular matrix.	Zheng et al., 2013.
3. Shemyan Kangfu (Chinese patents)	Decreases proteinuria.	Wang et al., 2013, trials
4. Yiqi Huaju Qingli	Reduces microalbuminuria	Wang et al., 2013
5. Mouten cortex	Reduces oxidative stress.	Zhang et al., 2014.
6. Chaihuan -Yishen	Decreases proteinuria.	
7. *Dioscorea bulbifera*	Controls blood pressure	Singh et al., 2013.
8. Huang Qi Elixir	Reduces proteinuria.	Xiang Tu et al., 2013.
9. Cortex Mori, dry root of *Morus alba* Linn.	Lowers blood sugar.	Yu Liu, Fang & Zhang, 2014.
10. *Pueraria tuberosa*	Balances antioxidant enzymes in the kidney.	Tripathi & Nagwani, 2010
11. *Cinnamomum cassia*	Balances antioxidant enzymes in the kidney.	Yan et al., 2015.
12. Zhen-wu-tang	Suppresses hyperactivity of renin-angiotensin system by modulating nephrin and podocin expressions.	Cai et al., 2010.
13. Loganin	Lead to reduced levels of AGE in kidney by downregulating its protein receptors.	Liu et al., 2015
14. Xiexin decoction combinations	Inflammation inhibition by NF-kB	Wu et al., 2014
15. *Ginkgo biloba*	Reduces glomerulosclerosis	Tang et al., 2014
16. *Cassia tora* (seeds)	Inhibition of AGEs accumulation	Kim et al., 2014
17. *Murraya paniculata*	Decreased expression of TGF-β1 and CTGF protein	Zou et al., 2014

- **Macerates:** These are cold infusion of plants with high mucilage-content such as sage, thyme, etc. Plants parts are chopped and added to cold water. They are left to stand for 7-12 hrs (depending on herb used). For most of the macerates 10 hrs is used.
- **Syrups:** Extracts of these herbs are made with honey or syrups. Sixty five parts of sugar are mixed with thirty five parts of water and herb. Whole is then boiled and macerated for three weeks.
- **Tinctures:** They are obtained by combining 100% pure ethanol (or a mixture of 100% ethanol with water) with the herb. Alcoholic extracts of herbs such as *Echinacea* extract. A completed tincture has 25% of ethanol percentage (sometimes up to 90%). Sometimes tincture is applied to preparations using other solvents than ethanol. Nux vomica (strychnine).
- **Tisanes:** These are hot water extracts of herb, such as chamomile.
- **Vinegars:** These are prepared as the same way as tinctures by using a solution of acetic acid as solvent.

Table 5. Classification of bioactive compounds in different plants for DKDs

Categories	Example	Plant source	Mechanism of Action	Reference
Lignans (polyphenolic compounds)	Vanillic acid	*Cladophora socialis*	↓ protein tyrosinase phosphatase-1β activity	Feng et al., 2007
	Cinnamaldehyde	*Cinnamonum zeylanicum*	↓oxidative stress, ↑insulin sensitivity	Mishra et al., 2010
Flavonoids or flavonols	Catechins	*Camellia, Zeylanicum*	↓ oxidative stress	Ramshini and Ayoubi, 2014
	Myrcetin	*Psidium guajava*	↓ oxidative stress, inflammation and glycative stress	Lin &Yin, 2012
	Apigain 6-Cβ-L fucopyranoside	*Averrhoe carambola*	↑insulin secretion	Cazarolli et al., 2009
	Quercetin	*Vaccinium vitis-idaea, Allium cepa*	↑AMPK pathway	Eid et al., 2010
	Steptogenin 4-o-β- D glucoside	*Morus alba*	↓ hyperglycemia	Zhang et al., 2009
	Cinchona	*Eriobotrya japonica*	↑insulin secretion	Qa'dan et al., 2009
Tannins	Proanthocyanidins	Grapes and berries	↓ AGEs, CTGF	Li et al., 2009
	Geranium	*Nephelium lappaceum*	↓hyperglycemia	Palanasamy et al., 2011
Terpenes	Auraptene	Citrus fruits	↓ MMP-1	Kuroyamy et al., 2008
	Karavitoside XI	*Momordica charantia*	↑AMPK pathway	Tan et al., 2008
	Triterpenoid	*Psidium guajava*	↑ insulin sensitivity	Kuang et al., 2012
Saponins	Ginsenoside	*Pomax jinseng*	↓ oxidative stress, ↓ AGEs	Kang et al., 2010
Others	Polysachharides	*Pueraria tuberosa*	↓malondialdehyde, ↑lipoprotein, ↓oxidative stress	Nagwani & Tripathi, 2010
	Curcumin	*Curcuma longa*	↓oxidative stress, ↓AGEs, ↓ NF-kB	Sharma et al., 2006

- **Whole Herb Consumption:** Either dried form (herbal powder) or fresh juice (fresh leaves and other plant parts).

Chemical compounds found in the plants mediate their effects on human body by binding to the receptor molecules present in the body; herbal medicines do not differ greatly from conventional drugs in terms of their mechanism of action. All plants produce various chemical compounds as part of their normal metabolic activities. These are divided into primary metabolites such as sugar and fats, found in all plants and secondary metabolites, compounds not essential for basic function; found in a smaller range of plants for specific purposes e.g. defense mechanisms (see Table 5).

Still inspite of modern research studies there is a wide search for new biomarkers to better diagnose patients with CKD according to the risk of the progression stages and mortality which is an underway process. Management of hypertension, glycosuria, lipid intake, consumption of dietary proteins is required for better outcomes in future with herbal assimilation of modern Ayurveda.

Last but not least nutritional management is of utmost importance for the prevention of DKDs and an important part of alternative medicine and therapy. It includes following points-

1. Maintenance of normal blood glucose level by food intake and exercise.
2. Achieving optimal blood pressure and serum lipids to reduce risk of cardiovascular diseases.
3. Management of body weight.
4. Maintaining biochemical parameters and fluid status.
5. Prevention of malnutrition to control gastroparesis.

CONCLUSION

Totally, herbal dependent approches can't cure the disease but definitely it will alter the lifestyle phenomenon by increasing the longevity. There is need for multitargeted approaches and their wise selection in different aspects of the disease. The nutrition management is fundamental for the prevention of diabetic kidney disease to ESRD. Thus, medicinal plants have been reported to affect metabolic enzymes involved in diabetegenesis correcting the imbalanced glucose metabolic disturbances, improving the glucose uptake, inhibiting gluconeogenic enzymes and modulating glycolytic and lipolytic pathways.

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KEY TERMS AND DEFINITIONS

Diabetic Kidney Diseases (DKDs): It is also known as Diabetic nephropathy. It is a disease that causes the damage of millions of tiny blood vessel clusters leading to the damage of delicate renal filtering system. It develops in severity of the cases of diabetic patients of Type 1 or Type 2.

Glomerular Filtration Rate (GFR): It is described as the rate of volume of the fluid filtered to remove excess wastes and fluids from the kidney glomerular capillaries into the Bowman's capsule per unit time.

Hyperglycemia: It means high (*hyper*) glucose (*gly*) or high blood sugar in the blood stream. It occurs due to the inability of the body to remove glucose from the blood so that cells can use it for energy, this adverse condition arises due to abnormal synthesis or utilization of insulin, often leads to the diabetes.

Metabolic Syndrome: Also known as syndrome X, insulin resistance or dysmetabolic syndrome. It is a cluster of biochemical and chemical metabolic risk factors that come together in a single individual, leading to disorder of energy utilization and storage. Occurrence of any three out of five abnormalities viz., abdominal (central) obesity, hypertension, elevated fasting plasma glucose, high serum triglycerides and low level of high density lipoprotein (HDL) results in cardiovascular disease and diabetes as the main part of metabolic syndrome.

Oxidative Stress: Oxidative stress is the phenomenon of imbalance between production of free radicals, also known as reactive intermediates e.g. O_2^-(superoxide radical), OH^-(hydroxyl radical), H_2O_2 (hydrogen peroxide) and the ability of the biological systems to counteract or detoxify their harmful effect on components of the cells which includes proteins, lipids, and DNA by neutralization through antioxidants.

Proteinuria: Proteinuria indicates the appearance of abnormal quantities of serum proteins in urine. It includes microalbuminuria and macroalbuminuria. It is a sign of chronic kidney diseases (CKDs) and EDRD.

Podocytes: It is an epithelial cell of the visceral layer of Bowman capsule that wrap around the capillaries of the glomerulus through long processes as foot projections called *pedicel* and leave slits between them.

APPENDIX: ABBREVIATIONS

AMPK = AMP- activated protein kinase
NAD^+ = Oxidised Nicotinamide Adenine Dinucleotide.
NADH = Reduced Nicotinamide Adenine Dinucleotide.
NADP = Nicotinamide Adenine Dinucleotide Phosphate.
NADPH = Reduced Nicotinamide Adenine Dinucleotide Phosphate.
GSH = Reduced Glutathione.
ROS = Reactive Oxygen Species.
AGE = Advanced Glycation End product.
PKC = Protein Kinase C.
DAG = Diacylglycerol.
DKD = Diabetic Kidney Diseases.
GAPDH = Glyceraldehyde 3-Phosphate Dehydrogenase.
IL = Interleukin.
VEGF = Vascular Endothelial Growth Factor.
PDGF = Platelet Derived Growth Factor.
CTGF = Connective Tissue Growth Factor.
DHAP = Dihydroxy Acetone Phosphate.
ECM = Extracellular Matrix.
TNF-α = Tissue Necrosis Factor- α.
GFAT = Glutamine Fructose-6-Phosphate Amidotransferase.
↑ = Increase.
↓ = Decrease.
OS = Oxidative Stress.
ICAM-1/ CD 54 = Intercellular Adhesion Molecule-1
CTGF/ CCN2 = Connective Tissue Growth Factor.
VEGF = Vascular Endothelial Growth Factor.
PDGF = Platelet Derived Growth Factor.
GFR = Glomerular Filtration Rate

Chapter 16
Lentils (*Lens culinaris*, L.): A Novel Functional Food

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ABSTRACT

Lentils have been part of human diet from ancient times. This chapter focuses on the nutritional composition, presence of bioactive substances, antioxidants and health rendering properties of lentils. Recent definitions have considered lentils as a prophylactic and therapeutic functional food due to its considerable content of essential macronutrients, namely functional proteins and carbohydrates, and essential micronutrients, as well as bioactive phytochemicals such as phytates and polyphenols. Indeed, the presence of an impressive arsenal of secondary metabolites, minerals and bioactive constituents in lentils have shown to be promising contributors in the management and prevention of several human chronic diseases, attributed to their anticarcinogenic, hypoglycemic, hypocholesterolemic and blood-pressure lowering properties.

INTRODUCTION

Lentils are a part of legume family and form an important constituent of traditional diets. There has been an emerging interest in lentils as functional food due to their high nutritional value, presence of bioactive components, antioxidants and other phytochemicals that render health properties to lentils. Evidence supports that consumption of lentils is related to reduced incidence of chronic diseases such as cardio-vascular disease, overweight and obesity, diabetes and cancers. This chapter aims to highlight the importance of human consumption of lentils and emphasize their contribution as a functional food in the diets. Specifically, the chapter is logically organized to provide an in-depth review and update about nutritional composition, presence of bioactive substances, antioxidants and other phytochemicals in lentils, followed by evidence on their vital role in promoting health of body systems, and reduction in incidence of chronic diseases and in alleviating their symptoms.

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BACKGROUND

Food and Agricultural Organization (FAO) has defined the terms legumes, pulses and lentils. A legume is a simple dry fruit which develops from a simple carpel and usually dehisces (opens along a seam) on two sides. Pulses are important food crops due to their high protein and essential amino acid content. Like many leguminous crops, pulses play a key role in crop rotation through their ability to fix atmospheric nitrogen. Lentils (*Lens culinaris* L.) are a member of the Leguminoceae family. Lentil plant is an annual plant with flattened edible seeds that constitutes one of the most important traditional dietary components (FAO, 1988). Its lens-shaped seeds exist with a spectrum of colors including yellow, red, orange, green, brown or black depending on the cultivar, and subsequently the composition of the seed coats and cotyledons (Xu & Chang, 2010).

Lentils are relatively tolerant to drought and are grown in all five continents of the world. FAO (2008) reported that world's production of lentils was about 2.83 million metric tons, primarily coming from Canada (36.9%) and India (28.7%), followed by Nepal, China and Turkey.

Lentils have been incorporated into different world cuisines throughout the globe. For example, lentils are commonly mixed with cereals such as rice, as in the South Asian dish "Khitchri", the Egyptian dish "Koshari", and the Syriandish "Mjaddara". It is also consumed as dehulled split lentil soup, the most customarily consumed form of lentils in many Middle Eastern countries (Dagher, 1991).

Legumes (pulses) are gaining enough interest as emerging functional foods. Several authors explicitly revised the chemical and nutritional values of lentils, as well as bioactive phytochemicals in pulses and their health benefits (Campos-Vega et al., 2010; Champ, 2002; Duranti, 2006; Rochfort & Panozzo, 2007; Roy et al., 2010; Scarafoni et al., 2007; Tharanathan & Mahadevamma, 2003). The health-improving and disease-preventing aspects of lentils have been supported by a large body of evidence, and have been critically reviewed elsewhere (Faris et al., 2013).

Interestingly, lentils had been mentioned in ancient treatment remedies and were documented by Dioscorides as one of the therapeutic plants (Lardos, 2006). Lentil seeds are used in the folk medicine of many ethnicities to treat different illnesses. They are used orally to treat diabetes (Giday et al., 2007), topically as a water paste to treat skin infections (Teklehaymanot et al., 2007) and for the treatment of burns, after being roasted, milled and applied directly to affected areas (Sezik et al., 2001). In addition, lentils are used as a source of lectins for the treatment and prophylaxis of retroviral infections including human immunodeficiency virus (HIV) infections (Alexandre et al., 2010). Ethnopharmacologically, lentil soup was a staple meal in the ancient world, and it was especially prepared for the ailing individual(s) and not for all members of the household unit (Totelin, 2015).

MAIN FOCUS OF THE CHAPTER

Macro and Micro Nutrients

The chemical composition and individual constituents of whole and split lentils are summarized in Table 1 (USDA, 2010).

- **Carbohydrates:** Total carbohydrates represent the major component of lentil seeds (Padovani et al., 2007) with starches occupying most of the carbohydrate mass (Table 1). Among twenty-three pulse grains, starch yield percent from lentils is the second highest, up to 47.1% (Hoover et al., 2010). In lentils, amylose represents only about 23.5-24.7% of total starch (Hoover & Ratnayake, 2002). This content is lower than in most other pulses but is similar to most grains. Furthermore, lentils are a valuable source of total dietary fibers, with insoluble dietary fiber of approximately 93-99.7% of total dietary fiber (USDA, 2010; Bednar et al., 2001) (Table 1).

Lentils are considered among the best sources of prebiotics (Dwivedi et al., 2014), and contain nutritionally significant amounts of prebiotic carbohydrates, including raffinose-family oligosaccharides (RFO), sugar alcohols, fructooligosaccharides (FOS), and resistant starch (RS) carbohydrates (Johnson et al., 2013). The functional significance of these carbohydrates arises from the fact that oligosaccharides work as selective promoters for the growth of beneficial gut microbes (prebiotics) that aid in improving gut health, restoring microbial balance, and preventing intestinal diseases (Fooks et al., 1999). Johnson et al. (2013) found that total prebiotic carbohydrate concentrations of lentils suggest that a 100 g serving of lentils may provide over 13 g (12.3 g-14.1 g) of prebiotics, thus emphasizing on the role of lentils as a leading source for these prebiotic carbohydrates.

Quantitatively, α-galactosides or raffinose family oligosaccharides account for 53.0% of the total sugars and oligosaccharides content in lentils (Vidal-Valverde et al., 2002). In these oligosaccharides, stachyose represents the major oligosaccharide, followed by ciceritol and raffinose (El-Adawy et al., 2003; Vidal-Valverde et al., 2002). The functional significance of these carbohydrates arises from the fact that oligosaccharides work as selective promoters for the growth of beneficial gut microbes that aid in improving gut health and preventing intestinal diseases (Fooks et al., 1999). Han (2005) found that among different legume pulses, ciceritol was uniquely identified in lentils and chickpeas, whereas verbascose was uniquely identified in lentils and peas.

- **Proteins:** Lentils and pulses are considered to be a good source of proteins that makes them a significant food source for developing countries and low-income people (Hoover et al., 2010; Lombardi-Boccia et al., 2003).

In addition to providing essential and nonessential amino acids and carbon skeletons for the metabolic needs of the human body, lentils are sources of some storage proteins that are usually consumed by the germ during seed germination. The most abundant class of storage proteins in pulses is the water-insoluble fraction, globulins, which forms an average of 47% of the total seed proteins, while the water-soluble protein fraction, predominantly albumins, contributes only 3.8% (Lombardi-Boccia et al., 2003). These storage proteins are described as biologically active proteins. These proteins have been historically referred to as ‘‘anti-nutritional’’ compounds such as lectins and protease inhibitors. These anti-nutrients result in reducing the digestibility of lentil proteins to about 79-92% (Grant et al., 2003).

The major amino acids in lentils are Glu, Asp, Arg, Leu, and Lys (Bamdad et al., 2006), with Glu and Asp making about 48% of the total amino acids in three cultivars of *L. culinaris*. Since lentil proteins are rich in lysine and limited in sulfur-containing amino acids, Met and Cys, and Trp, lentil proteins need to be nutritionally complemented with other sulfur amino acid-rich proteins such as those found in grains. Interestingly, such mutual complementation is quite common in Mediterranean and South-Asian cuisines (Faris & Takruri, 2003). On the other hand, the protein fraction of total lentil nitrogen, protein nitrogen (PN), is considerably high (4.49 g N/100g dry matter (DM)) representing about 89% of total nitrogen (5.03 g), while the non-protein nitrogen (NPN) part accounts for the remaining part (0.54 g N/100g DM) (El-Adawy et al., 2003), indicating better nitrogen usability than in high NPN foods.

- **Fats:** Lentils have relatively low fat and therefore low energy content (Table 1) (USDA, 2010). Ryan and colleagues found that lentil seeds contained a total fat of about 1.4 g/100 g, distributed unevenly over the fatty fractions as follows: saturated fatty acids (SFA), 16.7%; monounsaturated fatty acids (MUFA), 23.7% and polyunsaturated fatty acids (PUFA), 58.8% (Ryan et al., 2007).
- **Minerals:** Ash content of lentils is relatively high, with a range value of 3-5 g/100 g on dry matter (DM) basis. Indeed, the mineral content of lentils is comprised of relatively high levels of Mg, P, Ca and S (Demirbas, 2005; Padovani et al., 2007). In addition, lentils have a low Na and relatively high K contents, with a K: Na ratio of about 30:1 to 90:1. This differential Na: K ratio makes lentils quite appealing as a constituent of a healthy diet for patients with hypertension.

Iron (Fe) is also present in significant quantity in lentils (Demirbas, 2005; El-Adawy et al., 2003). However, the bioavailability of the iron in lentils is known to be reduced by iron-chelating phytochemicals, such as tannins, oxalates and phytates (Sandberg, 2002). These natural chelating agents could be minimized by cooking, germination and fermentation of lentils prior to ingestion (Rodríguez et al., 2008; Umeta et al., 2005). Lentils also contain Zn ranging between 3.2 to 6.3 mg/100 g (Demirbas, 2005; Umeta et al., 2005). Several other trace minerals have been reported in lentils including Cu, Mn, Mo, and B (Demirbas, 2005; Rodríguez et al., 2008; Umeta et al., 2005). Overall, lentils are considered a good dietary source of the aforementioned minerals. It is well noticed that lentil content of major and trace minerals is subject to a wide variation due to differences in soil conditions and agricultural practices.

Selenium content of lentils is directly related to the soil content in the land of origin. For example, it has been found that lentils grown in Saskatchewan province/Canada contain 425–673 µg Se/kg depending on location, soil characteristics, and growing conditions (Thavarajah et al., 2008). The latter quantities provide 80–120% of the Se recommended dietary allowance (RDA) in just a 100 g of dry lentils. In fact, the uniqueness of lentils as a rich natural source of Se has drawn significant interest as a target crop for Se biofortification to be used as a food-based solution for populations with Se deficiencies (Thavarajah et al., 2011).

- **Vitamins:** Lentils are a significant dietary source of a plethora of vitamins including folate, thiamin (B_1) and riboflavin (B_2) (USDA, 2010). Other water-soluble vitamins have also been reported in lentils as follows: niacin; pantothenic acid and pyridoxine. In addition, vitamin E (α, β and γ tocopherols) was measured in lentils by Ryan et al. (2007). The α-tocopherol, and β and γ-tocopherols contents were 1.6 and 4.5 mg/100 g, respectively. This, however, is far from the RDA value of α-tocopherol (15 mg/d). Further, phylloquinone, vitamin K, as reported by USDA (2010) averages about 5 µg/100 g. The daily value of vitamin K is about 80 µg (Table 1). The low vitamin K content renders lentils safe in cardiovascular patients on anticoagulant treatment.

Bioactive Functional Components

Considering the vast number of the ethnopharmacological uses of lentils, it is not surprising that bioactive phytochemicals or plant secondary metabolites have been identified and quantified in leguminous seeds. Based on their chemical structures, bioactive components in lentil seeds could be categorized into different functional bioactive compounds (Issa et al., 2006) as represented in Table 2.

Table 1. Nutrient content of whole and split lentils, g/100 g FM[a]

Nutrient	Unit	Whole Lentils	Split lentils
Water	g	10.4	11.8
Energy	Kcal	353	327
Protein	g	25.8	25
Total lipids (Fat)	g	1.1	2.2
Ash	g	2.7	1.9
Carbohydrates, by difference	g	60.1	59.2
Fibres, total dietary	g	30.5	10.8
Sugars, total	g	2.0	-
Sucrose	g	1.5	-
Glucose (Dextrose)	g	0.0	-
Fructose	g	0.3	-
Lactose	g	0.0	-
Maltose	g	0.3	-
Galactose	g	0.0	-
Calcium, Ca	mg	56	41
Iron, Fe	mg	7.5	7.6
Magnesium, Mg	mg	122	72
Phosphorus, P	mg	451	294
Potassium, K	mg	955	578
Sodium, Na	mg	6	7
Zinc, Zn	mg	4.8	3.9
Copper, Cu	mg	0.5	1.3
Manganese, Mn	mg	1.3	1.4
Selenium, Se	mg	8.3	8.2
Vitamin C, total ascorbic acid	mg	4.4	1.7
Thiamin	mg	0.9	0.5
Riboflavin	mg	0.2	0.1
Niacin	mg	2.6	1.5
Pantothenic acid	mg	2.1	0.3
Pyridoxine (B_6)	mg	0.5	0.4
Folate, total DFE	mg	479	204
Vitamin A, IU	IU	39	58
Vitamin A, RAE	µg	2	3
Carotene, beta	mg	23	35
Vitamin E (α-tocopherol)	mg	0.5	-
Tocopherol, (γ-tocopherol)	mg	4.2	-
Vitamin K (phylloquinone)	mg	5.0	-
Choline, total	mg	96.4	-
Fatty acids, total SFA	g	0.2	0.4
Fatty acids, total MUFA	g	0.2	0.5
Fatty acids, total PUFA	g	0.5	1.1
Cholesterol	mg	0.0	0.0

[a]Source: United States Department of Agriculture (USDA) National Nutrient Database for Standard Reference, Release 23 (2010). (Accessed Dec 2010).

1. **Phytosterols:** Phytosterols are nonnutritive compounds or phytochemicals with the same basic functions in plants as cholesterol in animals; that is, they regulate the membrane fluidity of plant cells and other physiologic functions associated with plant biology (Rao et al., 1998). Legumes are one of the major natural sources of phytosterols. Indeed, phytosterols have shown to be abundant

Table 2. Bioactive functional components in lentils[a]

Category	Individual Compounds
Proteins Trypsin inhibitors Lectins	Bowman-Birk Trypsin Inhibitors (BBI)
Polyphenolics Non-flavonoid Flavonoids	Hydroxybenzoic acid, Hydroxycinnamic acid Flavonols, Flavones, Trans-resveratrol-3- *O*-glucoside, Proanthocyanidins, Flavan-3-ols
Anthocyanins	Catechins, Gallocatechin
Tannins and tannin-related monomers	*p*-Coumaric acid, Ferulic acid, Sinapic acid, Quercetin, Kaempferol, Delphinidin, Cyanidins
Phytate	Phytic acid
Hydrocarbons	Squalene
Carotenoids Saponins	β-carotene

[a]Faris et al., 2013.

in lentil seeds. Researchers (Kalogeropoulos et al., 2010) reported that β-sitosterol represents the predominate phytosterol (about 15.0-24.0 mg/100 g FM) in cooked dry legumes.

2. **Squalene:** Squalene is a non-phenolic hydrocarbon phytochemical compound with chemopreventive potential against colorectal cancer (CRC) (Rao et al., 1998). It is a triterpene that contains six isoprene units and works as a key intermediate in the biosynthetic pathway to steroids in plants and animals. Lentils contain about 0.7 mg/100 g squalene, 0.0007% (Ryan et al., 2007). In other reports, squalene was found to be 0.14-0.16 mg/100 g FM, and 0.00015%, in cooked dry legumes. Thus, lentils could be described as a poor source for squalene.
3. **Phytic Acid:** Phytic acid (myo-inositol-1,2,3,4,5,6, hexabisphosphates, IP_6) is aubiquitous plant component that constitutes 1-5% by weight of most cereals, nuts, legumes, oil seeds, spores, needles and pollen (Graf & Eaton, 1990), and is considered as the major source of phosphorous in pulses (Morris & Hill, 1996). It usually occurs as a mixed Ca-Mg-K salt in discrete regions of the seeds. In the past, its primary functions during dormancy were believed to be the storage of cations and phosphorus, a cell wall precursor and as storehouse for potential energy (Graf & Eaton, 1990). However, nowadays phytic acid has been proposed to serve a vital role in protecting the seeds against the deleterious effects of oxygen and iron. Lentils are considered good sources for phytic acid and its related phytates (Ayet et al., 1997).
4. **Saponins:** Saponins are naturally occurring surface-active glycosides. They include a diverse group of compounds characterized by their structure containing a steroid or triterpenoid aglycone and one or more *ose* chains. Several reports have revealed that the hypoglycemic activity of most antidiabetic medicinal plants has been attributed to the presence of saponins (Elekofehinti, 2015). Lentils, like other legumes, are considered among the best sources of saponins. The lentil content of saponins could be as low as 25 mg depending on germination conditions (Güçlü-Üstündağ & Mazza, 2007).
5. **Lectins:** Hemagglutinins, or lectins, are a very important group of biologically active proteins or glycoproteins found in almost all organisms (De Mejía & Prisecaru, 2005). Their ability to agglutinate erythrocytes is a recognized physiological effect that depends on their specificity and high

binding affinity for a particular carbohydrate moiety on the cell surface (De Mejía & Prisecaru, 2005). Lectins are found naturally in lentils. From lentil seed storage proteins, two lectin-binding fractions were isolated (Freier & Rüdiger, 1990). These lectin-binding proteins were found to be strong stimulators of murine B lymphocyte proliferation.

6. **Defensins:** Defensins form a class of host defense peptides in plants and animals, and participate in development of the innate immune response. Plant defensins are small basic, cysteine-rich peptides. Recently, defensin has been characterized in germinated lentil seeds (Finkina et al., 2008), and was termed Lc-def. The Lc-def consists of 47 amino acid residues and has eight cysteines forming four disulfide bonds.
7. **Protease Inhibitors:** Protease inhibitors have been widely investigated in legumes. Trypsin inhibitors have been identified in lentil seeds with a range of 3–8 trypsin inhibitor unit (TIU)/mg in four different cultivars (Guillamon et al., 2008). From a historic point of view, the proteinase or protease inhibitors are considered as anti-nutritional components of legume seeds, due to their property of decreasing the digestibility of dietary proteins.

In legume seeds, Bowman-Birk type trypsin-chymotrypsin inhibitor (BBI) is present at higher concentrations compared to other plant families and tissues (Cheung & Ng, 2007). Unlike other legumes, however, kinetic studies have shown that the isolated BBI from *L. culinaris* seeds, *L. culinaris* trypsin inhibitor (LCTI) is characterized by unusual strong binding affinity to its target (Scarafoniet al., 2007). In addition; LCTI has been shown to be resistant to thermal denaturation over a wide range of temperature and pH values. The latter could be due to a generally conserved tertiary structure and hydrogen bond network. Such a unique stability explains the potential beneficial effects of BBIs even after the lentils are cooked (Lajolo & Genovese, 2002). Due to their proteolytic effect against reverse transcriptase enzyme involved in viral replication, trypsin inhibitors have been suggested in different medical applications, including inhibition of cancer and utilization in acquired immunodeficiency syndrome (AIDS) (de Almeida Costa et al., 2006).

8. **Dietary Fibers:** Lentils could be considered as a valuable source of dietary fibers (Table 1), most of which (93-99.7%) is insoluble and less than 7% soluble (USDA, 2010; Bednar et al., 2001; de Almeida Costa et al., 2006). The β-glucan component of soluble fibers in lentils is relatively low as compared to its good sources such as oats. However, it is relatively higher than that of peas, winter wheat and flaxseeds (Demirbas, 2005). This functional ingredient had been found to have a hypocholesterolemic effect, an ability to increase HDL-cholesterol and decrease LDL-cholesterol in addition to potential cancer preventive, antitumor, antibacterial and glucose control effects (Demirbas, 2005). Further, by virtue of their fiber content, green lentils supplemented to healthy subjects consuming typical Western diet had been found to increase their fecal weights significantly, thus aiding in protecting their gut from constipation and its harmful complications (Stephen et al., 1995).
9. **Resistant Starches:** Based on starch digestibility, starch had been classified into three groups, namely readily digestible starch (RDS), partially resistant or slowly digestible starch (SDS), and resistant starch (RS). According to this classification, starches that resist the hydrolytic effect of digestive enzymes are collectively called resistant starches. Thus, RS are defined as “the sum of starch and starch-degradation products that, on average, reach the human large intestine” (Perera et al., 2010), and being recognized as a significant contributor to gastrointestinal health.

Lentils contain about 25.4 g RS/100 g total starch on FM, representing about 47.7% of total starch content (García-Alonso et al., 1998), with an average value of 43.7–65.2% (Hoover et al., 2010). Other fractions of starch, RDS and SDS, were found to be 5.2–14.8 and 29.7–41.5% of total starch, respectively (Hoover et al., 2010). It has been reported that although lentils contain good quantities of fermentable soluble dietary fibers and RS, they exhibited the lowest bifidogenic effect when compared with that of other legumes such as peas and chickpeas after being cooked by similar procedures (Queiroz-Monici et al., 2005). Queiroz-Monici et al. (2005) reviewed the bifidogenic effect of dietary fibers and RS, assessed on the intestinal microbiota of rats fed diets based on different pulses including lentils. Later, other researchers (Hernández-Salazar et al., 2010) evaluated the antioxidant capacity and the *in vitro* fermentation by human fecal microflora of the indigestible fraction of cooked lentils and other pulses. They found that the insoluble indigestible fraction (IIF) was higher than the soluble counterpart, soluble indigestible fraction (SIF) in lentils and other pulses. The indigestible fraction (IF) of lentils and other pulses are fermented by colonic bacteria as shown by *in vitro* fermentation studies (Granito et al., 2001). IF from black bean and lentil were the best substrates for the fermentative production of short chain fatty acids (SCFA), especially butyric acid (Hernández-Salazar et al., 2010). Butyrate had been shown to play a regulatory role on the transepithelial fluid transport, reinforces the epithelial defense barrier, modulates visceral sensitivity and intestinal motility and ameliorates mucosal inflammation and oxidative status. Further, several studies have stressed the role of butyrate in the inhibition and prevention of colorectal cancer (CRC). Extraintestinally, butyrate exerts potentially useful effects on hemoglobinopathies, genetic metabolic diseases, hypercholesterolemia, insulin resistance, and ischemic stroke. The mechanisms of action of butyrate vary, mostly related to its potent regulatory effects on gene expression (Canani et al., 2011).

10. **Polyphenolics:** Lentils have the highest total phenolic content (TPC) in comparison to six other common legumes (Han, 2005; Xu & Chang, 2007). Their TPC based on DM was 759 mg gallic acid equivalents (GAE)/100 g, total flavonoid content of 221 mg catechin equivalents/100 g, and the condensed tannin content of 870 mg catechins equivalents/100 g. Tannins and tannin-related compounds play an important role in protecting seeds against oxidative damage induced by multiple environment factors (Salariya, 2005). These compounds are mainly concentrated in the testa, with lentils being among the richest leguminous seeds in their condensed tannin content, up to 915 mg/100 g (Salariya, 2005). Furthermore, lentils contain different tannin-related phenolic compounds (Troszyńska et al., 2006). It was evident that lentils had the greatest level of condensed tannins linked to the indigestible fraction of the seed, with about 23% of condensed tannins found in this fraction (Hernández-Salazar et al., 2010). Total phenolic content and antioxidant activity in lentils exhibit higher or compatible value with those of fruits or vegetables. In addition, total phenolic content of lentils exhibited significant correlation with total antioxidant activity, implying that phenolic compounds are major antioxidant compounds in lentils (Han, 2005). Recently, lentils scored the highest values among fourteen different types and varieties of legumes for simple polyphenols and the total phenolic contents, with total phenolic content of about 26 mg GAE /100 g FM (Kalogeropoulos et al., 2010).

The distribution of phenolic compounds differs in the cotyledon and the lentil seed coat, with non-flavonoid phenolic compounds, such as free and combined hydroxybenzoic and hydroxycinnamic acids, located mainly in the cotyledon of lentils (Dueñas et al., 2003). On the other hand, flavonoids, such as glycosides of flavonols and flavones, are mainly present in the seed coat of lentils. The coat also contains trans-resveratrol-3-*O*-glucoside, and large amounts of proanthocyanidins, with the major groups of phenolic compounds that are present in the seed coat, but absent in the cotyledon (Dueñas et al., 2002; Dueñas et al., 2003).

Interestingly, seed coat represents only a small percentage of the entire lentil seed weight, ranging from 8% to 11% (Bhattacharya et al., 2005; Duenas et al., 2006) but provides significant contribution to the overall benefits of lentils. It has been found that the darkness of the coat of colored legumes such as lentils is accompanied with their phenolic contents. Xu and coworkers (2007) found that dark colored legumes such as lentils possess higher phenolic content and antioxidant activities than the pale colored ones. Dark colored legumes, such as green or red whole lentils, had a significantly higher phenolic content and antioxidant capacity than that of the pale colored, green, yellow or white, legumes (Xu et al., 2007; Xu & Chang, 2010). Unfortunately, several Asian lentil dishes involve dehulled seeds to improve the texture, thereby reducing the beneficial properties of lentils.

Flavonoids and tannins have been widely investigated for their antioxidant potentials and possible clinical applications in the management and prophylaxis of cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases (Scalbert et al., 2005). Flavonoids have also been reported to induce xenobiotic-metabolizing and detoxifying enzymes such as glutathione-S-transferases (GST) (Moon et al., 2006), making the flavonoids appealing candidates for combating carcinogenesis. The cost-effectiveness of lentils and the ease at which flavonoids could be extracted give lentils an advantage over other natural sources of flavonoids.

11. **Minor Antioxidants:** In addition to the total polyphenols, other low molecular weight constituents present in lentils may contribute to their total antioxidant capacity (Fernandez-Orozco et al., 2003). They include tocopherols: α-T (0.56), β-T (0.29), γ-T (9.7), δ-T (0.25 mg/100 g DM), reduced glutathione (0.11 g/100 g DM), and soluble proteins (about 13.9 g/100g DM). It is worth mentioning, however, that the contribution of non-polyphenolic low molecular weight constituents to the total antioxidant capacity of lentils is considered low when compared to that of polyphenolics (Fernandez-Orozco et al., 2003).
12. **Phytoestrogens:** On the other hand, lentils are classified among the poor sources of phytoestrogens, with different isoflavones and lignans as follows: formononetin, daidzein, genistein, glycitein, matairesinol, lariciresinol, pinoresinol, secoisolariciresinol, forcoumestrol, with mean values of total isoflavones (9.5), total lignans (26.6), and total phytoestrogens (36.5 µg/100 g fresh matter (FM) (Thompson et al., 2006). Mazur et al. (1998) found that formononetin, biochanin A, daidzein, genistein, coumestrol, and secoisolariciresinol phytoestrogens contents for whole and split lentils were relatively of low levels in comparison with phytoestrogen-rich sources (Mazur et al., 1998).

Antioxidant Potential of Lentils

Lentils have shown the highest total antioxidant capacity (TAC) among tested pulses (peas, beans, chickpeas and soybeans) measured by ferric reducing antioxidant power (FRAP) and total radical-trapping antioxidant parameter (TRAP) measures, second only to broad beans by Trolox equivalent antioxidant capacity (TEAC) measure (Pellegrini et al., 2006). These findings were also confirmed by Duenas et al. (2006) who found that lentils had a greater antioxidant activity than peas (Duenas et al., 2006).

In another study, Xu and Chang (2008) found that lentils had the highest antioxidant capacity when measured as 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging capacity in comparison with green pea, yellow pea and chickpea. The same study also revealed that the oxygen radical absorbing capacity (ORAC) of lentils was significantly higher than that of green pea, yellow pea and chickpea. Lentils had a higher ORAC value than most of the common fruits and vegetables including apples, plums, blackberries, cherries, figs, peaches, pears, oranges, garlic, cabbage and almonds (USDA, 2010). Recently, lentils demonstrated the highest antioxidant activity among the most commonly used pulses such as pea, lentils, and chickpea ecotypes in the Southern of Italy (Fratianni et al., 2014).

Health Improving Effects of Lentils

Cardiovascular Health

Table 3 summarizes the health improving effects of lentils on cardiovascular and other body systems and functions. Legume seeds constitute an important group of protein sources not only in non-ruminant but also in ruminant diets, the bulk of this protein (about 80%) being in the form of storage proteins, mainly conglycinins and glycinins (Rubio, 2000). These storage proteins in beans, peas, and lentils were found by Kingman et al. (1993) to exert a hypocholesterolemic effect in pigs. They concluded that the mechanism for the hypocholesterolemic effect of legume feeding did not involve increased cholesterol clearance via the intestinal route, but rather the effects on plasma amino acids.

Legume consumption had been inversely associated with the incidence of CVD (Flight & Clifton, 2006). Lentils possess angiotensin I-converting enzyme (ACE) inhibitor activity, thereby concluding that red lentil protein hydrolysates could contribute to its blood pressure-lowering effects (Boye et al., 2010). Later, the ACE inhibitory effect in different hydrolysates obtained from protein concentrates of two lentil varieties by using *in vitro* gastrointestinal simulation was confirmed (Barbana & Boye, 2011). This blood-pressure lowering effect was revealed *in vivo* by lentils, which, when compared with dried beans, peas, and chickpeas, solely decreased blood pressure in spontaneously hypertensive rats (SHR), thus supporting the evidence on the important role of lentils in attenuating risk of CVD (Hanson et al., 2014). Recently, specific fragments were identified from legumin, vicilin and convicilin with amino acid sequences contributing to the antioxidant and ACE-inhibitory activity of lentil hydrolysates (Garcia-Mora et al., 2014). Among four types of pulses at 30% w/w concentration in the experimental diet given for four weeks to SHR, and using pulse wave velocity (PWV) and blood pressure (BP) measurements, only lentils significantly reduced the rise in BP and large-artery remodeling. Further, lentils were able to decrease the media:lumen ratio and media width of the aorta in the SHR, and led to decrease the levels of total cholesterol (TC) and LDL-cholesterol. These promising findings reinforce the significance of lentils as part of the therapeutic lifestyle changes (TLC) and dietary approaches to stop hypertension (DASH) diet prescribed for hypertensive patients (Hanson et al., 2014).

Accumulating evidence supports the cardioprotective, hypolipidemic, and hypohomocysteinemic effects of pulses, including lentils. Hyperhomocysteinemia has been linked to an increased risk of CVD (Ueland et al., 2000). The Framingham Heart study found that lentils contributed 1.7% of total folate intake; regardless the source of folate, whether food or supplement, serum folate concentrations significantly increased whereas serum homocysteine concentrations significantly decreased in a dose- dependent manner (Tucker et al., 1996). In a recent study conducted on 22 adult males with hypercholesterolemia or coronary artery disease, it was found that daily consumption of folate-rich foods, including 50 g beans

Table 3. Health improving effects of lentil components[a]

Health Effect	Responsible Component(s)
Antioxidant	Vitamin E, Vitamin C, Polyphenolics
Anticancer	Flavonoids, BBI, Phytic acid, Phytosterols, Squalene, Defensin, Lectins, RS, Saponins
Antibiotic	Defensin
Anti-inflammatory	Phytosterols, BBI
Hypolipidaemic	Phytosterols, Squalene
Reduction of glycemic load	RS when replacing digestible starch
Blood pressure-lowering effect	K, proteins
Anti atherogenic	Squalene
Laxative	Insoluble dietary fibres, RS
Bifidogenic	Raffinose family oligosaccharides, RS

[a]Faris et al., 2013.

of lentils, chickpea, kidney beans or peas, at a combined amount of 500 µg daily for five weeks, significantly decreased plasma total homocysteine (tHyc) to 8% reduction when compared to consumption of similar quantity of supplementary folic acid (Pintó et al., 2005). In Egypt, lentils were found among the leading source of dietary intake of folate, with an average value of 75 µg/100 g (Hefni et al., 2010).

In vivo, lentils were examined for their glycemic and lipidemic effects using the streptozotocin-induced diabetes rat model (Al-Tibi et al., 2010). In this study, the administration of lentils significantly increased HDL cholesterol in diabetic rats. However, the changes had no significant influence on other lipid profile including triacylglycerol (TAG), TC and LDL cholesterol. This discrepancy in the lipidemic effect of lentils may be due to the increase in adipose tissue lipolysis in absence of insulin, and to a decrease in lipoprotein lipase activity (Eidi & Eidi, 2009). The underlying mechanism of the hypocholesterolemic effect of lentils has not yet been studied. However, it has shown that the hypocholesterolemic effect of raw pea was probably due to increased fecal bile acid output and an increased bile acid formation (Martins et al., 2004), a topic that needs to be further investigated. Studies conducted by Jenkins et al. (1983) showed that daily consumption of 140 g of dried lentils and other pulses cooked or canned for 4 months by a group of seven-free living hyperlipidemic males significantly reduced serum TAG by 7% and total cholesterol by 25%, but did not significantly affect LDL- or HDL-cholesterol. Other researchers (Dabai et al., 1996) investigated the effects of different legume species on blood lipids and fecal steroids in Sprague-Dawley rats for 8-weeks. They found that lentils were second to bambara groundnuts in their hypocholesterolemic effect. In addition, their study revealed that plasma TAG concentrations were significantly reduced on lentils and other legume diets, as compared to a control Western-type human diet; similarly, plasma LDL-cholesterol concentration was significantly reduced on lentils and other legume diets, except bambara groundnuts, as compared to the control diet (Dabai et al., 1996). However, Shams et al. (Shams et al., 2010) found that the addition of 50 g cooked lentils to the diet of diabetic patients led to a significant decrease in TC but not in LDL, HDL and TAG.

The latter findings were previously confirmed by a controlled interventional study conducted by Duane (1997). In their cross-over study on 9 male subjects housed in a metabolic ward for 6-7 weeks, consumption of 120 g baked mixed pulses, 60% red, navy, and lima beans, 27% peas and 13% lentils, significantly reduced serum LDL-cholesterol by 8%, from 138 mg/dL at baseline to 126 mg/dL at the end of treatment, as compared to the isoenergetic control diet. However, no other significant change was detected in serum TC, HDL-cholesterol, or VLDL-cholesterol.

In a meta-analysis of randomized controlled trials on the blood cholesterol-lowering effect of non-soy legume consumption conducted by Bazzano and coworkers (Bazzano et al., 2011), it was found that the 10 clinical trials that included 268 participants given diets rich in non-soy pulses, beans, peas, lentils or chickpeas for a minimum duration of 3 weeks, resulted in a significant reduction in total and LDL-cholesterol levels. They recommended that dietary modification strategies that target the reduction of risk factors for CVD should include an increase in legume consumption in addition to other strategies, which have been of proven benefit.

Diabetes

It has been strongly suggested that eating pulses is beneficial in the prevention and management of diabetes. Therefore, consumption of a wide range of carbohydrate foods from cereals, vegetables, pulses, and fruits both for the general population and for people with diabetes, especially those with type II diabetes (Venn & Mann, 2004) is generally recommended. Pulses have shown an ability to improve blood glucose, lipid and lipoprotein metabolism in diabetic and healthy people. The acute metabolic advantage for pulses in glucose handling may partly be due to the intact structure of the pulse grain (Venn & Mann, 2004). Table 4 reviews the clinical trials conducted on the effect of lentils on serum glucose and lipid profile.

In addition to bowel movement improvement due to the high fiber content, lentil-derived leguminous fibers have been found to prevent the impairment of the metabolic control in diabetic rats when total carbohydrates intake was increased, suggesting that lentil carbohydrates, including dietary fibers, could have promising implications for diabetic patients (Wolever et al., 1994).

The hypoglycemic effect, or more accurately the ability to alleviate the glycemic load, of lentil has been demonstrated in experimentally induced diabetic rats, healthy volunteers, and insulin-dependent and non-insulin dependent diabetic patients (Al-Tibi et al., 2010; Shams, et al., 2010; Wolever et al., 1994). Shams et al. (2010) found that addition of 50 g cooked lentils to diabetic patient diet led to a significant decrease in fasting blood glucose. Results of this study were partly confirmed, where lentils were examined for their glycemic effects *in vivo* using the streptozotocin-induced diabetes rat model; wherein, the administration of lentils significantly decreased serum blood glucose (Al-Tibi et al., 2010).

Lentils have shown low glycemic index (GI) in healthy volunteers, with an average value of approximately 29 (Jenkins et al., 1981). Indeed, the values vary from 18 to 52, with an average value of 26 for red lentils (mean of 4 studies), 30 for green lentils (mean of 3 studies), 29 for NS type lentils (mean of 2 studies) and 52 (1 study) for green lentils canned in brine (Foster-Powell et al., 2002).

Increasing the proportion of low GI carbohydrates in the diet has been associated with a range of health benefits, including protection against diabetes type 2, CHD and obesity (Flight & Clifton, 2006; Hodge, English et al., 2004; Liu, 2007). There is a noticeable variation in the reported values of GI for lentils between *in vitro* and *in vivo*(Araya et al., 2002; Chung et al., 2008; Foster-Powell et al., 2002; Germaine et al., 2008; Hodge et al., 2004) that may reflect the effects of many factors such as botanical variation and agricultural conditions of growing lentils, the form of lentils and preparation methods, along with the variation in the *in vitro* assays. Despite this variation between *in vivo* and *in vitro* GI, lentils still had the lowest and the slowest rate of hydrolysis of starches, and the lowest estimated glycemic index (eGI) among tested pulse grains, chickpeas and peas (Chung et al., 2008).

Table 4. Summary of clinical trials on the effect of lentils on blood glucose, lipids, and homocysteine levels

Study	No. and Type of Subjects	Type of Design	Treatment	Tested Variable	Results
Pinto,et al. (2005)	20 male patients with hyperhomocysteinemia and coronary artery disease	Randomized, crossover intervention Trial	500 µg folate from dietary sources, including lentils and other pulses and foods	Plasma total hyperhomocysteinemia	Significantly reduced plasma tHcy concentrations (-8.6%)
Jenkins, et al. (1983)	7 male hyperlipidemic patients	Randomized controlled trials	140 g of dried lentils and other pulses cooked or canned for 4-month period.	Lipid profile	Significantly reduced serum TAG (- 7%) and TC (- 25%)
Duane, et al. (1997)	9 subjects on a metabolic ward during two randomly ordered 6-**7** week periods	Cross-over	120 g baked mixed pulses, 60% red, navy, and lima beans, 27% peas and 13% lentils,	Lipid profile	Significantly reduced serum LDL-cholesterol (-8%)
Shams, et al. (2010)	30 patients with type II diabetes mellitus	Randomized cross-over clinical trial	Normal diet with 50 gm cooked lentil and 6 gm canola oil substitute of 30gm bread and 20gm cheese	Serum lipids and glucose levels	Significant reduction of FBS and TC (-3.5%), and improvement of glycemic control (-1.6% blood glucose)
Jenkins et al. (2012)	121 (with DM2)	Parallel RCT	Low-GI legume diet. Control: high wheat-fibre diet, Target: 1 cup/day of cooked beans, chickpeas or lentils (adherence assessed by 7-d FR)		Low-GI legume diet 2 HbA1c (−0.5%), body weight (−2.7 kg), waist circumference (−1.4 cm), and total cholesterol (−8 mg/dL) Blood pressure and heart rate reduced on low-GI legume diet in comparison with control
Meta-Analysis of Clinical Studies					
Bazzano, et al. (2011)	268 in 10 trials	Randomized controlled trials	120-130 g lentil/ day for 30-56 days, macronutrient and total energy contents of intervention and control diets are the same	Lipid profile	Significantly reduced serum TC (-11.8 mg/ dl) and LDL (-8 mg/dl) for non-soy legumes including lentils

Overweight and Obesity

Obesity control is an important intervention in an effort to reduce the incidence of chronic diseases, including diabetes. Epidemiological and interventional studies have shown that the consumption of phenolic-rich foods is inversely associated with the prevalence of obesity and several chronic diseases (Kris-Etherton et al., 2002).Pulses contain components that have been shown to benefit weight control. Among the pulses that had shown "anti-obesity" effect are lentils. In human subjects, consumption of lentils with pasta and sauce were found to lower food intake when compared with consuming pasta and sauce only or consuming chickpeas with pasta and sauce (Mollard et al., 2012). Further, the high fiber content and low glycemic response of lentils have been looked at as a means for increasing satiety, reducing the food intake, and thus controlling body weight (Mollard et al., 2012). Among four different pulses, lentils exhibited the strongest satiating properties, resulting in lower food intake as compared to other dietary meals. Lentils led to 8% lower cumulative energy intake as compared to a reference mea (Mollard et al., 2012). This evidence improves the observational studies that consistently show an inverse relationship between pulse consumption and BMI or risk for obesity (McCrory et al., 2010).

Arginine has been shown to possess thermogenic properties, thus enhances carbohydrate and fat oxidation via increased mitochondrial biogenesis and modulation of genes that regulate energy expenditure (Trock et al., 1990). Analysis of lentils has demonstrated that arginine is a major amino acid constituent of lentil protein at 11.0–11.3 g/16 g N (Bhatty & Christison, 1984). In addition to arginine, lentils contain significant amounts of glutamine at approximately 15.0 g/16 g N (Bhatty & Christison, 1984), which has been shown to increase postprandial energy expenditure by 49% in human subjects (Marinangeli & Jones, 2012). Other integral factors in lentils that make it useful in preventing obesity and related co-morbidities include the inhibitory effect of lentils against α-glucosidase and lipase enzymes. The inhibition of α-glucosidase reduces intestinal glucose digestion and absorption, consequently controlling the post-prandial glycemic response, which is crucial in the management of type 2 diabetes (Balasubramaniam et al., 2013). The inhibition of lipase is considered to be one of the more effective strategies for managing obesity (Xu et al., 2005). Recently, Zhang et al. (2015) found that flavonols, not the flavanols, in lentils showed the inhibitory activities against α-glucosidase and pancreatic lipase, thus suggesting a potential role of lentil consumption in managing weight and control of blood glucose.

Cancers

Pulses, including lentils, are consumed traditionally in populations where cancers of the colon, breast, and prostate are low (Correa, 1981). In a prospective study on 90,630 women, and among a vast number of flavonoid-rich foods, lentils or beans were the only foods that exhibited an inverse association with the risk of breast cancer (Adebamowo et al., 2005). Consumption of foods with high glycemic index (GI) and high glycemic load (GL) is associated with hyperglycemia and hyperinsulinemia. These foods have also been suggested to cause metabolic disturbances correlated with increased incidence of colorectal cancer (CRC) (Bruce et al., 2000). Hence, the lower incidence of CRC in developing as compared to developed countries could be partially attributed to the consumption of larger quantities of low GI foods, such as pulses.

Lentils have shown significantly the highest polyphenolic content expressed in terms of total phenolic content. Possible mechanisms for chemopreventive activity of phenolic acids include inhibition of carcinogen uptake, inhibition of formation or activation of the carcinogen, deactivation or detoxification of the carcinogen, preventing the carcinogen binding to DNA, and enhancing the level or fidelity of DNA repair. In addition, antioxidant properties include scavenging reactive electrophils and oxygen radicals and inhibiting arachidonic acid metabolism into Prostaglandin-E_2 (PGE_2) by cyclooxygenases 1 & 2 (COX-1 & COX-2) (Nichenametla et al., 2006).

Plant lectins are unique group of proteins and glycoproteins with potent biological activity. Lentils are natural sources of lectins. Several lectins have been found to possess anticancer properties *in vitro*, *in vivo*, and in human case studies (De Mejía & Prisecaru, 2005); they are used as therapeutic agents, preferentially binding to cancer cell membranes or their receptors, causing cytotoxicity, apoptosis, and inhibition of tumor growth. They also affect the immune system by altering the production of various interleukins, or by activating certain protein kinases. Lectins can bind to ribosomes and inhibit protein synthesis, modify the cell cycle by inducing non-apoptotic G1-phase accumulation mechanisms, G2/M phase cell cycle arrest and apoptosis, can activate the caspases cascade, and can also down regulate telomerase activity and inhibit angiogenesis (De Mejía & Prisecaru, 2005). Mechanisms by which lectins exert their tumor suppressor effects were also summarized by Scarafoni et al. (2007). Hence, lectins seem to be promising therapeutic agents against tumorigenesis especially since these compounds have the advantage of being internalized into cells, causing cancer cell agglutination and/or aggregation.

In addition, other investigators (Sames et al., 2001; Wang et al., 2000) confirmed the inhibitory effect of *L. culinaris* Agglutinin (LCA) against hepatoma and skin melanoma cell lines. Interestingly, LCA-reactive fraction of serum α-fetoprotein (AFP-L_3) has been widely investigated as a valuable marker for evaluation of curability of surgical treatment and for improving the accuracy of prognosis. In addition, it has been suggested that lectins could be used as a noninvasive screening tool for colorectal neoplasms and for the early diagnosis of the cancer, as they exhibited ability for binding to human colonocytes, and thus predict the presence of malignant and premalignant lesions in the colon (Desilets et al., 1999). On the other hand, lectins derived from lentils have been shown to be non-toxic, which allows for safe utilization in medical diagnostic kits (Mitchell et al., 1998).

A novel peptide called "defensin" has been characterized recently in germinated lentil seeds (Finkina et al., 2008). Plant defensins are characterized by a broad spectrum of biological activities including antimicorbial activities against bacteria and fungi. The purified lentil defensin possesses an antifungal activity inhibiting the *Aspergillus niger* growth. Further, several reports demonstrated the ability of defensins to modify the activities of digestive enzymes, trypsin and α-amylases, and HIV-1 reverse transcriptase enzyme implicated in viral replication. Some defensins have also been shown to block ion channels and inhibit protein translation. Hence, they have been suggested to aid in halting tumorigenesis. Indeed, defensin exhibited an antiproliferative activity against more than one tumor cell line (Finkina et al., 2008).

Among the bioactive peptides that characterize pulses are the "BBI", for which beneficial biochemical and functional properties have been proved, such as the efficacy of BBI against tumor cells *in vitro* (Losso, 2008; Scarafoni et al., 2007). BBI are present at higher concentrations in pulses as compared to other plant families and tissues. Proteases are considered key factors in cancer progression and metastasis; therefore, suppressing their activities by protease inhibitors appears to be contributing to inhibiting carcinogenesis (Losso, 2008). Indeed, BBIs have shown to possess cancer preventive and suppressing agents in various *in vitro* and *in vivo* model systems (Kennedy, 1998). A compelling body of therapeutic evidence suggests potential clinical applications for BBI in radioprotection, skeletal muscle atrophy, obesity, autoimmune diseases, multiple sclerosis, and inflammation (Armstrong et al., 2000; Kennedy, 1998). In some cases, as in the treatment of oral leukoplakia lesions, the use of BBIs has reached phase II of clinical trials (Armstrong et al., 2000). Unlike other pulses, kinetic studies have shown that the isolated

BBI from *L. culinaris* seeds, *L. culinaris* trypsin inhibitor (LCTI), is characterized by unusual strong binding affinity to its target as compared to other natural BBI (Scarafoni et al., 2007). In addition, LCTI has shown to be resistant to thermal denaturation over a wide range of pH, probably due to its generally conserved tertiary structure and hydrogen bond network. Such a unique character explains the potential beneficial effects of BBIs even after cooking the lentils (Lajolo & Genovese, 2002). Mature lentil BBI inhibits cell proliferation of colon cancer cells in a dose dependent manner due to their intrinsic abilities to inhibit serine proteases (Armstrong et al., 2000).

Lentils contain considerably high amount of the folic acid, which is expected to be involved in the cancer preventive effect of lentils. Folate is essential for the *de novo* biosynthesis of purines and thymidylate, which affects DNA replication and cell division, and synthesis of S-adenosyl methionine (SAM) (Milner et al., 2001). Folic acid and SAM work as methylating agents that have the potential to prevent hypomethylation of DNA, which is observed in colorectal neoplasia in humans and may contribute to the loss of normal controls on proto-oncogene expression (Greenwald et al., 2001). Hence, folic acid is considered to be among the potent agents that suppress gene expression by DNA methylation (Chen & Kong, 2005). In humans, higher folate intake has been inversely associated with the risk of colon cancer (Chen & Kong, 2005). Folic acid is considered among the most potent and effective colon cancer chemopreventive agents in experimental rodents, with potency number of seven, in comparison with the most potent chemopreventive factor examined in this context, non-steroidal anti-inflammatory drug (NSAID) Celecoxib, with a potency factor of fourteen (Chen & Kong, 2005; Corpet & Taché, 2002).

Phytic acid (IP_6) is the major source of phosphorous in pulses (Morris & Hill, 1996). Dietary phytates have shown to be effective in halting colorectal carcinogenesis (Marks et al., 2006). Several molecular mechanisms have been suggested for the antineoplastic activities of IP_6. The modification of signal transduction pathways resulting in cell cycle arrest, thus reducing cell proliferation has been demonstrated as one mechanism. It has also been implicated in induction of apoptosis, inhibition of angiogenesis and tumor metastasis, induction of differentiation of malignant cells, and enhancement of immunity. Further, several studies have indicated anti-inflammatory and antioxidant properties, reduction of the expression of phase I xenobiotic metabolizing enzymes over expression of phase II detoxifying enzymes and tumor suppressor genes and suppression of protooncogens (Fox & Eberl, 2002; Verghese et al., 2006; Vucenik & Shamsuddin, 2006). Preliminary studies in human cancer patients have shown that IP_6 and inositol, an adjuvant to chemotherapy, appeared to enhance the anticancer effect of the conventional chemotherapy, control cancer metastases, and improve quality of life by reducing the side effects of common chemotherapy (Vucenik & Shamsuddin, 2006). Similar anti-inflammatory and anticarcinogenic effects induced by resistant-starch (RS)-rich pulses such as lentils could work as additional factors in preventing cancer, especially CRC (Perera et al., 2010).

In recent years, food and non-food sources of saponins have come into renewed focus due to increasing evidence of their positive health implications such as hypocholesterolemic and anticancer properties (Güçlü-Üstündağ & Mazza, 2007). Anticancer activity of saponins has been reported for many triterpenes and steroid saponins including, but not limited to, soya saponins present in pulses, including lentils (Güçlü-Üstündağ & Mazza, 2007). Different forms of saponins isolated from different plant sources have been identified as potential anticancer agents by the National Cancer Institute's anticancer drug screen program.

Soya saponins have been suggested to be potent chemopreventive agents against CRC, an effect that had been evidenced through several epidemiological, *in vivo* and *in vitro* laboratory studies that were critically reviewed by Gurfinkel and Rao (Gurfinkel & Rao, 2003).

Natural chemopreventive nutrients and phytochemicals act at multiple levels of prevention, and exert synergistic and additive effects when combined together by modulating one or several cell signaling pathways involved in the process of carcinogenesis (Issa, et al., 2006). In contrast to pharmacological chemopreventive agents, the dietary natural non-toxic constituents can reach the colon directly, where they will be able to exert their antitumor effects on their targets (Gossé, et al., 2005). Examples of promising and studied diet-derived chemopreventive agents include plant antioxidant nutrients and phytochemicals such as polyphenolic phytochemicals (Nichenametla, et al., 2006).

The presence of a wide spectrum of bioactive phytochemicals and peptides in lentils make it a functional food with chemopreventive effect against CRC. The chemopreventive potential of lentils against colorectal carcinogenesis was investigated (Faris et al., 2009; Shomaf et al., 2011) using azoxymethane (AOM) to chemically induce colon cancer in Fischer 344 rats that were fed different lentil diets- raw whole green, cooked whole green, raw split red and cooked split red, before and after the carcinogen injection, in order to mimic the initiation/promotion and progression model of human sporadic CRC. The lentils significantly reduced the number of dysplastic lesions and neoplasms in the colons of rats when compared with control (Shomaf et al., 2011).

In the other part (Faris et al., 2009), the preneoplastic lesions called aberrant crypt foci (ACF) were used as surrogate endpoints for chemoprevention trials; pre-cancerous lesions count, crypt size and multiplicity were significantly reduced in rat groups fed different lentils in comparison with the control group; cooked whole lentils being the most effective. For lentil diets, cooked whole lentils had a striking 77.8% reduction in large ACF, whereas the reduction was only 26.8% in rats fed with raw whole lentils. As large ACF have shown to predict more accurately preneoplastic potential, this suggested that the lentils, particularly cooked whole lentils, may act by retarding progression of the early aberrant crypts. This preferred effect is elucidated by the substantial reduction in the multicrypt foci, >4AC, by different treatments, and the ability of these dietary factors to considerably reduce the number of aberrant crypts derived from these large foci. Cooked whole lentils resulted in the highest reduction of the AC from large or multicrypt foci, with a percent reduction of about 65%. These findings of Faris et al. (Faris et al., 2009) were confirmed later by Busambwa and colleagues (Busambwa et al., 2014), who found that sprouted and non-sprouted lentils reduced AOM-induced ACF in Fischer 344 male rats, with a concomitant significant increase in glutathione, glutathione-S-transferases (GST) and catalase activities. Further, lentils exhibited greater chemopreventive effect in comparison with other grain legumes such as green and yellow peas (Busambwa et al., 2014).

It is noteworthy to indicate that the ability to reduce total ACF number reflects the ability of tested materials to prevent carcinogenesis initiation or working as blocking agents. According to Chen and Kong (2005), the blocking agents that inhibit colon carcinogenesis could exert their preventive effect by several mechanisms, including: enhancement of detoxification of carcinogens, inhibition of cytochrome P450 (CYP450) mediated activation of carcinogens, scavenging free radicals and halting antioxidant activity, and finally trapping the carcinogen and preventing their interaction with DNA.

For the large ACF, the reduced number of multicrypt foci is pivotal biomarker that reflects the ability of tested materials to prevent cancer promotion, or to work as suppressing agents. The reduction in the high multiplicity ACF has been associated with lowered levels of inducible nitric oxide synthase (iNOS) and COX-2 enzymes (Kwon & Magnuson, 2007; Kwon et al., 2004), and associated in other studies with suppression of proliferation, production of PGE_2, and Cyclin D1 protein expression, and upregulation of apoptosis (Sengupta et al., 2004; Tanaka et al., 2000; Tanaka et al., 2000). Other biomarkers such as urinary levels of oxidative DNA damage and expression of COX genes, COX-2 mRNA, in colonic mucosa have also been used in chemoprevention studies (Lala et al., 2006). So, further research is required to elaborate the molecular, genetic, and epigenetic mechanisms underlying the chemopreventive effect of lentils against CRC.

Faris et al. (2009) reported that the chemopreventive ability of lentils in F344 rats was accompanied with increased activity of the xenobiotic detoxifying liver enzymes glutathione-S-transferases (GSTs) in all lentil-fed groups in comparison with the control.

It has been reported that anticarcinogenic enzyme inducers can be either monofunctional which elevates only the Phase II enzymes involved in xenobiotic detoxification, e.g. GST, or bifunctional, which elevates both the Phase I enzymes that catalyze the metabolic activation of carcinogens, e.g. CYP450, and Phase II xenobiotic detoxifying enzymes (Talalay, 1989). Antioxidant polyphenolics present in lentils and other pulses are among the monofunctional inducers that increase the activity of xenobiotic detoxifying enzymes alone (Pool-Zobel et al., 2005). The finding that hepatic levels of antioxidant enzymes such as GST were significantly greater in rats fed chemopreventive lentil diets than in rats fed control diet implies an increased antioxidant capacity to defend against oxidative stress that was triggered by chemopreventive agents (Pool-Zobel et al., 2005).

Further, the induced GST in livers of rats fed on split lentils could be ascribed partly to the presence of appreciated quantities of phytic acid in the cotyledons. It was found that levels of GST were increased concomitantly with increasing phytic acid, inositol, and polyphenolics content in the tested diets, when compared with the control diet. Phytic acid could reduce colon cancer via chelation of iron and suppression of iron related initiation and promotion of carcinogenesis and it may have potential therapeutic use in cancer due to its property of enhancing the activity of natural killer cells associated with suppressed tumor incidence (Khatiwada et al., 2006).

Finally, the inhibitory action of lentils could be explained, in part, by its putative antioxidant activity, and by the presence of other chemopreventive agents in the cotyledons rather than the antioxidant phytochemicals accumulated in the seed coat, as presented in the rat fed the split lentils. Further, the high selenium content in lentils may also be a contributing factor to anticarcinogenic potential of lentils, as this element is involved in the induction of apoptosis and enhancement of immune system (Arthur et al., 2003).

Thus, it might be speculated that the antioxidant phytochemicals were not the only responsible factors for chemoprevention, as the chemopreventive ability was not restricted to polyphenolic-rich whole, non-split, and lentil seeds. The reduction in colon carcinogenesis in rats fed on split lentils could be attributed to the presence of anticancer macro- and micro-constituents in lentil cotyledons. Industrially, and in an attempt to popularize the consumption of the nutrient-dense, health-improving lentils by different sectors of the community, researchers have attempted to develop healthy snack bars that are based on lentils as a basic ingredient in the form of micronized flaked lentils (Ryland et al., 2010).

SOLUTIONS AND RECOMMENDATIONS

It is clear that lentils have been an integral part of traditional diets consumed for their nutritive value, taste, ease of availability and cooking in variety of cuisines. However, the advanced technology and research have uncovered newer aspects of lentils that direct the importance of considering lentils as functional food. It is, therefore, imperative to emphasize on the consumption of lentils in regular diets so as to benefit from their nutritional value, presence of bioactive components and other phytochemicals as well as reduction in the incidence of chronic diseases. Further, well-designed and larger-scaled randomized-controlled trials could be integrated for better understanding of the therapeutic effects of lentils, and to explain discrepancies in the clinical studies on the specific role of lentils consumption in different human ailments and diseases.

FUTURE RESEARCH DIRECTIONS

With the plethora of evidence emerging on the health benefits of lentils, it is recommended that the direction of future research focuses on the relationship of specific nutritional and bioactive components in lentils with the specific health or disease conditions. Further, the specific amounts of each integral component associated with the health effect must be determined. This will assist in estimating the amount of lentil consumption for therapeutic use. The molecular mechanisms underlying the chemopreventive effect of lentils in chemically-induced chronic diseases in animal models (namely cancer and diabetes) are required for better understanding of the effect of lentils on these diseases. *In vitro*, future research should enhance the information on the mechanisms involved in molecular and cytological modifications induced by lentil bioactive components; that will assist in developing drugs and medications from lentils bioactive functional components.

CONCLUSION

A compelling body of evidence investigating lentils, *L. culinaris,* confirms that lentil is one of the most nutritious and health improving foods known to man. According to recent definitions, lentil could be considered a prophylactic and therapeutic functional food due to its considerable content of essential macronutrients, namely functional proteins and carbohydrates, and essential micronutrients, as well as bioactive phytochemicals such as phytates and polyphenols. Indeed, lentils contain an impressive arsenal of secondary metabolites, minerals and bioactive constituents that have shown to be promising in the management and prevention of several human chronic illnesses due to their anticarcinogenic, hypoglycemic, hypocholesterolemic and blood-pressure lowering properties. Further research is required to improve the nutritional quality of lentil proteins and optimize the agricultural and culinary conditions to ensure maximum utilization of the rich supply of bioactive phytochemicals in lentils.

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Chapter 17
Food in Health Preservation and Promotion:
A Special Focus on the Interplay Between Oxidative Stress and Pro-Oxidant/Antioxidant

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ABSTRACT

Association between food and health is complex. Healthy food can promote and maintain good human health. Healthy food and nutrition is a key regulating factor for boosting the immunity and therapeutic effectiveness of a treatment strategy. Oxidative stress is well involved in the pathogenesis of diverse diseases and aging. Food always considered as good source of nutrients, protein, fat, carbohydrates, vitamins, minerals and antioxidants. Consumed as part of a normal diet, phytochemicals present in food like vitamins (vitamin C & E), minerals (like, zinc, selenium), phytoconstituents (phenolic compounds, flavonoids, carotenoids) confer additional health benefits, by virtue of their antioxidant property. A diet rich that rich in antioxidant molecule reduces the risk of several oxidative stress related diseases. Numerous antioxidant molecules isolated from food showed the curative and health promotion effect. This chapter majorly deals with the role antioxidant/pro-oxidant substances present in different foods on human body.

INTRODUCTION

Good health is elemental to living a productive life, meeting basic needs and contributing to healthy society. The components of health are numerous and their interactions with food are complex. Healthy diet is essential for the success of physical and mental potential for all individuals. Good food, physical

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activity and healthy lifestyle are the basic requirement for preservation and promotion of health. A good diet is about receiving the correct amount of nutrients, bioactive molecules to maintain good health. Foods not only contain protein, fat, carbohydrates, vitamins and minerals but also supply essential biomolecules like antioxidants which are boosting our health. A good food can support human health and improve health potential, and yet can also be an important factor influencing ill health.

In 1980s the name antioxidants came into spotlight when it identified as miracle substances for good health. Food contains numerous biomolecule (antioxidant), which prevent free radical induce diseases, increase immunity and also act as anti-aging molecule. Regular intake of fruits and vegetables has also been shown to protect human from number of diseases, and concurrent scientific investigations have confirmed that antioxidant substances present in those fruits and vegetables are playing a central role for their beneficial effect (Wahlqvist, 2013; Sen & Chakraborty, 2015). Fruits, vegetables and other food can boost the antioxidant capacity of body and thus helpful for human.

REDOX HOMEOSTASIS AND OXIDATIVE STRESS

ROS/RNS and Redox Homeostasis

Cellular redox homeostasis can be described as a normal physiological situation specifically the maintenance of normal level of free radical/reactive species in *in vivo* condition through the genetic control and array of enzymatic systems. In normal physiologic conditions, cells regulate the redox balance through production and elimination of reactive oxygen species (ROS) and reactive nitrogen species (RNS). Cells are well equipped with different enzymatic and non-enzymatic antioxidant systems to maintain the normal level of ROS/RNS in body by scavenging ROS/RNS, so that redox homeostasis sustains (Sen & Chakraborty, 2011; Trachootham, Lu, Ogasawara, Valle & Huang, 2008; Valko et al., 2007).

ROS and RNS consist of free radicals and different reactive species. Free radicals can be generated in both endogenous and exogenous environment. Production of free radicals in *in vivo* condition is continuous process as a part of normal physiology. Several process or system of our body like immune system, metabolic process (lipid peroxidation, metabolism of arachidonic acid, platelets, and macrophages), inflammation, and stress generates reactive species continuously. Drugs (adriamycin, bleomycin, mitomycin C, nitrofurantoin), chemicals (carbon tetrachloride, chloroform, paraquat, benzo pyrene, cleaning products, glue, paints, paint thinners, perfumes, and pesticides), smoking of tobacco products, radiation, pollution and some food are responsible for generation of free radicals (Sen, Chakraborty, Sridhar, Reddy, & De, 2010; Sen & Chakraborty, 2011). Generation of free radical also increased in pathological condition. ROS and RNS are essential for body in low/moderate concentration. It acts as intercellular signal molecules and also participate in immune mechanism. But at high concentration they induce molecular damage (Valko et al., 2007; Zorov et al., 2005). Table 1 describes different ROS and RNS along with their properties.

Oxidative Stress and Diseases

Normal physiological and biochemical function of cell maintain by the steady state concentration of reactive species, which determined by the balance between the generation and removal of reactive species by various antioxidants. Redox state cannot explain only as the state of redox pair, but it also demon-

Table 1. Properties of different reactive oxygen and nitrogen species

Reactive Oxygen Species (ROS)		
Oxygen-centered radicals	Superoxide anion ($O_2^{\bullet -}$)	● It is a reduced form of molecular oxygen that formed in mitochondria as initial free radical. ● $O_2^{\bullet -}$ contribute majorly in generation of other reactive species like H_2O_2, $^{\bullet}OH$, $^1O_2$, $OONO^-$. ● $O_2^{\bullet -}$ can reduce the activity of catalase and glutathione peroxidase ● One superoxide dismutase (SOD) converts two $O_2^{\bullet -}$ into one H_2O_2 and one oxygen molecule.
	Hydroxyl radical ($^{\bullet}OH$)	• $^{\bullet}OH$ is the neutral form of the hydroxide ion, which is highly reactive (half-life of approximately 10^{-9} s) and responsible for damage of lipid, polypeptides, proteins, DNA base. • $^{\bullet}OH$ generates from $O_2^{\bullet -}$ and H_2O_2 in presence of metal ions through Fenton reaction (except exercise), and as a by-product of immune action especially by the macrophages and microglia when exposed to certain bacteria. ● In reaction with aromatic compounds $^{\bullet}OH$ is responsible for generation of hydroxycyclohexadienyl radical, which in reaction with oxygen can produce peroxyl radical. ● $OH^{\bullet}$ can induce the conversion of many fatty acid side chains into lipid hydroxyl peroxides ● Catalase (CAT) causes dismutation of $^{\bullet}OH$ to H_2O and O_2, reduced glutathione (GSH) is also scavenge $^{\bullet}OH$.
	Peroxyl radical ($ROO^{\bullet}$)	● $ROO^{\bullet}$ generates through a direct reaction of oxygen with alkyl radicals ($R^{\bullet}$). Decomposition of alkyl peroxides (ROOH) also responsible for formation of $ROO^{\bullet}$ and $RO^{\bullet}$. ● Hydroperoxyl radical ($HOO^{\bullet}$) is the simplest peroxyl radical, which is the protonated form of $O_2^{\bullet -}$. ● Several enzymatic reactions (i.e. cycloxygenases, oxidases, lipoxygenases, peroxidases, and NADPH-cyt P_{450} reductases) and non-enzymatic reactions (LOOH-derived Fenton reaction, a reductive cleavage, or combination of two peroxyl radicals) can trigger the formation of $RO^{\bullet}$. ● $HOO^{\bullet}$ along with $^{\bullet}OH$ can affect the lipids profoundly. ● Lipid alkoxyl radical can induce damage of DNA or other surrounding organic molecules. ● Both the peroxyl and alkoxyl radicals are good oxidizing agents.
	Alkoxyl radical ($RO^{\bullet}$)	
Non-radicals	Hydrogen peroxide (H_2O_2)	● H_2O_2 produced through a dismutation reaction from $O_2^{\bullet -}$ induced by SOD. ● Several oxidase enzymes like amino acid oxidases, xanthine oxidase in cell are involve in the production of H_2O_2. ● H_2O_2 is weak oxidizing and reducing agent, and it is considered as least reactive molecule. ● H_2O_2 involve in the production of thyroid hormones, and also may act as intracellular signal molecule. ● Under physiological pH and in absence of metal ion H_2O_2 is stable. ● H_2O_2 can induce cell toxicity by inducing DNA damage, membrane disruption and release calcium ions within cell which is responsible for activation of calcium dependent proteolytic enzyme. ● H_2O_2 is responsible for generation of $^{\bullet}OH$, $O_2^{\bullet -}$.
	Hypochlorous acid (HOCl)	● HOCl is generated by the enzyme myeloperoxidase in activated neutrophils and initiates the deactivation of antiproteases and activation of latent proteases which is responsible for tissue damage. ● HOCl can cause damage of biomolecules, directly and also decomposes to liberate toxic chlorine. ● During inflammation activated neutrophils and eosinophils can generate several ROS including HOCl and HOBr. ● HOCl and HOBr contribute to the generation of ROS and radicals through different secondary reactions. ● HOCl and HOBr causes the formation of advanced oxidation products (AOPPs) which alter the cell structure and physiology by targeting thiols, thioethers, disulfides, amines and amides
	Hypobromous acid (HOBr)	
	Ozone (O_3)	● It is not generated *in vivo*, but considered as an unwanted oxidant and very toxic air pollutant. On exposure to lung ozone cause tissue damage. O_3 directly or via free radical can induced oxidation or peroxidation of biomolecules.
	Singlet oxygen ($^1O_2$)	● Singlet oxygen is an excited status, mild and nontoxic for mammalian tissue compare to other ROS. ● It involved in cholesterol oxidation. • $^1O_2$ can be generated from H_2O_2, which reacts with $O_2^{\bullet -}$ or with HOCl or chloroamines in cells and tissues.
Reactive Nitrogen Species (RNS)		
Radicals	Nitric oxide ($NO^{\bullet}$)	● $NO^{\bullet}$ is formed from the amino acid L-arginine by NO synthase in vascular endothelial cells, phagocytes, and many other cell types. ● NO● in low concentration act as biological signaling molecule and involved in regulation of several biological functions like neurotransmission, regulation of blood pressure, defense mechanisms, smooth muscle relaxation and immune function. ● It is as such not a highly reactive free radical, but ischemia reperfusion, neurodegenerative and chronic inflammatory diseases can be caused by the overproduction of $NO^{\bullet}$. ● NO after exposed in plasma can reduce the level of ascorbic acid and uric acid, and can initiate lipid peroxidation. ● NO● can react with oxygen and water to generate nitrate and nitrite anions.
	Nitrogen dioxide ($NO_2^{\bullet}$)	● $NO_2^{\bullet}$ is generated from the reaction between peroxyl radical and NO, polluted air and smoking. ● $NO_2^{\bullet}$ can initiate lipid peroxidation and responsible for generation of other free radicals. ● It involve in the oxidation of ascorbic acid.
Non-radicals	Peroxynitrite ($ONOO^-$)	● $ONOO^-$ can be formed by the reaction of $NO^{\bullet}$ and superoxide anion. ● Peroxynitrite is a cytotoxic molecule and good oxidizing agent, which can oxidizes LDL and cause tissue injury. It also involved in the direct protein and DNA base oxidation, modification of DNA base. ● Peroxynitrite also involved in the pathogenesis of several disorders like neurodegenerative and kidney diseases. ● Peroxynitrite-mediated reactions are responsible for formation of nitrotyrosine.
	Nitrous acid (HNO_2)	● Nitrous oxide acts as a precursor of HNO_2. It encourages the deamination of DNA bases (cytosine, adenine and guanine) containing free NH_2 groups.
	Dinitrogen trioxide(N_2O_3)	● N_2O_3 is the anhydride of nitrous acid, which is generated through the reaction of $NO^{\bullet}$ and $NO_2^{\bullet}$. N_2O_3 is a strong oxidizing agent and responsible for nitrosylation of phenols.
	Peroxynitrous acid (ONOOH)	● ONOOH can induce a cycle of events leading to the generation of highly reactive and damaging radicals like $CO_3^{\bullet -}$, NO_2^+, NO_2, $O_2^{\bullet -}$, $OH^{\bullet}$, which can lead to significant damage in biological milieu.
Other reactive nitrogen species includes alkyl peroxynitrites (ROONO), nitronium (nitryl) cation (NO_2^+), Nitrosyl cation (NO^+), Nitroxyl anion (NO^-), Dinitrogen tetroxide (N_2O_4)		

Halliwell and Gutteridge (1999); Jiang, Zhang, and Dusting (2011); Lee, Koo, and Min (2004); Marcinkiewicz (2010); Sen and Chakraborty (2011); Soneja, Drews, and Malinski (2005); Valko et al. (2007)

strates the redox environment of a cell. Usually in normal conditions, redox state of a biological system is preserved towards more negative redox potential values. Level of ROS and RNS produced inside the cell tightly regulated by the different endogenous antioxidants. Though, augment in ROS production or reduction in antioxidant protection within cells responsible for less negative redox potential values, which in turn results the oxidizing environment. This change from reducing status to oxidizing status is explained as oxidative stress (Kunwar & Priyadarsini, 2011). Oxidative stress is responsible for the damage of biomolecules like lipids, proteins, carbohydrates and nucleic acids, and such oxidative modification of biomolecules due to toxic concentration of ROS and RNS lead to deleterious consequences such as loss of cell function and diseases state. Due to high elevation of ROS/RNS level, mitochondria lose its function which in turn responsible for ATP depletion and necrotic cell death, while moderate oxidation can induce apoptosis (Kunwar & Priyadarsini, 2011; Sen & Chakraborty, 2011). Reactive species are responsible for change of cell function and alteration of signal pathway. Oxidative stress causes damage to lipid present in membrane of subcellular organelles, alters enzyme activity, and modifies function & structure of protein. Reactive species also leads to DNA fragmentation, mutation, damage, and apoptosis through the activation of the poly (ADP-ribose) syntheses (Sen & Chakraborty, 2011; Valko et al., 2007).

'Oxidative stress' is a basic phenomenon which is used to describe the relation between free radicals and molecular damage. Long time exposure to reactive species, even at a low concentration may cause tissue injury through the damage of biomolecules. Recent researches identified oxidative stress as a key underlying cause of different diseases and aging process. Majorly, four key processes in oxidative stress involve in the pathogenesis of numerous diseases, (1) membrane lipid peroxidation, (2) protein oxidation, (3) DNA damage and (4) disturbance in reducing equivalents of the cell (Sen & Chakraborty, 2011; Valko et al., 2007).

ANTIOXIDANTS AND PROXIDANTS

Antioxidants and Their Effect on Health

Antioxidants are the molecule which essential to maintain structural and tissue integrity. Antioxidants scavenge free radicals, stabilize the level of reactive species and thus play a key role in maintenance of optimal cellular and systemic health. Antioxidants include diverse substances like enzyme, vitamins, minerals, phytoconstituents etc. They generally retard the process of oxidative degeneration or oxidative damage. Level of antioxidant and free radical influenced by several factors like production/destruction rate of reactive species, potency and concentration of antioxidant, gene expression, diet, stress, hormones, smoking, drugs intake, pollution and lifestyle condition, pathological condition etc (Hegde, Rai, & Padmanabhan, 2009; Van't Veer, Jansen, Klerk, & Kok, 2000; Sen & Chakraborty, 2011). Antioxidant system can be classified majorly in three groups. (1) Primary antioxidant defense: these are also known as chain breaking antioxidants which can neutralize free radicals by giving one of their own electron, and thus end the electron "stealing" reaction. (2) Secondary antioxidant defense: antioxidants under these classes are called as preventive antioxidants, which act through number of mechanism including sequestration of transition metal ions, removal of peroxides by antioxidant enzyme, removal of ROS. (3) Tertiary antioxidant defenses: they mainly involve in repair mechanism. Though, antioxidants can be classified in several way based on origin, nature/structure, chemical-physical properties, and mechanism (Vertuani, Angusti, & Manfredini, 2004; Tandaon, Verma, Singh, & Mahajan, 2005).

Based on the origin and nature the antioxidants can be classified as,

1. Natural antioxidants
    a. Endogenous antioxidants
        i. **Enzymatic antioxidants:** Superoxide dismutase (SOD), Catalase (CAT), Glutathione peroxidase (GPx), Glutathione reductase (GR), Glutathione-*S*-transferase (GST)
        ii. **Non-enzymatic antioxidants:** Glutathione (GSH), bilirubin, albumin, vitamin C, vitamin E, β-carotene, ferritin, uric acid, transferring, ubiquinone.
    b. Natural exogenous antioxidants
        i. **Vitamins:** Vitamin C, Vitamin A (ß-carotene)
        ii. **Minerals:** Selenium, Copper, Iron, Zinc and Manganese.
        iii. **Phytochemicals:** Phenols, Flavonoids, Alkaloids,
2. Synthetic antioxidant: Butylated hydroxyl anisole (BHA), Butylated hydroxy toluene (BHT), Tertiary butylated hydroxy quinine (TBHQ)

Table 2. Different types of endogenous antioxidants & their function

Antioxidant	Location and Importance
Superoxide dismutase (SOD).	There are three isomer of SOD in human. SOD1 located on cytoplasm, SOD2 in mitochondria, and SOD3 present in extracellular area Superoxide dismutase (SOD) is an important endogenous antioxidant enzyme. SOD scavenge $O_2^{\bullet -}$ to H_2O_2 and O_2.
Catalase (CAT)	Located in intracellular area and decomposes H_2O_2 to water and oxygen.
Glutathione peroxidase (GPx)	Present in plasma and intracellular area. GPx remove H_2O_2 and inhibit the formation of hydroxyl radical. It inactivates hydroperoxides.
Glutathione reductase (GR)	GR a key intracellular antioxidant enzyme require for the conversion of GSH from glutathione disulphide.
Glutathione-*S*-transferase (GST)	Present intracellularlly, conjugates xenobiotics and alkylating substances for excretion with GSH.
Glutathione (GSH)	Located in plasma, cytosol, nuclei and mitochondria. Maintain redox potential and –SH groups in other biomolecules. GSH scavenge $OH^{\bullet}$, singlet oxygen directly. GSH involved in the detoxification of H_2O_2 and lipid peroxides, regeneration of some antioxidants like vitamins C and vitamin E.
Bilirubin	Present is plasma. It is a free radical scavenger. Nonconjugated bilirubin acts as endogenous lipid antioxidant.
Albumin	Present in plasma. Act by binding with metal ions such as Fe, Cu.
Ascorbic acid	Present in extracellular fluid. Neutralize ROS in aqueous phase before the initiation of lipid peroxidation. It induces the regeneration of α-tocopherol.
Vitamin E	Present in plasma. Act as electron donor, H^+ donor and quencher of $^1O_2$. It acts as chain-breaking antioxidant within the cell membrane and protects membrane fatty acids from lipid peroxidation
β-carotene	Located in plasma and in cell membrane. Act as electron donor and quencher of $^1O_2$.
Ferritin	Present in plasma. Act by binding with Fe ions
Uric acid	Present in plasma. Act by binding with free Fe ions, and also scavenge $^1O_2$and $OH^{\bullet}$.
Transferrin	Present in plasma. It act by binding with free Fe ions, and inhibits iron-catalyzed radical formation.
Ubiquinone	Present in plasma. It can prevent the initiation and/or propagation of lipid peroxidation.

Yuan and Kitts (1997); Sies, Stahl, and Sundquist (1992); Halliwell and Gutteridge (1999)

In nature, antioxidants confer protective effect in living organisms from oxidative damage. Antioxidant system is essential for protection and integrity of cell structure and function. Foods like fruits, vegetable, food grains are essential for health. Current understanding reveled that they contain abundant antioxidant in addition to the other numerous biomolecule. The favorable effect of vegetables, fruits, and other foods against degenerative diseases has been credited, in part, to the antioxidants they provide. Consumption of food rich in antioxidant believed to confer benefit by protecting the body's cells.

Antioxidants eliminate free radicals that damage cells and also involve in damage cell repair mechanism, promotion of cell growth, protection of cells against premature and abnormal ageing, prevention of diseases. Antioxidants also offer excellent support for our immune system (Sen & Chakraborty, 2011). Current researches have confirmed that free radical induced oxidative stress has been implicated in several diseases like cancer, cardiovascular diseases (hypertension, atherosclerosis, ischemic heart disease, cardiomyopathies and congestive heart failure), neurological disorders (Parkinson's disease, Alzheimer's disease, Multiple Sclerosis and amyolotrophic lateral sclerosis), gastrointestinal diseases (peptic ulcers, gastrointestinal cancers, and inflammatory bowel disease), kidney disease (urolithiasis, diabetic nephropathy), diseases of premature infants (bronchopulmonary, dysplasia, periventricular leukomalacia), lung disease (asthma, pulmonary fibrosis), eye disease (cataract, age related macular degeneration, diabetic retinopathy), joint disorder, diabetes, malaria, chronic fatigue syndrome, lichen planus, vitiligo, autism, infection and aging (Gupta et al., 2014; Adly, 2010; Sen et al., 2010). Thus numerous researches devote to exploring and utilizing antioxidants in the prevention and treatment of such diseases. However, synthetic antioxidants showed several toxic effects to some extents, thus utilization of natural antioxidants could be the best way to defend oxidative stress (Li et al., 2014). Due to the beneficial effect of antioxidants the use of antioxidant dietary supplements are in rise.

Pro-Oxidants and Health

Prooxidants are any endobiotic or xenobiotic substances/molecule that results generation of ROS or inhibition of antioxidant system and thus induce oxidative stress. Overproduction of pro-oxidants can induce significant damage to cell or cell death. Pro-oxidant capable to induce the damage of mitochondria, genetic material and thus leads to reduced adaptability, disease and aging. Chemically, pro-oxidants have an electron-imbalance – they have chemically very unstable unpaired electron. Thus pro-oxidants aggressively want to receive an electron from another molecule around them. All ROS/RNS, drugs, and pesticides even some cases popular antioxidants also reported to act as prooxidant in specific environment. Different pro-oxidants includes, (1) Drugs, chemicals and pesticide – drugs like NSAIDS or anticancer drugs, pesticide such as DDT can induce organ damage by inducing the generation of ROS, alteration of antioxidant defence mechanism and lipid peroxidation. (2) Transition metals (i.e. magnesium, copper iron etc) which can induce diseases like chronic magnesium, Wilson disease, and hemochromatosis. These metal cause generation of free radicals through Fenton reaction and Haber-Weiss reaction. (3) Excessive physical exercise and mental stress/anxiety also responsible for oxidative stress. (4) Diseases - disease condition like local ischemia can enhance ROS generation. (5) Environmental factor i.e. heat, cold, pollution increase ROS production through the disruption of electron transfer caused by decreased membrane fluidity of mitochondria. (6) Antioxidants – under specific condition, well known antioxidants like ascorbic acid, vitamin E, polyphenols can behave like pro-oxidants (Rahal et al., 2014).

It is also true that pro-oxidants are not essentially "bad" in-and-of themselves. They of course play a key role in our health and survival by helping to generate the inflammatory responses that protect us. Several molecules can serve as either antioxidants or pro-oxidants, depending on environment. A number of studies indicated that exogenous antioxidants may act as pro-oxidant and may cause damage of health, though results are controversial. Some studies mostly *in vitro* have shown that exogenous antioxidants, under certain conditions, like high doses or presence of metal ions can act as pro-oxidant, and may responsible for damage of biomolecules, and the consequent cellular death. (Teeguarden, 2007; Yordi, Pérez, Matos & Villares, 2012)

ANTIOXIDANT POTENTIAL OF FOOD AND HEALTH

Exogenous Antioxidant and Their Health Benefit

Food from plant contains diverse phytochemicals like dietary fiber, antioxidants, detoxifying substances, immunity-boosting chemicals and neuropharmacological substances, which have disease-preventing functions. Polyphenolic compounds, carotenoids, flavonoids, anthocyanidines and isothiocyanates are the major antioxidant constituents present in the food. Several vitamins (i.e. vitamin E, vitamin C), minerals (i.e. zinc, selenium) are also present in food and exert free radical scavenging activity. Foods rich in antioxidant molecule are exhibiting disease-protecting and health promotion effect. Foods like cereals, pulses, fruits, oils, spices, and vegetable are the good sources of antioxidant constituents. Majority of the plant foods contain phenolic and flavonoids as antioxidant. Green leafy vegetables, fruits and yellow vegetables are the rich source of carotenoids, flavonoids and vitamin C. These phytochemicals inhibit lipid peroxidation and also support the endogenous antioxidants. In general, total antioxidant potential of a food is estimated by considering its capacity to prevent lipid peroxidation in an *in vitro* system. However, the effectiveness of antioxidants or activity of antioxidant containing foods are not only depend on the level of antioxidant present in foods but also on their bioavailability, that is, the level to which the of antioxidants in active forms are released from the food and absorbed through the gut. It was observed that few flavonoids and phenolic antioxidants are rather poorly absorbed; they usually form insoluble complexes with metals. The level of oxidants in food is a determinant factor of antioxidant potency of a diet, for example, high PUFA content can decrease the antioxidant potency of food as PUFA is prone to formation of lipid peroxide (Rao, 2003).

Recent studies have proved the positive association between polyphenolic compounds and disease prevention. Consumption of food and beverages rich in polyphenolic compounds increases the antioxidative capacity of plasma. Several clinical trials have indicated that consumption of food containing polyphenolic compounds reduces the incidence of cardiovascular disease, cancer and other oxidative induce diseases. Polyphenols are powerful inhibitors of LDL oxidation and showed their potent effect as cardioprotective agents. Beneficial effect of quercetin and resveratrol in coronary heart disease, flavonol-rich dark chocolate in reduction blood pressure was studied. Flavonol cocoa drink consumption is associated in arterial dilation in people with smoking-related endothelial dysfunction was reported. Anticancer activity of different polyphenol (like, theaflavins and thearubigins, soy isoflavones, quercetin, catechins, isoflavones, lignans, flavanones ellagic acid, red wine polyphenols, resveratrol and curcumin) against different types of cancer like mouth, stomach, duodenum, colon, liver, lung, renal, breast, prostate and skin have been observed through clinical trials and *in vivo* or *in vitro* studies. Potential benefit of (+) catechin, (-)epicatechin, (-)epigallocatechin, epicatechin gallate, quercetin, soyabeans isoflavones, tannic acid, glycyrrhizin, chlorogenic acid, curcumin and ferulic acid were observed in diabetes or in diabetic complications. Curcumin also found to boost immunity. Epidemiological observations indicated positive association between polyphenols and obstructive lung disease, osteoporosis. Soy isoflavone, genistein promotes lung function in asthmatic people; while genistein, daidzein helpful to prevents the loss of bone mineral density and trabecular volume due to ovariectomy. Polyphenols also protect skin damages induced by sunlight. Polyphenols present in the tea may protect the skin from UV light. Polyphenols like theaflavin 3 3' digallate, and theaflavin 3' gallateare reported to possess antiviral activity. Consumption of fruit and with high levels of flavonoids may exert anti-aging effect. Tea catechins, resveratrol a grape polyphenol emerged as potent anti-aging substance. Daidzein and genistein investigated for their hepatoprotective effect. Another key effect of polyphenol is their beneficial effect against different degenerative diseases and also helpful in maintaining central nervous system health (Pandey & Rizvi, 2009; Stevenson & Hurst, 2007; Han, Shen & Lou, 2007).

Mode of Action of Antioxidants

Vitamin E

Vitamin E denotes a group of potent, lipid-soluble antioxidants. Naturally occurring different form of vitamin E includes tocopherols (α, β, γ, δ) and tocotrienols (α, β, γ, δ). Vitamin E is chain-breaking antioxidants which avert the propagation of free radical reactions. Vitamin E terminates free radical chain reactions by interacting with lipid peroxyl radical, and thus inhibits the generation of new radical. Vitamin E also promote endogenous antioxidant defense like up-regulation of GPX, CAT from liver, SOD, GST, GR and NAD(P)H, along with its direct ROD scavenging activity. Vitamin E can be recycled back to its previous unoxidized state after oxidation by several antioxidants like vitamin C and ubiquinol. This process averts the gathering of vitamin E radicals and their subsequent peroxidation of lipids which can be crucial for its antioxidant effect. α-tocopherol is the most abundant form found in nature and has the potent biological activity. A number of research confirmed that vitamin E could be beneficial in cancer, cardiovascular diseases, coronary artery diseases, diabetes etc. *In vitro* studies also found that vitamin E may exert anti- and pro-oxidative effects depending on the environment (Brigelius-flohe & Traber, 1999; Farbstein, Kozak-Blickstein & Levy, 2010; Vertuani et al., 2004)

Vitamin C

Vitamin C is an electron donor and powerful water-soluble antioxidant. Ascorbic acid is widely distributed in fresh fruits especially citrus fruit. Green leafy vegetable also have high level of vitamin C. Now a days, synthetic ascorbic acid which is identical to natural ascorbic acid available as tablets, capsules, chewable tablets, crystalline powder. Average daily intake of ascorbic acid which is essential to meet the nutritional requirement or recommended dietary allowances (RDA) for adults are 90 mg/day (man) and 75 mg/day (women). Ascorbic acid can react with radicals and terminate the reaction, thus protects the cell from oxidative stress. Vitamin C gives two electrons from a double bond between the second and third carbons of six-carbon molecule. Ascorbic acid prevents other substances from being oxidized by donating its electrons. Vitamin C scavenges ROS and RNS and thus protects the biological macromolecules from oxidative damage. It also involves in many enzymatic reactions as co-factor, and acts as plasma localized anti-oxidant. Once oxidized, ascorbate generates ascorbate free radical, although this free radical can donate another electron but does not undergo further oxidation. L-ascorbate radical can increase redox reactions in presence of transition metals, therefore some investigations suggested that vitamin C might serve as a pro-oxidant depends on physiological environment. For example, in atherosclerotic plaque where ferric iron is present, vitamin C could act as a pro-oxidant rather than as an anti-oxidant. But majority of *in vivo* studies fails to establish the pro-oxidant of vitamin C (Farbstein et al, 2010; Padayatty et al., 2003; Carr & Frei, 1999).

Polyphenolic Compounds

Polyphenolic compounds are the largest group of phytochemicals widely distributed in different plant based food. Polyphenolic phytochemicals emerged as source of potent therapeutic for diverse diseases. Intake of large amount of food with a high level of such compounds may promote health by reducing the risk of a number of diseases due to their antioxidant potential, among other factors. Over 8000 phenolic compounds are currently known, of which more than 4000 flavonoids have been discovered. Fruits, vegetables, grains, beverages like tea, chocolate are rich sources of polyphenols. Polyphenols are the group of natural substances that is highly diverse and can be categorized as several sub-groups, such as, flavonoids, phenolic acid, tannins, simple phenol, stilbenes, lignans, xanthones, coumarins (Tsao, 2010). Polyphenols mainly exhibit the antioxidant and free radical scavenging effect by several mechanisms. (1) They act as primary antioxidant and scavenge free radicals by donating hydrogen atom. Some cases these reactions can leads to the generation of another radical but this is less reactive compare to previous one. O–H group in phenolic compound is most important for this effect. (2) Polyphenols also act by chelating transition metals ions, leading to stable complexed compounds (Leopoldini, Russo & Toscano, 2011). Several researchers have found that several polyphenol antioxidants may act as pro-oxidant under certain conditions like high doses or presence of metal ions. Though, most of the investigations determining pro-oxidant effect of antioxidants are inconclusive and sometimes contradictory. Polyphenols, particularly different flavonoids and phenolic acid showed such dual behavior, but mostly in *in vitro* studies. Pro-oxidant activity of quercetin, myricetin, kaempferol and phenolic acids (i.e. caffeic, coumaric, salicylic, vanillic, hydroxybenzoic, vanillic, syringic, protocatechuic, gallic, ellagic, chlorogenic and ferulic acids) have been investigated. Therefore safety aspects, structure-activity, bioavailability and metabolism of such antioxidant compounds need to be investigate properly. Current research also indicated that pro-oxidant effect of natural antioxidant polyphenols could be useful in prevention of certain types of cancer. Pro-oxidant activity of certain dietary polyphenols can cause mitochondrial dysfunction, apoptosis and could mobilize endogenous copper in humans which may contribute in anti-cancer mechanism of such agents (Yordi et al., 2012).

Flavonoids are a group of ubiquitous polyphenolic compounds readily found in plant with variable phenolic structures. Flavonoids as a dietary component have health-promoting activity, which largely due to their high antioxidant activity. Flavonoids cannot be synthesized by humans and animals. Depending on chemical structure flavonoid can be divided into several classes, i.e. flavanols (catechin, epicatechin, epigallocatechin), flavones (apigenin, rutin, luteolin), flavonols (kaempferol, quercitrin, myricetin, quercetin), flavanones (hesperidin, naringenin), isoflavones (genistin, daidzin), anthocyanins (apigenidin, cyanidin), flavanonols (dihydroquercetin) and chalcones (phloretin, arbutin). Flavonoids are the most potent antioxidants available in plants. Potent antioxidant effect of flavonoids is due to the presence of hydroxyl groups in positions 3’ and 4’ of the B ring, which exert increased stability to the formed radical by joining in the displacement of the electron. Double bond present between carbons C2 and C3 (ring C) together with carbonyl group at C4 position helps in an electron displacement from ring

B. Free hydroxyl groups in 3rd position of ring C and 5th position of ring A, together with the carbonyl group in 4th position, are also significant for the antioxidant activity of flavonoids. However, the efficiency of flavonoids reduces with the substitution of hydroxyl groups for sugars, as glycosides possess less antioxidant capacity compare to their corresponding aglycons. Flavonoids can suppress the formation of ROS either by enzymes (i.e. microsomal monooxygenase, glutathione S-transferase, mitochondrial succinoxidase, NADH oxidase) inhibition or by chelating trace elements involved in the generation of radicals, scavenging of ROS, and upregulation of antioxidant defenses. Flavonoids can inhibit lipid peroxidation, and significantly scavenge superoxide, hydroxyl, alkoxyl, and peroxyl radicals by donation of hydrogen atom, and thus protect biomolecule from oxidative damage. Different flavonoids have shown antimicrobial, hepatoprotective, anti-inflammatory, nephroprotective, anticancer, antiallergic, antimutagenic, antiviral, anti-thrombotic, and vasodilatory actions (Kumar & Pandey, 2013; Giada, 2013).

Phenolic acids are another non-flavonoid polyphenolic compounds that can be subdivided into two major classes, benzoic acid (protocatechuic acids, vanillic acids, syringic acid, gentisic acid, salicylic acid, p-hydroxybenzoic acid and gallic acid)and cinnamic acid derivatives (*p*-coumaric, ferulic, caffeic and sinapic acids). It was observed that phenolic acid and their esters have potent antioxidant effect, especially hydroxybenzoic acid, hydroxycinnamic acid, caffeic acid and chlorogenic acid, and although the number of hydroxyl groups found in constituent also detrimental for antioxidant activity. Usually, hydroxylated cinnamic acids exert better effect than benzoic acids derivatives (Tsao, 2010; Giada, 2013).

Stilbenes are relatively small group of non-flavonoid phenolic substance found in a large number of plant sources. Resveratrol, a key stilbene mainly found in grapes skin showed beneficial effect against cancer, diabetes, obesity, cardiovascular, neurodegenerative diseases. Currently, pterostilbene and pinosylvin have also been attracted the interest of scientist due to their beneficial effect on health. Stilbenes exert cellular defence against oxidative stress which is mediated through the nuclear factor-erythroid-2-related factor-2 (Nrf2). These agents also have potential roles in SQSTM1/p62 protein in Nrf2/Keap1 signaling and autophagy (Reinisalo, Karlund, Koskela, Kaarniranta & Karjalainen, 2015). Lignans, xanthones are also representing important class of polyphenolic compounds. *Xanthones* like 8-hydroxycudraxanthone G, gartanin, α-mangostin, γ-mangostin, smeathxanthone A showed potent antioxidant activity (Jung, Su, Keller, Mehta & Kinghorn, 2006). *Lignans* are a group of the polyphenoic compound, that have phenylpropane dimer linkage with a 1,4-diarylbutane structure by β-β bonds (MacRae & Towers, 1984). They possess good antioxidant and anticancer activity. Example of lignans includes secoisolariciresinol, mataisoresinol, and pinoresinol. Few polyphenols may contain N-containing functional substituents. Two such groups of polyphenolic amides are capsaicinoids in chili peppers and avenanthramides in oats (Tsao, 2010)

Tannins are phenolic compounds, which denoted as antinutrients of plant origin as tannin precipitate proteins, inhibit digestive enzymes, and reduces the consumption of vitamins and minerals. Although, tannins also been recorded for their health-promoting effect. Tannins acknowledged widely for antioxidant, antiradical, anticarcinogenic, antimutagenic, antimicrobial activities. Tannins are mainly divided into two groups: hydrolysable tannins (i.e. ellagitannins, gallotannins) and non-hydrolysable or condensed tannins (i.e. polymers of catechin and/or leucoanthocyanidin). Tannin act as both primary and secondary antioxidant, as they donate hydrogen atom or electrons to terminate free radical chain reaction and also to chelate metal ions such as iron by interfering the steps involve Fenton reaction. Tannins also inhibit the lipid peroxidation. Some research also found that extract rich in tannins i.e. extracts of hazelnuts (prepared from green leafy cover) has better antioxidant effect than those of extracts contain less tannins i.e. extract prepared from hazelnut kernels (Amarowicz, 2007; Ghosh, 2015).

Coumarins are the secondary metabolites widely distributed in plants. Coumarins are present in nature as free form or as glycosides. Over 300 coumarins have been discovered from nature particularly from green plants. Some coumarins constituents include aesculin and esculetin (simple hydroxycoumarins), psoralen and isopsoralen (furocoumarins and isofurocoumarin), xanthyletin, xanthoxyletin, seselin, khellactone and praeuptorin A (pyranocoumarins), biscoumarins, bergenin (dihydroisocoumarins) etc. Beneficial effects of coumarins include in different diseases like cancer, inflammation, diabetes, cardio-vascular and brain diseases, and these activity of coumarins related with their strong antioxidant effect may be in part (Kostova, et al., 20111; Bubols et al., 2013).

Carotenoids are a group of more than 600 fat-soluble plant pigments that provide color. Apart from the aesthetic role of carotenoids, they are found abundantly in foods and considered to be beneficial in treatment/prevention of several ailments. Nearly fifty different carotenoids have been found in the human diet and approximately twenty have been present in plasma and tissues. Major carotenoids available in diet include β-carotene, α-carotene, lycopene, β-cryptoxanthin, lutein and zeaxanthin. Carotenoids can efficiently quenche singlet oxygen and other ROS. Carotenoids also serve as chemical quenchers undergoing irreversible oxygenation. Though, exact molecular mechanisms underlying antioxidant and pro-oxidant activity of carotenoids are not fully understood. But numerous studies suggested that anti-oxidant activity of carotenoids have great impact on human health, by preventing oxidative stress situation. β-carotene and α-tocopherol can act synergistically as an effective "radical-trapping antioxidant" in biological membranes. The inhibition of lipid peroxidation by a combination of the two fat-soluble antioxidants was shown to be greater than the sum of the individual inhibitions. β-carotene, zeaxanthin, cryptoxanthin, α-carotene is the strong quencher of singlet molecular oxygen. Carotenoids also deactivate peroxyl radical efficiently (Fiedor & Burda, 2014; Krinsky and Johnson, 2005; Patrick, 2000; Stahl & Sies, 2003).

Primarily physical quenching takes place between carotenoids with $^1O_2$, which involves direct energy transfer between both molecules. Singlet molecular oxygen transferred the energy to carotenoid molecule and thus ground state oxygen and a triplet excited carotene molecule formed. Carotenoids are beck to ground state dissipating the energy, instead of any other chemical reactions. In comparison to physical quenching, chemical reactions between $^1O_2$ and carotenoids are of minor importance (Stahl & Sies, 2003).

β-carotene is the major source of vitamin A. Major source of β-carotene includes apricot, carrots, spinach, green collard, cantaloupe, beet green, broccoli, tomato. β-carotene was established as an anti-oxidant that can prevent cancer, heart disease, macular degeneration, ageing etc and also act as immuno-modulator. In both observational and case control studies found that intake of fruits and vegetables rich in β-carotene can reduce the risk for cardiovascular disease. Protective effect of β-carotene supplementation on sunburn and other disorder was investigated, but the effect of β-carotene supplementation on cancer risk is controcertial (Burri, 1997; Patrick, 2000; Rao and Rao, 2007; Sen and Chakraborty, 2015).

Various investigations also showed that other phytochemicals like saponin, alkaloids, steroids from different plant are the produce strong antioxidant activities.

Food as Potential Source of Antioxidants

Fruits and vegetables are the rich source of diverse free phenolic acids. Phenolic acid in bound form present in grains and seeds, particularly in bran or hull. Hydroxycinnamic acids found in bluberry, cranberry, pear, sweet cherry, apple, orange, grape, apple juice, lemon, peach, potato, lettuce, spinach, coffee beans, tea, coffee, cider; while strawberry, raspberry, grape juice, longan seed, pomegranate juice contain hydroxybenzoic acids. Capsaicin (a capsaicinoids), main component responsible for chili hotness has also strong antioxidant effect. Tannins present in number of fruits, vegetables and beverages like bananas, sorghum, grapes, apple, strawberries, raspberries, pomegranate, blackberry, olive, plum walnuts, chick pea, black-eyed peas, lentils, curry leaves spinach, red wine, persimmons, chocolate, tea and coffee. Red and bluish-red cherries contain high percentage of anthocyanidins, while proanthocyanidins are available in grape, red wine. Other source of anthocyanidin includes black and blue berries, black grape, strawberries, cherries, plums, cranberry, pomegranate, raspberry and red wine. Vegetables (like celery, onions, dock leaves, fennel, hot peppers, tomatoes, spinach, lettuce, broccoli, kale), cereal (i.e. buckwheat, green/yellow beans), fruits (apples, apricots, grapes, plums, berries, currants, cherries, black currant juice, apple juice, ginkgo biloba), red wine, green and black tea, cocoa are rich source of flavonols. Quercetin, a important antioxidant molecule found in fruits and vegetables like green-yellow onions, apples, broccoli, cherries, grapes and red cabbage. Citrus fruits and juice, peppermint contains flavanones. Flavones are available in celery, olives, hot peppers, celery hearts, fresh parsley, oregano, rosemary, dry parsley, thyme. Different fruits (i.e. apples, apricots, grapes, pears, plums, raspberries, cherries, blackberries, blueberries, cranberries), red and white wine, green and black tea, chocolate, wine, cocoa contain different flavanols. Isoflavones i.e. genistein and daidzein are available in beans, tofu, soy milk, grape, flour, miso, tea, coffee, spinach and potato. Hesperidin is available in oranges and lemons peels, narangin is found in many fruits such as orange, lemon and grapefruit. Grapes and vegetables are the good source of ellagic acid, on the other hand kaempferol is abundant in vegetables like broccoli, beets. Green and black tea is considered as rich sources of catechins. Grapes, peanut, red wine contain resveratrol and trans-resveratrol (Ghosh, 2015; Yordi et al., 2012; Tsao, 2010; Han et al. 2007). Flaxseed and grains like wheat are the great source of lignans. Content of polyphenolic substance in foods are largely affected by environmental factors, soil, sunlight, rainfall etc. Stage of ripeness also affects the proportions of various antioxidants present in fruit. For example, content of phenolic acid reduces during ripening, whereas anthocyanin level increases (Pande & Rizvi, 2009). The major source of coumarin includes green plants, fruits (e.g. bilberry, cloudberry), olive oil, and beverages (coffee, wine, and tea) (Kostova et al., 20111; Bubols et al., 2013). Green leafy vegetables, orange and yellow fruits are the major source of β-carotene. Dietary lycopene is predominately found from tomatoes and tomato products, while lutein and zeaxanthin is more in spinach and kale (Krinsky & Johnson, 2005).

Cereals and millets are the popular food grain consumed as main food around the world. Wheat, rice, maize, barley, oat, rye etc. confer nutritional benefits and helpful to promote the health. They contain a large variety of health promoting phytochemicals, including antioxidants. Generally cereals are rich in phenolic acids which are found as free, soluble conjugates or as bound forms in endosperm, germ, and bran fractions of grains (Goufo & Trindade, 2014). Rice (*Oryza sativa*) is the major food in different Asian countries like India, Bangladesh. Several epidemiological researches have suggested that rice-consuming regions of the world have low incidence of certain chronic diseases, which might be due to the presence of antioxidant molecules in rice (Goufo & Trindade, 2014). Wheat is one of the most important cereals and considered as an important source of nutrients. It was observed that among the 4 fractions (seed capsule, aleurone layer, outer endosperm and inner endosperm) of wheat (surface layer to the centre of a grain), total phenolic content and antioxidant activity of ethanol extract is as high in aleurone layer than those of other fractions (Shi, Tian, Ru & Guo, 2011). Pearl millet a key cereal of India, an investigation has found that bran rich fraction of millet contains high tannin, phytic acid and flavonoid. Pearl millet is a rich source of antioxidant molecule thus it could possible that pearl millet could confer beneficial effect in cancer, hyperlipedemia, and in prevention of liposome oxidation, proliferation of HT-29 ad-

Table 3. Antioxidant/pro-oxidant molecules in food (by focusing on common food)

Food		Phytoconstituents (Mainly Antioxidant/Pro-Oxidant Molecules)
Cereals & Millets	Rice (*Oryza sativa*)	phenolic acids (gallic, protocatechuic, *p*-hydroxybenzoic, vanillic, syringic acids, *p*-coumaric, ferulic, caffeic, sinapic, chlorogenic, and cinnamic, ellagic acids), flavonoids (tricin, luteolin, apigenin, quercetin, isorhamnetin, kaempferol, myricetin, tricin 4′-*O*-(*erythro-β* guaiacylglyceryl) ether, tricin 4′-*O*-(*threo-β* guaiacylglyceryl) ether, isovitexin, naringenin, hesperidin, rutin, luteolin-7-*O*-glucoside, apigenin-7-*O*-glucoside, qrcetin-3-*O*-glucoside, quercetin-3-*O*-rutinoside, isorhamnetin-3-*O*-glucoside, isorhamnetin-3-*O*-acetylglucoside, isorhamnetin-7-*O*-rutinoside, taxifolin-7-*O*-glucoside, 5,3′,4′,5′-tetrahydroxyflavanone-7-*O*-glucoside, myricetin-7-*O*-glucoside, 5,6,3′,4′,5-′pentahydroxyflavone-7-*O*-glucoside, apigenin-6-*C*-glucoside-8-*C*-arabinoside, (+)-3′-*O*-methyltaxifolin, brassicin, isorhamnetin-4′-*O*-glucoside, 3′-*O*-methyltaxifolin-5-*O*-glucoside, 3′-*O*-methyltaxifolin-7-*O*-glucoside, 3′-*O*-methyltaxifolin-4′-*O*-glucoside, isorhamnetin-7-*O*-cellobioside, and brassicin-4′-*O*-glucoside), anthocyanins (cyaniding-3-*O*-glucoside, peonidin-3-*O*-glucoside, cyaniding-3-*O*-rutinoside, cyaniding-3-*O*-galactoside, cyaniding-3-*O*-sophoroside, peonidin-3-*O*-rutinoside, cyaniding-3,5-*O*-diglucoside, peonidin-3,5-*O*-diglucoside, pelargonidin-3-*O*-glucoside, delphinidin-3-*O*-glucoside, petunidin-3-*O*-glucoside, petunidin-3-*O*-galactoside, petunidin-3-*O*-arabinoside, delphinidin-3-*O*-galactoside, delphinidin-3-*O*-arabinoside, malvidin-3-*O*-galactoside, malvidin-3-*O*-glucoside, pelargonidin-3,5-*O*-diglucoside), proanthocyanidins (catechin, epicatechin), Vitamin E ($\alpha,\beta,\gamma,\delta$-tocotrienol, $\alpha,\beta,\gamma,\delta$-tocopherol), γ-oryzanol, and phytic acid (Goufo & Trindade, 2014).
	Pearl millet (*Pennisetum typhoideum*)	Flavonoids likes tricin, 7-OMe luteolin, acacetin, glucosyl orientin, glucosyl vitexin, and phenolic acids (i.e. vanillic, syringic, ferulic p-hydroxy benzoic acid, *cis/trans* pcoumaric acids). It is also rich source several antioxidants minerals like zinc, copper etc and omega 3-fatty acid (Daniel, Denni & Chauhan, 2012; Nambiar, Dhaduk, Sareen, Shahu & Desai, 2011)
	Wheat (*Triticum aestivum*)	Phenolic compounds (phenolic acids, anthocyanidins, quinones, flavonoids and amino phenolic compounds), several tocopherols and tocotrienols like α-tocopherol, β-tocopherol, α-tocotrienol, and β-tocotrienol, carotenoid like *trans* lutein were found in different wheat species. Flavonoids (cyanidin 3-galactoside, cyanidin 3-glucoside, cyanidin 3-rutinoside, delphinidin 3-glucoside, delphinidin 3-rutinoside, peonidin-3-glucoside, petunidin-3-glucoside, petunidin-3-rutinoside, pelargonidin-3-glucoside, apigenin glycosides, tricin), lignans. Level of ferulic acid and diferulates are found in significant level in wheat (Abdel-Aal & Rabalski, 2008; El-Baky, 2009; Dykes & Roonwy, 2007).
	Finger millet or ragi (*Eleusine coracana*)	A number of phenolics like benzoic acid and cinnamic acid derivatives (i.e. gallic, protocatechuic, *p*-hydroxybenzoic, vanillic, ferulic, syringic, *trans*-cinnamic, gentisic, sinapic and *p*-coumaric acids) identified in ragi. Several tannins, flavonoid like quercetin, orientin, isoorientin, vitexin, isovitexin, saponarin, violanthin, lucenin-1, and tricin are present in finger millet (Mathangi & Sudha, 2012; Banerjee, Sanjay, Chethan, & Malleshi, 2012).
	Purple corn or maize (*Zea mays*)	Phenolic compounds like chlorogenic acid, caffeic acid, rutin, ferulic acid, morin, quercetin, naringenin, kaempferol, anthocyanins, cyanidin-3-glucoside, pelargonidin-3-glucoside, peonidin-3-glucoside, cyaniding-3-(6′′-malonylglucoside), pelargonidin-3-(6′′-malonylglucoside), peonidin-3-(6′′-malonylglucoside), cyaniding-3-(6′′-ethylmalonylglucoside), pelargonidin-3-(6′′-ethylmalonylglucoside), peonidin-3-(6′′-ethylmalonylglucoside). Flavanol anthocyanins like catechin-(4,8)-cyanidin-3-glucoside, catechin-(4,8)-cyanidin-3-malonylglucoside, epicatechin-(4,8)-cyanidin-3-malonylglucoside, catechin-(4,8)-peonidin-3-glucoside, epicatechin-(4,8)-peonidin-3-glucoside, catechin-(4,8)-pelargonidin-3-glucoside, catechin-(4,8)-cyanidin-3,5-diglucoside, catechin-(4,8)-cyanidin-3-malonylglucoside-5-glucoside, epicatechin-(4,8)-cyanidin-3-malonylglucoside-5-glucoside. Phenolic acids i.e. *p*-coumaric acid, vanillic acid, protocatechuic acid, ferulic acid, *p*-hydroxybenzoic acid, *p*-hydroxyphenyl acetic acid, syringic acid, caffeic, sinapic acid. Derivatives of hesperitin and quercetin (Pedreschi & Cisneros-Zevallos, 2007; Escudero, Munoz, Alvarado-Ortiz, Alvarado & Yanez, 2012).
	Great millet or jowar (*Sorghum vulgare*)	Phenolic acid (gallic, protecatechuic, *p*-hydroxybenzoic, gentisic, salicylic, vanillic, syringic, ferulic, caffeic, *p*-coumaric, cinnamic and sinapic acid), flavonoids (apigeninidin, apigeninidin-5-glucoside, luteolinidine, luteolinidine 5-glucoside, 5-glucoside, 5-methoxyapigeninidin, 7-methoxyapigeninidin, 7-methoxyapigeninidin 5-methoxyluteolinidin, 5-methoxyluteolinidin 7-glucoside, 7-methoxyluteolinidin, luteolin, apigenin, eriodictyol, eriodictyol 5-glucoside, naringenin, kaempferol 3-rutinoside-7-glucuronide, taxifolin, taxifolin 7-glucoside, apiforol, luteoforol, catechin and its derivatives, procyanidin, proluteolinidin, procyanidin B-1, fisetinidin, cyanidin, pelargonidin, peonidin, 3-deoxyanthocyanidins, 7-*O*-methyl luteolin), condensed tannin (Dykes & Roonwy, 2007; Awika & Rooney, 2004).
	Barley (*Hordeum vulgare*)	A number of phenolic antioxidants like benzoic and cinnamic acid derivative, proanthocyanidine, flavonols, chalcones, flavones etc present in barley. Phenolic acid (protecatechuic, salicylic, vanillic, syringic, ferulic, *o*-coumaric, *m*-coumaric, *p*-coumaric, and sinapic acid), Anthocyanins (apigeninidin, apigeninidin-5-glucoside, cyanidin, cyanidin-3-galactoside, cyanidin-3-glucoside, cyanidin 3-rutinoside), flavonoids (cyanidin, cyanidin-3-glucoside, delphinidin, pelargonidin, pelargonidin glycosides, petunidin 3-glucoside, chrysoeriol, catechin, leucocyanidin, leucopelargonidin, procyanidin B-3, prodelphinidin B-3), lignans (Dykes & Roonwy, 2007; Gamel & Abdel-Aal, 2012).
	Rye or sarsoo (*Secale cereale*)	Phenolic acid (protecatechuic, *p*-hydroxybenzoic, vanillic, syringic, ferulic, caffeic, *p*-coumaric and sinapic acid), flavonoids (cyanidin-3-glucoside, peonidin-3-glucoside, delphinidin 3-rutinoside), alkylresorsinols, lignans, tannin (Dykes & Roonwy, 2007).
	Oats (*Avena sativa*)	A number of phytoconstituents like avenanthramides, an indole alkaloidgramine, flavonoids, flavonolignans, triterpenoid saponins, sterols (β-sitosterol, Δ^5-avenasterol, Δ^7-avenasterol) and tocols present in oats. Phenolic acid (gallic, protecatechuic, *p*-hydroxybenzoic, *p*-hydroxyphenylacetic, vanillic, syringic, ferulic, caffeic, *p*-coumaric, *o*-coumaric and sinapic acid), flavonoids (tricin, apigenin, apigenin-6-C-glucoside, apigenin-8-C-glucoside luteolin, isovitexin, tricin, vitexin, homoeriodictyol, kaempferol, kaempferol 3-*O*-rutinoside, kaempferol 3-rutinoside-7-glucuronide, quercetin, quercerin 3-*O*-rutinoside, catechol,), lignans, tocol (α-tocotrienol, α-tocopherol), phytic acid (Dykes & Roonwy, 2007; Paterson, 2001)
Pulses and Legumes	Black gram, Urad dal (*Vigna mungo*)	β-carotene, ascorbic acid, various tocopherols, phenolic compounds, flavonoids, condensed tannins, minerals like zinc, iron, copper. Phenolic acid (gallic, protocatechuic, gentisic, vanillic, syringic, caffeic and ferulic acids), apigenin, 7-methoxy apigenin (Luthria, Singh & D’souza, 2014; Soris, Kala, Mohan & Vadivel, 2010; Girish, Pratape & Rao, 2012)

continued on following page

Table 3. Continued

Food		Phytoconstituents (Mainly Antioxidant/Pro-Oxidant Molecules)
	Bengal gram or Chana (*Cicer arietinum*)	Flavonoids like (+)-catechin, (–)-epicatechin, naringenin, naringenin-7- *O* -β-D-glucopyranoside, (epi)afzelechin, epicatechin, epicatechin 3-gallate, epigallocatechin, epigallocatechin 3-gallate, catechin, gallocatechin, daidzein, genistein, matairesinol, secoisolariciresinol, kaempferol, kaempferol 3-*O*-β-D-glucopyranoside, kaempferol 3-*O*-rutinoside, kaempferide, quercetin 3-*O*- β-D-glucopyranoside, rutin, kaempferol and quercetin derivatives, including methylated such as isorhamnetin (3-*O*-methoxyquercetin) and myricetin-*O*-methyl ethers and glycosides; aromadendrin, apigenin and their derivatives. Isoflavones (like biochanin A, genistein, formononetin, orobol and two isomers of dalpanin), *α*-resorcylic acid, biochanin glucoside, antioxidant minerals, carotenoids (β-carotene, lutein, zeaxanthin, β-cryptoxanthin, lycopene and α-carotene), sterols (β-sitosterol, Δ^5-avenasterol, Δ^7-avenasterol), cajaninstilbene acid, pinostrobin, vitexin and orientin, phenolic acid (gallic, p-hydroxybenzoic and caffeoylquinic, sinapic, ferulic, *p*-coumaric, vanillic acids and their derivatives), saponins (Bhagwat, Haytowitz & Holden, 2011; Jukanti, Gaur, Gowda & Chibbar, 2012; Wu et al., 2009; Mekky et al., 2015).
	Green gram, mug dal *(Vigna radiata)*	Luteolin, kaempferol, myricetin, quercetin, aureol, coumestrol, cyclokievitone, dalbergioidin, 2,3-dehydrokievitone, 5- deoxykievitone, genistein, 2'-hydroxygenistein, isovitexin, kievitone, myrtillin, phaseol, phaseollidin, vitexin, ß-sitosterol, stigmasterol, soyasapogenol C (Battu, Male, Haripriya, Malleswari & Reeshma, 2011).
	Peas green *(Pisium sativum)*	Phenolic acids (protocatechuic, gentisic, sinapic, *m*-hydroxybenzoic, vanillic, syringic, caffeic, *o*-coumaric, *p*-coumaric, ferrulic, veratric and 2,3-dihydroxybenzoic acid), kaempferol, quercetin, daidzein, formononetin, isoformononetin, prunetin (Troszynska & Ciska, 2002; Amarowicz, Karamac & Weidner, 2001).
	Rajmah *(Phaseolus vulgaris)*	Anthocyanidins (pelargonidin, malvidin, petunidin, cyanidin, delphinidin, peonidin), catechin, catechol, saponin, and phenolic acids (gallic, vanillic, caffeic, coumaric, sinapic, chlorogenic, caffeine, cholchecien, *p*-hydroxybenzoic, chrysin, p-coumaric, protocatechuic and ferrulic acid), quercetin 3-*O*-glucoside and protoanthocyanidins (condensed tannins), vitamin C, vitamin E, kaempferol 3-*O*-glucoside, kaempferol 3-*O*-acetyl-glucoside (Bhagwat et al., 2011; Nyau, 2014; Camara, Urrea & Schlegel, 2013; Hassan & Youssef, 2012).
	Soya bean *(Glycine max)*	Simple phenols, benzoic acid derivatives, flavonoids, tannins, lignans, isoflavones, anthocyanins, saponin. Phytic acid (phytate), saponins, plant sterols (phytosterols), vitamins (γ-tocopherol) and minerals. Luteolin, kaempferol, myricetin, quercetin, phenolic acid (chlorogenic acid, caffeic acid, ferulic acid, and *p*-coumaric acid), anthocyanins (delphinidin-3-glucoside, cyanidin-3-galactoside, cyanidin-3-glucoside, petunidin-3-glucoside, peonidin-3-glucoside, and malvidin-3-glucoside), aroma compounds (1-octen-3-ol, maltol, phenylethyl alcohol, hexanol) isoflavones (glucosides, i.e., daidzin, genistin and glycitin; acetylglucosides, i.e. acetyldaidzin, acetylgenistin and acetylglycitin; malonylglucosides, i.e. malonyldadzin, malonylgenistin and malonylglycitin; and structure unconjugated aglycone, like daidzein, genistein and glycitein) (Bhagwat et al., 2011; Zhang et al., 2011; Lee, & Shibamoto, 2000; Cheng, 2009; Martino et al., 2011; Reynoso-Camacho, Ramos-Gomez & Loarca-Pina, 2006).
	Lentil, massor dal (*Lens esculenta*, syn. *Lens culinaris*)	Phenolic acids, flavanols, flavonols, soyasaponins, phytic acid, hydroxycinnamates, procyanidins, gallates, flavonols, dihydroflavonols, dihydrochalcones and condensed tannins. catechin and epicatechin derivatives, epicatechin, epicatechin 3-gallate, epigallocatechin, epigallocatechin 3-gallate, catechin, gallocatechin, kaempferol glycosides, 3′,5′-di-*c*-*β*-glucopyranosyl phloretin, catechin-3-*o*-glucoside, β-sitosteryl-3-(2′-n-eicosanyloxy)-benzoate, n-octadec-9-enoyl-1-β-d-glucurano-pyranoside, α-d-galactopyranosyl-(6→1′)-α-d-galactopyranosyl-(6′→1″)-α-d-galactopyranosyl-(6″→1‴)-α-d-galactopyranoside, benzoyl-o-α-d-glucopyranosyl-(2a→1b)-o-α-d-glucopyranosyl-(2b→1c)-o-α-d-glucopyranosyl-(6c→1d)-o-α-d-glucopyranosyl-(6d→1e)-o-α-d-gluco-pyranoside, n-heptadecanyl n-octadec-9-enoate, β-sitosterol, cis-n-docos-15-enoic acid, n-dodecanoyl-*O*-ß-D-glucuranopyranoside, n-tetradecanoyl-*O*-ß-D–arabinopyranoside, n-eicosanoyl-*O*-ß-D–arabinopyranoside, epicatechin glucosides, procyanidin dimers, quercetin diglycoside, *trans*-*p*-coumaric acid (Bhagwat et al., 2011; Zou, Chang, Gu & Qian, 2011; Jameel, Ali & Ali, 2015a,b)
Edible Oils	Coconut oil	Virgin coconut oil contain tocopherol and phenolic compounds like protocatechuic acid, vanillic acid, syringic acid, p-coumaric acid, caffeic acid and ferulic acid. Presence of catechin is reported in commercial and traditional coconut oil (Marina, Man, Nazimah & Amin, 2009; Arlee, Suanphairoch & Pakdeechanuan, 2013).
	Rice bran oil	Gamma oryzanol and other phytosterols like β-sitosterol, squalene. Sterol esters, triterpene, tocopherols, tocotrienols, ferulic acid and other phenolic compounds (Patel & Naik, 2004)
	Olive oil	Oleic acid (i.e. omega-6 fatty acid, linoleic acid), Phenolic compounds (hydroxytyrosol, tyrosol, oleuropein, ligstroside, hydroxytyrosol, tyrosol, oleuropein), squalene, tocopherols. Extra virgin/virgin olive oil contain phenolic acids like caffeic, vanillic, syringic, *p*-coumaric, *o*-coumaric, protocatechuic, sinapic, *p*-hydroxybenzoic, ferulic, cinnamic and gallic acid; falvonoids (taxifolin, luteolin and apigenin); phenolic alcohols like 3,4-dihydroxyphenyl ethanol and *p*-hydroxyphenyl ethanol; lignans like (+)-1-acetoxypinoresinol and (+)-pinoresinol (Servili et al., 2014; Waterman & Lockwood, 2007; Bendini et al., 2007; Bulotta et al., 2014).
	Palm oil	Vitamin E (tocotrienol, tocopherol, tocotrie), 5-avenasterol, carotenoids (different carotene including beta carotene, lycopene), coenzyme Q10, polyphenols, squalene. Major phenolics in palm includes cinnamic acid, ferulic acid, caumaric acid (Sundram, 2015)
	Mustard oil	Vitamin E omega alpha 3 and omega alpha 6 fatty acid, selenium and magnesium, phenolic compounds (Khan, Sankhyan & Kumar, 2013; Sarwar, Rahman, Raza, Rouf & Rahman, 2014).
	Sunflower oil	α/β/γ/δ tocopherol, α/γ/δ tocotrienol, sterols (β-sitosterol, Δ^5-avenasterol, Δ^7-avenasterol, Δ^7-stigmasterol), minerals (like: iron, copper, zinc, selenium), omega 3 and omega 6 fatty acid (Khan, Choudhary, Pandey, Khan & Thomas, 2015; Warner, Vick, Kleingartner, Isaak & Doroff, 2015).
	Peanut/ groundnut oil	Resveratrol, α/β/γ/δ tocopherol, tocotrienol, sterols (β-sitosterol, Δ^5-avenasterol, Δ^7-avenasterol, Δ^7-stigmasterol), squalene, β-carotene, *p*-coumaric acid (Akhtar, Khalid, Ahmed, Shahzad, Suleria, 2014).
Spices and Herb	Nutmeg (*Myristica fragrans*)	Essential oil contain α-pinenes, camphene, p-cymene, sabinene, β-phellandrene, γ-terpinene, limonene, myrcene, (linalool, geraniol, terpineol, myristicin, elemicin, safrole. Saponin, tannins, epicatechin, cyanidin, carotene (Latha et al., 2005)
	Curry leaf (*Murraya koenigii*)	alkaloids (mahanine, koenine, koenigine, koenidine, girinimbiol, girinimibine, koenimbine, *O*-methyl murrayamine A, isomahanine), Vitamin C, carotene, 5,8-dimethyl furanocoumarin, β-sitosterol, coumarin glycoside like scopotin, murrayanine. Essential oil from leaves contain di- α-phellandrene, D-sabinene, D-α-pinene, dipentene, D-α-terpinol and caryophyllene (Ajay et al., 2011).
	Clove (*Syzygium aromaticum*)	Eugenol, eugenol acetate, limonin, ferulic aldehyde, tamarixetin 3-*O*-b-D-glucopyranoside, ombuin 3-*O*-b-D-glucopyranoside, quercetin, D-glucopyranoside, biflorin, kaempferol, rhamnocitrin, myricetin, gallic acid, ellagic acid, oleanolic acid, orsellinic acid (Nassar et al., 2007).

continued on following page

Table 3. Continued

Food		Phytoconstituents (Mainly Antioxidant/Pro-Oxidant Molecules)
	Aniseed (*Pimpinella anisum*)	*trans* and *cis*-anethole, palmitic and oleic acids, eugenol *trans*-anethole, methylchavicol, anisaldehyde, estragole, scopoletin, umbelliferone, estrols, terpene hydrocarbons, estragole, (E)-methyleugenol, *α*-cuparene, *α* and *γ* -himachalene, *β*-bisabolene, *p*-anisaldehyde, carvone, *β*-caryophyllene, dihydrocarvyl acetate, limonene, coumarins, *cis*-pseudoisoeugenyl 2-methylbutyrate, *trans*-pseudoisoeugenyl 2-methylbutyrate, 4-(*β*-d-glucopyranosyloxy) benzoic acid, (E)-3-hydroxy-anethole *β*-d-glucopyranoside, (E)-10-(2-hydroxy-5-methoxyphenyl) propane *β*-d-glucopyranoside, 3-hydroxyestragole *β*-d-glucopyranoside, methyl syringate 4-*O*-*β*-d-glucopyranoside, hexane-1,5-diol 1-*O*-*β*-d-glucopyranoside, 1-deoxy-l-erythritol 3-*O*-*β*-dglucopyranoside, quercetin 3-glucuronide, rutin, luteolin 7-glucoside, isoorientin, isovitexin, apigenin 7-glucoside, luteolin glycoside (Shojaii & Fard, 2012).
	Saffron *(Crocus sativus)*	Carotenoids (zeaxanthin, lycopene, α and β carotenes), carotenes, crocetin, picrocrocin, rutin, quercetin, luteolin, hesperidin, and bioflavonoids, terpenes, terpene alcohols and their esters, safranal. 3,5-β-diglucosides of delphinidin and petunidin, 3-β-rutinosides, delphinidin 3-*O*-(β-d-glucopyranoside)-5-*O*-(6-*O*-malonyl-β-d-glucopyranoside), petudin 3,7-di-*O*-(β-d-glucopyranoside). 3,7 di-*O*-β-d-glucoside and 3,5 di-*O*-β-d-glucosides of delphinidin, petunidin, kaempferol 3-*O*-α-(2,3-di-*O*-β-d-glucopyranosyl) rhamnopyranoside and 3,8 dihydroxy1methylanthroquinone-2-carboxylic (Srivastava, Ahmed, Dixit, Dharamveer & Saraf, 2010; Gohari, Saeidnia & Mahmoodabadi, 2013).
	Rose mary (*Rosmarinus officinalis)*	Carnosic acid, carnosol, carnosol isomer, cirsimaritin, epiisorosmanol, epirosmanol, epirosmanol methyl ether, gallocatechin, genkwanin, hesperidin, homoplantaginin, luteolin 3'-*o*-(*o*-acetyl)-β-d-glucuronide isomer I, luteolin 3'-*o*-(*o*-acetyl)-β-d-glucuronide isomer II, luteolin-3'-glucuronide, micromeric acid, nepetrin, quinic acid, rosmadial, rosmanol, rosmaridiphenol, rosmarinic acid, rosmarinic acid-3-*O*-glucoside, siringic acid, ursolic acid, [9]-shogaol, [9]-shogaol isomer, 12-metoxy-carnosic acid, 6-hydroxyluteolin 7-glucoside, naringenin, apigenin, luteolin, isorhamnetin, kaempferol, quercetin, anemosapogenin, asiatic acid, augustic acid, benthamic acid, betulinic acid, and 2,3,4,4a,10,10a-hexahidro-5,6-dihydroxy-1,1-dimethyl-7- (1-methylethyl)-9(1h)-phenantrenone (Bhagwat et al., 2011; Borras-Linares et al., 2014).
	Cumin (*Cuminum cyminum*)	Cuminaldehyde, limonene, α- and β-pinene, 1,8-cineole, *o*- and *p*-cymene, α- and γ-terpinene, safranal, linalool, myrcene, limonene, *p*-mentha-1, 3-dien-7-ol, caryophyllene, β-bisabolene, β-phellandrene, D-terpinene, cuminyl alcohol, β-farnesene, α-phellandrene, cis and trans sabinene, myrtenol, α-terpineol, phellandral, quercitrin (Nadeem & Riaz, 2012; Johri, 2011).
	Caraway (*Carum carvi)*	Carvacrol, carvone, α and β-pinene, limonene, γ-terpinene, linalool, carvenone, *p*-cymene, β-myrcene, thujone, anethole, sabinene, β-selinene, β-cyclolavandulal, quercetin 3-methyl ether, isoquercetin, quercetin 3-*O*-glucuronide, quercetin 3-*O*-caffeyl-glucoside, kaempferol 3-glucoside, isorhamnetin glycoside (Agrahari & Singh, 2014; Johri, 2011).
	Fenugreek (*Trigonella foenum-graecum*)	Trimethylamine, neurin, trigonelline, gentianine, carpaine, betain, graecunins, fenugrin, fenugreekine, trigofoenosides, yamogenin, diosgenin, smilagenin, sarsasapogenin, tigogenin, neotigogenin, gitogenin, neogitogenin, yuccagenin, saponaretin, coumarin, anethol, 4-hydroxyisoleucin, arginine, piperidine, trigonelloside C, yamogenin tetroside B and C, tenugrin B, tigogenin, yuccagenin, lilagenin, quercetin, luteolin, vitexin, isovitexin, homoerietin, vicenin-1, vicenin-2, coumarin acid, scopoletin acid, chlorogenic acid, caffeic acid and *p*-coumaric acid (Yadav & Kaushik, 2011; Patil & Jain, 2014).
	Ginger, (*Zingiber officinale)*	Gingerol, camphene, betaphellandrene, curcumene, cineole, geranyl acetate, terphineol, terpenes, borneol, geraniol, limonene, linalool, α-zingiberene, β-sesquiphellandrene, betabisabolene, α-farmesene, (-)-zingiberene, β-sesquiphellandrene, bisabolene, farnesene, β-phelladrene, cineol, amadaldehyde, paradols, gingerdiols, gingerdiacetates, gingerdiones, 6-gingersulfonic acid, gingerenones, gingerglycolipids A-C, diaryleheptanonesgingerenones A-C, isogingerenone B, methylegingediol, gingediacetates, methylegingediacetates (Ghosh, Banerjee, Mullick & Banerjee, 2011).
	Fennel *(Foeniculum vulgare)*	Vitamin C, trans-anethole, fenchone, estragol, α-phellandrene, (+) fenchone, p-anisaldehyde, 3-*O*-caffeoylquinic acid, 4-*O*-caffeoylquinic acid, 5-*O*-caffeoylquinic acid, 1,3-*O*-di-caffeoylquinic acid, 1,4-*O*-di-caffeoylquinic acid, 1,5-*O*-di-caffeoylquinic acid, eriodictyol-7-rutinoside, quercetin-3-rutinoside, rosmarinic acid, quercetin-3-*O*-galactoside, kaempferol-3-*O*-rutinoside, kaempferol-3-*O*-glucoside, quercitin-3-*O*-glucuronide, kampferol-3-*O*-glucuronide, isoquercitin, isorhamnetin-3-*O*-glucoside, cis and trans-miyabenol C, trans-resveratrol-3-*O*-β-D-glucopyranoside, sinapyl glucoside, syringin-4-O-b-glucoside, oleanolic acid, 7-α-hydroxycampesterol, (3b,5a,8a,22E) 5,8-epidioxy-ergosta-6,22-dien-3-ol, and 2,3-dihydropropylheptadec-5-onoate (Rather, Dar, Sofi, Bhat & Qurishi, 2012).
	Turmeric (*Curcuma longa*)	Curcumin I-III, diketones demethoxycurcumin, bis-demethoxycurcumin, tumerones (a and b), curdione, curzerenone, mono and di demethoxycurcumin, α-phellandrene, sabinene, cineol, borneol, zingiberene, sesquiterpines, (6S)-2-methyl-6-(4- hydroxyphenyl-3-methyl)-2-hepten-4-one, bisabolane sesquiterpenes, calebin derivatives (Yadav, Yadav, Khar, Mujeeb, & Akhtar, 2013).
	Tulsi (*Ocimum sanctum*)	Euginal, urosolic acid, linalool, limatrol, caryophyllene, methyl carvicol, estragol, rosmarinic acid, apigenin, cirsimaritin, isothymusin, isothymonin, orientin, vicenin (Rahaman, Islam, Kamruzzaman, Alam & Jamal, 2011).
Beverages	Tea	Alkaloids (caffeine, theophylline, and theobromine), amino acids, carbohydrates, proteins, chlorophyll, volatile compounds, fluoride, mineral (Se, Zn). Phenolic compounds in tea includes (-)-epigallocatechin gallate, (-)-epigallocatechin, (-)-epicatechin gallate, (-)-epicatechin, gallic acid, (-)-epicatechin (Cabrera, Gimeanez & Loapez, 2003).
	Green tea	Proteins, amino acids, carbohydrates, lipids, acids; sterols as stigmasterol, vitamins (vitamin B, C, E); alkaloids (caffeine and theophyllin), chlorophyll, carotenoids, volatile compounds, minerals and (like, Mg, Cr, Mn, Fe, Cu, Zn, Se, etc.), flavonoids like catechins are (-)-epigallocatechin-3-gallate, (-)-epigallocatechin, (-)-epicatechin-3-gallate, (-)-epicatechin, gallic acid, kaempferol, myricetin, quercetin and phenolic acids such as chlorogenic acid, caffeic acid (Cabrera, Artacho & Gimeanez, 2006).
	Coffee	3,4-dicaffeoylquinic acid, 3,5-dicaffeoylquinic acid, 3-caffeoylquinic acid, 3-feruloylquinic acid, 4,5-dicaffeoylquinic acid, 4-caffeoylqunic acid, 5-feruloylquinicacid, 5-caffeoylquinicacid, 5-feruloylquinicacid, caffeic acid, 4-ethylguaiacol, 4-vinylguaiacol, 3-methylcatechol, 4-ethylcatechol, 4-methylcatechol, guaiacol, catechol, pyrogallol (Tresserra-Rimbau, Medina-Remon, Estruch & Lamuela-Raventos, 2014).
	Beer	4-hydroxy benzoic acid, protocatechuic acid, vanillic acid, gallic acid, syringic acid, *o*-vanillin, (+)-catechin, (-)-epicatechin, gallocatechin, catechin gallate, 3´-*O*-methylcatechin, cinnamic acid, *p*-coumaric acid, caffeic acid, ferulic acid, sinapic acid, procyanidin, prodelphinidin, apigenin, tricin, vitexin, saponarin, saponaretin, isoxanthohumol, naringerin, taxifolin, kaempferol, myricetin, myticitrin, quercetin, quercitrin, rutin, isoquercitrin, kaempferol-3-rhamnosid (Saura-Calixto, Serrano, Perez-Jimemez, 2008)

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Table 3. Continued

Food		Phytoconstituents (Mainly Antioxidant/Pro-Oxidant Molecules)
Fruits & Vegetable	Kiwi (*Actinidia deliciosa planch*)	Phenolic acids (protocatechuic, vanillic, chlorogenic, catechol, caffeine, catechin and cinnamic acid), pyrogallol, coumarin, flavonoids like rosmarinic acid, narengnin, hespererctin (Shehata & Soltan, 2013).
	Avocado (*Persea americana*)	Phenolic acids (protocatechuic, vanillic, catechol, catechin, ferulic, coumarin and ellagic acid), pyrogallol, flavonoids like rosmarinic, hespererctin, rutin, quercitrinic, quercitin, kampferol (Shehata & Soltan, 2013).
	Amla (*Emblica officinalis*)	Vitamin C, gallic acid, ellagic acid, quercetin, 1-*O*-galloyl-beta-D-glucose, 3,6-di-*O*-galloyl-D-glucose, chebulinic acid, quercetin, chebulagic acid, 1,6-di-*O*-galloyl beta-D-glucose, 3-ethylgallic acid, isostrictinin, kaempferol-3-O-alpha L-(6''-methyl) rhamnopyranoside, kaempferol-3-*O*-α-L(6''-ethyl) rhamnopyranoside (Dasaroju & Gottumukkala, 2014).
	Lichi (*Litchi chinensis*)	Anthocyanins (i.e., cyanidin-3-glucoside, cyanidin-3-rutinoside, malvidin-3-glucoside), epicatechin, quercetin glycosides, 2-(2-hydroxyl-5-(methoxycarbonyl) phenoxy benzoic acid, kaempferol, isolariciresinol, stigmasterol, butylated hydroxytoluene, 3,4-dihydroxyl benzoate, methyl shikimate and ethyl shikimate, 3,4-dihydroxybenzoic acid, (+)-catechin, vanillic acid, caffeic acid, syringic acid, (-)-epicatechin, 4-methylcatechol, ferulic acid, rutin and quercetin (Li et al., 2012; Jiang et al., 2013; Su et al., 2014).
	Apple (*Malus* x *domestica)*	Quercetin, quercetin-3-galactoside, quercetin-3-glucoside, quercetin-3-rhamnoside, catechin, epicatechin, cyanidin, procyanidin, cyanidin-3-galactoside, coumaric acid, chlorogenic acid, gallic acid, and phloridzin, hydroxycinnamates, vitamin C (Francini & Sebastiani, 2013; Boyer & Liu, 2004).
	Guava (*Psidium guajava)*	Vitamin C, vitamin E, carotenoids (lycopene), polyphenols (gallic acid, myricetin, apigenin, elagic acid), saponin combined with oleanolic acid, morin-3-*O*-α-L-lyxopyranoside, morin-3-*O*-α-L-arabopyranoside, flavonoids like guaijavarin and quercetin (Rueda, 2005; Dweck & Data, 2015)
	Watermelon (*Citrullus lanatus)*	Vitamin C, vitamin E, zinc, carotene-alpha, crypto-xanthin-beta, lutein-zeaxanthin, lycopene, flavonoids, tannins and catechin. Vanillic acid, *p*-coumaric acid glucoside, protocatechuic acid glycoside, sinapic acid glucoside, taxifolin-*O*-hexoside, rutin, dihydrophilonotisflavone, rutin, naringenin, quercetin rhamnoside, isovitexin, ferulic acid hexoside, calodendroside A, dihydrokaempferol 7-glycoside, luteolin-*O*-hexoside, apigenin-*O*-hexoside, dihydrophilonotisflavone, cyanidin, delphinidin, malvidin (Reidah, 2013; Bhagwat et al., 2011).
	Date palm (*Phoenix dactylifera)*	Phenolic acids (protocatechuic, vanillic, syringic, ferulic, gallic, protocatechuic, p-hydroxybenzoic, vanillic, caffeic syringic, sinapic, p-coumaric and o-coumaric acid), quercetin, chlorogenic acids, proanthocyanidins, β-carotene, apigenin and luteolin. Different glycosides of luteolin, quercetin, and apigenin (Al-Orf et al., 2012; Hong, Tomas-Barberan, Kader & Mitchell, 2006).
	Grapes (*Vitis vinifera*	Phenolic acids (gallic, protocatechuic, p-hydroxybenzoic, vanillic, caffeic, p-coumaric, salicylic, ferulic, anisic and sinapic acid), stilbene derivatives (resveratrol), flavan-3-ols (catechin, epicatechin), flavonols (kaempferol, quercetin, myricetin), anthocyanins, proanthocyanidins, ellagic acid, kaempferol, trans-resveratrol, flavanones (didymin, eriocitrin, hesperidin, naringin, narirutin, neoeriocitrin, neohesperidin, poncirin) (Gorinstein et al., 2004; Chiou et al., 2007; Peterson et al., 2006).
	Strawberry (*Arbutus unedo*)	Vitamin C, carotenoid, quercetin, ellagic acid, kaempferol-3-glucuronide, quercetin-3-glucuronide, quercetin-3-glucoside, pelargonidin-3-glucoside, pelargonidin-3-rutinoside, cyanidin-3-glucoside, catechin, apiginin, silybin, fisetine and naringin, tocopherol, triterpenoids, arbutin, β-D-glucogalline. Gallic acid, gallic acid 4-*O*-β-D-glucopyranoside, 3-*O*-galloylquinic acid, 5-*O*-galloylquinic acid, 3-*O*-galloylshikimic acid, and 5-*O*-galloylshikimic acid. Phenolic acids (gallic, protocatechuic, gentisic, p-hydroxibenzoic, vanillic and m-anisic acid), delphinidin-3-galactoside, cyanidin-3-galactoside, cyanidin-3-arabinoside, delphinidin, cyanidin, ellagic acid diglucoside, ellagic acid glucoside, myricetin-3-xyloside, methylellagic acid rhamnoside, ellagic acid arabinoside, ellagic acid xyloside, quercetin-3-rutinoside, quercetin-3-xyloside, quercetin-3-rhamnoside, ellagic acid, myricetin, quercetin, gallocatechin, theogallin (3-*O*-galloylquinic acid), gallocatechin-4,8-catechin, epicatechin-4,8-catechin, catechin-4,8-catechin, epicatechin-4,8-epicatechin-4,8-catechin, catechin, epicatechin-4,8-epicatechin, epicatechin, epicatechin-4,8-epicatechin-4,8-epicatechin, epicatechin-4,6-catechin, epicatechin-4,6-catechin (Pawlowska, Leo & Braca, 2006; Pallauf, Rivas-Gonzalo, del Castillo, Cano & de Pascual-Teresa, 2008; Bouzid et al., 2015; Xie et al., 2015).
	Jamun (*Syzygium cumini*)	Ellagitannins, condensed tannins (B-type oligomers of epiafzelechin), kaempferol 7-*O*-methylether, γ-sitosterol, *β*-sitosterol, corilagin, ellagitannins, ellagic acid, galloyl-galactoside, gallic acid, oleanolic acid, quercetin, myricetin, kaempferol, anthocyanins (3,5-diglucosides of delphinidin, petunidin and malvidin), carotenoids (Faria, Marques & Mercadante, 2011; Swami, Thakor, Patil & Haldankar, 2012; Afify, Fayed, Shalaby & El-Shemy, 2011; Zhang & Lin, 2009).
	Cucumber (*Cucumis sativus*)	Glycosides of salicylic acid, vanillic acid, *p*-coumaric acid, saponarin. Chlorogenic acid, sinapic acid hexoside, rutin, luteolin and apigenin derivatives, kaempherol-*O*-glycoside, quercetin-3-*O*-pentosyl-rutinoside, kaempferol derivatives, quercetin derivatives, naringenin-*O*-glucoside, theaflavanoside (Reidah, 2013).
	Mango (*Mangifera indica*)	Mangiferin, isomangiferin, quercetin 3-*O*-galactoside, quercetin-3-*O*-glucoside, quercetin-3-*O*-xyloside, quercetin-3-*O*-arabinopyranoside, quercetin-3-*O*-arabinofuranoside, quercetin 3-*O*-rhamnoside, kaempferol 3-*O*-glucoside, quercetin, rhamnetin and its glycoside (Masibo & He, 2008).
	Indian date/palm (*Ziziphus jujube)*	Anthocyanins, delphinidin, petunidin, malvidin-diglucosides, rutin, quercetin, quercitrin, phlorizin, catechol, gallic acid, catechin, chlorogenic acid, caffeic acid, epicatechin, *p*-coumaric acid, ferulic acid, quinic acid, sinapic acid, kaempferol, *p*-hydroxy benzoic acid, protocatechuic acid, rutin, vitamin C, vitamin E, zinc, selenium, beta-catotene, triterpenoic acids (Zhao, Zhang & Yang, 2014; Wu, Gao, Kjelgren, Guo & Wang, 2013; Swami et al., 2012)
	Pomegranate (*Punica granatum*)	Ellagic acid, gallic acid, catechin, catechol, cyanidin 3-*O*-glucoside, cyanidin 3,5-di-*O*-glucoside, delphinidin 3-*O*-glucoside, delphinidin 3,5-di-*O*-glucoside, epicatechin, epigallocatechin 3-gallate, isoquercetin, pelargonidin 3-*O*-glucoside, pelargonidin 3,5-di-*O*-glucoside, procyanidin, quercetin, tryptamine, melatonin (Wang, Ding, Liu, Xiang & Du, 2010).
	Cabbage (*Brassica oleracea* var capitata*)*	Vitamin C, β-carotene, lutein, DL-α-tocopherol, phenolics compounds [quercetin-3-*O*-sophoroside-7-*O*-glucoside, quercetin-3,7-di-*O*-glucoside, quercetin-3-*O*-sophoroside, quercetin-3-*O*-(caffeoyl)-sophoroside-7-*O*-glucoside, quercetin-3-*O*-(methoxycaffeoyl)-sophoroside-7-*O*-glucoside, quercetin-3-*O*-(sinapoyl)-sophoroside-7-*O*-glucoside, quercetin-3-*O*-(feruloyl)-sophoroside, kaempferol-3-*O*-sophorotrioside-7-*O*-sophoroside, kaempferol-3,7-di-*O*-glucoside, kaempferol-3-*O*-sophoroside, kaempferol-7-*O*-glucoside, kaempferol-3-*O*-(caffeoyl) sophoroside-7-*O*-glucoside, kaempferol-3-*O*-(methoxycaffeoyl)sophoroside-7-*O*-glucoside, kaempferol-3-*O*-(sinapoyl)-sophoroside-7-*O*-glucoside, kaempferol-3-*O*-(feruloyl)-sophoroside-7-*O*-glucoside, kaempferol-3-*O*-(*p*-coumaroyl)-sophoroside-7-*O*glucoside, kaempferol-3-*O*-(methoxycaffeoyl)-sophoroside, kaempferol-3-*O*-(sinapoyl)-sophoroside, kaempferol-3-*O*-(feruloyl)-sophoroside, kaempferol-3-*O*-(*p*-coumaroyl)-sophoroside, 3-caffeoyl quinic acid, 3-*p*-coumaroyl quinic acid, 4-caffeoyl quinic acid, sinapylglucoside, 4-feruloyl quinic acid, sinapic acid (Cartea, Francisco, Soengas & Velasco, 2011; Singh et al., 2006).

continued on following page

Table 3. Continued

Food		Phytoconstituents (Mainly Antioxidant/Pro-Oxidant Molecules)
	Ivy gourd (*Coccinia indica*)	Taraxerone, taraxerol, and (24R)-24- ethylcholest- 5-en- 3β-ol glucoside, β- carotene, lycopene, cryptoxanthin, apo-6’-lycopenal, β-sitosterol, taraxerol (Deokate & Khadabadi, 2012)
	Bottle gourd (*Lagenaria siceraria*)	Ascorbic acid, β-carotene, 22-deoxocurcubitacin-d, 22-deoxoisocurcubitacin-d, 7-*O*-glucosyl-6-C-glucoside apigenin, 6-C-glucoside apigenin, 6-C-glucoside luteolin, and 7,4′-*O*-diglucosyl-6-C-glucoside apigenin. Flavonoids like isovitexin, isoorientin, saponarin, and saponarin 4′-*O*-glucoside. Triterpenes such as 3 b-*O*-(*E*)-feruloyl D:*C*-friedooleana-7,9(11)-dien-29-ol, 3b-*O*-(*E*)-coumaroyl-D:*C*-friedooleana-7,9(11)-dien-29-ol, 3b-*O*-(*E*) coumaroyl-d:*C*-friedooleana-7,9(11)-dien-29-oic acid, methyl 2b,3b-dihydroxy-D:C-friedoolean-8-en-29-oate, 3-epikarounidiol, 3-oxo-d:C-friedoolena-7,9 (11)-dien-29-oic acid, bryonolol, bryononic acid, 20-epibryonolic acid. Volatile essential oil (Prajapati, Kalariya, Parmar & Sheth, 2010).
	Tamato (*Lycopersicon esculentum*)	Vitamins C, vitamin E, selenium, zinc, quercetin, kaempferol, lycopene, gallic acid, catechin, chlorogenic acid, caffeic acid, coumarin, rutin, quercitrin, luteolin, β-carotene. cis *p*-coumaric acid derivative, caffeic acid hexoside, 4-*O*-caffeolyquinic acid, 5-*O*-caffeolyquinic acid, trans *p*-coumaric acid hexoside, cis *p*-coumaric acid hexoside, ferulic acid hexoside, 4-*O*-*p*-coumarolyquinic acid, caffeic acid, 5-*O*-*p*-coumarolyquinic acid, syringic acid hexoside derivative, quercetin pentosylrutinoside, trans-*p*-coumaric acid, quercetin-3-*O*-rutinoside, kaempferol pentosylrutinoside, kaempferol-3-*O*-rutinoside (Barros et al., 2012; Akomolafe & Oboh, 2015)
	Papaya (*Carica papaya*)	Vitamin C, volatile compounds (linalol, benzylisothiocynate, cis and trans 2, 6-dimethyl-3,6 expoxy-7 octen-2-ol), α-carpaine, benzyl-β-d glucoside, 2-phenylethl-β-D-glucoside, 4-hydroxyl -phenyl-2 ethyl-B-D glucoside. Myristic, palmitic, stearic, linoleic, linolenic acids-vaccenic acid and oleic acids. β carotene, crytoxanthin, violaxanthin, zeaxanthin (Karunamoorthi, Kim, Jegajeevanram, Xavier & Vijayalakshmi, 2014; Krishna, Paridhavi & Patel, 2008).
	Bitter gourd (*Momordica charantia)*	Momordicin, charantin, cryptoxanthin, cucurbitins, cucurbitacins, cucurbitanes, cycloartenols, diosgenin, gentisic acid, goyaglycosides, goyasaponins, karounidiols, lanosterol, lauric acid, linoleic acid, linolenic acid, momorcharasides, momorcharins, momordenol, momordicillin, momordicinin, momordicosides, momordin, momordolo, multiflorenol, myristic acid, nerolidol, oleanolic acid, oleic acid, rosmarinic acid, rubixanthin, spinasterol, steroidal glycosides, stigmastadiols, stigmasterol, taraxerol, trehalose, verbascoside, zeatin, zeatinriboside, zeaxanthin, zeinoxanthin, β-sistosterol-d-glucicide, citruline, elasterol, flavochrome, lutein, lycopene, curbitacin B, catechin, vitamin C, zinc (Gupta, Sharma, Gautam & Bhadauria, 2011).
	Centella (*Centella asiatica*)	Hydrocotylin, asiaticoside A and B, madecassoside, centelloside, indocentelloside, brahmoside, brahminoside, thankuniside, iso-thankuniside, 3-glucosylquercetin, 3-glucosylkaempferol, 7-glucosylkaempferol, kaempferol, quercetin, stigmasterol, sitosterol, carotenoids, vitamin C, ursolic acid, triterpene acids (asiatic, madecassic, terminolic, centic, centellic, madasiatic acid), centellasaponin B, C and D (Jamil, Nizami & Salam, 2007).
	Sponse gourd (*Luffa cylindrical)*	*p*-coumaric acid, 1-*O*-feruloyl-β-D-glucose, 1-*O*-*p*-coumaroyl-β-D-glucose, 1-*O*-caffeoyl- β-D-glucose, 1-*O*-(4-hydroxybenzoyl)glucose, diosmetin-7-*O*-β-D-glucuronide methyl ester, apigenin-7-*O*- β-D-glucuronide methyl ester, luteolin-7-*O*-β-D-glucuronide methyl ester (Du et al., 2011).
	Potato (*Solanum tuberosum*)	catechin, epicatechin, erodictyol, kaempeferol, naringenin, rutin, lutein, zeaxanthin, violaxanthin, neoxanthin, β-carotene, vitamins C and E, cyanidin,pelargonidin, malvidin (Ezekiel, Singh, Sharma & Kaur, 2013)
	Broccoli (*Brassica oleracea* var *botrytis italica*)	Ferulic acid, caffeic acid, sinapinic acid, kaempferol, quercetin, and isorhamnetin. Quercetin derivatives like quercetin -3-*O*-sophorotrioside-7-*O*-sophoroside, quercetin -3-*O*-sophorotrioside-7-glucoside, quercetin -3-*O*-sophoroside-7-*O*-glucoside, quercetin -3,7-di-*O*-glucoside, quercetin-3-*O*-sophoroside, quercetin -3-*O*-glucoside, quercetin-3-*O*-(caffeoyl)-sophorotrioside-7-*O*-glucoside, quercetin-3-*O*-(sinapoyl)-sophorotrioside-7-*O*-glucoside, quercetin-3-*O*-(feruloyl)-sophorotrioside-7-*O*-glucosid, quercetin-3-*O*-(*p*-coumaroyl)-sophorotrioside-7-*O*glucoside, quercetin-3-*O*-(caffeoyl)-sophoroside-7-*O*-glucoside, quercetin-3-*O*-(*p*-coumaroyl)-sophoroside-7-*O*-glucoside, quercetin-3-*O*-(feruloyl)-sophoroside). Kaempferol derivatives like K-3-*O*-sophorotrioside-7-*O*-sophoroside, kaempferol-3-*O*-sohorotrioside-7-*O*-glucoside, kaempferol-3-*O*-sophoroside-7-*O*-diglucoside, kaempferol-3-*O*-sophoroside-7-*O*-glucoside, kaempferol-3,7-di-*O*-glucoside, kaempferol-3-*O*-sophoroside, kaempferol-3-*O*-sophoroside-7-*O*-glucoside, kaempferol-3,7-di-*O*-glucoside, kaempferol-3-*O*-sophoroside, kaempferol-3-*O*-glucoside, kaempferol-3-*O*-(caffeoyl)-sophorotrioside-7-*O*sophoroside, kaempferol-3-*O*-(methoxycaffeoyl)-sophorotrioside-7-*O*-sophoroside, kaempferol-*O*-(sinapoyl)-sophorotrioside-7-*O*-sophoroside, kaempferol-*O*-(feruloyl)-sophorotrioside-7-*O*-sophoroside, kaempferol-3-*O*-(*p*-coumaroyl)-sophorotrioside-7-*O*-sophoroside, kaempferol-3-*O*-(caffeoyl)-sophorotrioside-7-*O*-glucoside, kaempferol-3-*O*-(methoxycaffeoyl)-sophorotrioside-7-*O*glucoside, kaempferol-*O*-(sinapoyl)-sophorotrioside-7-*O*-glucoside, kaempferol-*O*-(feruloyl)-sophorotrioside-7-*O*-glucoside, kaempferol-3-*O*-(caffeoyl)sophoroside-7-*O*-glucoside. 1,2-disinapoylgentiobiose, 1-sinapoyl-2-feruloylgentiobiose, 1,2,2’-trisinapoylgentiobiose, 1,2’-disinapoyl-2-feruloylgentiobiose (Gawlik-Dziki, 2008; Cartea et al., 2011).
	Indian spinach (*Basella alba*)	Vitamins A and C, thaimine, betacyanin, oxalic acid, acacetin, 4,7- dihydroxy kempferol, 4’-methoxyisovitexin, vanilla, syringic and ferulic acid, betacyanins and gomphrenin (Kumar, Prasad, Iyer & Vaidya, 2013)
	Spinach (*Spinacia oleracea)*	β-carotene, violaxanthin, 9’-(Z)-neoxanhin, vitamin A, vitaminE, vitamin C, iron, zinc, copper, querecetin, myricetin, kampeferol, apigenin, luteolin, patuletin, spinacetin, jaceidin, 4´-glu-curonide, 5,3´,4´-trihydroxy-3-methoxy-6:7-methylenedioxyflavone-4´-glucuronide, 5,4’-dihydroxy-3.3´-dimethoxy-6:7-methylene dioxyflavone-4´-glu-curonide, 5,4´-dihydroxi-3,3´-dimithoxi-6,7-methylene-dioxi-flavone, 3,5,7,3´,4´-pentahydroxi-6-methoxiflavone, *p*-coumaric acid, ferulic acid, *o*-coumaric acid (Subhash, Virbhadrappa & Vasanth, 2010).

*Antioxidant present in the grain, friut, vegitables etc. can be vary with environment, soli types etc.

enocarcinoma (Daniel et al., 2012). Different varieties of rice, wheat, ragi, maize, jowar, barley, oats, rye have been investigated for antioxidant activity and showed moderate to strong antioxidant effect. A number of studies found that regular intake of wheat whole grains and whole grain products responsible for reduced risk of cardiovascular disease, stroke, diabetes, some cancers (El-Baky, 2009). A number of reports observed the beneficial effect of maize on obesity, diabetes, cancer, immunity, kidney and urinary tract infection, gout, inflammation etc. (Pedreschi & Cisneros-Zevallos, 2007; Escudero et al, 2012), antioxidant phytochemicals present in maize may responsible for their beneficial effect. Available epidemiological surveys have shown that sorghum intake lower the risk of certain types of human cancer compared to other cereals. Sorghum phytochemicals are also helpful to promote cardiovascular health and reduce obesity. High level of antioxidant phytochemicals present in sorghum may be partly responsible for its health beneficial effect (Awika & Rooney, 2004; Mathangi, 2012). Pharmacological screenings showed that oats possesses antioxidant, immunomodulatory, antidiabetic, anticholesterolaemic, antiinflammatory, wound healing activities. Phytoconstituents of oats found to protect LDL during oxidation, cardiovascular and coronary artery diseases (Singh, De, & Belkheir, 2013). Health benefit of barley, rye also reported in several epidemiological and scientific investigations. Cereals & millets are very good source of dietary phenolic and other antioxidants which may have potential health promotive and diseases preventive effects.

Legumes belong to the most important family leguminosae, which include 700 genera and 20,000 species. They are the second most significant source of food and fodder. Legumes can be divided into two groups: (*i*) oil seeds like soybeans and peanuts, and (*ii*) grain legumes, including common beans, lentils, lima beans, and common peas. Grain legumes are commonly recognized as pulses. Legumes are rich in nutrient content, and contain starch, protein, dietary fibre, oligosaccharides, phytochemicals and minerals. In addition, legumes are also the rich sources numerous bioactive phytochemicals which possess antioxidant activity. Different bioactive compounds such as simple phenols, phytosterols, saponins, phenyl propanoids, phenolic acids, flavonoids, stilbenes, tannins, lignans and lignins are present in legumes which have been acknowledged to promote good health and have therapeutic potential. Proanthocyanidines (i.e. condensed tannins) are also the key phenolic substances found in legume seeds, which mainly found in seed coats (hulls). Some studies also correlate the antioxidant activity of different legumes with their protein content and suggested that proteins of different legume seeds might have antioxidant potential. Legumes have been used as therapeutic medicine since ancient time in old traditional medicine. Current researches and observational studies found that legumes confer significant health benefit and beneficial to improve serum lipid profiles, platelet activity, and inflammation and in the treatment of cardiovascular disease, coronary artery diseases, cancer. A number of investigational studies also confirmed that different extract/parts of legumes have free radical and antioxidant effect. Natural polyphenols possess antioxidant and free radical scavenging activities and thus confer miscellaneous therapeutic effects for disease prevention and health promotion. Phytochemicals like saponins, tannin, phenolic acid, flavonoid, sterol etc. found in legumes possess antioxidant activity, which inpart or fully responsible for their protective or therapeutic effect (Venter & van Eyssen, 2011; Kappor, 2015; Petchiammal & Hopper, 2014).

Edible oils are used as important cooking ingredients, and as salad dressing, margarine spreads, and dips around the world. These oils are extracted from different sources like plants (e.g., soybean, canola), seeds (e.g., sunflower) and husk (e.g., rice bran), nuts (e.g., walnut) and fruits (e.g., olive, coconut). Several phenolic antioxidants are also used as edible oil preservatives to prevent rancidity (Dauqan, Abdullah & Sani, 2011; Pantsi, Bester, Esterhuyse & Aboua, 2014). Intake of virgin coconut oil found beneficial in reducing lipid profile and LDL oxidation by physiological oxidants. This effect may be due to presence of polyphenol components in virgin coconut oil. Another study showed that virgin coconut oil supplemented diet increases antioxidant level in experimental animals (Nevin & Rajamohan, 2006, 2014). Olive oil is important vegetable oil believed to produce its beneficial effect majorly via antioxidant constituents. Although the composition of olive oil is complex, but majority of its compounds likes oleic acid, phenolics, and squalene can inhibit oxidative stress. Olive oil consumption found useful in several diseases conditions like cancer, coronary heart disease, blood pressure, high lipid content etc (Waterman & Lockwood, 2007). Vitamin E in different isomer form, coenzyme Q10 and squalene present in palm oil possess strong antioxidant effect and found beneficial in several oxidative stress induced diseases (Loganathan, Selvaduray, Radhakrishnan, & Nesaretnam, 2010). Gamma-oryzanol is a mixture of sterol esters of ferulic acid and triterpene alcohols. Rice bran oil showed very potent antioxidant activity and reduces triglyceride level. Rice bran oil also contains omega-3, omega-6 and omega-9 fatty acid. It is also rich in essential vitamin E complex (α, β, γ, δ tocopherols and α, β, γ, δ tocotrienols). Gamma-oryzanol showed antioxidant, antihyperlipedemic, antidiabetic, anti-inflammatory and anticancer effect. It reduces platelet aggregation, increase the muscle mass and used to treat the disorders of menopause (Vorarat, Managit, Iamthanakul, Soparat & Kamkaen, 2010; Patel & Naik, 2004). Sunflower oil contain several components including antioxidant substance which responsible for several curative effect of the oil such as anti-inflammatory, anti-bacterial, anti-fungal, anti-cancer, cardioprotective and dermoprotective (Warner et al., 2015; Khan et al., 2015). Peanut has been acknowledged as a functional food due to its role in a health promoting effect. Several fatty acid and antioxidant found in peanut oil which provide protection against oxidative stress. Phenolic compound resveratrol present is peanut oil that exhibits antiplatelet, anti-inflammatory, anticancer, antimutagenic, antifungal effect, and reduces lipid peroxidation. Peanut oil also contain vitamin E, squalene, β-carotene which also known well for their curative effect (Akhtar et al., 2014).

Herbs and spices are traditionally used as flavor-enhancement substance in food and considered to have low nutritional value. Though, the spices are used as medicine since encient time. Recent investigations showed that herbs and spices contain various phytochemicals, many of which possess powerful antioxidant activity. They inhibit lipid peoxidation, promote antioxidant defence mechanism, protect LDL cholesterol from oxidation, inhibit cyclooxygenase and lipoxygenase enzymes, and produce anticancer or antimicrobial effect. Epidemiological and preclinical evidence indicated that herbs and spices though used as minor dietary constituents but possess anticancer activity. Herb and spice and their chemical constituents are poved effective in the treatment of neurodegenerative disorders (e.g. Alzheimer's disease, Parkinson's disease and multiple sclerosis), cardiovascular diseases i.e. stroke. Herb and spice also exert immune enhancing effect. Ginsenosides, a active principal of Ginseng species, curcumin from turmeric and other phytoconstituent are reported for diverse beneficial effect on health (Kaefer & Milner, 2008; Dharmananda, 2005; Craig, 1999).

Tea is the most common beverage with antioxidant potency. Tea is rich in natural antioxidants, and reported to be used in management of different types of cancer, stone, dental caries, and other diseases. Wide number of research found that green tea is useful in variety of implications, including cancer, heart disease, liver disease, diabetes, inflammatory bowel disease, skin disorders, hair loss, weight loss etc. Flavonoids present in green tea mainly responsible for such effects (Sinija & Mishra, 2008). Several epidemiological studies have suggested that moderate coffee consumption may helpful to prevent diseases, like diabetes mellitus, Parkinson's disease and liver diseases. Though, some studies have indicated revrese association between coffee consumption and cardiovascular diseases (Higdon & Frei, 2006). Little to moderate beer consumption could helpful in prevention of cardiovascular diseases, coronary artery diseases, risk of developing gallstones, risk of osteoporosis etc. (Anonymous, 2002)

Fruits and vegetable are the key source of diverse antioxidant molecules. Consumption of fruits and vegetables in proper quantity has been associated with protection against various diseases and aging. Though, role of diet is complex in describing their action against chronic and acute diseases. It was estimated that a typical diet may supply more than 25,000 bioactive food constituents, and several of them can alter magnitude of diseases through the multitude of processes. Due to such complexity it is essential to understand the role of these bioactive substances in prevention, cure or development of disease. Majority of bioactive constituents from diet mainly from plant sources are redox active molecules and therefore identified as antioxidants (Carlsen et al., 2010). Fruits and vegetable contain several well characterized antioxidant substances, including vitamins C, vitamin E, phenolic substances, β-carotene and minerals (zinc, selenium), which showed prominent beneficial effect against oxidative stress induced diseases. A study has investigated the antioxidant activity of more than 3100 foods, beverages, spices, herbs and supplements used around the world, and reported that different foods possess moderate to high antioxidant activity. Spices, herbs, fruits like berries, nuts, chocolate, and vegetables showed potent antioxidant activity (Carlsen et al., 2010). In last few decade the usefulness of antioxidant substances are in spotlight and thus number of researches are going on in this regard. Huge numbers of epidemiological studies are conducted or going on and majority of such studies found that consumption of fruit and vegetable which has high polyphenolic antioxidants showed beneficial effect on health. Antioxidant potency of fruits and vegetables may be influenced genetics and environmental factors. Cooking also may alter the antioxidant activity of a food. Several chemical and biological properties of antioxidant molecule such as absorption, cellular uptake, biotransformation, transport and excretion may eventually modify the action antioxidant substance containing diet. A number of epidemiological survey and researchers have suggested the inverse association of fruit and vegetable intake with the risk of cardiovascular disease, diabetes, cancer, neurodegenerative diseases etc. (Bazzano et al., 2002; Hu et al., 2013, Key, 2011; Isao et al., 2013; Patrice et al., 2010).

Of cource, diet from animal sources also confers strong antioxidant activity. Milk, dairy products, fish, meat also contain numerous antioxidant molecule. Milk contains vitamin A, E which may contribute the antioxidant capacity of milk (Tijerina-Saenz, Innis & Kitts, 2009). Several molecules like ascorbic acid, tocopherols, omega-3 fatty acids are available in fish, beneficial effect of these compounds already been reported by the researchers.

PRO-OXIDANT EFFECT OF ANTIOXIDANTS

Some flavonoids have shown prooxidant activity provided a transition metal is available. The OH substitution is essential for antioxidant activity of flavonoids. If OH substitution is absents in then the molecule will not produce neither antioxidant nor transition metal initiated prooxidant activities. Copper induced prooxidant effect of a flavonoid largely depends on number of free OH substitutions present in molecule, if the number of OH substitutions is more than the prooxidant activity will be stronger. Flavonoids from foods usually present as *O*-glycosides with sugars bound at the C3 position. Methylation or glycosidic alteration of OH substitutions causes the inactivation of transition metal-induced prooxidant activity of a flavonoid. Mostly *in vitro* studies found that flavonoids like quercetin and kaempferol can cause nuclear

DNA damage and lipid peroxidation if transition metals are present. Though, *in vivo* studies didn't found significant transition metal-initiated prooxidant actions of flavonoids, ascorbic acid and vitamin E. It is possible that result of *in vivo* studies are negative as in normal condition (except metal toxicity case) transition metal like copper ion will be mostly sequestered in the tissues. Several researches also confirmed that quercetin, a flavonoid can prevent ion-induced lipid peroxidation in liver cells (Rahal et al., 2014). An *in vitro* study concluded that phenolic compounds like quercetin, rutin, protocatechuic acid with low oxidation potentials (Epa lower than 0.45) confer antioxidant activity, whereas compounds (i.e. vanillic acid, syringic acid, coumaric acid) with high Epa values (>0.45) produce prooxidant activity (Simic, Manojlovic, Segan & Todorovic, 2007).

ANTIOXIDANT SUPPLEMENTS VS. FOOD RICH IN ANTIOXIDANT MOLECULE

In recent years the role of oxidative stress in different diseases came in focus and thus use of antioxidant supplements have increased significantly among the general people with the hope to prevent diseases. A number of researches mainly epidemiological and observational studies reported the positive effect of antioxidant supplements. Similar beneficial effect of antioxidant supplements are also confirmed by different several randomized controlled trials (RCTs). However, the reports are not consistent and several of the RCTs also reported null/negative effect when antioxidant supplements consumed for long time and in high dose. For example, a clinical study on 47 street workers (who exposed to high level of ozone) found beneficial effect of vitamin E (75 mg), vitamin C (650 mg) and β-carotene (15 mg) supplement given for the period of 6 months. A study in US, Canada, and Puerto Rico found that vitamin E produces negative effect on incidence of prostate cancer. Though most of the clinical trial showed null effect, like long term supplementation of vitamin C (500 mg/day), vitamin E (600 IU every other day), β-carotene (50 mg every other day) in different combinations did not show any effect on the outcome of cancer risk, diabetes and secondary cardiovascular diseases. High doses of isolated compounds also may cause toxic, or prooxidative effects. Exogenous antioxidants may exibit diuble-edged phenomenon in cellular redox states depends upon physiological environment and dose (Sen & Chakraborty, 2015; Bouayed & Bohn, 2010). Thus potential clinical benefit deriving from antioxidant supplements for the general population is still under wide debate.

Fruits and vegetables contain antioxidant molecules, vitamins, micronutrients and macronutrients which act through different mechanisms. Thus a diet rich in fruit and vegetables is vital for optimum health. It was observed that reduce intake of nutritional and antioxidant food may increase the chance of oxidative stress which may leads to cell damage. Thus intake of fruit, vegetable, beverages and natural antioxidant containing product may confer protective effect against free radical induced diseases through diverse mechanism. Experimental study also shown that rice, different food grains, vegetables, fruits, animal products, tea, and other beverages exert significant antioxidant activity and a number of bioactive antioxidant molecules isolated from those. Thus it is essential to have food containing antioxidant molecule in proper rationally a better health (Sen & Chakraborty, 2015).

CONCLUSION

Maintenance of redox balance is believed to be critical in maintaining disease free good health. However, in modern era change in life style, less consumption of health food, stress, pollutions etc make us more prone to oxidative stress. Thus it is required to consume endogenous antioxidant for maintenance of health. Of course excessive intake of exogenous antioxidants especially isolated compounds may exert prooxidative effects or can disrupt redox balance, which intern responsible for harmful effect. But food like fruit, vegetables, food grain etc contain numerous vitamin, minerals, nutrient and phytochemicals, among them several substances are greatly acknowledged for antioxidant property. It is evident that consumption of natural food are associated with health promotive and disease preventive effect which may fully/partly associate related with antioxidant molecule presents such food. Thus it is truly essential consumption of a healthy and antioxidant rich natural diet for better and healthy life.

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Chapter 18
Health Promoting Effects of Kimchi

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ABSTRACT

Kimchi is a traditional Korean food manufactured by fermenting vegetables with probiotic Lactic Acid Bacteria (LAB). Many bacteria are involved in the fermentation of kimchi, but LAB become dominant while the putrefactive bacteria are suppressed during salting of baechu cabbage and the fermentation. The addition of other subingredients and formation of fermentation byproducts of LAB promote the fermentation process of LAB to eventually lead to eradication of putrefactive and pathogenic bacteria, and also increase the functionalities of kimchi. Accordingly, kimchi can be considered a vegetable probiotic food that contributes health benefits in a similar manner as yogurt as a dairy probiotic food. Further, the major ingredients of kimchi are cruciferous vegetables; and other healthy functional foods such as garlic, ginger, red pepper powder, and so on are added to kimchi as subingredients. As all of these ingredients undergo fermentation by LAB, kimchi is regarded as a source of LAB; and the fermentative byproducts from the functional ingredients significantly boost its functionality. Because kimchi is both tasty and highly functional, it is typically served with steamed rice at every Korean meal. Health functionality of kimchi, based upon our research and that of other, includes anticancer, antiobesity, anticonstipation, colorectal health promotion, probiotic properties, cholesterol reduction, fibrolytic effect, antioxidative and antiaging properties, brain health promotion, immune promotion, and skin health promotion. In this review we describe the health functionalities of kimchi and the probiotic properties of its LAB.

BLOOD CIRCULATION EFFECTS

Lipid Lowering Effects

Cholesterol in the blood is essential to maintain homeostasis of the human body, being involved in several physiological functions such as producing hormones and vitamins, and maintaining cell membranes,

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and nerve cells. It is derived from both exogenous dietary sources and endogenous biosynthetic pathways. Dietary cholesterol plays a huge role in serum cholesterol levels, since cholesterol is synthesized to a minimal level for balancing. As diet patterns have been changing towards western style, elevated blood cholesterol is becoming more common. Hypercholesterolemia is one of the major risk factors for cardiovascular disease, and the leading cause of death in many countries (Law et al., 1994). The risk of heart attack is three times higher in those with hypercholesterolemia, compared to those who have normal blood lipid profiles, and it was reported that hypercholesterolemia contributed to 45% of heart attacks in Western Europe and 35% of heart attacks in Central and Eastern Europe from 1999 to 2003 (Yusuf et al., 2004).

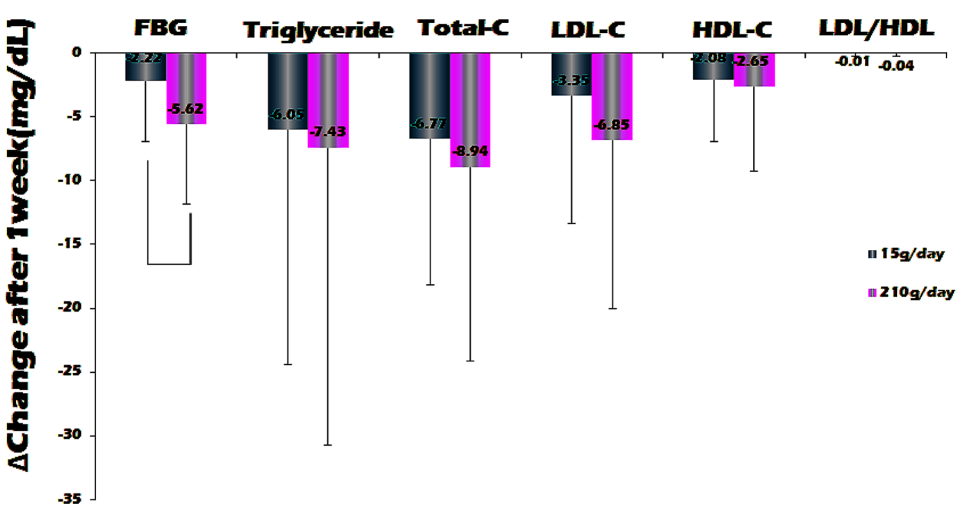
In a study investigating blood lipid concentration according to kimchi consumption in middle-aged males, individuals with greater kimchi consumption showed higher dietary fiber and calcium intake, and HDL-cholesterol was positively correlated with kimchi consumption. Meanwhile, there was a positive correlation for salty taste preference with blood neutral lipids and total cholesterol levels, and there was a negative correlation for spicy taste preference with systolic blood pressure, blood neutral lipids, and total cholesterol levels, and these results are consistent with animal studies (Kwon et al., 1999). In one study, the kimchi ingredients known to have a particularly good antioxidant effect were added at 30% the amount of mustard leaf to make cabbage kimchi; this was manufactured into a pill, and when subjects ate 3g per day for 6 weeks, although there was no change in body fat or obesity, blood neutral lipid levels and LDL/HDL-cholesterol ratio significantly decreased. When the water-soluble and water-insoluble fractions of kimchi were made into separate pills, both groups showed a blood lipid-reducing effect, but the water-soluble pill had a greater neutral lipid-reducing effect, and the water-insoluble pill had a greater effect of increasing HDL-cholesterol concentration. Therefore, it is thought that there is a difference in the active ingredients or mechanisms of the two solvent extracts (Choi et al., 2001). These lipid-reducing effects of kimchi and kimchi ingredients have been reported in epidemiological studies, animal studies, and clinical trials. Lactic acid bacteria (LAB) have attracted attention with its cholesterol lowering functionality, especially considering the fact that members of the genera Lactobacillus, Lactococcus, are most commonly given safe or generally recognized as safe (GRAS) status, and the safety of probiotics has been well proved over a long period of experiences. Supplementation of *L. plantarum* CIB 001 can have short-term (6 weeks) effects on blood lipids and liver injury, as well as on the atherogenic index and cardiac risk factors (Cha et al., 2012). Leu. Kimchi GJ2 isolated from kimchi exerts an antiatherosclerotic effect by reducing serum and liver cholesterol levels (Lee et al., 2008). In spite of continued interest in cholesterol lowering potential of LAB strains, all related mechanisms are not fully understood yet, and several hypotheses are still being investigated in an attempt to explain the observed hypocholesterolaemic effects. A study group focused on the effect of 3 LAB strains (*Lactobacillus plantarum* A6a2, *Lactobacillus sakei* C10, *Lactobacillus brevis* J23) isolated from kimchi, for controlling cholesterol efflux in enterocytes, by ATP binding cassette (ABC) transporters, which are direct target genes of liver X receptors (LXR α/ß). *Lactobacillus rhamnosus* LGG was used as control. The treatment of Caco-2 cells with the LAB strains resulted in up-regulation of the LXRs and an increased expression of intestinal sterol efflux transporters ABCG5/ABCG8. Furthermore, cholesterol isotope assay confirmed the results, showing an increase in cholesterol efflux, and therefore, suggesting that up-regulation of LXR-ABCG5/8 is one of the mechanisms for the cholesterol lowering ability of LABs (Kim, 2012). LXRs are ligand-activated transcription factors and key regulators of cholesterol homeostasis. When activated by ligands, they undergo a conformational change that recruits coactivator proteins and regulate transport, catabolism, and elimination of lipid, by enhancing transcription of the target genes. With a microarray analysis of mouse intestine and liver genes, which were up-regulated by a LXR agonist and in vivo studies using knockout mice, it has been proposed that ABCG5 and ABCG8 could promote efflux of cholesterol and sitosterol (plant sterol) (Duan et al., 2004; Jiang et al., 2008)

A *kimchi* pill supplementation (3 g/day) study with 12 middle aged healthy Korean adults showed the atherogenic index for the *kimchi* group decreased compared to placebo group (Choi et al. 2001). High *kimchi* intake (210g/day) improved fasting blood glucose and total serum cholesterol compared to low *kimchi* intake (15g/day) in young healthy adults (Choi et al. 2013, Figure 1).

Antiatherosclerosis Effects

Among serum lipids, cholesterol is the number one risk factor for atherosclerosis. The consumption of kimchi has been reported to have a positive effect on lipid metabolism and the efficacy of kimchi in cholesterol regulation has been confirmed. When lipid metabolism was investigated after feeding white rats with 3%, 5%, and 10% cabbage kimchi feed, blood neutral lipids, blood cholesterol, and phospholipid levels decreases significantly in the kimchi intake groups. In all kimchi groups, the lipid concentration in the liver decreased, and the high-density lipoprotein (HDL) cholesterol levels and fecal lipid excretion function increased. Atherosclerotic index and HMG-CoA reductase activity decreased in the kimchi groups in a concentration-dependent manner. HMG-CoA reductase is an enzyme that controls new cholesterol synthesis, and the fact that its activity decreases with kimchi intake is thought to lead to suppression of new cholesterol synthesis, decreasing blood cholesterol levels (Kwon et al., 1997). In an experiment on rabbits, feeding with kimchi for 12 weeks was reported to have a preventative effect against atherosclerosis, decreasing plasma cholesterol, neutral lipids, very low-density lipoprotein, and LDL concentration, and increasing HDL concentration (Kwon et al., 1998). Oxidative transformation of low-density lipoproteins (LDLs) is highly related to the formation of atherosclerosis. Rabbits that ate cholesterol feed had increase LDL, plasma thiobarbituric acid reactive substance (TBARS), and peroxide value (POV) content by rearing term. However, compared to the control group, these values

Figure 1. Changes in plasma biochemical parameters of the subjects after 7 days of kimchi consumption
Source: (Choi et al. 2013).



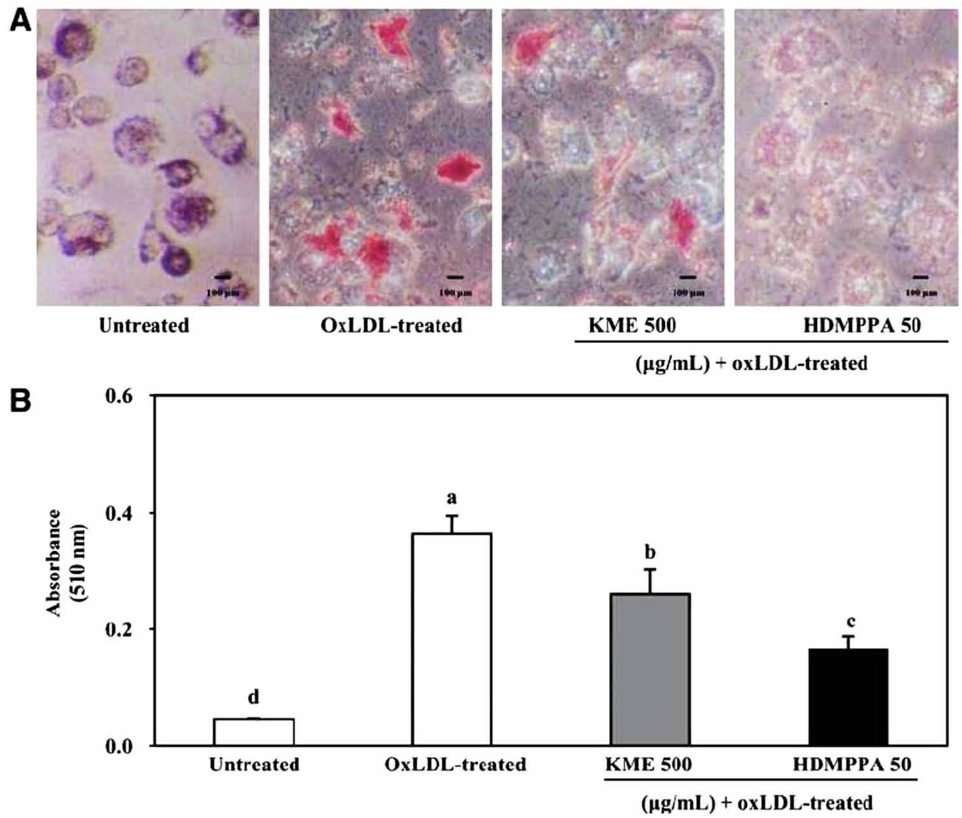
were decreased in groups that ate cabbage, red pepper powder, and garlic. In particular, lipoperoxide formation was suppressed in chili pepper and garlic groups compared to the control group (Kwon et al., 2003a, 2003b). The active principle, 3-(4'-hydroxyl-3'5'-dimethoxyphenyl) propionic acid (HDMPPA) in *baechu kimchi* responsible for lowering lipid lowering activity also showed anti-atherogenic effects (Lee et al., 2004; Kim et al., 2007; Noh et al., 2013). The β-sitosterol and S-methylcystein sulfoxide in cabbage are reported to have an effect of reducing cholesterol concentration, and the allin and allicin contained in garlic are known to combine with the SH group of coenzyme A to reduce fatty acids, neutral lipids, phospholipids, and cholesterol concentration.

Oxysterols such as 7-ketocholesterol (7-KC) have been reported to be partially responsible for the cytotoxicity of oxLDL and induce endoplasmic reticulum (ER) stress which eventually causes apoptosis. 7-KC causes aberrant ER stress and apoptosis, all of which are inhibited by Kimchi methanol extract (KME) and glutathione. The inhibitory expression of ER stress markers highlights its new protective role against oxLDL-induced ER stress, apoptosis, and subsequent atherosclerosis (Kim et al., 2012). OxLDL strongly induced cell death and lipid peroxidation in THP-1-derived macrophages. However, KME and HDMPPA significantly improved cell viability and inhibited lipid peroxidation induced by oxLDL in THP-1-derived macrophages. Moreover, KME and HDMPPA suppressed CD36 and PPAR-gamma expressions, both of which participate in cholesterol influx. In contrast, KME and HDMPPA augmented LXRα, PPARα, and ABCA1 expression, which are associated with cholesterol efflux. Consequently, KME and HDMPPA suppressed lipid accumulation (Yun et al., 2014, Figure 2).

Antithrombotic Effects

Kimchi consumption has a preventative effect against atherosclerosis because it decreases serum cholesterol levels and has fibrolytic activity, which suppresses blood clotting. Thrombus formation is one of the major causes of atherosclerosis. Accordingly, suppression of thrombosis is known to be an important method for preventing atherosclerosis. In order to investigate the fibrolytic activity of kimchi, white rats were reared for 6 weeks on a diet of 3%, 5%, or 10% added kimchi. When plasma isolated from the blood of these rats was inspected for fibrolytic activity, although there was not a large difference between control group and the 3% and 5% kimchi groups, the 10% kimchi group showed higher fibrolytic activity than the control group. This activity increased with increasing kimchi content. In order to identify the fibrolytic substances in kimchi, based on experimental results such as these, kimchi and kimchi ingredients were first extracted using water and methanol, and the activity of these extract was examined. For water extracts, fibrolytic activity was highest for water dropwort, and was also relatively high in spring onion and radish. Meanwhile, of the methanol extracts, chili pepper showed superior fibrolytic activity, while radish, kimchi, and spring onion also had high activity. The fibrolytic activity of kimchi methanol extract was higher than water extract, suggesting that the active substances are likely to be non-protein substances. Of the water extracts, fibrolytic activity was highest for water dropwort, followed by spring onion, radish, and cabbage, while for the methanol extracts, activity was highest for red pepper powder, followed by radish, spring onion, and cabbage. The fibrolytic activity of red pepper powder methanol extract was highest of all the ingredients tested (Kim et al., 1998). Meanwhile, when the bacterial strains that produce thrombolytic enzymes were isolated and identified, they were found to be *Bacillus amyloliquefacins*, *Bacillus brevis*, and *Micrococcus luteus* (Noh et al., 1999). Also, of the ingredients in kimchi, garlic in particular has been reported to have thrombolytic properties in clinical

Figure 2. Inhibitory effect of KME (500 ug/mL) and HDMPPA (50 ug/mL) on lipid accumulation by Oil Red O staining. THP-1-derived macrophages were incubated with or without KME or HDMPPA for 24 h followed by addition of oxLDL (100 mg/mL) for 48 h, following which Oil Red O staining was performed. Stained cells were observed under a microscope (A) and quantified at 510 nm (B). Data are expressed as mean – SD (n = 3, p<0.05). [a~d] *Indicates significant difference*
Source: (Yun et al., 2014).



studies (Sainani et al., 1979; Ariga et al., 1999), and chilli peppers and salted fish paste are known to have thrombolytic activity (Jang et al., 1998).

Blood Pressure Lowering Effects

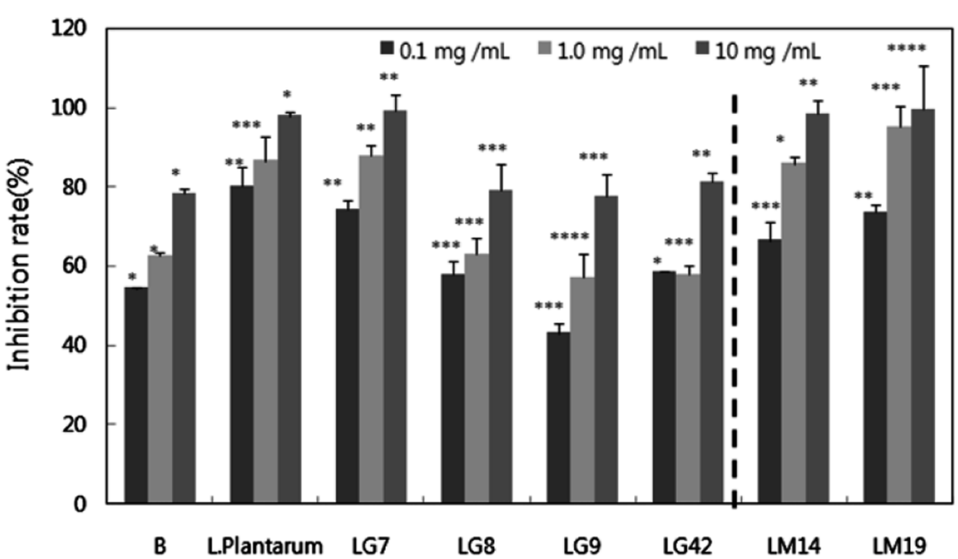
Anti-hypertensive effect of Lactobacillus sp. isolated from Kimchi by examining its effects on renal angiotensin-converting enzyme (ACE) inhibitory activity, lipid components and blood pressure using the spontaneously hypertensive rat (SHR) system. Most Lactobacillus sp. extracts (lysozyme, sonication and ethyl acetate extracts) showed higher capacities for the inhibition of ACE activity than those of cultured media. Particularly, LG 7, 8 and 42 of Lactobacillus sp. showed the strongest inhibitory activity among the Lactobacillus sp. extracts. The concentrations of total cholesterol and triglycerides in the serum were lower in the Lactobacillus sp. administration groups than in the control group, but these differences were not significant. The HDL-cholesterol concentrations of the LG 42 administration groups (IX, X) were significantly higher than that of the control group. At 4 weeks, the systolic blood pressure (SBP) in the LG 42 Lactobacillus sp. (1×109 cfu/mL) group (XI) was about 27% lower than that of the control group (V). No adverse effects were observed on the liver and there was no difference in the aspartate aminotransferase (AST) and alanine aminotransferase (ALT) values among groups. The results of this study suggest that long term consumption of LG 42 Lactobacillus sp. may be beneficial to the prevention of high blood pressure (Yu et al., 2009, Figure 3). In leaves of improved Dolsan leaf mustard (DLM) at the 60th day growth, angiotensin converting enzyme (ACE) inhibitory effect was the highest about 94.0%. The cytotoxicity against HepG2 was the highest in roots of DLM. And the anti-oxidative and ACE inhibitory effect in leaves of DLM were higher than those of other parts (Yu, 2004).

IMMUNE MODULATION EFFECTS

Anticancer Effects

The ingredients in kimchi contain antioxidants (vitamin C, carotin, flavonoids), digestible fiber, sulfurous compounds (glucosinolates, isothiocyanates, indoles, allyl compounds), capsaicin, and peptidoglucans. Because these compounds remove toxic substances from the body and suppress the activation of carcinogens, they have anticancer and antimutagenic effects. Cruciferous vegetables and some of the chemical compounds they contain are known to protect against carcinogens, and to stimulate the activity of phase I and phase II enzymes that act as detoxifying enzymes. In particular, sulforaphane (S-methylsulfinylbutyl isothiocyanate) is a type of isothiocyanate that activates phase II enzymes (glutathione S-transferase, GST), but does not activate some phase I enzymes that contribute to the activation of procarcinogens to carcinogens. Recently, there has been increasing interest in the chemoprotection of sulforaphane-containing cruciferous vegetables. These vegetables contain several types of isothiocyanate, including

*Figure 3. Inhibitory effect of Lactobacillus metabolite (cultured broth) on the ACE; data are expressed as mean ± SD (n=3). *p<0.0005, **p<0.001, ***p<0.005, ****p<0.01, *****p<0.05 (t-test).*
Source: (Yu MH et al., 2009).



sulforaphane, and these isothiocyanates have anticancer and anticarcinogenic effects in numerous animal organs, such as the liver, kidneys, and small intestine.

The first stage in the development of cancer involves normal cells undergoing genetic mutations due to carcinogens. After making a methanol extract of cabbage kimchi and its fractions and applying them to the Ames test and SOS chromotest, which are tests of *in vitro* antimutagenic activity, a mutation-suppressing effect was observed for mutations caused by the carcinogens MNNG and AFB1. Also, when mouse embryo cells (C3H/10T1/2 cell) were exposed to the carcinogen MCA, foci of morphologically altered cells formed, but the extract reduced the total number of type II and type III foci (reduction rate 92%) and possible cancers in mice were considerably suppressed (Park, 1995, 2014).

There has recently been a lot of research on the anticancer effects of kimchi and kimchi extracts. *In vitro* anticancer tests, such as the SRB test, MTT test, and the growth inhibition test have shown Kimchi extracts to suppress the proliferation of human cancer cells such as AGS human gastric cancer cells, HT-29 human colon adenocarcinoma cells, MG 63 human osteosarcoma cells, HL-60 human leukemia cells, and Hep 3B human hepatoma cells. Kimchi fractions also inhibited DNA synthesis in cancer cells. When a sarcoma 180 cell was grafted into a particular mouse line (Balb/c mouse) and the mouse was administered with kimchi extract, measurements of the change in tumor weight showed that kimchi extract had a tumor growth-suppressing effect *in vivo*, as well (Lee et al., 1996; Oh et al., 1993).

Furthermore, colonic *Lactobacilli* from kimchi that have reached the colon via the stomach have been found to suppress the activity of enzymes like b-glucosidase and b-glucuronidase, which convert procarcinogens into carcinogens. This has been reported to be related to the low incidence of colon cancer in Korean individuals (Lee et al., 1996; Oh et al., 1993).

There are a large number of epidemiological survey results suggesting that the cabbage, garlic, and onions used in kimchi have a cancer suppressing effect in humans. When the Harvard Medical School in the United States surveyed the lifestyles of 47,909 bladder cancer patients between 1986 and 1996, they found that the incidence of bladder cancer was lower with increasing consumption of cabbage and other cruciferous vegetables, and cabbage and broccoli were particularly reported to reduce the risk of bladder cancer (Michaud et al., 1999). Also, when the lifestyles of 129 brain cancer patients were surveyed in China between 1993 and 1995, brain cancer incidence was reported to be lower in individuals who ate fresh vegetables, especially cabbage and onions, and people who ate fresh fish (Hu et al., 1999). There is an inverse correlation between the risk of lung cancer and intake of cabbage, cauliflower, and broccoli, and consumption of *Brassica* has also been reported to have an inverse correlation with gastric cancer (Vehoeven et al., 1996). At Austria's Wien University, cabbage and garlic were reported to have a protective effect against cancer (Frohlich et al., 1997). There are also reports that garlic can reduce the risk of cancer. The Unites States National Cancer Institute (NCI) discovered that the residents of Changshan County in China's Shandong Province had a low prevalence of stomach cancer and surveyed 214 residents. The results showed that garlic consumption was inversely correlated with *Helicobacter pylori* infection, and it was estimated that garlic could suppress the progression of early-stage gastric cancer (You et al., 1998). When a dietary survey was conducted on 223 colorectal cancer patients in Lausanne, Switzerland, from 1992 to 1997, garlic was concluded to have the highest protective effect against cancer (Levi et al., 1999). When 345 breast cancer patients were surveyed in France from 1986 to 1989, the risk of breast cancer was reported to decrease with increased fiber, garlic, and onion consumption (Challier et al., 1998).

Mutation Preventing Effects

Several ingredients and Lactobacilli in kimchi contribute to fermentation, and their immune activity-promoting action is recently becoming a subject of interest. Kimchi extracts lead to increased phagocytic activity by phagocytes *in vitro* and *in vivo*. Macrophages become active when they are simulated by exogenous infections, which leads to a process of proliferation involving spreading, phagocytic activity, pinocytosis, lysozymes, and cytoplasmic granules, and ultimately result in antibacterial and antitumoral activity. Among extracts, kimchi that has been fermented for 3 weeks showed higher activity (Choi et al., 1997). Also, kimchi solvent extracts show immune strengthening activity, increasing the production of interleukin-2 and the activity of natural killer (NK) cells (Kim et al., 1998), and they also have a positive effect on the immune system, including promoting the production of NO by macrophages, regulating transforming growth factor b1 (TGF-β1) in cancer cells, and production if interleukin-6 by spleen cells (Kim et al., 2001). Meanwhile, immune activity-strengthening action has also been demonstrated for kimchi *Lactobacilli*. When ascites tumor was induced in mice using sarcoma-180 cells before orally administering kimchi *Lactobacilli* homogenate, immune activity increased compared to the untreated group. Intestinally secreted IgA is a major index for protective action against infectious bacteria in the gut, and IgA was lowest in normal mice treated with *Lactobacilli*, followed by cholangiocarcinoma mice (ascites tumor induced with sarcoma-180) treated with *Lactobacilli*, untreated normal mice, and untreated cholangiocarcinoma mice. These results demonstrate that, even in cholangiocarcinoma mice, administration with *Lactobacilli* resulted in an increased in intestinal antibody secretion compared to the untreated group. Moreover, macrophages isolated from the *Lactobacilli*-treated group showed 66% increased NO production compared to macrophages isolated from the untreated group, and even for cholangiocarcinoma mice, NO production increased for the *Lactobacilli*-treated group by 12–27%, depending on the stimulator, compared to the untreated group. This shows that, when kimchi *Lactobacilli* are administered to cholangiocarcinoma mice, although there is a slight decrease in abdominal macrophages compared to healthy mice, there is an immune-activating effect and this effect can be seen to contribute to suppression of ascites tumors and solid tumors (Shin et al., 1998; Korea Food Research Institute, 1997; Yu, 1995). In conclusion, kimchi demonstrates various immune activity-promoting effects, such as partially increasing the proliferation speed of immune cells in the spleen and small intestine, increasing the production of NO by abdominal macrophages, increasing the production of IgA secreted in the colon, increasing the concentration of interleukin-2, and increasing the number of specific antibody cells. When the yeast *Candida albicans* is administered to mice and they are fed appropriately matured kimchi (pH 4.3, acidity 0.6%), macrophage activity doubles. Kimchi consumption considerably increases the activity of NK cells, increasing anticancer function. Lactobacilli from Kimchi may modulate the Th1/Th2 balance via macrophage activation in the hypersensitive reaction caused by Th2 cells (Won et al., 2011).

Asthma Preventing Effects

Asthma is an inflammatory disease characterized by bronchial hyper-responsiveness that can proceed to life-threatening airway obstruction. The T helper 2 (Th2)-type cytokines interleukins-4 (IL-4), IL-5, and IL-13, produced by activated CD4+ T cells play a central role in the pathogenesis of asthma by controlling the key process of immunoglobulin E (IgE) production, growth of mast cells and the differentiation and activation of mast cells and eosinophils (Corrigan et al., 1993; Renz et al., 1993). In contrast, Th1 cytokines such as interferon-γ (IFN-γ) and IL-12, which down-regulate Th2 responses, inhibit the development of allergic lung inflammation [13,39]. Thus, interventions that inhibit Th2 cytokines by enhancing Th1 cytokine production, may be useful in the treatment of allergic asthma [36].

The relationship between dietary factors and asthma in a representative population-based sample of 19,659 men and women, aged 19-64 years, using data from the fourth and fifth Korean National Health and Nutrition Examination Survey (KNHANES), 2007-2011 was studied. The prevalence of asthma in Korean adults was 2.4%. Adults with asthma consumed fewer amounts of kimchi (P=.0444) and fish (P=.0175) but had a higher cereal intake than those without asthma (P=.0056). Multiple logistic regression analysis after controlling for confounding factors showed a significant inverse relationship between kimchi consumption and the prevalence of asthma [odds ratio (95% confidence interval) for subjects consuming 1 to <2 servings (40-79.9 g), 2 to <3 servings (80-119.9 g), and ≥3 servings (≥120 g), relative to those consuming <1 serving (<40 g): 0.726 (0.534-0.987), 0.506 (0.348-0.736), and 0.678 (0.502-0.916), respectively; P for trend=0.0131]. These results warrant future studies to explore the mechanisms responsible for the association between kimchi consumption and asthma (Kim et al., 2014). Probiotics have been shown to be effective in reducing symptoms. Three heat-killed lactobacilli, Lactobacillus plantarum, Lactobacillus curvatus and Lactobacillus sakei subsp sakei, isolated from kimchi, exerted inhibitory effects on airway hyper-responsiveness in a murine asthma model (Hong et al., 2010).

Anti-Viral Effects

Kimchi *Lactobacilli* have proven treatment effects against the influenza virus, bacterial diseases, and especially against avian influenza, and the reason that Korea suffered less loss from SARS or avian influenza has been revealed to be because of the immune function-strengthening effects of kimchi.

Influenza A viruses belong to the family Orthomyxoviridae and contain a genome composed of eight segments of single-stranded, negativesense RNA that each encodes one or two proteins (Neumann et al., 2009). 'Spanish influenza (H1N1). The pandemic of 1918-1919 killed as many as 50 million people worldwide, and remains unprecedented in its severity. The mortality pattern of the 'Spanish' influenza was unusual with high mortality rates for young adults. The typical mortality pattern observed with the Spanish influenza remains unexplained to date. 'Asian' influenza (H2N2). The 'Asian' influenza originated in Southern China in February 1957. From there, it spread to Singapore (March 1957), Hong Kong (April 1957), Japan (May 1957), and the United States and United Kingdom (October 1957). A second wave was detected in January 1958. In the United States, excess mortality was estimated to be 70,000. The pandemic was caused by a human/avian reassortant that introduced avian virus H2 HA and N2 NA genes into human populations. Furthermore, the Asian influenza virus also possessed a PB1 gene of avian virus origin (Gabriele Neumann et al., 2009).

Avian influenza (AI) is caused by viruses that are classified as members of the family Orthomyxoviridae and genus Influenzavirus A (Swayne & Suarez, 2000). These are pleomorphic RNA viruses with helical symmetry and glycoprotein projections from the envelope that have hemagglutinin (HA) and neuraminidase (NA) (Calnek et al., 1997). AI is classified into subtypes according to the combination of 16 HA and 9 NA molecules (Fouchier et al., 2005).

The antiviral efficacy of *L. plantarum* YML009 was compared with oseltamivir (Tamiflu). It was shown that YML009 proved tobemore effective than Tamiflu. Therefore, based on our results, it could be concluded that *L. plantarum* YML009 may be a novel probiotic candidate as anti-influenza prevention and infection. The study ends with the developmentofan anti-influenza probiotic candidate *L. plantarum* YML009 (Choi, 2014). Avian Influenza virus can be synergistically reduced in combination with probiotics therapy and there are resultant different mechanisms of action. *Leu. mesenteroides* YML003 has antiviral activities against LPAI H9N2 virus, after proper in vivo experiments; it may become a candidate to be applied to animals and humans (Seo, 2012a, 2012b).

Probiotics was first defined as "substances" produced by microorganisms that stimulate the growth of other microorganisms (Lilley et al., 1965). It was discovered that some bacteria were able to multiply and colonize an area more efficiently in the presence of "helpful" bacteria. This is particularly true for normal microflora residing in the gut of human and animals. It was observed that bacteria or their products commonly used for food preparations or food supplements were able to improve the growth of normal microflora in the gut of individuals as well as provide substantial protection against gastrointestinal diseases. Hence, it was proposed that the concept of probiotics be redefined as "viable microbial agents which, when used in animal or man, beneficially affects the host possibly by improving the balance of the indigenous microflora" (Salminen et al., 1999). Several lactic acid bacteria belonging to the *Lactobacillus*, *Leuconostoc*, *Lactococcus* species isolated from kimchi as well as *Enterococcus* isolated from Korean shrimp possess antiviral properties against porcine epidemic diarrhea virus (PEDV). The antiviral compounds are heat tolerant and showed moderate resistance to proteolytic digestion by trypsin (Cruz, 2006).

GUT MICROBIOTA IMPROVING EFFECTS

Obesity Preventing Effects

Kimchi has the ability to help prevent obesity, and it contains compounds with this functionality. In order to prevent obesity, there is a need for functions that promote energy metabolism, functions that promote burning of body fats, and functions that promote restriction and excretion of calorie intake. In other words, calorie intake must be restricted, energy metabolism must be promoted, and stored body fats must be broken down and burned off. Also, fecal excretion should be aided as a way of sending the energy and waste products in organs outside of the body (van der Klaauw, 2015).

The capsaicin in chili peppers that gives kimchi its spicy flavor displays several types of physiological activity, and of these, it plays an important role in obesity treatment and prevention. The capsaicin in chili peppers acts to promote energy metabolism, and in particular the burning of fats. Capsaicin stimulates the parasympathetic nervous system, increasing the secretion of adrenalin. This promotes the catalysis of white fat tissues and increases heat production by the body's energy-consuming brown fat cells, which results in the overall breakdown of body fats and a decrease in the amount of fat accumulated in the body (Lee et al., 2013). 3T3-L1 cells were treated with capsaicin with medium to observe the change in the expression of the obesity-related genes by using dot blot assay. As results, the treatment with capsaicin caused an up-regulation of the UCP-2 expression. And decrease body weight, serum triglyceride, serum total cholesterol and white adipose tissue (Lee, 2003). A group eating a high-fat diet with 5% added red pepper powder and a group eating a diet with 10% added kimchi (5% red pepper powder content) both showed a significant decrease in body weight compared to a group fed only a high-fat diet. Furthermore, body fat decrease even more in the group with added kimchi with red pepper powder and other kimchi ingredients, than in the group with the same amount of red pepper powder added by itself. Even when eating a high-fat diet, when kimchi was consumed at the same time, a similar body weight to the control group was maintained (Park, 1995). According to studies in humans, after eating 5g of red pepper powder (approximately the amount in 100g of kimchi) the increase in energy metabolism reached its peak within 60 minutes (approximately 40% increase), and after that, it gradually declined. Also, when the effect of capsaicin on heat production was investigated during a high-sugar, high-fat diet, it was reported to promote body heat production and increase burning of body fats, demonstrating a clear body fat-reducing effect, and suggesting that it would be capable of suppressing obesity (Galgani et al., 2010). Kimchi also acts to promote energy metabolism. Some of the functional, physiologically active substances in kimchi act to promote metabolism of energy-producing nutrients (especially lipids, sugars, etc.). Kimchi contains vitamin B complexes such as thiamine, riboflavin, niacin, and pantothenic acid, which act as coenzymes for various enzymes that participate directly in sugar and fat metabolism in the body. Kimchi also contains citric acid and acetic acid generated by *Lactobacillus* fermentation. Meanwhile, the most proactive method for preventing and treating obesity is the restriction of calories intake (especially sugars and fats), reducing the digestion and absorption of calories that have been consumed, and excretion outside of the body. The important substance that performs these roles is digestible fiber, and there it is contained in abundance in kimchi. The digestible fiber in kimchi helps to restrict calorie consumption, alleviate constipation, and promote excretion, which are important roles in the prevention and treatment of obesity. Soluble fiber has various types of physiological activity, but the most important actions are to give a feeling of satiety and the delay the absorption of glucose. Soluble fiber is easily dissolved in the gut, and during this process, it expands and becomes viscous, giving a sense of satiety. Accordingly, due to the feeling of fullness and the lack of appetite, food (calorie) consumption decreases. Soluble fiber also has the secondary function of making absorption and usage of digested glucose slower. Meanwhile, insoluble fiber cannot be digested by the human digestive system, and it is excreted without change. In particular, insoluble fiber increases the amount of feces, and so improves the speed of fecal excretion and aids the excretion of some waste substances and calories outside of the body. There are large amount of both soluble and insoluble fiber in kimchi (Cheigh & Park, 1994).

Kimchi has few calories compared to other foods, and because it contains large quantities of digestible fiber, it gives a sense of satiety, and it acts to remove waste substances from the gut to the outside of the body, helping regulation of body weight (Cheigh & Park, 1994). Moreover, when kimchi has been matured appropriately, its weight-loss effect increases (Kim et al., 2011). Also, when the effect of capsaicin on heat production was investigated during a high-sugar, high-fat diet, it was reported to promote the production of heat in the body, and to increase burning of body fats, providing a clear body fat-reducing effect and suggesting that it could help to suppress obesity (Kawada et al., 1986). In terms of its weight-loss, the capsaicin in red pepper powder promotes the breakdown of fats and increases heat production, raising energy consumption. According to a study in humans, following the consumption of 5g of red pepper powder (the amount in approximately 100g of kimchi), the increase in energy metabolism reached a peak within 60 minutes (approximately 40% increase) and then gradually declined. Also, when the effect of capsaicin on heat production was investigated during a high-sugar, high-fat diet, it was reported to promote the production of heat in the body, and to increase burning of body fats, providing a clear body fat-reducing effect and suggesting that it could help to suppress obesity (Kang, 2009). The intake of fermented red pepper during the weight control program decreased the body fat especially abdominal fat and prevent the decline of RMR during weight reduction period (Chang et al., 2003). Red pepper powder and kimchi stimulated the lipid metabolism of blood and adipose tissues (Choi, 2001).

There has also been a study on the effects of kimchi consumption and exercise on body composition and blood lipids in obese female middle school students. The subjects were divided into an exercise and kimchi consumption group (EKG), an exercise group (EG), a kimchi consumption group (KG), and a control group (CG). The experiment was conducted for 6 weeks, but during the experiment period, the average daily kimchi consumption in the EKG and KG was approximately 40g, which is less than the average daily consumption for the total Korean population. The results showed that the EKG and the KG demonstrated a significant decrease in body weight, BMI, obesity, total body fat, body fat percentage, and abdominal fat compared to the other groups. In particular, during the course of the experiment obesity changes were -5.82% for the EKG, -4.43% for the KG, and -3.16% for the EG, demonstrating a clear effect of kimchi consumption in the partial treatment of obesity across several parameters, including body weight and body composition, and confirming that the weight-loss effects are even greater when kimchi consumption is combined with exercise (Baek, 2001). W. koreensis OK1-6 supplementation has the potential antiobesity and glycemic control effect in mice fed a high-fat diet, which may be mediated by inhibiting body fat accumulations, altering lipid profile in liver and serum, down-regulating obesity related gene expressions in liver, and alleviating the insulin resistance. Kimch manufactured with the starter of the ornithine-producing lactic acid bacteria Weissella koreensis OK1-6 can be used as functional food in Korean diet and its health-promoting effect could be beneficial for preventing obesity and obesity-induced diabetes (Park et al., 2012). Twenty-two obese patients, who's BMI (basal metabolic index) was 25 kg/m2, did not have any fermented food including Kimchi for 2 weeks. The 22 patients then were randomly ordered two 4-week diet phases that were separated by a 4-week washout period (cross-over design). During each diet phase, the subjects consumed either fresh Kimchi or Kimchi ripened for 10 days (fermented Kimchi). In this 4-month-experiment, ingestion of Kimchi showed positive effects on various factors associated with metabolic syndrome (weight, BMI, waist to hip ratio, body fat percentage). Even more, positive effects including decreased systolic/diastolic BP, % body fat, fasting glucose, total cholesterol, and decreased trend of fasting insulin and leptin were shown after ingestion of fermented Kimchi compared to fresh Kimchi (Ahn, 2011).

Symbiotic Effects

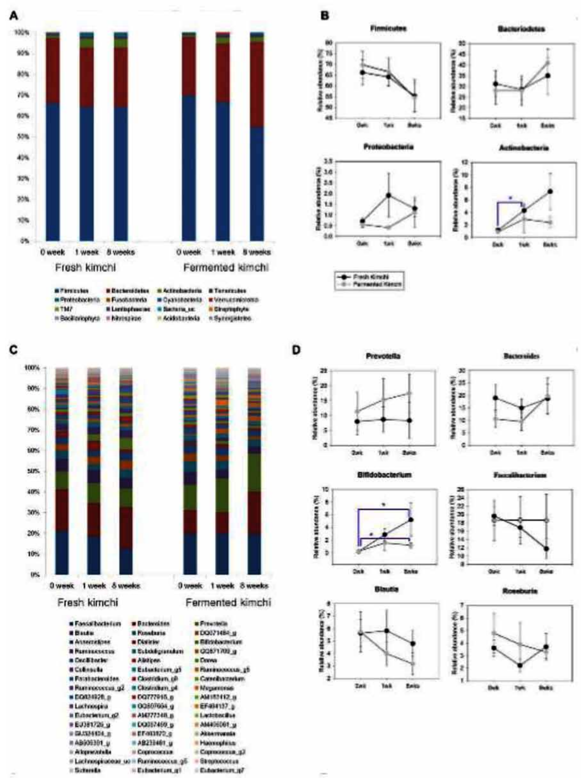
Accumulating evidence suggests relationship of compositional changes of gut microbiota with onset of metabolic disorders and obesity. Kimchi, a traditional Korean side dish, is known for its beneficial impact on metabolic parameters and anti-obesity effects. Twenty-four obese women were randomly assigned to either fresh or fermented kimchi group for eight weeks of kimchi intervention. Pyrosequencing of fecal microbiota and microarray analyses of blood samples revealed that fresh and fermented kimchi interventions exerted differential effects on the obesity-related clinical parameters. Correlations of these effects with changes in blood gene expression and gut microbial population were more evident in the fermented kimchi group than the fresh kimchi group (Han et al., 2015, Figure 4).

ANTI-OXIDANT EFFECTS

Kimchi contains antioxidants (or free radical scavengers) that prevent lipid peroxidation and remove reactive oxygen species (ROS) and various free radicals (Cheigh, 1999).

Antioxidants in kimchi include polyphenols, such as carotenoids, flavonoids, and anthocyanins, as well as chlorophylls, and vitamin C and E. As kimchi's main ingredient, cabbage also contains antioxidant flavonols, such as hydroxybenzoic acid, hydroxycinnamic acid, kaempferol, and quercetin, as well as chlorophylls and carotenoids. In terms of spices, when the alcohol extracts of chili pepper seeds and chili

Figure 4. Comparison of relative abundance of gut microbiota after eight weeks of kimchi intervention. Fecal samples were collected three times, before the initiation as well as after one and eight weeks of the intervention. (A) The compositions of phyla in the samples of a particular time-period were compared using bar plots. (B) The time-dependent compositional changes of major phylum are shown in line plots. (C) The compositions of genus in the samples of a particular time-period were compared using bar plots. (D) The time-dependent compositional changes of major genus are shown in line plots.
Source: (Han K et al., 2015).



pepper skin were added to soybeans and the ability to suppress peroxide formation was compared, chili pepper skin powder had a stronger antioxidant effect, and this was reported to result from tocopherols, carotenoids, and capsaicin (Cheigh & Park, 1994). Garlic contains substances such as allinin, garlic acid, and scorinin, and the ethanol fraction of garlic suppresses the production of lipoperoxide. The ethanol fraction of garlic contains sulfides, and it is probable that garlic's antioxidizing effect is related to the reducing nature of sulfide sulfhydryl (-SH) groups (Chan, 2013). Meanwhile, when the organic solvent extract of ginger was added to soybean oil in different concentrations to investigate its antioxidizing effect, all treatment groups showed an antioxidizing effect. The 3% solution was a superior antioxidant to tocopherol, and a similar level to butylated hydroxy anisol (BHA). Ginger's flavor components, such as gingerol, gingeron, and shogaol, are also known to act as antioxidants (Butt, 2011). Spring onion also contains antioxidant flavonoids, including quercetin 4'-O-b-D-glucoside, quercetin 3, 4'-O-bis-glucoside, and quercetin 7-4'-O-bis-glucoside, and has high levels of b-carotene and ascorbic acid (Jang et al., 1991; Han et al., 1995). The green parts of chives contain kaempferol 3-O-b-D-glucoside, kaempferol

3-O-b-xylosyl-D-glucoside, and quercetin 3-O-glucoside, which contribute to the antoxidizing effect (Jang et al., 1991; Jung et al., 1999; Lee et al., 1988).

Skin Care Effects

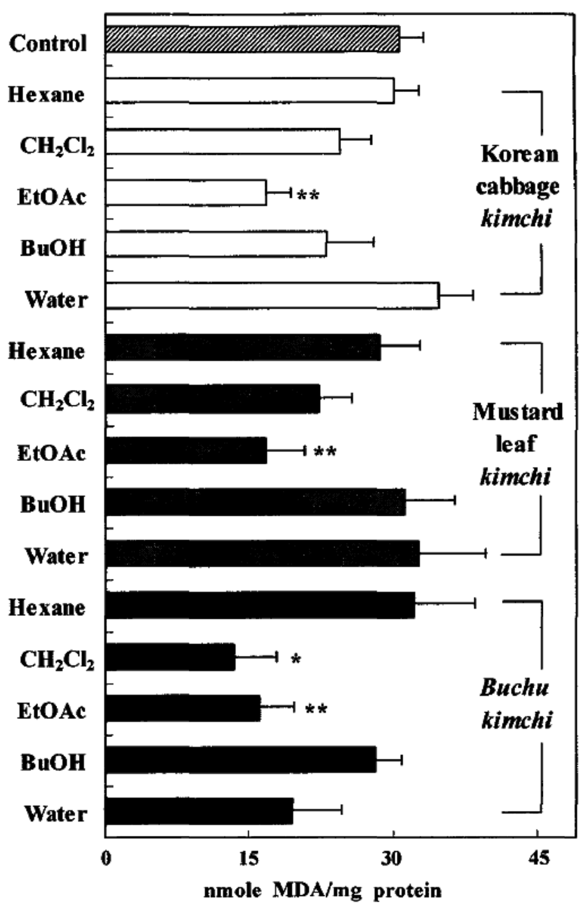
Kimchi contains antioxidants like vitamin C, polyphenol compounds, and chlorophyll, and so it inhibits the production of ROS within the body and eliminates them, suppressing aging and damage to skin cells in particular, while also protecting the skin from ultraviolet (UV) light. Kimchi solvent extracts have an effect of suppressing skin aging. When keratinocytes, the main epidermal cells, were artificially given an oxidizing stimulus by short-term exposure to hydrogen peroxide, and extracts from kimchi of different fermentation periods (1–5 weeks) were tested for detoxifying effect against hydrogen peroxide, 2-week fermented kimchi had by far the strongest effect. Inhibitory effects against oxidative stress from long-term exposure showed a similar tendency. When hydrogen peroxide was applied to fibroblasts, hypodermal cells in the skin, 2-week fermented kimchi showed the strongest cytotoxicity-suppressing effect among the different kimchi extracts (Ryu et al., 1997; Ryu et al., 1997). There are also results for kimchi's preventative effect against skin aging in hairless mice. Hairless mice that consumed cabbage kimchi, mustard lead kimchi, and chive kimchi had a thicker epidermis and thinner keratinized layer than the control group, as well as greater new collagen formation, demonstrating a preventative effect of kimchi consumption against skin aging. In a study looking at the cytotoxicity-suppressing effects of kimchi extract according to the method for inducing ROS, 2-week fermented kimchi had the greatest effect, while 0-week and 3-week fermented kimchi also showed an effect, but the effects were not as clear as they were in keratinocytes. The fermentation period-dependent difference in effect that was shown by this study is assumed to be due to changes in kimchi constituents according to fermentation time. As the skin ages, the thickness of the epidermis and the amount of collagen in the hypodermis decrease, while mucopolysaccharides increase. However, in the added kimchi group, the change in collagen content and the activity of fibroblasts were slower compared to the control group, and cytomorphological changes were observed in the mustard lead kimchi group in particular. In addition, the rate of keratinization of the skin was also slower in the kimchi group, and this trend of delayed skin aging was greater in the mustard leaf kimchi and chive kimchi groups compared to the cabbage kimchi group (Ryu et al. 2004). As physiological aging progresses, the epidermis becomes thinner and there is an increase in cytokeratine, which participates in skin keratinization. Furthermore, the activity of rough endoplasmic reticulum (RER) in hypodermal fibroblasts decreases, impairing collagen production (Gilchrest, 1984). However, in studies investigating the anti-skin aging activity of cabbage kimchi, mustard leaf kimchi, and chive kimchi, the hairless mice in the kimchi consumption groups had a thicker epidermis and thinner keratinized layer in their skin than the control group, and the mustard leaf kimchi and cabbage kimchi groups had far greater development of the hypodermal RER, demonstrating a preventative effect of kimchi consumption against skin aging. Also, there was an effect of reducing lipid oxidation in skin homogenate, and the cabbage kimchi group had low TBARS content in the EtOAc layer, as shown in Figure 5. The mustard leaf kimchi group had low TBARS in the EtOAc and CH_2Cl_2 layers, and this group in particular was found to have a ROS-eliminating effect as well. The fractions of these types of kimchi in different solvents were found to have hydrogen-donating activity, peroxide-inhibiting activity, and a protective effect against UV rays, but these effects were slightly different according to the kimchi type and extracted fraction (Gilchrest, 1984). When several kimchi solvent fractions were added to a cream and applied to the back of hairless mice before exposure to UV, there was less erythema for the

CH_2Cl_2 layer for cabbage kimchi, the EtOAc layer for mustard lead kimchi, and the H_2O layer for chive kimchi, which shows that these fraction layers contain protective substances against UV radiation. Here, the protective effect differs according to the type of kimchi, with slightly more erythema occurring for chive kimchi than for cabbage kimchi or mustard leaf kimchi, and in particular, the hexane layer of chive kimchi had a weaker effect for suppressing erythema. This is thought to be because cabbage kimchi and mustard leaf kimchi, in addition to chlorophylls, also contain carotenoids, which have antioxidant and light-protective effects, but chive kimchi contains only chlorophylls (Ryu, 2000).

Anti-Aging Effect

There are also studies investigating the *in vivo* effects on senescence-accelerated mice (SAM) of types of kimchi that were found to have anti-aging functions *in vitro*. In groups that consumed kimchi, there

*Figure 5. Antioxidant effect of solvent fractions of various kimchi on UV-irradiated mouse skin homogenate; Values are means ± SD (n=3). CH_2Cl_2, EtOAC, and BuOH were expressed dichloromethane, ethylacetate, and butanol respectively. *Significantly different from control at $p<0.01$. **Significantly different from control at $p<0.05$.*
Source: (Ryu BM et al., 2004).



was a blood lipid-reducing effect, and HMG-CoA reductase activity was lower than the control group. Also, in SAM that consumed kimchi, when looking at total ROS, antioxidant enzyme activity, and lipid concentration in various organs with age, although there were differences according to the kimchi ingredients, the organ, and the amount of aging, the kimchi consumption groups showed a clear anti-aging effect in terms of *in vivo* lipid composition, antioxidant enzyme activity, etc. Also, the concentration of lipofuscin, which is produced in the eye due to aging, was much lower in SAM that were fed kimchi (Lee, 2001). Exopolysaccharides produced by Bacillus Sp. Strains isolated from Korea fermented food, kimchi, has antioxidant and antiaging activity (Song, 2010).

In order to determine whether kimchi consumption has an anti-aging effect in humans, kimchi consumption was investigated in 20–29 year olds (n=93) and a 65-and-over elderly group (n=143) residing in the Gyeongsangnam-do region. After obtaining a blood sample, indices of aging such as total free radicals, OH radicals, GSH, GSSG, GSH/GSSG, and TBARS were measured, and the results are very interesting. When the surveyed subjects were divided into a high kimchi consumption and a low kimchi consumption group based on the average kimchi consumption of 112g, there was no significant difference within the 20–29 year old group, but in the elderly group, those subjects who consumed more than the average amount of kimchi had 21% and 26% lower total free radicals and OH radicals, respectively ($p<0.05$), while the antioxidant GSH and the GSH/GSSG ratio increased 8% an 12% ($p<0.05$), and there was no difference in GSSG concentration. This result provides one piece of evidence that kimchi consumption suppresses aging in humans. Also, a negative correlation between kimchi consumption and total free radicals ($r=-0.1862$) was established, while a positive correlation was established with GSH/GSSG ($r=0.1861$). Generally, in the human body, blood lipid concentration, TBARS, and free radical concentration increase with aging, and there is also a reduction in the antioxidation system GSH/GSSG, which acts to protect against aging, such that tissue damage due to oxidation cannot be suppressed, and this results in the progression of aging. In this study, there was little effect of kimchi consumption in 20–29 year olds, but in the elderly who consumed more than the average amount of kimchi, free radical production was suppressed, and the antioxidant system that responds to free radicals was enhanced (Kim et al., 2002a, b). As a result, we can expect that tissue damage due to oxidation would be inhibited and ultimately, kimchi consumption would suppress aging in the human body. The treatment of kimchi, especially optimally ripened kimchi (pH 4.1) attenuated cellular oxidative stress through increase in cell viability and inhibition of lipid peroxidation. In addition, the lifespan of young-, middle-, and old-aged WI-38 cell was extended, suggesting promising role of kimchi as an anti-aging agent. Kimchi during fermentation downregulated the age-related inflammatory gene expressions, NF-κB, COX-2, and iNOS. The present results indicate that anti-aging effect of kimchi against oxidative stress is related to extension of lifespan in HDFs as well as downregulations of mRNA and protein expressions of COX-2 and iNOS through NF-κB regulation. Therefore, this study suggests that kimchi, especially fermented kimchi, is a promising anti-aging functional food with protective activities against aging induced oxidative stress induced premature senescence (Kim et al., 2011).

OTHER HEALTH PROMOTING EFFECTS

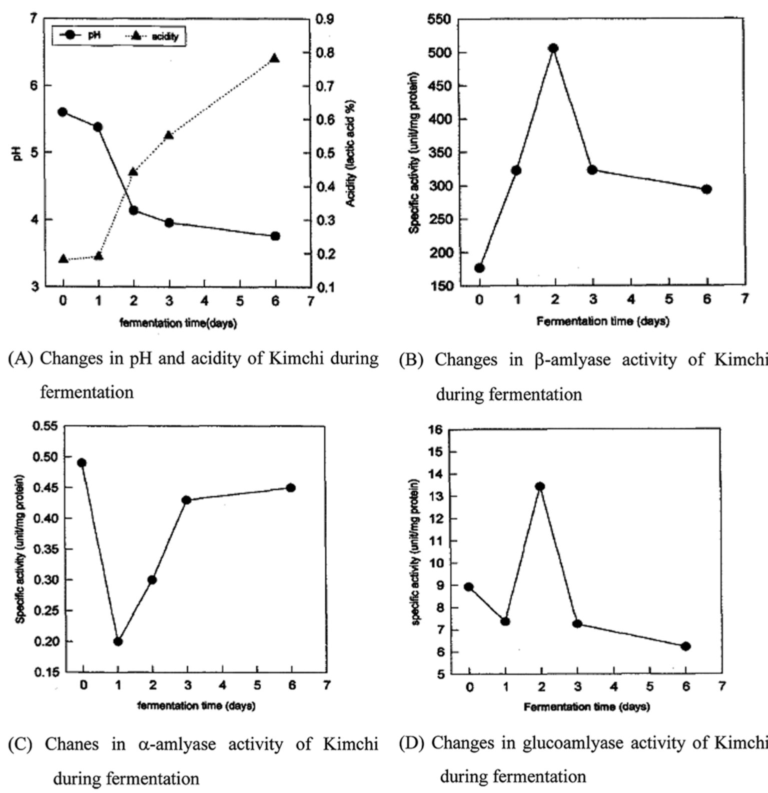
Digestion Promoting Effects

Several investigators have observed that a high fiber diet causes a great fecal excretion and alter in vitro or in vivo digestibility of food proteins (Pantack et al., 1976). Reduction of in vitro digestibility by Godulbaegi was greater than that by fermented kimchi, but there was no a stepwise reduction in digestibility by the increased plant-to-protein weiht ratio. This indicates that the fiber constituents in raw Godulbaegi were more active in interfering with protein sources when compared to fermented plants (kimchi) (Hwang et al., 1995). The amlyolytic enzymes (α-amlyase, β-amlyase, glucoamlyase) and protease of kimchi showed the highest activity at the 2nd day of fermentation at 20°C (Hahn et al., 2002, Figure 6).

Diabetes Alleviation Effects

Consumption of both fresh (1-day-old) and fermented (10-day-old) kimchi significantly decreased body weight, body mass index, and waist circumference. Fermented kimchi had additional effects on blood pressure and insulin resistance/sensitivity. The percentage of participants who showed improvement in

Figure 6. Changes in pH, acicity, β-amlyase, α-amlyase and glucoamlyase activity of Kimchi during fermentation
Source: (Hahn YS et al., 2002).



(A) Changes in pH and acidity of Kimchi during fermentation

(B) Changes in β-amlyase activity of Kimchi during fermentation

(C) Chanes in α-amlyase activity of Kimchi during fermentation

(D) Changes in glucoamlyase activity of Kimchi during fermentation glucose tolerance was high in the fermented kimchi group (An et al., 2013). Dietary Baechu kimchi has some antidiabetic effects even when fed with a high fat containing diet. Lower fasting blood glucose and better glucose tolerance were observed in the kimchi high (2.0% of freeze-dried Korean traditional Baechu kimchi) groups compared to the diabetic control groups and kimchi low (0.5% of freeze-dried Korean traditional Baechu kimchi) (Islam et al., 2009).

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Chapter 19
Functional Foods of the Indian Subcontinent

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ABSTRACT

The medicinal effects of food have been recognized on the Indian subcontinent since many centuries. The current thinking on functional foods can easily be applied to many traditional Indian subcontinent foods as these are based on whole grains, legumes, oilseeds, nuts, vegetables, fruits, spices, condiments, and many fermented milk products. Consumption of such foods on a regular basis not only provides most of nutrients in adequate quantities but also improve gastrointestinal health, boost immune functions, improve bone health, lower cholesterol, oxidative stress, reduce the risk of cardiovascular diseases, various types of cancers, neurodegenerative diseases, ill-effects of obesity, and metabolic syndrome. Various chemical and biological components present in Indian subcontinent traditional foods, such as phytochemicals, dietary fiber, oligosaccharides, lignins, omega-3 fatty acids, phenolics, flavonoids, carotenoids, and probiotic bacteria play an important role in improving the health of consumers of these foods. The history of Indian traditional foods has been adequately reviewed by Srinivasan (2011). The traditional food habits of each specific area of the Indian subcontinent have been influenced by the culture and the availability of locally grown food materials. Some of the important functional foods of India subcontinent will be briefly discussed in this chapter.

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FUNCTIONAL FOODS FROM VARIOUS COMMODITIES

Under this section, functional foods based on cereals, legumes, milk and milk products, oilseeds, herbs and condiments, fruits, vegetables, nuts and some miscellaneous commodities will be briefly discussed.

Cereals

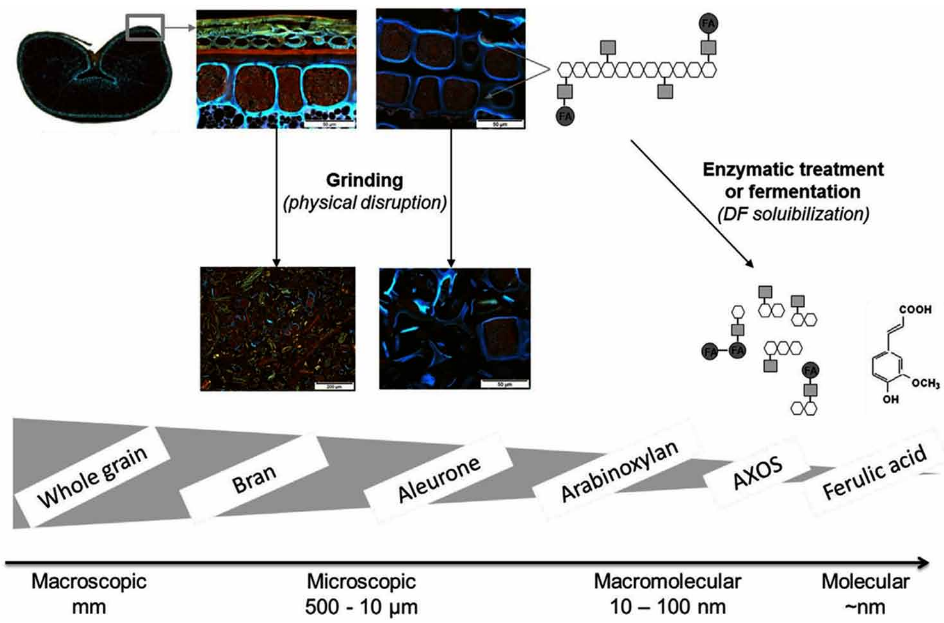
The food industry is focused on producing functional foods based on various cereals due to consumer demands for healthier foods. Some of the major cereals such as wheat, barley, and oats being rich in many phytochemicals and other nutrients, thus offer an excellent opportunity for the production of functional foods (Sidhu et al. 1989; Seibel et al. 1990; Singh et al. 1993; Sidhu, 1995). Whole grain wheat is rich in dietary fiber which has association with cardiovascular diseases, type-2 diabetes, bowl function and colon cancer; vitamins and provitamins such as vitamin E, B-group vitamins, carotenoids; minerals like magnesium and selenium; other bio-actives, such as, polyphenols, phenolic acids, ferulic acid, alkylresorcinols, flavonoids, phytosterols, lignins (Dalton et al. 2012; Zhu et al. 2015; Lu et al. 2015a). Bran, aleurone and germ are the components of whole grains that are rich in above mentioned nutritional compounds (Table 1 and Figure 1) providing high health benefits (Chhabra & Sidhu 1988; Bajaj et al. 1991; Sidhu et al. 1999; Al-Hooti et al. 2000; Al-Saqer et al. 2000; Sidhu et al. 2001; Al-Hooti et al. 2001; Adom et al. 2005; Chen et al. 2015; Rosa-Sibakov et al. 2015; Levent et al. 2015). With reduction in particle size of bran as well as during fermentation of wheat dough, a significant increase in extraction of anthocyanins, carotenoids and antioxidant properties has been reported (Chhabra & Sidhu 1988; Brewer et al. 2014; Pekkinen et al. 2014; Savolainen et al. 2015).

Table 1. Principal components and phytochemicals (g/100g) in wheat grain fractions

Constituents	Whole Grain	Bran	Aleurone
Arabinoxylan	6.5	22-30	24.3
β-glucans	0.7	2.2-2.6	3.9
Lignin	1.9	5.6	-
Cellulose	2.1	6.5-9.9	3.0
Ferulic acid monomer	0.02-0.21	0.5-0.7	0.66-.82
Ferulic acid dimer	0.01	0.8-1.0	0.03-0.1
Sinapic acid	0.06	0.02	0.03
***p*-Coumaric acid**	0.00	0.01	0.02
Flavonoids (in μg)	37	28	8
Lignans (in μg)	0.2-0.7	5	7
Phytic acid	0.90	4.20	15-20
Minerals	1.1	3.4	12.0
Alkylresorcinols	0.07	0.27	0.17
Betaine	0.02	0.87	1.50

Adapted from: Rosa-Sibakov et al. (2015)

Figure 1. Nutritionally important technological fractions of wheat grain
Source: Rosa-Sibakov et al. (2015)



Genotype, growing environment and their interaction have been shown to significantly affect the selected health components and antioxidant properties of soft wheat bran (Lu et al. 2015b). Sprouting of different grains (durum, spelt, einkorn, emmer and soft wheat) into wheatgrass produced increased amounts of phytochemicals and other high value nutrients, which might potentially be valuable for the development of functional foods (Zilic et al. 2014; Benincasa et al. 2015). Cereal grains are also known to be an important source of fructans, a kind of carbohydrate that has health promoting potential not only as a dietary fiber source but also serves as a prebiotic (Verspreet et al. 2015). Dietary fiber is one of the major phytochemicals present in cereals and is of two categories according to their water solubility. Water-soluble fraction (soluble fiber) is mainly of nonstarchy polysaccharides such as β-glucans and pentosans. This fraction is known to decrease serum cholesterol, postprandial blood glucose, and insulin levels in humans (Edge et al. 2005). Water-insoluble fraction (insoluble fiber) consists of lignin, cellulose, hemicelluloses and prevents constipation. The average values for the total dietary fiber in barley, wheat and oats have been reported to be 10, 12 and 14% (dry basis), respectively (Charalampopoulos et al. 2002).

Because of their phytochemicals and nutritional potential, there has been a considerable increase in interest in the utilization of sorghum, millets and pseudo-cereals for developing gluten-free food products. Enhanced nutritional traits such as higher amylopectin, higher lysine, improved protein digestibility and utilization, higher provitamin A, higher iron and zinc contents, and improved mineral bioavailability thru phytate reduction, are being explored using traditional breeding and recombinant DNA technology (Taylor et al. 2014). Anthocyanins and other phytochemicals in purple wheat have been measured using HPLC techniques by Hosseinian et al (2008). In addition to anthocyanins, they also reported the presence of a lignin (secoisolariciresinol diglucoside) and melatonin, which may contribute to the health benefits associated with the consumption of purple wheat or other colored cereal grains.

Resistant starch (not digested by salivary amylases) has been shown to provide benefits for the production of short-chain fatty acids (SCFA) in the large intestine. This resistant starch in the large intestine can serve as prebiotics for growth of probiotic bacteria which are known to decrease the risk of bowel diseases (Yue & Waring 1998). Phytic acid, a natural plant antioxidant present in wheat bran in relatively high amounts (4.8%) has been shown to suppress iron-catalyzed oxidative reactions. The bran layers of cereal grains are relatively rich in antioxidants. The antioxidants present in bran layers are either water- or fat-soluble and nearly one half are insoluble. Soluble antioxidants in oats include phenolic acids, flavonoids, tocopherols, tocotrienols, and avenanthramides (Slavin, 2004). Ferulic acid present in bran may provide health benefits because of its antioxidant properties (Thompson 1994). In addition, ferulic acid has been shown to have nitrite scavenging effect as efficient as that of ascorbic acid under acidic conditions (Moller et al. 1998). Wheat, barley and oats are also known to contain many other bioactive compounds, namely, lignans, phytosterols, isoflavones, resorcyclic acid lactones, coumestans, unsaturated fatty acids, lutein, cryptoxanthin, zeaxanthin, tocopherols, tocotrienols, glutathione, melatonin. These compounds may affect gastrointestinal physiology and provide protection against chronic diseases like coronary heart disease and some cancers (Jacobs et al. 2002; Zielinski 2002; Slavin 2003; Zhou et al. 2004). The phytochemicals present in cereal grains have also been extensively reviewed by Sidhu et al (2007).

Legumes (Pulses)

Legumes have been staple food and are important source of proteins, several vitamins, minerals, dietary fiber and many phytochemicals throughout the history of mankind. In addition to their low fat and higher dietary fiber contents, pulses are important sources of many potentially useful bioactive compounds, such as enzyme inhibitors, lectins, phytates, oxalates, polyphenolics, saponins and phytosterols (Dilis & Trihopoulou 2009; Marathe et al. 2011; Faris et al. 2013; Nasir & Sidhu, 2013; Vila-Donat et al. 2015). As the awareness of the potential of legumes consumption to reduce many chronic diseases has increased during the last decade, it is expected that legume consumption will increase tremendously. The consumption of dry beans having low glycemic index is known to improve the glycemic control in case of hyperglycemic patients, lowers blood cholesterol, and reduces body fat (Anderson et al 2004; Bazzano et al 2011a, b; Tucker & Thomas, 2009). Dry beans are natural sources of both the soluble and insoluble dietary fiber and produces lower glycemic response compared to carbohydrates from food sources (Livesey et al. 2008). Low GI legume consumption also reduces all the metabolic syndrome risks associated with obesity such as high blood pressure, insulin resistance, and hypertriglyceridemia.

The only one study that specifically examined the relationship between one serving of bean consumption and the risk of CVD found 38% lower risk of myocardial infarction compared with individuals who rarely consumed beans (Kabagambe et al. 2005). Compared with a calorie-restricted legume-free diet, the obese subjects when fed a calorie-restricted legume-based diet consisting of beans, chickpeas, lentils or peas, lost more weight and had a significant reduction in plasma C-reactive protein (Hermsdorff et al. 2011). The nutritional quality of legumes and their potential contribution in cardiometabolic risk prevention has recently been reviewed by Bouchenak & Lamri-Senhadji, 2013). The health potential of pulses and the bioactivity of their isoflavones, phytosterols, resistant starch, bioactive carbohydrates, alkaloids and saponins, as well as the effect of processing and cooking on these potentially beneficial bioactive compounds has been discussed by Rochfort and Panozzo (2007).

Black soybean is reported to have the highest saponin and phytic acid contents, peroxyl radical scavenging capacity and the strongest cellular antioxidant activity, thus can serve as an excellent dietary source of natural antioxidants for health promotion and cancer prevention (Xu & Chang 2012). Sprouting of various pulses has been shown to enhance the folate, vitamin C, total phenolics and total antioxidant activities and these values varied among various cultivars (Shohag et al. 2012). According to their results, folate content was the highest in soybean (815.2 μg/100g, fresh wt.) and mung bean (675.4 μg/100g, fresh wt.) on 4th day of germination. The vitamin C (not detected in raw seeds) increased rapidly in sprouts of soybean and mung bean on the 4th day of germination (29 and 27.7 mg/100g fresh wt., respectively). Total phenolics and total antioxidant capacity were also the highest on the 4th day of germination thus providing maximum health-promoting properties by these pulses.

Oilseeds

Oilseeds are extremely popular edible grains that are often added to cereal flours to enhance their nutritional and sensory qualities. Soybean (Glycine max) is one of the most widely cultivated oilseeds in the world, because of its higher protein (40-50%) and oil (20-30%) contents. Various bioactive components, such as, isoflavones, saponins, phytic acid, phytosterols, trypsin inhibitors, peptides, and stilbenoids, present in oilseeds have become the subject of extensive scientific research, especially due to their functionality in disease prevention and treatment (Isanga and Zhang, 2008; Kisbenedek et al. 2014). Soy foods have been suggested to provide protection against breast, intestine, bladder, liver, prostate, skin and stomach cancer. Consumption of soybean based products is also known to reduce the risk of osteoporosis, lowers LDL cholesterol, increases HDL cholesterol, helps in chronic renal disease, lowers the risk of coronary heart disease, and shows antiatherosclerotic activity (Messina et al. 1994; Ranich et al. 2001). A number of studies have been reported on the beneficial effect of fermentation of soy products. In fermented soy products (soy milk, soy sauce, soy meal), the enhanced amounts of bioactive components and their antioxidant capacities confers health-promoting effects (Duenas et al. 2012; Ma & Huang 2014; Xu et al. 2015; Silva & Perrone, 2015).

Peanuts are grown in a number of countries and it makes a multibillion US$ industry in the world. The dibble part of peanuts is the kernel and the protective skin. The skin has pinkish-red color and astringent taste, because of which it is usually discarded. Peanuts are known to be rich in proteins, trans-fatty acids-free lipids, monounsaturated fatty acids, vitamin E, folate, potassium, magnesium, zinc, dietary fiber and many health-promoting phytochemicals (resveratrol, flavonoids, isoflavones, flavonols, phenolic acids, phytosterols). Peanut skins, a byproduct of processing, have been reported to be a good source of antioxidant phenolics, such as phenolic acids, flavonoids, and stilbene (Yu et al. 2005; Isanga & Zhang 2007; Chukwumah et al. 2007; Ressureccion et al. 2009; Camargo et al. 2012).

Sunflower is another oilseed crop where health-promoting phenolic compounds are present in abundance. These phenolics get bound to the sunflower proteins during oil extraction, thus their antioxidant properties are preserved in the meals (Salgado et al. 2012). Safflower (*Carthamus tinctorius* L.) is another oilseed that has also been reported to be valuable source of bioactive compounds that can impart functional food and natural antioxidant properties (Yu et al. 2013). Members of the Brassica family (e.g., mustard, Brussels sprouts, broccoli, cabbage, cauliflower, kale, chard) are known as dietary sources of glucosinolates, which are a large group of organic compounds containing sulfur and nitrogen. Glucosinolates and their breakdown products during chopping/cooking/processing are largely responsible for their bitter/astringent taste and characteristic aroma that limits the consumer acceptability of these vegetables. The seeds as well as leaves of the Brassica family are reported to be a good source of many bioactive compounds that have antioxidant, chemoprotective and anti-carcinogenic properties (Bala et al. 2012; Ghawi et al. 2014).

Bioactive Compounds From Milk and Milk Products

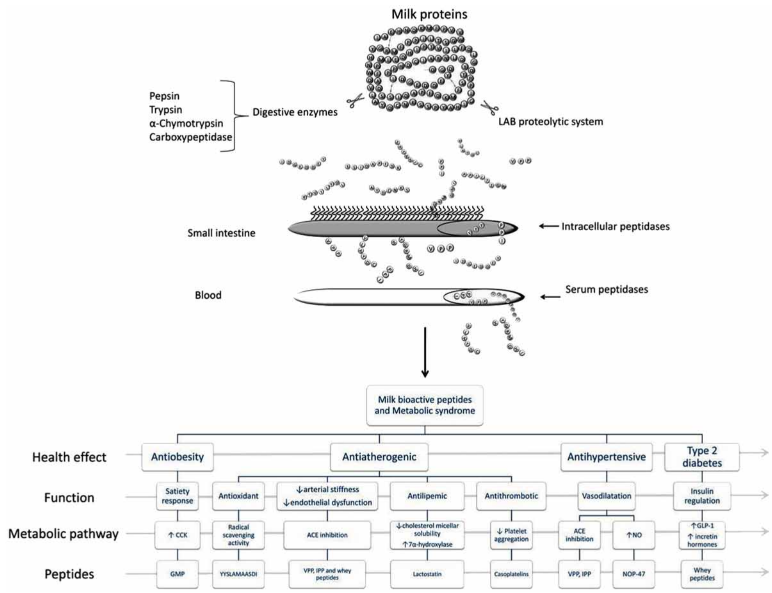
Milk is one of the nature's best gifts for feeding the off-springs after birth. Milk proteins have attracted extensive interest from the food scientists and nutritionists because of the various bioactive peptides generated during their digestion. Both human milk and infant formulae based on bovine's milk have been found to be the potential sources of bioactive peptides which have multiple health-promoting properties (Raikos & Dassios 2014). Some of the natural bioactive compounds, such as, β-lactoglobulin, α-lactalbumin, immunoglobulins, cytokines, lactoferrin, sphingolipids, conjugated linoleic acid, phospholipids, lactoperoxidase system and lysozyme in milk have been identified (Kavaz & Bakirci 2009). The bioactive peptides produced from both casein and whey proteins during enzymic digestion or microbial fermentation have been presented in Figure 2 (Ricci-Cabello et al. 2012). Depending upon the number and/or sequence of amino acids in the food-derived bioactive peptides, diverse activities, such as, enhancement of mineral bioavailability, opoid activity, boosting of immune system, anticancinogenic activity, and antihypertensive activity have been exhibited (Mills et al. 2011; Koliwer-Brandl et al. 2011; Mallik et al. 2013; Tan et al. 2014; Wada & Lonnerdal 2014; Nongonierma & Fitzgerald 2015a; Irshad et al. 2015). Using whey proteins (a by-product of cheese industry), Brandelli et al (2015) have produced bioactive peptides having all the above mentioned health-promoting properties.

Tryptophan is one of the essential amino acid present in milk proteins that serves as a precursor for certain biomolecules important for human health. Some of these are: serotonin, melatonin, tryptamine, niacin, adenine dinucleotide (NAD), phosphorylated NAD (NADP), quinolinic acid and kynureric acid. Free tryptophan is also shown to have some effect on cognition and hypotensive properties, however, higher bioactive potency has been observed with specific tryptophan-containing peptides than the free tryptophan (Nongonierma & FitzGerald 2015b). Cow milk has also been reported to contain bioactive secondary phenolic compounds which are formed by gut bacterial flora from plant phenolic compounds (Tsen et al. 2014). Equol and total phenolic compounds correlated positively with the milk lipid concentrations, and these were distributed to a large extent in the lipid fraction than in the aqueous fraction of cow milk. Evidently, skim milk will be of lower overall nutritive value and functional properties than the full cream milk.

Goat milk lactoferrin is a good candidate for use in infant foods because of its high homology with its human counterpart (Parc et al. 2014). Their results showed that among the N-glycans, 37% were sialylated and 34% were fucosylated. They demonstrated the existence of similar glycans in human and goat milk and also identified some novel glycan in goat milk which were never found in human milk. Goat milk is a good source of antioxidant bioactive compounds (including lactoferrin) and can be used in food products beneficial to human nutrition (Ahmad et al. 2015). Kiss et al (2014) have developed suitable packaging materials for sheep and goat milk yogurt which preserved the bioactive compounds throughout the 35 days of storage without any significant loss in nutritional value.

The composition of bioactive compounds in fermented dairy products depends on their content in raw milk and the processing conditions employed for the production of such products. Cais- Sokolinska et al (2015) have produced kefir from goat milk after feeding these animals with flax cake in their diet. Milk and kefir produced from these goats contained higher amounts of bioactive compounds (PUFA including

Figure 2. Release of bioactive peptides from milk proteins by lactic acid bacteria
Source: Ricci-Cabello et al. (2012)



CLA, omega-3 fatty acids). Higher amounts of bioactive lipids (MUFA, PUFA) in milk have also been reported from cows fed with flax seed and fresh forage (Guerra et al. 2015). The daily intake of yogurt enriched with bioactive components has been suggested to manage the stress in a double-blinded randomized controlled trial (Jaatinen et al. 2014). Garcia-Tejedor et al (2015) have used casein and the yeast, *Debaryomyces hansenii*, to produce bioactive peptides having antihypertensive properties. Colostrum is known to be a rich source of high quality proteins, minerals, vitamins and bioactive compounds (e.g., immunoglobulins, lactoferrin, etc.) which exert positive health effects on human health. Hyrslova et al (2014) have produced yogurt from colostrum without influencing sensory quality of the final product.

Herbs and Condiments

On the Indian subcontinent, spices are integral part of any cooking and these spices are used mainly to enhance the flavor of a dish. The most common spices used are turmeric, chilli pepper, cumin, coriander, fenugreek, garlic, ginger, onion, mustard seeds, saffron, cinnamon, cloves, cardamom and asafetida. Some of these spices such as ginger, turmeric, garlic, onions, fenugreek seeds and saffron are known to contain many antioxidant and certain bioactive compounds such as curcumin, alliin, flavonoids, carotenoids and essential oils. Besides contributing flavor, color to the diet, these spices and condiments possess chemical constituents having beneficial physiological health effects. With a long history of use of spices and condiments in Indian subcontinent cooking dating back to 5000 years BC, these spices as functional foods have significantly contributed to the human health by supplying many health-promoting bioactive compounds in the diet.

Historically, ginger has been used in treating various ailments such as alleviating symptoms of nausea, vomiting, reduction of inflammation and pain, and is also known for its antioxidant, antimicrobial activities, and its possible beneficial effects against CVD due to its action against inflammation, platelet aggregation and hypertension (Singletary 2010: Gundala et al. 2014). The anticancer activities of ginger extract (GE) due to its phytochemicals, 6-gingerol, 8-gingerol, 10-gingerol and 6-shogaol and their effect on cytochrome P450 enzyme activity have been investigated by Mukkavilli et al (2014).Ginger has also been shown to protect live again the toxic effects of xenobiotic compounds and inhibits prostate cancer cell proliferation (Haniadka et al. 2013: Brahmbhatt et al. 2013).

Onion (*Allium cepa*) is a vegetable widely sued all over the world not only for its culinary properties but also for its medicinal values. The flavonoids present in onions have been reported to have a range of health benefits such as anticancer properties, antiplatelet activity, antithrombotic activity, antiasthmatic and anti-microbial activity (Jan et al. 2010; Joung & Jung 2014; Suleria et al. 2015; Lee et al. 2015: Sidhu et al. 2015). Onion extract has been shown to ameliorate high blood sugar and cholesterol in women with gestational diabetes (Anon 2015). Storage of fresh-cut onions at $0^{o}C$ has been shown to preserve phenolics, anthocyanin and quercetin contents (Berno et al. 2014).

Garlic (*Allium sativum*) has long been used both for culinary as well as medicinal purposes in Asian countries. Preliminary investigations have suggested various health benefits of garlic consumption such as lowered risk of esophageal, stomach and prostate cancers, lowering of blood cholesterol, antiplatelet aggregation properties, antimicrobial, antioxidant, immune boosting, antidiabetic, hepatoprotective, antifibrinolytic, and its potential role in preventing cardiovascular diseases (Santhosha et al. 2013; Akan 2014; Trio et al. 2014; Matysiak et al. 2015; Seham et al. 2015; Suru & Ugwu 2015).

Turmeric (Curcuma longa) is a spice used extensively as one of the important components of curry powder in Asia for centuries. It is used as a natural coloring agent in culinary preparations has found many applications in functional foods (Pathak et al. 2015; Siruguri and Bhat 2015). The major chemical constituents of turmeric, curcumin, demethoxycurcumin, and bisdemethoxycurcumin) are commonly known as curcuminoids. Many benefits of turmeric, such as, anticarcinogenic, hepatoprotective, thrombo-suppressive, cardioprotective, antiarthritic, antimicrobial, antioxidative, lowering of plasma triglycerides (TG), lowering of plasma β-amyloid, protective against neurodegenerative diseases, improvement in life span, have been reported (Vankar 2008; Singletary 2010; DiSilvestro et al. 2012;Monray et al. 2013). However, some of the limitations of curcumin are its poor solubility, low absorption from the GI tract, rapid metabolism and rapid systemic elimination from the body. Use of hydrophilic carrier, cellulosic derivatives and natural antioxidants has been reported to significantly increase the absorption from the gut into the blood (Jager et al. 2015).

Fenugreek (*Trigonella foenum-graecum*) seeds have been used as a condiment in Asia for thousands of years in the culinary preparations as well as for medicinal uses. Fenugreek seeds are rich in many bioactive compounds, such as, flavonoids, isoflavones, saponins, oil, proteins insoluble and soluble dietary fiber. Fenugreek seeds have been shown to provide many health benefits, including, hypolipaemic activity, lowering of TG, LDL, amelioration of abnormalities in lipid homeostasis (Ramulu & Udayasekhararao 2006; Losso et al. 2010; Vijay Kumar et al. 2010).

Since ancient times, saffron (*Crocus sativus* L.) is being used as a flavoring and coloring agent in many culinary preparations, but the chemical, biological, nutritional value and health benefits of the world's most expensive spice have been reviewed in detail by Melnyk et al (2010). Saffron obtained from the stigmas and styles of the blue-purple saffron flower. Due to the presence of proteins, vitamins, minerals, carbohydrates, carotenoids and phytochemicals has been found to provide health-promoting properties as an antioxidant, antitumor, memory enhancer, antidepressant, anxiolytic, aphrodisiac, but has no toxicity. One of the carotenoid present in saffron, a highly water-soluble crocin (mono and diglycosyl esters of a polyene dicarboxylic acid, called crocetin) is the main constituent responsible for its color (Alavizadeh & Hosseinzadeh, 2014; Rahaiee et al. 2015).

Black cumin (*Nigella sativa* L.) is a spice used in the preparation of pickles. Nigella oil has been shown to rich in many bioactive phytochemicals such as essential oils, showing antifungal, antibacterial and antioxidant potentials. This oil had shown complete inhibition zones against Gram-negative and Gram-positive bacteria and some fungi too. The antioxidant potential of nigella oil was even superior to that of synthetic antioxidants (Ramadan, 2015).

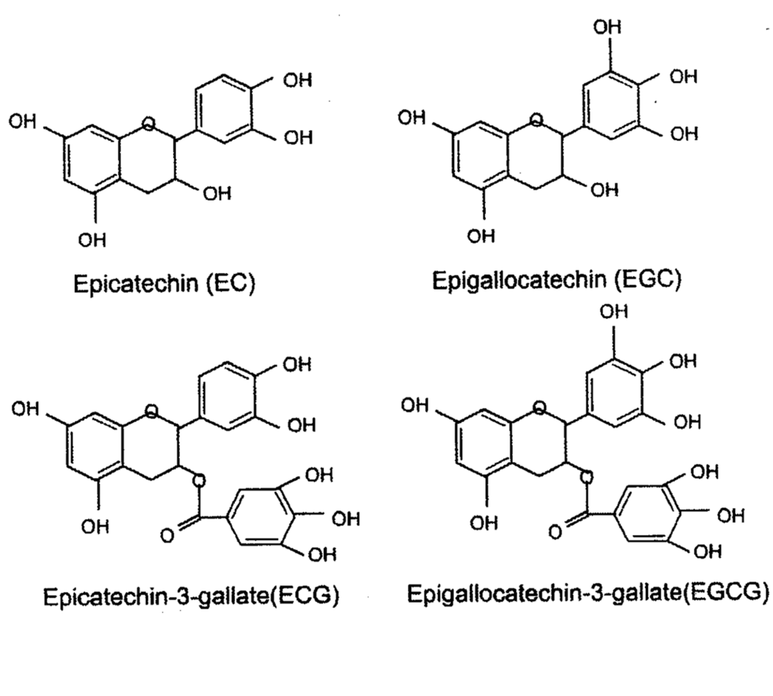
Green tea (*Camellia sinensis*) is an ancient beverage popular in China but now is gaining interest in Western countries mainly because of its antioxidant properties. Green tea is known to be the richest source of many bioactive polyphenolic compounds, mainly catechins (Figure 3), which may be responsible for the proposed health benefits of providing protection against CVD (Murray et al. 2015). The research data were found to be insufficient to grant a health claim to the green tea for the protection against CVD.

Fruits

Ber (Zizyphus) Fruit

Ber or jujube (*Zizyphus)* is a tropical and subtropical fruit, which grows on a spiny shrub or tree. It belongs to the genus *Zizyphus* of the family Rhamnaceae. Its tree or shrub reaches to the height of 10-40 feet. *Ber* is among the ancient fruits originated in the Indo-Malaysian region of South and South Asia. Archaeological remains indicate that 7000 years ago, along with date fruits, *ber* was the main food for people in some parts of Pakistan (Ahmed, 2014), while Chinese jujube is known to be domesticated 4000 years ago (Liu, 2006). The two major dominated jujubes are however, *Zizyphus mauritiana* Lamk

Figure 3. Chemical structure of the major phenolic compounds in green tea
Source: Murray et al. (2015)



(Indian jujube) and *Zizyphus jujube* Mill (Chinese jujube). Although *ber* is extensively grown in India and Pakistan, it is underutilized and commercialized compared to the Chinese jujube. Chinese jujube and Indian jujube both grow in different climate such as Chinese jujube needs a temperate climate whereas Indian jujube grows in hot arid regions.

Ber fruit comes in various shapes and sizes from oval to round about 1-2.5 inch long. When fresh, its flesh is white and its skin greenish yellow that changes to red to dark maroon on ripening. The fruit is slightly juicy with sour sweet flavor and aroma. Most commonly, it is consumed raw in India and Pakistan and some as pickled and in dried form as a whole *ber* or powdered and added to other foods such as in beverages. On the other hand Chinese jujube is a highly profitable fruit with annual production of 1.4 million tons in 2001, which is 90% of the world jujube production. It is consumed mostly in fresh and dried forms and is used as an additive and flavorant to other foods. It has been used as a crude drug in traditional Chinese medicines palliative, analeptic and antibechic purposes for thousands of years. Chinese jujube has been studied more than any anyone else and therefore, the demand for it has increased in the last 10 years not only as a food but for pharmaceutical applications as well (Li et al., 2007).

Nutritional Characteristics

Ber is highly nutritious with abundant amount of vitamin C and a fair amount of vitamins A and B-complex. It also contains a fair amount of minerals such as iron, zinc, phosphorus and calcium. The proximate composition varies with the variety (Table 2). Ascorbic content ranges around 65-76 mg/100g whereas citric acid is 0.2-1.1 mg/100g. Other organic acids are malic and malonic acids. Pareek (2013) in their review of Jujube Fruit expressed that consumption one *ber* fruit a day fulfils the daily requirement for vitamin C of an adult as per WHO recommendations. It is known to have high vitamin P (bioflavonoid). Simple sugar content of *B*er is 22 g/100g while fiber content is 1.3 g/100g. The major simple sugars are glucose, fructose and galactose (Muchuweti et al., 2005).

Antioxidant Compounds

Antioxidants are organic compounds found in various foods that scavenge free radicals being constantly produced in the body due to oxidative stress and as a result of metabolic activities. Besides vitamins such as vitamins C, E and A, which are natural antioxidants in vegetable sources of our diet, phenolic compounds are also powerful antioxidants found in various fruits and vegetables. Increased oxidative stress in the body can cause chronic and degenerative disorders including type-2 diabetes, cardiovascular diseases and cancers (John & Shahidi, 2010). Adding a generous amount of fruits and vegetables that are a good source of antioxidants and polyphenols are recommended by health professionals.

Ber fruit is loaded with these antioxidants including vitamin C, tocopherol, vitamin A and β-carotenes as well as many phenolic compounds. The phenolic compounds found in *ber* fruit in abundance include, p-hydroxybenzoic, caffeic, ferulic and p-coumaric acids with concentrations of about 366, 31, 20 and 19 mg/kg (d. b.), respectively, whereas the least abundant is vanillic acid with a concentration of about 2.5 mg/kg (Pareek et al). Antioxidant activity and phenolic content of 12 Indian commercial cultivars of *Zizyphus mauritiana* Lamk are given in Table 3 showing a range of total phenolics from 172 to 329 mg GAE /100g, total flavonoids from 8 to 22 mg CAE/100g and ascorbic acid from 20 to 99 mg/100g (Koley et al. 2011). The antioxidant properties of *ber* (Z. mauritiana) fruit have been reported to decrease during irradiation but a dosage of 0.25 to 0.5 kGy was better to retain the natural antioxidants in fruit (Kavitha et al. 2015).

Table 2. Nutrient composition of fresh Jujube fruit (units/100g)

Analysis	Nutrient (units)	Content
Proximate composition	Water (g)	77.86
	Energy (kcal)	79
	Protein (g)	1.20
	Total Lipid (g)	0.20
	Carbohydrate (g)	20.23
Minerals	Calcium, Ca (mg)	21
	Iron, Fe (mg)	0.48
	Magnesium, Mg (mg)	10
	Phosphorus, P (mg)	23
	Potassium, K (mg)	250
	Sodium, Na (mg)	3
	Zinc, Zn (mg)	0.05
Vitamins	Vitamin C (mg)	69.0
	Thiamin (mg)	0.02
	Riboflavin (mg)	0.04
	Niacin (mg)	0.9
	Vitamin B-6 (mg)	0.081
	Vitamin A, RAE (μg_RAE)	2
	Vitamin A (IU)	40

Adapted from USDA National Nutrient Database (2011)

Table 3. Total phenolics, flavonoids and ascorbic acid content of some Zizyphus genotypes

Cultivar	Total Phenolics[1]	Total Flavonoids[2]	Ascorbic Acid[3]
Chuhara	258.06 ± 37.99^{cb}	8.36 ± 1.47^{e}	99.49 ± 1.53^{a}
Mundia	243.13 ± 41.59^{dcb}	12.7 ± 1.11^{edc}	93.88 ± 1.02^{a}
Thornless	237.83 ± 37.09^{dc}	12.38 ± 0.45^{ed}	94.9 ± 2.04^{a}
Jogia	241.26 ± 57.76^{dc}	18.47 ± 3.03^{b}	59.69 ± 0.51^{d}
Gola	252.23 ± 18.29^{dcb}	21.97 ± 2.09^{b}	57.65 ± 4.59^{d}
Kaithali	187.48 ± 34.16^{ed}	13.09 ± 3.93^{edc}	71.94 ± 1.53^{c}
Umran	172.08 ± 31.77^{e}	10.76 ± 0.85^{ed}	19.54 ± 1.85^{f}
Seb	203.23 ± 2.82^{edc}	15.62 ± 1.92^{dc}	21.95 ± 0.5^{f}
ZG-3	328.65 ± 13.98^{a}	14.58 ± 0.59^{dc}	83.16 ± 0.51^{b}
Sonaur-5	309.51 ± 46.73^{ba}	11.47 ± 1.83^{ed}	36.22 ± 0.51^{e}
Rashmi	261.21 ± 43.68^{cb}	14.71 ± 1.85^{dc}	39.29 ± 3.57^{e}
Elaichi	267.28 ± 18.39^{cba}	16.07 ± 2.58^{dc}	71.56 ± 1.15^{c}

Values represent the mean of three replicates. Mean followed by the same superscripts are not significantly different ($p < 0.05$).[1]Total phenolics expressed as mg GAE/100 g.[2]Total flavonoids expressed as mg CAE/100 g. [3]Ascorbic acid expressed as mg/100 g.

Adapted from: Tammay et al. (2011)

Similar variations in the antioxidant activities of five different Chinese jujube fruit were found. The free radical scavenging effect on the diphenyl-1-pycril-hydrazyl (DPPH) radicals reduced in the order of *Z. jujuba* cv.Jinisixiaozao > *Z. jujuba* cv. Yazao > *Z. jujuba* cv. Jianzao > *Z. jujuba* cv. Junzao > *Z. jujuba* cv. Sanbianhong. They also reported that the antioxidative activities in the extracts of these cultivars were stronger than α-tocopherol (Li et al 2005). The nutritional composition and phenolic contents are subjected to changes during growth and maturation of the fruit. For example, the ascorbic acid, sugars, carotenoids and polyphenol content of *ber* are reported to be initially low in the under ripe fruit but increase considerably when the fruit reaches a full physiological maturity (Zozio et al 2015).

Health Benefits of Ber Fruit

Consumption of foods that are high in fiber and antioxidants are promoted for various health benefits. Plant foods such as whole grains, vegetables and fruits including *ber* are known to be rich in natural antioxidants of vitamin origin as well as phenolic compounds. Health related functional characteristics and antioxidant properties of mucilage (dietary fiber) from Indian jujube fruit has been investigated by Sangeethapriya & Siddhuraju (2014) and they suggested the crude mucilage fraction from Indian jujube fruit to have an excellent potential in nutraceutical and functional foods. Although not much scientific research is available on the health benefits of jujube fruit, but have been traditionally used for medicinal purposes in many Asian countries particularly India, Pakistan, Afghanistan, Iran, China, and Taiwan. Li et al (2005) reported its use for the treatment of simple allergies to insomnia, urinary tract infections and liver diseases in China dating back to 4000 years. In Algeria, *Zizyphus lotus* L (Desf.) is used for its medicinal effect for lowering inflammation in the body, for sedation and anti-diabetic purposes. Benammer et al (2010) analyzed the *Zizyphus lotus* L. (Desf.) the fruit pulp, seeds, leaves, stem and roots for vitamins and antioxidant content and assessed the effect of their extracts on human T-cell proliferation. Their results showed higher amount of vitamin A and C in the fruit pulp than the other parts, while the seeds were richer in vitamin C than the leaves, stem and roots. The immunosuppressive effect was exerted by extracts from all parts of the fruit however; the most dominant effect on T-cells proliferation and IL-2 mRNA expression was seen by the seed extract only.

The seeds of the Indian jujube *Zizyphus mauritiana* Lamk were also tested in hyperlipidemic rats and resulted in improved blood glucose and serum lipids levels as well as had an anti-inflammatory effect (Al-Reza et al, 2010). The antiproliferative effect on cancer cells and regulation of immune function is probably due to the presence of phenolic compounds, flavonoids, saponins that affect the protection against free radicals and cell damage against oxidative stress in biological processes (Siddiqui & Patil 2015; Dahiru & Obidoa, 2008; Kamiloglu et al. 2009; Zhang et al. 2010; Bhatia & Mishra 2010).

Jamun (*Syzygium Cumini*) Fruit: The Indian Blackberry

Jamun (*Syzygium cumini* L.) belonging to Myrtaceae family, is a deep purplish blue color berry with pinkish pulp has sweet and astringent flavor. *Jamun* also known as *jamoon* or black plum in English has different names, such as, *Jambul* in Hindi, *Jamalu* in Punjabi and *Kala Jam* in Bengali. It is a summer fruit, which is available abundantly but only for short period of time. The Jamun fruit gradually changes color during ripening, starting from green color. The pigments, chlorophyll and carotenoids decrease while anthocyanins accumulate changing the original color of immature fruit from green to deep purple on full maturity. In the fully mature fruit, the total sugars increase but starch and amino acids decrease significantly (Patel & Ramana Rao 2014). *Jamun* tree is tall reaching up to a height of 30 meters, which is ever green that grows naturally in tropical and subtropical regions of Southeast Asia, such as, India, Pakistan, Bangladesh, Sri Lanka, Nepal, Myanmar, Afghanistan, Malaysia and Indonesia. The tree can live up to 100 years (Kalaivani & Chitra Devi 2013).

Health Benefits of Jamun

Jamun is known to have numerous properties and has been used as an important medicinal plant/fruit in various traditional systems of medicine for centuries. It has been shown to be effective in the treatment of type-2 diabetes, inflammation, diarrhea, and ulcers (Ayyanar et al. 2013). Swami et al (2012) have recently reviewed the food and medicinal uses of Jamun fruit. The fruit is rich in many bioactive compounds, such as, anthocyanins, glucoside, ellagic acid, isoquercetin, kaempferol and myrecetin. The seed is reported to contain alkaloid, jambosine, and glycoside jambolin, which stops diastatic activity of salivary enzyme that converts starch into sugar. The major component of its essential oil, α–pinene has significant anti-Leishmania activity (Rodrigues et al. 2015). *Jamun* fruit is reported to have antidiabetic, antiulcer, hepatoprotective, antiallergic, antiarthritic, anti-inflammatory, antihyperlipidemic, antimicrobial, antiplaque, radioprotective, antifertility, antipyretic, neuropsychopharmacological, nephroprotective, antidiarrhoeal, and antioxidant activities. These health benefits are mainly attributed to various phytochemicals, such as, tannins, steroids, flavonoids, alkaloids, fatty acids, terpenoids, phenolics, vitamins and minerals present in the fruit (Banerjee et al. 2005; Veigas et al. 2008; De Bona et al. 2011; Srivastava & Chandra 2012).

Nutritional Characteristics

The *jamun* fruit is known for its higher content of anthocyanins, plant pigments responsible for its purple color (Aqil et al. 2012). Anthocyanins have been extracted with 2% ethanol and containing 1% acetic acid and purified from *jamun* fruit using ion-exchange resin, and structural stability confirmed by HPLC-MS/MS techniques by a number of workers (Chaudhary & Mukhopadhyay 2013; Jampani et al. 2014). Prakash Maran et al (2014) have optimized the supercritical fluid extraction of anthocyanins and phenolic compounds from *jamun* fruit pulp. A pressure of 162 bar, extraction temperature of 50^{o}C and co-solvent flow rate of 2.0g/min was suggested as optimal conditions of extraction of anthocyanins. Biochemical and histopathological effects of *jamun* juice as a source of natural antioxidants in comparison with BHT as synthetic antioxidant on rat health have been examined by El-Anany & Ali (2014). BHT produced significant changes in the liver and kidney enzymes but *jamun* juice did not cause any adverse effect on these organs.

Antioxidant Profile of Seeds and Leaves

Almost all parts of *jamun* fruit have been reported to be useful for various applications. Leaves of this tree have successfully used for the biosorption of zinc from aqueous solutions (King et al. 2008). The *jamun* seeds have been shown to possess significant anti-inflammatory activity, thus supporting the medicinal value of this plant (Kumar et al. 2008). Other applications, such as cadmium removal from aqueous solutions with *jamun* leaf powder (Srinivasa Rao et al. 2010), wound healing with seed extract (Murti et al. 2012), bio-inspired green synthesis of magnetite (Fe3O4) spherical magnetic nanoparticles using *jamun* seed extract (Venkateshwarlu et al., 2014), methylene blue biosorption from aqueous solutions using *jamun* leaf powder (Talathoti et al., 2014), use of *jamun* seed extract as green corrosion inhibitor in mild steel products under acidic conditions (Singh & Quraishi, 2015), use of malvidin anthocyanin in quorum quenching activity of *jamun* fruit against Klebsiella pneumoniae (Gopu et al., 2015), and use of anti-phytopathogenic activity of essential oils, hydrocarbon fractions and the other novel constituents from jamun to control fungal diseases in plants (Saroj et al., 2015), have also been reported. For antioxidant properties and the health benefits of *amla* fruit, the Indian Gooseberry (*Emblica officinalis* Gaertn or *Phyllanthus emblica* L.), the reader is referred to a chapter on super fruits by (Sidhu & Zafar, 2012).

Miscellaneous Foods

Flaxseed has attracted the attention of health professionals due to the presence of α-linolenic acid, a lignin (secoisolariciresinol diglyceride, SDG), high quality proteins, dietary fiber, phenolics, cyclic peptides, polysaccharides, alkaloids, cyanogenic glycosides, cadmium, and phytoestrogens (Shim et al, 2014; Kajla et al., 2015). Some of the diverse industrial, food and cosmetic products obtained from processing of flaxseed have been reviewed by Shim et al (2015). Flaxseed-enriched cereal-based products, such as, bread, pasta, muffins, cookies, cakes, and bars to highlight suitable processing conditions for producing healthy alternatives have been reviewed by Mercier et al (2014). The consumption of flaxseed lignan, SDG, has been suggested to prevent many diseases like cardiovascular, diabetic, lupus nephritis, bones, kidney, menopause, reproduction, mental stress, immunity, atherosclerosis, hemopoietic, liver necrosis and urinary disorders, because of its anti-inflammatory, antioxidant, antimutagenic, antimicrobial, antiobesity, antihypolipidemic and neuroprotective properties (Imran et al., 2015).

Psyllium husk is known to be an important source of water soluble dietary fiber and has been utilized to produce healthy baked products, such as, bread, buns, muffins, cake, and cookies (Ahluwalia et al., 1995; Sidhu, 2004; Bhise & Kaur, 2015). Psyllium husk has also been utilized for the production of low-fat yogurt with excellent sensory and eating qualities (Sadat-Ladjevardi et al., 2015). Okra (*Abelmoschus esculentus,* M.) is a popular health food due to its high dietary fiber, vitamin C, folate, calcium, potassium and antioxidant contents. Okra is reported to have many bioactive components (e.g., 4'-hydroxy phenethyl trans-ferulate) having anticancer properties (Ying et al., 2014). Another medicinal plant, *Aloe vera* gel has been reported to be a rich source of potent bioactive component with antioxidant (mainly phenolics) and UV absorbing activity (Ray et al., 2013). Meat and fermented meat products have been investigated as a good source of bioactive peptides having antioxidant, antihypertensive, and antimicrobial properties (Stadnik & Keska, 2015). For functional foods based on tree nuts (such as almonds, walnuts, pistachio, cashewnut and pine nuts etc.), the readers are referred to a recent publication by Kabir and Sidhu (2011).

FUTURE RESEARCH NEEDED

Since many centuries, the Asian countries have made use of many plants and animal products as medicinal foods. A number of foods have been mentioned in the folklore medicine literature. With the development of our capabilities in the analysis of food products, the role of various chemical constituents of food products is being suggested with a certain amount scientific basis. Various foods, such as, cereal grains, legumes, oilseeds, milk and milk products, herbs and condiments, exotic fruits and grain products are now being analysed for their phytochemical and other bioactive components. But still, there is a need for more research to determine complete nutritional profile of these food products to substantiate their medical and health claims for curing various human disease conditions. Obviously, more clinical studies involving human subjects are needed to elucidate the antioxidant effects on health parameters of these nutritionally important food products in order to fully appreciate their health benefits for the human population.

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Chapter 20
Functional Properties of Camel Milk

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ABSTRACT

This chapter focuses on the potential health benefits of camel milk including angiotension I-converting enzyme-inhibitory, anti-cancer and antioxidant activities, antidiabetic, antimicrobial and hypoallergenicity effects. The bioactivity of oligosaccharide, conjugated linoleic acid and D-amino acid in camel milk is provided. The proposed mechanisms behind these bioactive components and potential health claims are explained. This chapter also describes camel milk composition, nutritional value, production and population. The current available information in the literature on camel milk is not abundant. More research is needed to give better understanding on functional properties of camel milk.

INTRODUCTION

The primary purpose of food including dairy products is to provide nutrients to fulfil the body's traditional requirements and other functions including cultural and social wellbeing. Although, in the recent decades life style has changed and become more complicated regarding life standard, hygiene, diet, use of antibiotics and other antimicrobial substances, hence a new concept of food need to be introduced. It has long been recognized that some non-traditional foods, for example camel milk, fortified food and beverages that provide particular health benefits and interestingly, in recent decades they have been modified to provide disease-preventive attributes, in addition to their particular functional health benefits. The concept of functional foods has also been developed and their types have been expanded to become one of the popular foods worldwide. The estimated growth rate of functional food in the global market is 15-20% per year, and the industry is claimed to be worth up to US$168 billion of the annual share (Euromonitor, 2010; Hilliam, 2003). However, there is no internationally accepted definition of functional foods exist, because it is a more of a concept rather than a well-defined group of food products (ILSI, 1999). So far, various definitions have been proposed by a number of researchers and/or foundations including International Food Information Council (IFIC) in 2011 as "food thought to provide benefits

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beyond basic nutrition and may play a role in reducing or minimizing the risk of certain diseases and other health conditions". The EU official directives have not given functional foods a firm definition, but the International Life Science Institute (ILSI) Europe in 1999 has proposed a working definition as food can be considered as 'functional' if it is "satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease".

Consumers are now more aware of functional foods than before, in 2013, 46% of consumers strongly agree that certain foods have health benefits beyond basic nutrition (IFIC, 2013). The recent information by IFIC showed that 91% of consumers are aware about the healthfulness of their food and beverages, furthermore, 88% knowledge a lot about food ingredients (IFIC, 2015).

According to the latest statistics of the Food and Agriculture Organization (FAO), the total heads of camels worldwide is estimated to be about 27 million, which mainly live in Africa (82.5%) and Asia (17.5%) (FAOSTAT, 2013). Camels are mainly classified into two species belonging to the genus *Camelus*; Dromedary camels having one- humped (*Camelus dromedarius*) are the dominant species which tend to live in the arid regions, whereas Bactrian camel having two-humped (*Camelus bactrianus*) mainly prefer living in the cooler regions (Al haj & Al Kanhal, 2010).The dairy camels in the world produce about 3 million ton of whole fresh milk per year distributed between Asia (8.7%) and Africa (91.3%), whereas Somalia is the biggest producer worldwide followed by Kenya, Mali, Ethiopia, and Saudi Arabia, respectively (FAOSTAT, 2013). Humans consume only 1.3 million tons per year while remaining amount are fed to calves (FAO, 2008). This is because most of the camel herds are located in the arid and desert regions which are far from the commercial markets. Recently very few camel milk products are available in the urban markets. Nowadays, there is a general need to launch a number of camel milk based functional products to the commercial market due to increasing demand in recent years (Al haj & Al Kanhal, 2010). These products have to be clinically proven and scientifically evident supported (Ghosh, 2009). This chapter focuses on the functional properties of camel milk components as well as proposed mechanism behind each health claim. The compositional and nutritional aspects of camel milk are also highlighted.

BACKGROUND

Camel Milk Composition

Camel milk has an important role in human nutrition in the arid regions; however camel milk is generally described as opaque-white, frothy, sweet and sharp but sometimes salty in taste (Al haj & Al Kanhal, 2010). These variations in taste are due to the type of fodder and unavailability of water (Farah, 1996). Although camel milk shows convergent gross chemical composition compared to other mammalian milks, on the other hand few differences were found in some sub-constituents for example absence of β-Lactoglobulin, high β-casein, and low αs-casein content (Table 1). These differences provide camel milk with some additional functional properties, for example, hypoallergenicity and higher digestibility in the gut of infants (El-Agamy *et al*., 2009; Abou-Soliman, 2005). Nevertheless, references data (Claeys *et al.*, 2014; Al haj & Al Kanhal, 2010; Konuspayeva *et al.*, 2009) have exhibited wide ranges of variation in camel milk composition. Since these variations was due to several factors such as analytical measurement procedures, regional locations, stage of lactation, age, nutrient conditions and breeds

(Khaskheli *et al.*, 2005; Al haj & Al Kanhal, 2010). The mean values of camel milk composition and range of variation are shown in Table 1.

CAMEL MILK BIOACTIVITY

Camel milk is an important nutritional and functional source that consist a complex mixture of high quality proteins, carbohydrates, fats, minerals, and vitamins; which deliver human health with several key bioactive properties (Al haj & Al Kanhal, 2010). Early reports (Abdelgadir *et al.*, 1998; Shalash, 1984) showed that non-fermented or fermented camel milk were used worldwide as a potential treatment for a number of diseases including tuberculosis, dropsy, asthma jaundice and leishmaniasis. Furthermore, children having biliary atresia and postpartum respiratory insufficiency were given camel milk until their liver transplant and lungs developed and function well (Yagil, 1987). These potential health claims were due to a number of bioactive components, which either exist naturally in camel milk (Agrawal *et al.*, 2007; El-Agamy*et al.*, 1992); or encrypted in the primary structure of camel milk constitutes and could be released *in vivo* by gastrointestinal digests or *in vitro* by digestive or microbial proteolytic enzymes (Alhaj *et al*., 2016; Moslehishad *et al.*, 2013; Salami *et al.*, 2011; Alhaj *et al*., 2010; Salami *et al*., 2010; Korhonen & Pihlanto, 2003). Bioactive components are defined by Park (2009) as "compounds either naturally existing in food or ones formed and/or formulated during food processing that may have physiological and biochemical functions when consumed by humans". Bioactive components derived from camel milk were found to be stable even after sterilization process and provide potential health benefits including ACE-inhibitory activity, antimicrobial, anticancer and antioxidant effect (Alhaj *et al*., 2016; Amr *et al.,* 2015; Al-Saleh *et al.,* 2014; Alhaj *et al*., 2011). In contrast, lactoferrin were completely inactivated after pasteurization (Claeys *et al*., 2014). Several studies have shown that bioactive components in camel milk could provide a number of health benefits (Abd El-Salam & El-Shibiny, 2013; Al-Juboori, 2013; Al haj & Al Kanhal, 2010; Shamsia, 2009).

BIOACTIVITY OF CAMEL MILK PROTEINS

Many food proteins including egg, corn, dairy products, wheat gluten, rice, fish and soybean proteins were found to encrypt bioactive peptides in their primary structures (Kitts & Weiler, 2003). Milk and dairy products have developed a high reputation as the most significant home of bioactivities because most of the well-known bioactive peptides are derived from milk proteins (Meisel, 2004). Furthermore, milk proteins, in addition to their high nutritional value, are available in the market in large amounts at moderate cost (Léonil *et al*., 2000). The protein content in bovine milk is 3.3% compared to 3.1% in camel milk which is made up of amino acids. The range of health claims is usually depending of the amino acid sequence of bioactive peptides. It has been reported that most of the milk protein derived bioactive peptides contain up to 23 amino acid residues per molecule (Otte *et al.*, 2007; Korhonen & Pihlanto, 2003). Kitts & Weiler (2003) have defined bioactive peptides as "specific protein fragments that have a positive impact on body functions or conditions and may ultimately influence health". Bioactive peptides in milk could be generated or enriched by adding starter or non-starter cultures due to their metabolic products required for their growth (Alhaj *et al*., 2007). Thence, milk cultured with combination of two or more type of strains exhibited a wider variety of functional components (Kuwabara *et al.*,

Table 1. Mean values, standard deviation (SD), and range of variation of camel milk components

Components	Mean Value (SD)	Range of Variation
Total solids	11.9% (±1.5)	8.64 - 15.06%
Proteins	3.1% (±0.5)	2.15 - 4.90%
Casein/whey ratio	N/A	2.7 – 3.2
Casein (CN)	N/A	1.63-2.76% or 22.1 – 26 g/l*
β- CN	65%	N/A
α_{s1}- CN	21%	N/A
κ- CN	3.47%	N/A
Whey proteins	N/A	0.63 - 0.80% or 5.9 - 8.1 g/l*
β-Lactoglobulin	absent*	absent
α-Lactalbumin	N/A	0.8 - 3.5 g/l*
Lactoferrin	N/A	0.02 - 7.28 g/l*
Lysozyme	N/A	(60 - 1350) x 10^{-6}*
Immunoglobulins (Ig)	N/A	1.5 – 19.6 g/l*
NPN	0.68 g/l*	N/A
Lactose	4.4% (±0.7)	2.40 - 5.80%
Fat	3.5% (±1.0)	1.2 - 6.4%
Cholesterol	34.5 mg / 100g	31.3 – 37.1 mg / 100 ml*
Conjugated linoleic acid (CLA)	0.4%*	N/A
Mineral	0.79% (±0.07)	0.60 - 0.90%
Potassium (K)	155.66 mg / 100 g (±37.88)	58 - 104 mg / 100 ml*
Calcium (Ca)	114.34 mg / 100 g (±13.35)	105 – 157 mg / 100 ml*
Sodium (Na)	58.87 mg / 100 g (±16.22)	36 – 73 mg / 100 ml*
Magnesium (Mg)	10.45 mg / 100 g (±1.78)	8 – 16 mg / 100 ml*
Zinc (Zn)	0.53 mg / 100 g (±0.08)	0.19 – 0.6 mg / 100 ml*
Iron (Fe)	0.29 mg / 100 g (±0.09)	0.7 – 0.37 mg / 100 ml*
Manganese (Mn)	0.05 mg / 100 g (±0.03)	N/A
Vitamin	N/A	N/A
A	N/A	5 - 97μg / 100 ml*
D	N/A	0.3 – 1.6 μg / 100 ml*
E	N/A	21 – 150 μg / 100 ml*
C	N/A	2400 – 18,400 μg / 100 ml*
B1	N/A	10 – 60 μg / 100 ml*
B2	N/A	42 – 168 μg / 100 ml*
B3	N/A	400 – 770 μg / 100 ml*
B5	N/A	88 – 368 μg / 100 ml*
B6	N/A	50 – 55 μg / 100 ml*
B12	0.2 μg / 100 ml*	N/A

Mean values, standard deviation (SD) and range of variation were adapted from Al haj & Al Kanhal, (2010); *adopted from Claeys *et al.* (2014). N/A stands not available.

1995). However, the addition of *Lactobacillus helveticus* or/and *Lactobacillus acidophilus* solely or in combination to camel milk was reported to release ACE-inhibitory peptides (Alhaj, 2012); antioxidant peptides (Al-Saleh *et al.*, 2014); antimicrobial peptides (Alhaj, 2015). Likewise, the ACE-inhibitory, antimicrobial and antioxidant activities of camel whey proteins were found to improve after treatment with proteolytic enzymes such as trypsin, chymotrypsin and pepsin (Salami *et al*., 2011; 2010). The potential health claims and activities of camel milk will be discussed individually in the following sections.

Angiotension Converting Enzyme (Ace) Inhibitory Activity

ACE-inhibitory peptides are one of the most favored bioactive peptides applied in foodstuff formula to provide health benefits (Meisel & Bockelmann, 1999). The inhibition of angiotension converting enzyme using milk bioactive peptides is the most intensive studied mechanism internationally. As one of the major blood pressure regulators, the angiotensin-I-converting enzyme (ACE) was defined by Pan *et al.* (2005) as "an exopeptidase that cleaves dipeptides from the C-terminal ends of various peptide substrates and regulates the activity of several endogenous bioactive peptides" (P. 123). ACE acts on angiotensin-I in renin angiotensin system to hydrolyze the dipeptide; His-Leu from its C-terminal lead to producing a potent vasopressor angiotensin-II (Skeggs *et al.*, 1956). Thus, a small decrease of 5-mm Hg in diastolic blood pressure (DBP) can reduce 15% of the risk of developing cardiovascular diseases (Meisel *et al.*, 2006).

ACE-inhibitory peptides are present in the primary structure of various food proteins sources including milk protein (Meisel *et al.*, 2006; Jang & Lee, 2005; Li *et al.*, 2004). The level of ACE-inhibitory activity was found to essentially depend on the strain and degree of hydrolysis of protein (Alhaj *et al*., 2016), type of proteolytic enzyme and molecular weight (Salami *et al*., 2011). ACE-inhibitory bioactive peptides are produced using individual or combined cultures. The addition of *L. rhamnosus* to camel milk was recently studied and exhibited ACE-I activity (Moslehishad *et al.*, 2013). Furthermore, Quan *et al.* (2008) identified ACE-inhibitory peptides (Ala-Ile-Pro-Pro-Lys-Lys-Asn-Gln-Asp) from Mongolia camel milk proteins using *Lactobacillus helveticus* 130B4. In another study, Alhaj *et al.,* (2012) identified two ACE-inhibitory peptides corresponding to β-casein from water soluble permeates (WSP) of dromedary camel milk using *Lactobacillus acidophilus* solely. The identified ACE- inhibitory peptides were FQEPFPDPVR and VLPFQEPVPDPVRG. Donker *et al*. (2007) pointed out that most effective ACE-inhibitory peptides were originated from β-casein which represents about 65% of the total camel milk caseins (Kappeler *et al*., 2003). Furthermore, Seven ACE-inhibitory peptides were identified from WSP of dromedary camel milk incubated with *Lactobacillus helveticus* solely (Alhaj *et al.*, 2012). Three peptides were released from sequences 1 (LSLSQF, SLSQF, or SQF) KVLPVPQ, three peptides of the sequences 2 (TDLEN, DLEN, or LEN) LHLPLPL, and one peptide of the sequence 3 KVLPVVPQQMVPYPQ. All identified ACE-inhibitory peptides were corresponding to β-casein of *Camelus dromedarius* milk and some contain at least one proline (P) residue at their C-terminal position. The C-terminal sequence of ACE-inhibitory peptides play important role in the binding to the ACE (López-Fandiño *et al.*, 2006). Thus, amino acids having hydrophobic properties such as tryptophan (W), phenylalanine (F), tyrosine (Y) and especially proline (P) are appeared to contribute substantially to inhibitory potency (López-Fandiño *et al.*, 2006; Li *et al.*, 2004).

Antidiabetic Activity

It has been early reported that camel milk has good results for stabilization of juvenile diabetes (Yagil, 1987). Camel milk supplementation can improve the glycemic control and reduce the doses of insulin for type 1 diabetes patients (Khan *et al.*, 2012; Agrawal *et al.*, 2011; Agrawal *et al.*, 2003). In another study, the consumption of camel milk in India has lowered the prevalence of diabetes in the Raica community (Agrawal *et al.*, 2007; Singh *et al.,* 2008). In animal study, the supplementation of camel milk has reduced the level of blood glucose of diabetic albino rats (Baragob, 2015) and alloxan-induced diabetic dogs (Sboui *et al*., 2010) and the effect was depending on the amount of camel milk. The hypo-glycemic activity of camel milk is attributed to the presence of various components including the existence of high concentration of insulin like substances such as half-cystine, in addition to the regulatory and small size immunoglobulins functions of camel milk on β-cell (Breitling, 2002). Moreover, camel milk does not react to acid and form coagulation in human stomach; this could be another reason for hypoglycemic effect in camel milk (Agrawal *et al.*, 2003).

Antimicrobial Activity

Camel milk was reported to contain a various antimicrobial agents including immunoglobulins, lactoperoxidase, lactoferrin, hydrogen peroxide and lysozyme (Al-Juboori *et al*., 2013). The amount of these agents in camel milk is greater than that reported for other mammalian antibacterial proteins (Kappeler *et al*. 1999). Xanthine oxidoreductase (XOR) protein is another antimicrobial compound in camel milk which could play an important antimicrobial defensive role in the neonatal gut (Harrison, 2006). Other antimicrobial compound was also isolated from camel milk but not detected in cow milk such as peptidoglycan recognition protein (PGRP) (Kappeler *et al.*, 1999). Aforementioned components exist naturally in camel milk and have an antimicrobial effect against pathogenic strains including *Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella typhimurium*and *Escherichia coli* (Benkerroum *et al.*, 2004; El-Agamy *et al.*, 1992). Immunoglobulins are another natural protector in camel milk which functions against infections in the gut of newborns. These antimicrobial substances work with different inhibitory mechanisms, for instance, PGRP inactivate pathogenic strains by binding to peptidoglycan structures in the cell wall (Abd El-Salam & El-Shibiny, 2013).While, the inhibitory action of lactoferrin in camel milk against *S. typhimurium* is through binding iron and making it unavailable for its growth (Ochoa & Cleary, 2009). In contrast, the presence of lysozyme in camel milk was reported to prolong the gelation process of yoghurt due to the delay of yoghurt culture growth in camel milk (Jumah *et al*., 2001). It is evident that antimicrobial substances in camel milk lose their complete activity after heat treatment at 100 °C for 30 min (El-Agamy, 2000).

Camel milk encrypts antimicrobial peptides in their primary structure and could be released using digestive or microbial proteolytic enzymes. The activity of these antimicrobial peptides depends on strain, incubation time and peptides molecular weight. Additional factors were also found to enhance the antimicrobial effect including structural activity (Gobbetti *et al.*, 2004). Whereas, the alteration of Asp (D) with Arg (R) and the addition of Lys (K) residues to the *C*-terminus of antimicrobial peptide were found to increase the bactericidal activity to Gram-negative bacteria (Pellegrini *et al*., 2001). Camel milk inoculated with two added combined culture (*Lactobacillus acidophilus* and *Streptococcus thermophilus* or *Lactobacillus helveticus* and *Streptococcus thermophilus*) was found to exhibit varying degree of inhibition against *B. cereus*, *S. typhimurium* and *S. aureus* (Alhaj *et al.,* 2016). This effect was mainly found to depend on culture, incubation time and antimicrobial peptide molecular weight. However, the antimicrobial inhibition activity of camel milk containing *L. helveticus* and *S. thermophilus* was higher than that noticed in camel milk containing *L. acidophilus* and *S. thermophilus*. This is attributed to the nature of proteolytic system of *L. helveticus* which result in more antimicrobial peptides formation.

Antioxidant Activity

There is strong evidence between diabetic, cardiovascular diseases, aging, cancer and the imbalance of free radical levels in the body (Sah *et al*., 2014; Shori, 2013). The formation of free radicals (superoxide anion radical and hydroxyl radical) is a normal result of aerobic organisms during respiration (Virtanen *et al*., 2007). An excess of free radicals formation could led to cause cellular or tissue injury by oxidizing cellular proteins, enzymes, membrane lipids and DNA (Sah *et al*., 2014). Under normal conditions, defense system shall prevent body from this damage using antioxidant enzymes and low molecular massnon-enzymatic antioxidant compounds (Virtanen *et al*., 2007). Antioxidants peptides could be derived from various food proteins including milk and dairy products; these peptides contain 5-16 amino acid residues and considered to be safe, low cost, healthy and easily absorbed in small intestine (Sarmadia & Ismail, 2010). According to the recent information by IFIC about 34% of consumers get enough food contain potential antioxidant effect (IFIC, 2013). The antioxidant activity of camel milk has been approved through a number of *in vitro* studies (Al-Saleh *et al*., 2014; Jrad *et al*., 2014; Shori, 2013; Salami *et al*., 2011) and *in vivo* studies (AL-Ayadhi & Elamin, 2013). Various methods based on radical scavenging inhibition (hydroxyl radical and DPPH) were adopted to determine the antioxidant activity of camel milk. The DPPH radical scavenging activity, total phenol compounds and reducing power of camel casein hydrolysate were reported to be greater than those of bovine casein hydrolysate and un-hydrolysed camel casein (Al-Saleh *et al*., 2014). These findings were supported by a recent study, which showed that free radical scavenging of camel casein and camel casein hydrolysate were higher than those found for camel milk whole protein and its hydrolysate (Jrad *et al*., 2014). This is attributed to the presence of camel β-casein (main casein in camel milk protein) which showed high antioxidant activity after hydrolysis with chymotrypsin (Salami *et al*., 2011). Moreover, the exposure of free radical scavenging amino acid residues such as phenylalanine, tryptophan, methionine, tyrosine and cysteine were found to increase the oxidative stability of casein hydrolysate (Moure *et al*., 2006).

Anti-Cancer Activity

According to the latest statistics of International Agency of Research on Cancer (IARC) in 2012 worldwide, the number of new cancer cases was 14.1 million, whereas the number of cancer deaths was 8.2 million. Moreover, people living with cancer (within 5 years of diagnosis) were 32.6 million (WHO, 2012). Colorectal cancer (CRC) is highly affected by the dietary and lifestyle factors thus could be substantially reduced by controlling the different risk factors, including the dietary ones. In general, the relation between dairy products and CRC are controversial (Gill & Rowland, 2003). There are some studies exhibited no significant effect associated between dairy products consumption and CRC. While, several studies suggested that increased consumption of dairy products including camel milk may elevate the risk of CRC (Amr *et al*., 2015, Korashy *et al.,* 2012, Quita & Kurdi, 2010). Camel milk was reported to have superior chemo-preventive properties over cow milk, thus extensively consumed by cancer patients in the Middle East (Quita & Kurdi, 2010). The chemo-preventive effect of unfermented and fermented camel milk against different kind of cancers was studied using different cancer biomarkers. This effect is attributed to the bioactive components presence in milk and dairy products including conjugated linoleic acid, sphingolipids, calcium, lactoferrin, casein or addition of probiotic and prebiotic (Gill & Rowland, 2003). Camel milk has shown to inhibit the hepatic and breast cancers and to alleviate the hepatotoxicity induced by natural toxicants. Camel milk intubated to albino mice has significantly inhibited the micronucleated polychromatic erythrocytes (MnPCEs) in the bone marrow and increased the mitotic index induced by cisplatin chemotherapy (Quita & Kurdi, 2010). In another animal study, camel milk showed therapeutic effects to rats after aflatoxin B1 intoxication using amelioration of cancer blood biomarkers (Abdel Magjeed, 2005). In another research, camel milk has significantly inhibited cancer cells proliferation through the activation of caspase-3 mRNA and the induction of extrinsic and intrinsic apoptotic signaling pathways (Korashy *et al.,* 2012). Recently, Amr *et al.* (2015) has studied the chemopreventive potential of camel milk compared to bovine milk, however both milks exhibited chemopreventive potential on Fischer rates against preneoplastic lesions as expressed by ACF in the early stages of colon carcinogenesis.

Hypoallergenicity Activity

Some infants are born allergic to various food components including milk and even soy milk. Approximately 70% of sensation to food allergens is being disappeared at the age of six (Kulig *et al*., 1999). On the other hand, up to 23% of children are sensitized without showing symptoms (Kirjanvainen, 2003). There is no doubt; mothers' milk is the ideal nutrition for newborn infants during the early months of life. Although, infants in many cases need to complete their necessary nutrition with some alternative formulae such as soy milk, goat milk or extensively hydrolyzed milk protein formulae (El-Agamy, 2007). Approximately 10-20% of children showed allergenicity to bovine milk are also expressed sensation to soy derivatives (El-Agamay *et al.*, 2009, Maldonado *et al.*, 1998, Businco *et al.*, 1992). Researchers have recently proposed camel milk proteins as alternative to children allergic to bovine milk. It is evident that high incidence of allergenicity in bovine milk is related to the high percentage of αs- casein (Taylor, 1986) and β-lactoglobulin (El-Agmay, 2007). In contrast, camel milk is hypo-allergic similar to mothers' milk due to the high percentage of β-casein, low percentage of αs- casein (El-Agamay *et al.,* 2009), similarity of immunoglobulins (Shabo *et al.,* 2005) and deficiency of β-lactoglobulin (Kappeler, 1998). Accordingly, camel milk is expected to cause a little hypersensitivity reactions (El-Agamay *et al.*, 2009). Nevertheless, no immunological similarity was found between camel and cow milk using ELISA technique (El-Agamay *et al.*, 2009). Therefore, camel milk could be proposed as a new protein source for children allergic to bovine milk.

BIOACTIVITY OF CAMEL MILK OLIGOSACCHARIDE

Like other milk sources, lactose is the dominant saccharide in camel milk and consist 4.4% of total milk composition (Al haj & Al Kanhal, 2010). Other substantial quantities of saccharides including neutral and acidic oligosaccharides, glucose, fructose, and glucosamine were also found in camel milk (Fox & McSweeney, 1998). Oligosaccharides are carbohydrates with a degree of polymerization contain a small number of saccharide units (between 3 and 14), most of these have lactose residue and some N-acetyl groups (Walstra *et al*., 2008). The potential health claims of milk oligosaccharides and their proposed mechanisms are discussed by Boehm & Stahl (2007) and Kunz and Rudloff (2006). These claims are summarized as follows: modulate the intestinal flora, affect different gastrointestinal activities, effect on mineral absorption, anti-adhesion effect against pathogens, enhance the immune system, and enhance the growth of *Bifidobacterium bifidum*. In particular attention, 3'-GL oligosaccharide which is considered as a prebiotic component was detected in camel milk (Alhaj *et al*., 2013). This oligosaccharide could be used as a food additive in infant formula (Urashima *et al*., 2009).

The number and concentration of identified oligosaccharides in human milk is much higher than that reported for domestic mammalian animals including camel milk (Alhaj *et al*., 2013; Fukuda *et al*., 2010; Urashima *et al*., 1997). Researchers (Boehm & Stahl, 2003) recorded eighty-seven oligosaccharides in human milk compared to thirteen and seven characterized oligosaccharides in Bactrian camel milk /colostrum (Fukuda *et al*., 2010), and in Dromedary camel milk (Alhaj *et al*., 2013), respectively. Furthermore, the concentration of oligosaccharides in camel and bovine milk compared to human milk was found to decrease during lactation (Finke, 2000; Martin *et al*., 2001; Fukuda, *et al*., 2010). On the other hand, significant homology and heterogeneity differences were reported in the oligosaccharides structure between human and camel milk (Alhaj *et al*., 2013; Fukuda *et al*., 2010; Mehra & Kelly, 2006). Two oligosaccharides; Sialyl -3'-galactosyllactose and sialyllacto-N-novopentaose-a were not detected in human milk/colostrum but detected in camel milk. In contrast, 3'-GL, LNnH, 3'-SL, 6'-SL and MSLNnH oligosaccharides are both detected in dromedary camel and human milk (Alhaj *et al*., 2013). The following oligosaccharides, Sialyllacto-N-novopentaose-a, LNnH and MFLNnH, which contain Gal(β1–4)GlcNAc(N-acetyllactosamine), are categorized as Type II oligosaccharides and only found in Dromedary and Bactrian camel milk (Alhaj *et al*., 2013). Accordingly, the presence or absence of Type I oligosaccharide that contain Gal(β1–3)GlcNAc (lacto-N-biose I) is expected to be the main significant contrast between human and camel or bovine milk oligosaccharide (Fukuda *et al*., 2010).

BIOACTIVITY OF CAMEL CONJUGATED LINOLEIC ACID (CLA)

For many years the concept of eating dairy products was likely associated for being harmful to health due to the presence of saturated fat and cholesterol. This concept was misleading and often inaccurate because not all fatty acids or saturated fatty acids have the same biological effects. Researchers concluded that fatty acid within a whole diet context has to be considered individually to clarify the link between health and diet (Parodi, 2009; Lock *et al*., 2008). Bauman *et al.* (2006) highlighted a number of bioactive components in milk fat (e.g. essential fatty acids including conjugated linoleic acid, vaccenic acid, butyric acid, sphingolipids, 13-methyltetradecanoic acid, stearic acid, ether lipids,omega-3 fatty acids and vitamins A, D). Conjugated linoleic acid (CLA) is the most important bioactive component in milk fat due to its inhibitory effect on cancer, immune function, inflammation, diabetes and atherosclerosis (Gnädig *et al*., 2003). The concentration of CLA in camel milk fat is 4.56 mg/g which is greater than that reported for cow milk (Al-khdier *et al.,* 2014; Cardak *et al.*, 2003). This concentration was found to increase in camel milk through addition of some starter cultures including *Bifidobacterium angulatum*, *Bifidobacterium longum* subsp. *Infantis* and *Lactobacillus delbrueckii* subsp. *bulgaricus* (Al-khdier *et al.,* 2014). More extensive research is needed to investigate the functional properties of CLA in camel milk fat. The current information is highly important but not enough to warrant a strong conclusion.

BIOACTIVITY OF D AND L AMINO ACID IN CAMEL MILK

Among the proteinaceous foodstuffs, milk is of major importance not only for infants but also for children and adults. This is attributed to its high nutritional value in terms of essential AAs and contents of calcium. Although L-amino acids are the major structure blocks of peptides and proteins of all living organisms; however, the corresponding stereoisomers (enantiomers) of L-amino acids is called D-amino acids which occur in low amounts in milk as well as most tissues of all mammals. In recent years, positive health effects of some D-amino acids established and some were used as pharmaceutical drugs including D-Asp stimulates testosterone synthesis, increases human sperm count and mobility, and is implicated in human pre-ovulatory follicular fluid (D'Aniello *et al.*, 2007, Topo *et al.,* 2009). The Mg-salt of DL-Asp is also used as magnesium supplement and protection against heart diseases, D-Ser is used to treat the schizophrenia and D-Phe for treatment of Parkinson's disease (Stenberg *et al.*, 2002).

In the last decades, many studies have analyzed the presence of D-amino acids in many processed foods. These studies assumed that D-amino acids are released in dairy products, fermented beverages and other products matured by the presence of some active bacteria (Brueckner & Hausch, 1990). However, raw milk is usually contaminated with microorganisms, such as anaerobic bacteria of the genera *Bacterioides, Ruminococcus* and *Butyrivibrio*. The low amount of free D-amino acids found in milk is significant and expected to be due to the result of the bacterial digestion and autolysis (Brückner & Fujii, 2010). The addition of cultures to camel milk of various dairy products has significantly enhanced the D-amino acid content. For example, the addition of three starter cultures (*Lactobacillus acidophilus* and *Streptococcus thermophilus; Lactobacillus helveticus* and *Streptococcus thermophilus; and Lactobacillus bulgaricus* and *Streptococcus thermophilus*) have relatively increased the concentration of D- Ala, D-Val, D-Orn, D-Lys and D-Arg in fermented camel milk (Alhaj, 2015). The amino acid content was varied depending on starter culture and fermentation process. The current available information on D-amino acid content in camel milk is scarce in the literature; further work is needed to highlight the importance of D-amino acid in camel milk.

CONCLUSION AND FUTURE RESEARCH

Camel milk is a good source of bioactive components for the people living in the arid and urban areas. The current available information is highly important but extensive research is required to support the present potential health claims and their proposed mechanisms. Functional products based on camel milk source are required in the commercial market due to increasing demand in recent years. These products have to be clinically proven, scientifically evident supported and exhibit no side effect after consumption. Consumers have to be given more awareness about the healthfulness and importance of camel milk.

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