Critical Explorations

Veterinary Science

Breakthroughs in Research and Practice

Information Resources Management Association

Veterinary Science:

Breakthroughs in Research and Practice

Information Resources Management Association
USA

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DISSEMINATOR OF KNOWLEDGE

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List of Contributors

Abrantes, Ana Margarida / *Biophysics Institute, University of Coimbra, Portugal* 132
Albrecht, Katherine / *CASPIAN Consumer Privacy, USA* 51
Alpi, Kristine M. / *North Carolina State University, USA* 344
Baicherova, Anzhelika / *Stavropol State Agrarian University, Russia* 214
Bannikova, Natalia / *Stavropol State Agrarian University, Russia* 214
Bosco, Alejandra / *Autonomous University of Barcelona, Spain* 332
Botelho, Maria Filomena / *CIMAGO, CNC.IBILI, University of Coimbra, Portugal* 132
Boulaki, Vasiliki / *Academy of Athens, Greece* 116
Briggs, Deborah J. / *Global Alliance for Rabies Control, USA* 175
Carrigan, Esther / *Texas A&M University, USA* 344
Chapman-Waterhouse, Emily / *Harper Adams University, UK* 304, 317
Costa, Peter / *Global Alliance for Rabies Control, USA* 175
Desale, Nayan / *Savitribai Phule Pune University, India* 1
Fue, Kadeghe / *Sokoine University of Agriculture, Tanzania* 159
Gabriel, Joaquim / *INEGI, University of Porto, Portugal* 132
Geofrey, Anna / *Sokoine University of Agriculture, Tanzania* 159
Gil da Costa, Rui M. / *LEPABE, CI-IPOP, University of Porto, Portugal* 132
Hietaoja, Juha / *University of Helsinki, Finland* 34
Ivolga, Anna / *Stavropol State Agrarian University, Russia* 214
Jawalkar, Mayur Sunil / *Savitribai Phule Pune University, India* 1
Khanna, Neha / *Gauatam Buddha University, India* 236
Khoramshahi, Ehsan / *University of Helsinki, Finland* 34
Kipanyula, Maulilio J. / *Sokoine University of Agriculture, Tanzania* 159
Kossida, Sophia / *Academy of Athens, Greece* 116
Lamkhade, Amol / *Savitribai Phule Pune University, India* 1
Leskinen, Sonja / *Åbo Akademi University, Finland* 194
Liu, Yun / *University of Electronic Science and Technology of China, China & Sichuan Vocational and Technical College of Communications, China* 20
Mahalle, Parikshit N. / *Savitribai Phule Pune University, India* 1
Maharaj, Rohanie / *The University of Trinidad and Tobago, Trinidad and Tobago* 278
Moberly, Heather K. / *Oklahoma State University, USA* 344
Oliveira, Paula Alexandra / *CITAB, University of Trás-os-Montes and Alto Douro, Portugal* 132
Page, Jessica / *The Ohio State University, USA* 344
Pastell, Matti / *University of Helsinki, Finland* 34
Railkar, Poonam N. / *Savitribai Phule Pune University, India* 1

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Preface

The everchanging landscape surrounding diverse scientific areas can make it very challenging to stay on the forefront of innovative research trends. That is why IGI Global is pleased to offer this one-volume comprehensive reference that will empower students, researchers, practitioners, and academicians with a stronger understanding of veterinary science and the latest research topics and technological innovations in the field.

This compilation is designed to act as a single reference source on conceptual, methodological, and technical aspects, and will provide insight into emerging topics including, but not limited to, tracking and traceability of animals, innovative methods in veterinary education, health monitoring technologies, and diagnostic techniques such as thermography. The chapters within this publication are sure to provide readers the tools necessary for further research and discovery, whether they hold a clinical, administrative, and/or research role.

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

1. Animal Tracking and Sensor Technologies;
2. Disease Diagnosis and Prevention;
3. Equine and Livestock Care; and
4. Veterinary Education.

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

Section 1, "Animal Tracking and Sensor Technologies," opens this extensive reference source by highlighting the latest trends in animal tracking and microchip implantation. Through perspectives on mobile transceivers, electronic pedigrees, and animal sensor networks, this section demonstrates critical issues surrounding intelligent animal tracking systems and the role they play in animal identification and preservation. The presented research also facilitates discussion on the ethical considerations and potential health impacts of these devices and technologies on different animal species.

Section 2, "Disease Diagnosis and Prevention," presents research on the impact of web-based information systems and advanced imaging processes that can be used in preventing and treating animal diseases and injuries. Including discussions on disease awareness, magnetic resonance imaging, and thermography, the presented research examines the impact of web-based information systems and advanced imaging processes and their contributions to emerging innovations. This inclusive information also assists in advancing current practices in implementing integrated information systems into rabies surveillance.

Section 3, "Equine and Livestock Care," presents diverse perspectives on the economic, environmental, and health issues associated with equine and livestock care. The chapters within this section focus on both the health and wellbeing of the animals as well as the long-term environmental and economic impacts associated with breeding, boarding, and care. The changing role of veterinary services has a direct impact on sustainability in livestock farming and production, and as such, the topic of food security is also covered in length within this section. Through innovative discussions on vaccination protocols and feeding models, this section highlights the innovative directions taking place and how mobile technologies are being integrated into this specialized veterinary care.

Section 4, "Veterinary Education," discusses instructional design techniques and pedagogical approaches for online veterinary learning environments. Through analyses on reusable learning objects and summative assessment, readers are presented with pivotal information on the latest trends in curriculum development. Additionally, this section also provides coverage on strategies for developing and maintaining high-quality veterinary resource collections in libraries.

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.

Section 1

Animal Tracking and Sensor Technologies

Chapter 1
Intelligent Wildlife Tracking Using Ubiquitous Technological Suite

Mayur Sunil Jawalkar
Savitribai Phule Pune University, India

Nayan Desale
Savitribai Phule Pune University, India

Fanil Suratwala
Savitribai Phule Pune University, India

Amol Lamkhade
Savitribai Phule Pune University, India

Parikshit N. Mahalle
Savitribai Phule Pune University, India

Poonam N. Railkar
Savitribai Phule Pune University, India

ABSTRACT

This paper proposes an intelligent system to track location of an individual animal or animals in wildlife sanctuary. Existing systems makes use of various technologies such as RFID, GPS, GSM, etc. RFID based systems either lack in range if passive tags are used or lack in cost effectiveness if active tags are used. Similarly, GSM based system becomes costlier and requires constant network connectivity. Hence this paper proposes a Wi-Fi based tracking system. Proposed system makes use of ubiquitous technology which encourages the use of Wi-Fi Transceivers. The Stationary Wi-Fi Transceiver consists of ESP8266 NodeMCU development board which detects the Mobile Transceiver. The Mobile Transceiver consists of ESP8266 NodeMCU attached to animals. The Stationary Wi-Fi transceiver detects Mobile Transceivers under its vicinity and sends the data to other Stationary transceiver through hop based transmission and ultimately the data is stored in the database. The mobile application accesses the location information from the database for particular animal and plots it onto the Map. This paper comprises of system architecture, proposed algorithm and mathematical model.

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INTRODUCTION

With the growth in human society wildlife is marching towards danger. But for ecological balance every living creature is equally important. Hence humans are taking efforts to keep animals safe in forests under our constant observations by creating wildlife sanctuaries, national parks, etc. By the passing years lots of humans are curious about exploring such places to observe wild animals. But the main problem is to locate wild animals in wildlife sanctuaries. Animals are not always located at same place. They keep moving across the jungle. Thus, practically visitors may not be able to observe an intended animal within acceptable time. Hence wildlife tracking system turns out to be beneficial in order to conveniently observe and monitor wild animals.

Considering the need for wildlife tracking, this paper proposes an intelligent system to track wild animals' location using ubiquitous technology. This system makes use of Wi-Fi technology. Stationary Wi-Fi modules are distributed all over across the jungle. Animals are equipped with Wi-Fi transceivers. These transceivers are detected by stationary Wi-Fi modules. Then the location information of every animal is transmitted to the base station by all stationary Wi-Fi modules. The transmission is done through flooding protocol. The final Wi-Fi transceiver will send complete data to the database server. The database server takes care of updating the location of the animals. Now whenever user requests for location of any animal, server responds with the location information available in the database. The location coordinates get plotted onto the map. Hence the user is able to locate the animals with ease. Thus, proposed system will be convenient for visitors, scientific researchers or conservation agencies to track location of an intended animal in wildlife sanctuary.

The term ubiquitous technology can be defined as: "Ubiquitous computing is a concept where computing is made to appear everywhere using any device, in any location and in any format" (Meshram et al., 2016).

In this paper, section 2 focus on motivation of the paper. Section 3 explains the idea of the system in detail. Section 4 gives abstract information about related papers. All possible methodologies are elaborated in section 5. Section 6 and section 7 provides detailed information about the proposed system architecture and algorithm. Data structures used in these algorithms are mentioned in section 8. Section 9 represents complete system into mathematical model. Flow of the system with the help of sequence diagram is explained in section 10. Section 11 and 12 elaborates about resources, tools and techniques which can be used for implementation of proposed system. Section 13 gives brief idea about estimated cost of system implementation. Verification and validation of system is explained in section 14. Consequently section 15 and 16 deals with features and constrains of the proposed system. Section 17 briefs about future scope and conclusion of the system.

MOTIVATION

The motive behind this idea is to design a system that covers maximum flaws of the existing systems in regards of the efficiency, power consumption, weight, range factors, low maintenance as well as cost effectiveness. The existing systems makes use of GPS or GSM technologies. Also, some systems are implemented with RFID technologies. But few flaws are observed while thinking of these systems. GPS-GSM based system requires constant network connectivity which increase the power consumption of the system. Such kind of functionality requires heavy hardware which increases the weight of the device mounted on animals. It also increases the cost of the system. Some systems make use of GSM network to transmit the GPS coordinates. These systems are weather dependent which fails to track the location of animals in harsh environment. GPS based systems requires considerable field efforts. Systems based on RFID based transmissions have low range and requires line of sight which is again impractical to use in sanctuaries. One major flaw can be enlisted as lack of user friendly application to track animals. Also, many existing systems lack in efficient data retrievals. Hence to overcome all these flaws this paper proposes an intelligent system to track wildlife animals.

PROJECT IDEA

Now-a-days people are interested in observing wildlife. But animals are not always located at fixed locations. It is really a challenging task to find out the exact location of every animal. Hence this paper proposes a system that gives dynamic location of every animal in the sanctuary so that visitor always gets a chance to visit the animals of his/her choice. Goal behind this proposal is to design an intelligent system to track wildlife animals' location using Ubiquitous Technological Suite which will help individuals (tourists, scientific researchers or conservation agencies) who are interested in effectively observing wildlife animals.

Some Goals of the system include the following:

1. Network Establishment with maximum critical range;
2. Design algorithm for data collection;
3. Design an interface for efficient data retrieval.

Scope of the Project Idea

The proposed system will manage the process of tracking the locations of the animals present in the sanctuary and store them in the central database. It will also let users search for a particular animal(s) and get the location plotted on map on the respective application. The stationary modules will take care of registering the mobile modules coming under its vicinity and forwarding it to other stationary modules through hop based transmissions. This data consists of MAC address of the respective Wi-Fi Transceiver which is used to locate that particular animal. Scope also concerns about providing efficient, low maintenance, low power consumption, cost effective and user friendly application to the users.

LITERATURE SURVEY

The purpose of the paper (Kim et al., 2010) is to present a comprehensive review of the recent literature on sensor networks especially in Animal Tracking. Wireless sensor networks (WSNs) have gained worldwide attention in recent years in several applications (Nair et al., 2011; Dey et al., 2012a; 2012b; 2012c; Kumar, & Nagarajan, 2013; Graham et al., 2013; Chakraborty et al., 2015; Binh et al., 2016; Sawlikar et al., 2016; Mukherjee et al., 2016). Particularly, with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. An intelligent animal situation tracking service for zoological gardens, based on GPS, RFID, and sensors is proposed in paper (Jukan et al., 2016). As per paper (Markham, 2008) the notion of animal welfare is used in broad terms, to review the technologies for assessing whether animals are healthy, free of pain and suffering, and also positively stimulated in their environment. Also, the notion of smart computing and sensing is used in broad terms, to refer to computing and sensing systems that are not isolated but interconnected with communication networks, and capable of remote data collection, processing, exchange and analysis. The paper (Khan et al., 2012) is motivated by the diversity of animals, a hybrid wildlife tracking system, Eco Locate, is proposed, with lightweight VHF-like tags and high performance GPS enabled tags, bound by a common wireless network design. Paper (Mustafa et al., 2013) states that the use of GSM and GPS technologies allows the system to track object and provides the most up-to-date information about ongoing trips. According to paper (Sasikumar et al., 2014) WSN's are a very good tool to overcome accessibility of semi-domestic animals under harsh weather conditions and it is also an important tool that provides useful information about animals' activities.

The Table 1 summarizes the detailed information present in the referenced papers. The following points are used for discernment purpose:

- **Paper Name:** Name of the proposed Papers which are referred during the survey;
- **Algorithms Used:** Algorithms used in the system;
- **Overall System Cost:** Cost of the Complete System including installation and maintenance cost;
- **Technologies Used:** Technologies proposed in the paper to build the system;
- **Limitations:** Certain disadvantages of the system;
- **Accuracy:** Speed or efficiency in calculating the location details and computation tasks;
- **Feasibility:** How feasible or convenient the system is;
- **Average System Life:** Life of the proposed system excluding battery life which will be taken care during system maintenance.

METHODOLOGIES

Primary Method

The system is based on effective communication between:

1. Mobile transceiver to Stationary Transceiver;
2. One Stationary Transceiver to another Stationary Transceiver;
3. Final Stationary Transceiver to Database;
4. Database to Mobile Application.

These communications must be synchronized and efficient:

- Initially, the stationary module continuously scan for mobile modules by broadcasting the REQUEST message;
- When an animal comes in vicinity of stationary module, it answers this REQUEST message by sending RESPONSE message consisting of its MAC address;

Table 1. Evaluation of related work

Sr. No.	Paper Name	Algorithm Used	Overall System Cost	Technology Used	Limitations	Accuracy	Feasibility	Average System Life (Excluding Battery Life)
(Kim et al., 2010)	Animal Situation Tracking Service Using RFID, GPS, and Sensors.	Sensors and Ad-hoc network	High	RFID, GPS	Inefficient in Low temperatures, Maintenance Cost	Highly Accurate	Enough resources, Low failure rates	5-10 years.
(Jukan et al., 2016)	Smart Computing and Sensing Technologies for Animal Welfare.	WSN routing algorithms, machine learning algorithms.	Less	RFID Tags and RFID Readers	Low range, require line of sight	Less Accurate	Better for short distance tracking and animal identification	8-10 years.
(Markham, 2008)	On a Wildlife Tracking and Telemetry System.	Localization algorithms	Less	Heterogeneous Networks, MEMS Reed Sensor	Accessibility, Danger of animal might eat or destroy the equipment	Accurate	System produces expedite results.	3-6 years.
(Khan et al., 2012)	GPS GSM Based Tracking System.	User Defined	Moderate	GSM, Tracking unit aka GPS, tele monitoring system	Battery Durability	Accurate	Better for large sanctuaries. Adequate number of subjects	10-12 years.
(Mustafa et al., 2013)	Animal Sensor Networks.	Localization Algorithms	High	GSM, GPRS, Wi-Fi enabled RFID’s	Logistics cost, Continuous need for calibration	Highly Accurate	Better for large sanctuaries, Low failure rates.	6-10 years.
(Sasikumar et al., 2014)	An Analysis on Animal Tracking System using Wireless Sensors	Optimized Recovery algorithm	Moderate	Analog sensing, MEMS	Limited processing and computing resource	Accurate	Manageable, Affordable in time and money	2-5 years.

- All these received MAC addresses are transferred to the nearest stationary module using Nearest Neighbour routing protocols. It is repeated for all animals in vicinity;
- The second stationary module combines its own vicinity information with the received information;
- This process is repeated until the data reaches the database where all the location coordinates of animals are updated;
- Lastly, the mobile user accesses the coordinates of the animals through android application which gets plotted onto the map.

Secondary Method

This method replaces the ESP8266 NodeMCU with following devices:

- ESP 8266 Wi-Fi module;
- Microcontroller Arduino ATMEGA328/ATMEGA2560;
- Voltage Regulator LD1117.

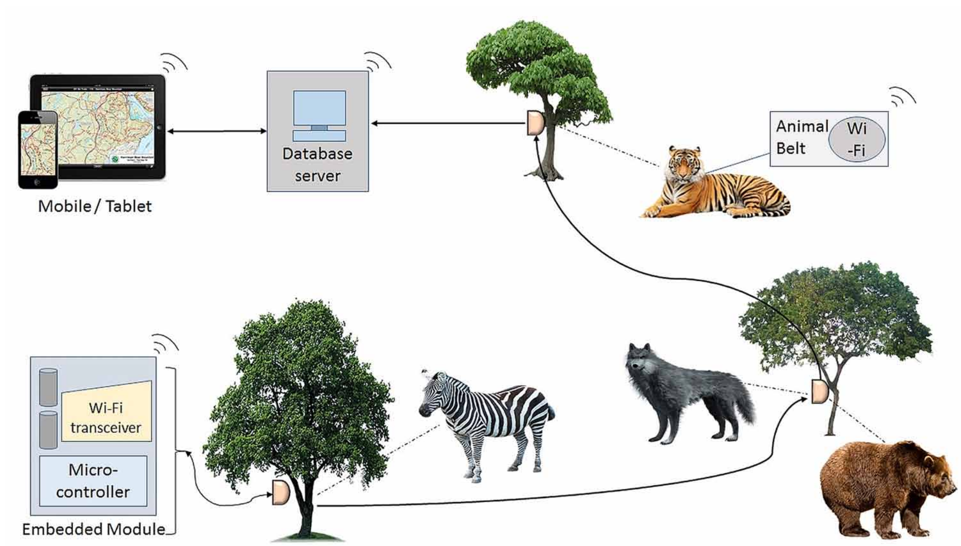
Now, for the stationary part we will require to integrate ESP8266 Wi-Fi module with Arduino board and voltage regulator mounted on PIC Controller. The mobile part will only involve ESP8266 Wi-Fi module equipped with battery.

The primary method is more feasible and practical to use. Hence the system is proposed based on this method.

SYSTEM ARCHITECTURE

In this proposed system, Wi-Fi transceivers are used for communication purpose. Figure 1 shows the architecture of proposed wildlife tracking system. In this system, stationary Wi-Fi modules i.e. ESP8266 NodeMCU are placed at fixed locations such as trees or rocks whichever is feasible. The location of every stationary module will be known right from the time of system installation. Therefore, system can effectively avoid the use of GPS devices. The stationary modules consist of Wi-Fi transceiver ESP8266 NodeMCU and batteries on a small chip. Animals are equipped with ESP8266 NodeMCU devices we can call them as "tags". These Wi-Fi tags are nothing but battery powered Wi-Fi transceivers. This paper proposes a system with the use of ESP-8266 as Wi-Fi transceiver and Arduino board as microcontroller

Figure 1. System architecture



together forming ESP8266 NodeMCU. Hence in further reference we are calling the stationary modules as 'ESP-Arduino modules' and Wi-Fi tags attached to animals as 'mobile ESP modules'. ESP-Arduino module is responsible for tracking animals in its vicinity. These modules are enabled to identify animals in its vicinity by communicating with mobile ESP modules attached to animals. Communication between ESP-Arduino module and mobile ESP module takes place by the simple handshaking protocol. Multiple ESP-Arduino modules communicate with each other to transmit the location information of an identified animal to the central database server. Database server maintains location information of all animals in the jungle. Every individual who wants to observe wildlife is given a mobile application. This application communicates with database server to get the location of intended animal which user wants to observe. After getting locations of individual animals they are plotted on the map to make it easier for user to locate intended animals.

PROPOSED ALGORITHM

The algorithm works in two phases:

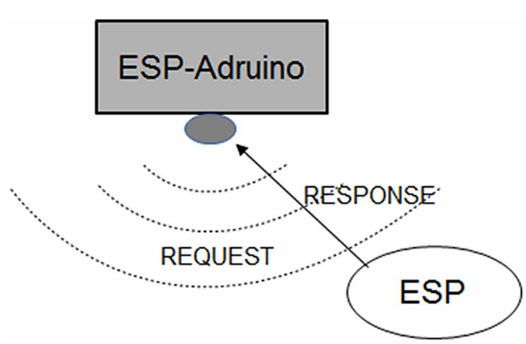
- Data Collection phase;
- Data transfer phase.

Overall System Algorithm

Steps followed by algorithm are as follows:

1. The ESP module combined with Arduino board acts as the central Wi-Fi transmitter and receiver which is kept stationary on trees. The other ESP module which is placed on animal's skin is mobile which consist of unique MAC address which is used to identify the animal in the sanctuary;
2. In data collection phase, as shown in Figure 2 the stationary Arduino module scans for mobile ESP modules placed on animals by broadcasting the REQUEST message using its ESP module transmitter;
3. This broadcasted message consists of MAC address of stationary ESP-Arduino module. The data collection is done on specific interval to lower the power consumption. When an animal in vicin-

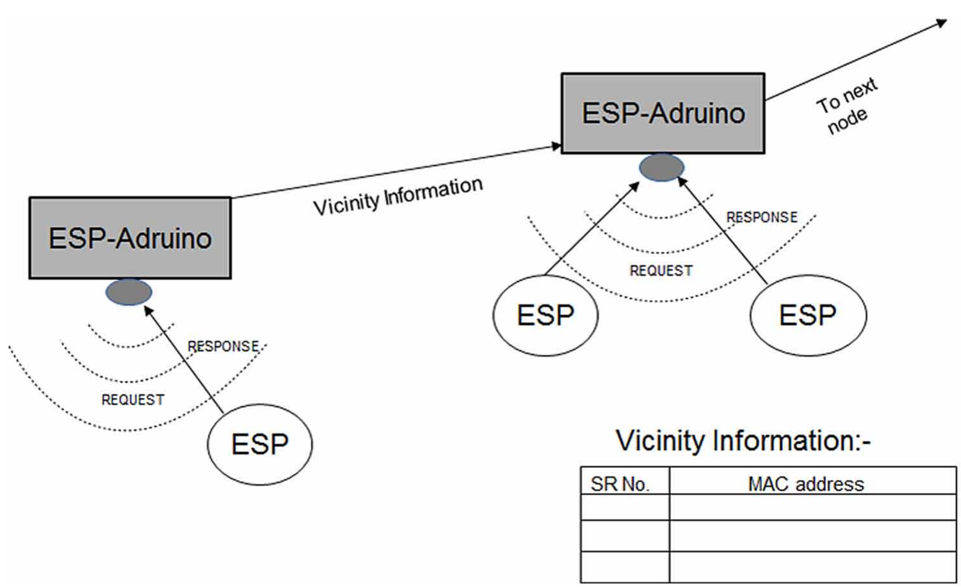
Figure 2. Stationary module - Mobile module communication



ity receives the broadcasted REQUEST message of stationary ESP-module, then the ESP module of that animal forms a packet consisting of its own MAC address as source address and the MAC address of broadcaster which was received earlier as destination address. This packet is considered as RESPONSE message. All animals in vicinity will follow the same step as given above and transmits their MAC addresses to their stationary ESP-Arduino module. These MAC-addresses act as unique identifier to identify which animal it is;

4. These stationary ESP modules store these MAC addresses into the Arduino Uno's memory. Each stationary ESP-Arduino module has also a MAC address but this MAC-address is used to identify that area. This area along with the animals wandering around the area is identified later using MAC addresses and GPS-coordinates;
5. All these stored MAC addresses are then transferred to all the nearest stationary ESP-Arduino modules as shown in Figure 3 to carry out the flooding protocol of WSN;
6. Each nearest ESP-Arduino module will then combine their own MAC addresses received from their animals in vicinity with the received MAC addresses data;
7. These stationary ESP-Arduino modules flood the network with the MAC addresses until it eventually reaches to the base station;
8. Once the data reached to the base station, it is stored into the database. The MAC addresses of stationary ESP-Arduino module are mapped to their respective GPS co-ordinates which were assigned at the time of setting up the system;
9. The tourists or visitors of the sanctuaries are provided with the smart tabs or phones with the animal tracking app;
10. This app connects to the base station database to obtain the MAC addresses of the stationary-ESP module and mobile ESP modules as shown in Figure 4 to identify the area and the animals wandering in that area and uses the GPS co-ordinates to track the area on Google's map;

Figure 3. Stationary module - Stationary module communication



11. The base station running Glassfish server gets the request from the client's app and then search for the MAC addresses of the stationary ESP-Arduino modules in which the requested animal is present;
12. Once the server finds the MAC addresses of the stationary modules then it uses these MAC addresses to find the latitude and longitude of those stationary ESP-Arduino modules in the Coordinate table by using MAC addresses as foreign key;
13. The server then forms a response message consist of the latitude and longitude of the stationary ESP-Arduino modules around which the animals are wandering. And sends this response message to the client;
14. The client then passes these Latitude and Longitude values to the Google's Map API which then converts these values into the Location in the MAP and displays that MAP on the container.

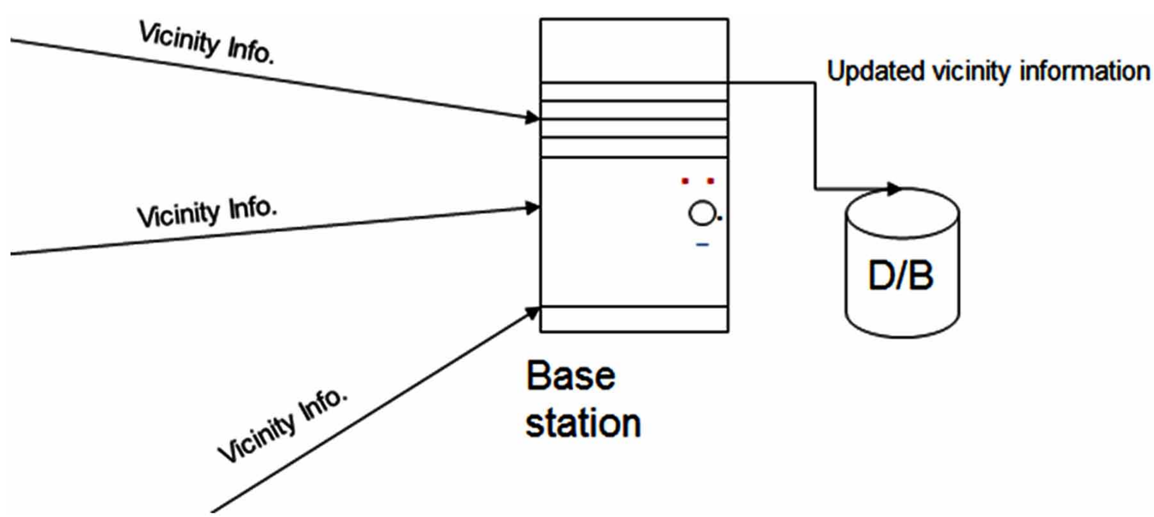
Pseudo Code for Server

1. Create socket using socket();
2. Bind socket on port number 80;
3. Connect the socket to the end stationary NodeMCU using:

Socket.connect(portno)

4. Send the request to the NodeMCU using socket.send();
5. Get the file consisting of MAC addresses of all animals and stationary modules;
6. Save the file on local disk and extract the MAC addresses of all NodeMCUs and store them into the database;
7. Send these MAC addresses and their locations to the client upon request.

Figure 4. Data collection at database



Pseudo Code for Stationary Object

1. Set the mode to wifi.STATIONAP using wifi.setmode(wifi.STATIONAP);
2. Set the SSID (Service Set Identifier) and password:

wifi.ap.config({ssid=”NAME”,pwd=”PASSWORD”})

3. Create TCP server using:

net.createServer(net.TCP)

4. Listen to port 80 using net.listen(80);
5. Create an event which will be executed when connection is stablished:

conn:on(“receive”, function() ())

6. Receive the connection request from mobile NodeMCU;
7. Receive the MAC address of the mobile NodeMCU;
8. Create or open file if already exists and store the MAC address into it;
9. Find the nearest stationary module using RSSI (Received Signal Strength Indicator) and send the file to it.

Pseudo Code for Mobile Wi-Fi Station

1. Set the mode to wifi.STATION using wifi.setmode(wifi.STATION);
2. Find the list of access points using wifi.ap.getlist();
3. Get the strength of all access points using RSSI (Received Signal Strength Indicator);
4. Find the minimum value of RSSI;
5. Connect to the access point using the BSSID (Basic Service Set Identification) and password;
6. Send the MAC address of the Station using conn:send() method.

Time Complexity

Time complexity of proposed system will be:

$O\ (n + p)$

where:

n = number of neighboring nodes of the central ESP-Arduino module

p = number of intermediate nodes between the stationary module and base station through which packet traverse

DATA STRUCTURES USED IN ALGORITHM

Table

Basically, the ESP-Arduino modules are programmed with the LUA programming language. Hence, we need to use the data structures and libraries provided by LUA language only. The Table is an abstract data type available in LUA language.

The Table data structure comprises auxiliary functions to manipulate tables as arrays. In algorithm, the stationary ESP-Arduino module transmits its information in the form of Table to another module. This Table in Table 2 consists of two fields the Sr.no and MAC address.

Once the stationary ESP-Arduino module store the MAC addresses of the animals wandering around then into this table it forwards it to the nearest ESP-Arduino module along with its own MAC address as Area identifier using flooding protocol. Hence the network actually flooded with the tables. Once this complete table reaches to the base station, it extracts the MAC addresses from the table and store them into the Co-ordinate database where the latitude and longitude of the Area are stored.

Container

Container in a class is an abstract data type whose instances are the collections of other objects. It is used to contain the list of animals and their area identifiers at server side. Container is also used in the stationary ESP-Arduino module to store the collection of the Table objects. The container is used to hold these Table objects. The reason behind the use of container data type is it provides easy way to transmit the data over the network using the stream protocols.

MATHEMATICAL MODEL

- **Input:**
  - I = id, D
    - Id- MAC address attached to the animal
    - D - Data from other Esp-Arduino modules
- **Output:**
  - O= G, id, Aid, Dg
    - G - GPS coordinates
    - Id - MAC address attached to the animal
    - Aid - Area identifier
    - D - Data from other Esp-Arduino modules

Table 2. Table structure

Sr. No.	MAC Address

- **Classes:**
    - class Esp_Arduino {
    - int MACIdentiFIer
    - int GPSCoordinates
    - }
- **Functions:**
    - ReadMAC():- activate Wi-Fi module to read the MAC address
    - ReadGpsCoordinates():-reads the GPS coordinates
    - ReadData():- reads the data from other modules if available
- **Success Condition:**
    - Packet is sent successfully to a base station
    - Wi-Fi reads the MAC correctly
    - Coordinates read successfully
- **Failure Condition:**
    - Packet gets lost during transmission
    - Battery drained

UML DIAGRAMS

Sequence Diagram

Figure 5 shows the sequence diagram of the proposed system.

PROJECT RESOURCES

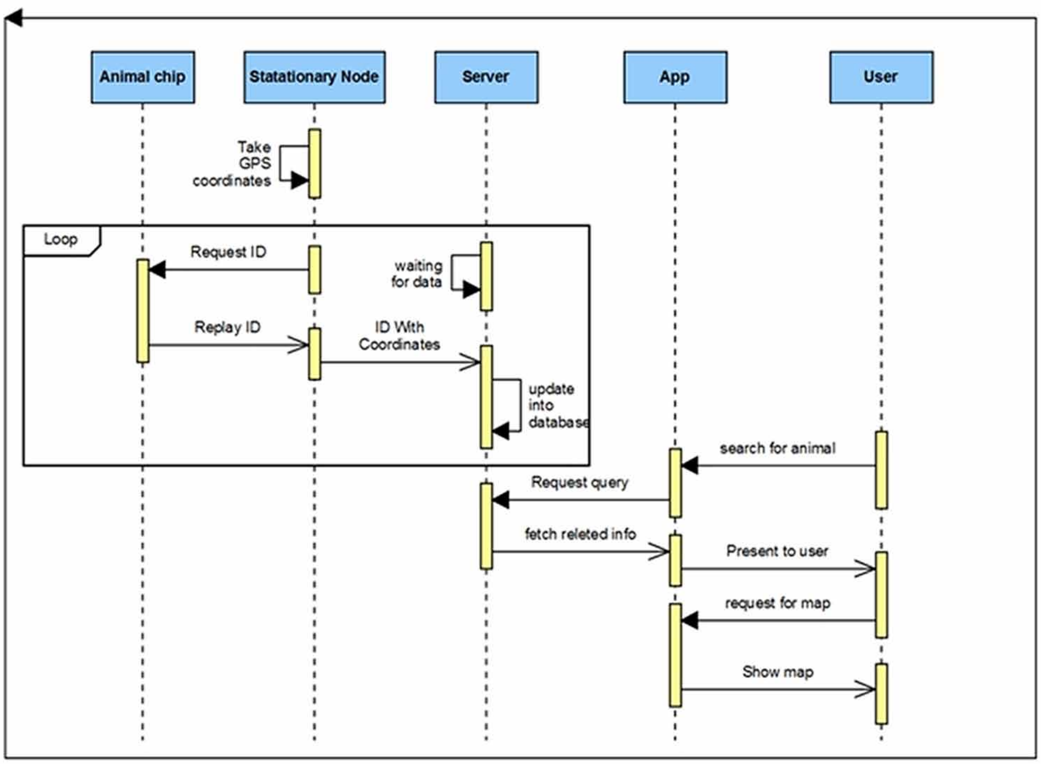
Hardware Resource

- For Server:
    - Processor: i3 or Higher
    - RAM: 2 GB +
    - Hard Disk: 20 GB +
- Printer
- GSM Modem
- Android Phone / Tablet: 4.1 Jelly bean +
- ESP8266 NodeMCU
- Batteries

Software Resource

- Operating System: Windows
- Mobile OS: Android 4.1+
- Front end Server Side: VB.net

Figure 5. Sequence diagram



- Back end Server Side: MySQL 5.1
- Scripts: JavaScript, Lua
- Glassfish server

TOOLS AND TECHNOLOGIES USED

Netbeans

The Netbeans is a java IDE (Integrated Development Environment) which is used to write java programs. The netbeans also provide the support for Glassfish server through plugins and libraries. The netbeans makes it easy for a developer to create the java project as it provides the definitions of all abstract methods and Listener interfaces.

Glassfish Server

GlassFish is an open-source application server project started by Sun Microsystems for the Java EE platform and now sponsored by Oracle Corporation. The glassfish server libraries are included in Netbeans IDE. This glassfish server is used at server side to accept the client requests and send the responses to them. The response includes latitude and longitude of the animal. The glassfish server is used instead of Apache Tomcat.

VB.net

Visual Basic .NET (VB.NET) is a multi-paradigm, object-oriented programming language, implemented on the .NET Framework.

VB.net is used to interact with MySQL and update the database. VB.net allows to add new animal in the database along with its new ID (MAC ID). It is also used to get the data from last stationary ESP module. It writes this updated data to the database.

LUA

The LUA language is used to program the hardware functions of the ESP 8266 NodeMCU. The LUA language provides the abstract datatype: TABLE which allows to store the MAC addresses of the animals. The NodeMCU connects to the stationary module and sends its MAC address to it. The stationary module then transmits it to the nearest neighbor. The LUA language provides the functions to work the node as STATION or Access Point.

LUA Loader

LuaLoader is a Windows program for uploading files to the ESP8266 and working with the Lua serial interface. It is compatible with all versions of Windows from Windows 95 to Windows 10.

LUA loader is a Graphical interface to the ESP 8266 module. It provides various functions like Load file to the hardware, remove file, Run file, compile file. It also allows us to view the content of the 8266 module at an instance. LUA loader is basically used to burn the file inside the module and run it.

PROJECT ESTIMATES

In the Estimate Costs process, the cost of each project activity is estimated. In estimate cost process, the cost of each activity is determined, including the cost of human hours, the cost of equipment, and the cost of materials used as well as the contingency cost i.e. the cost to cover the identified risks.

Some estimation carried out in the project activity include:

- **Analogous Estimation:** This estimation was carried out with very low level details excluding minor costs and focusing on major aspects of the system;
- **Parametric Estimation:** This included the men, materials and work estimations required for cost estimation.

Cost Estimate

- Single ESP8266 NodeMCU = ₹ 500;
- Battery = ₹100;

- Maintaining Printer = ₹ 1000 per Month;
- Maintaining SMS Gateway Services (if required) = ₹ 6000/lakh messages;
- Mobile Application = Depends on the application updates;
- Maintenance of system = depends on the area and devices mounted in sanctuary approximately ₹ 5000;
- Server Maintenance = ₹ 500- ₹1000;
- Total Approximate Cost = ₹ 12000 - ₹ 15000 / month.

Time Estimate in Days

See Table 3.

VERIFICATION AND VALIDATION OF SYSTEM

Verification

Verification is a process of evaluating the intermediary work products of a software development lifecycle to check if the development process is in the right track of creating the final product. The traceability matrix can be considered for verification. It is given in Table 4.

Table 3. Time estimate

Module	Expected Time	Completion Time
Requirements Gathering	5 days	5 days
Design	7 days	7 days
Implementation Total:	40 days	42 days
ESP 8266 NodeMCU	10 days	13 days
Database server	15 days	15 days
Mobile Application	12 days	11 days
Synchronizing communication	3 days	3 days
Testing	15 days	15 days

Table 4. Traceability matrix

Sr. No.	Module Name	Application Roles	Description
1.	Login page	Administrator and customer.	**Customer:** Customer uses login module to access the system using coupon code provided and search the animal using Google's MAP. **Manager:** Manager uses login module to add or remove an animal from the database and set the MAC address of the NodeMCU.
2.	Server	Administrator	Administrator uses server to view the set of activities going on the server side and database.

In short verification is a process to evaluate the mediator products of software to check whether the products satisfy the conditions imposed during the beginning of the phase. Verification is carried out during the development.

Validation

Validation is the process of evaluating the final product to check whether the software meets the business needs. In simple words the test execution which we do in our day to day life are actually the validation activity which includes smoke testing, functional testing, regression testing, systems testing.

Table 5 outlines the Smoke testing matrix.

KEY FEATURES OF SYSTEM

This paper proposes a system which has following key features:

- It is easily scalable;
- It provides long term storage facility which is useful for data analysis;
- It provides multiuser support;
- It requires very less human efforts;
- It turns out to be cost effective as compared to GPS and GSM based systems;
- It covers longer range than RFID based systems;
- It is only applicable to mammals or animals with considerably average size. Because it is not possible to equip smaller animals with Wi-Fi tags.

CONSTRAINTS

Every system has its own flaws. Similarly, this system also has some flaws. Those flaws or constrains associated with system are as follows:

Table 5. Smoke testing

TID	Test Scenarios	Description	Test Data	Expected Result	Actual Result	Status
1.	Valid login credentials	Test the login functionality of the web application to ensure that a registered user is allowed to login with coupon code.	Code XYZ	Login Application should get launched.	Application launched successfully	Pass
2.	Adding Animal functionality	Able to add animal to the database	Animal: Bear	Categories list should get displayed	Categories list is displayed	Pass
3.	Animal request	Check whether the animal latitude and longitude are available or not	Animal: Deer	It should display the position on the Google's map	The location is displayed on Map	Pass

- The Mobile Transceiver is only applicable to mammals. In other words, it can only be applicable to animals with size compatible to wolf or larger;
- Batteries of the system requires maintenance;
- There is always a danger of animals eating/tampering with the device;
- Weight factor always plays an important role while mounting devices on small animals.

CONCLUSION

This paper surveys the recent advances in technology which is used for the benefits of wildlife tracking system. Thus, the integration of ESP8266 with microcontroller that gives ESP8266 NodeMCU is used and it is advanced microcontroller. This Modules are placed throughout the sanctuary and used to track the other ESP8266 NodeMCU module that comes under its vicinity ultimately the entire data is gathered at the base station which is managed by the server and from there the location coordinates of animals are accessed by the mobile application which is android operating system based. This provides convenience to users who want to visit the animals of their choice without wasting much of time and thus saving time, efforts and other resources.

Many areas can benefit from this technology. Human society is entering an era of ubiquitous computing, where everything is networked. Wi-Fi Based animal tracking system is the future. We can clearly say that, this technology will spawn revolutionary changes in the modern animal tracking systems and become a pivot technology. When we compare Wi-Fi based tracking system with other technologies, this will give a better performance over other.

The system proposed in this paper can be extended in future by adding some analysis algorithms which can be used to monitor animals' tendency to stay at specific location over a typical period of time. Also, this will benefit in collecting some statistical data. Some sensors can be added to this system which will make it more intelligent. The heart rates of animals can be monitored and necessary measures can be taken on time. Fire detection sensors can be embedded in stationary modules with the help of which hazardous conditions can be determined at early stages. Addition of temperature sensors, health monitoring systems in mobile modules will benefit in monitoring animal health. The system will be very beneficial for the researchers and wildlife conservatory agencies. The animal's health reports can also be obtained and the population growth of the animals can be monitored. Hence in future advances we can even integrate the existing system with other networking technologies to improve efficiency.

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Chapter 2
The Application of RFID in the Life-Time Traceability of Animals

Yun Liu
University of Electronic Science and Technology of China, China & Sichuan Vocational and Technical College of Communications, China

Peiji Shao
University of Electronic Science and Technology of China, China

ABSTRACT

This paper discusses how to use the RFID technology to realize the life-time traceability of animals. In order to record movements of an animal, the authors adapt the electronic pedigree designed for drugs to animals, which acts as standard data elements and is transferred between partners. Then a CIS is proposed based on the methodology which ensures movements of the animal to be recorded correctly. Results in a case study show that the solution can facilitate the life-time traceability of animals. It is reliable, convenient to query, easy to understand and use, and compatible with existing information systems.

INTRODUCTION

Animal identification and tracing is so important in securing food supply and preventing disease spreading that such projects as the National Animal Identification System (NAIS) in the United States and the National Livestock Identification System (NLIS) in Australia are developed, and the National Animal Identification and Tracing (NAIT) in New Zealand is being proposed.

In NAIS, the United States Department of Agriculture (USDA) only requires the producer in a registered premise to report certain animal movements that might have a potential impact on spreading a disease (USDA, 2006). This is different from Food and Drug Administration (FDA) who want to record all movements in the pharmaceutical supply chain in order to fight counterfeit drugs.

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The drug pedigree, which records the sale by a pharmaceutical manufacturer, the acquisition and sale by a wholesaler and final sale to a pharmacy (EPCGlobal, 2007), enables the life-time traceability of drugs. We borrow this idea and adapt the electronic pedigree designed for drugs to animals. The RFID technology helps read and write the electronic pedigree stored in the RFID tag.

The electronic pedigree cannot fulfill the life-time traceability of animals alone. When the animal moves on, new information must be added to the electronic pedigree to reflect its movement. Since information is produced in distributed information systems, so another problem in the life-time traceability of animals is information system integration, which requires the development of the collaborative business process model.

This paper discusses how to use the RFID technology to realize the life-time traceability of animals, which is organized as the following: first we review the application of the RFID technology in animal identification and tracing and the knowledge about the electronic pedigree. Next after putting forward existing problems, we introduce the electronic pedigree redesigned for animals and the methodology to build the collaborative business process model and develop a CIS (Collaborative Information System) which combines methods of Rajsiri, Lorre, Benaben, and Pingaud (2007) and Chaari, Binnier, Favrel, and Amar (2006). In a case study of the pet's management, we demonstrate how to use them step by step. Finally, we discuss impacts of our solution and describe our future research direction.

BACKGROUND

The Application of RFID in Animal Identification and Tracing

In China, the RFID technology is applied first in pet identification. Increasing pets oblige the public to think about problems in the pet's management and turn to get helps from other countries' experiences.

Since it is the right time that market-ready RFID technologies are gradually taking place of traditional eartags, tattoos and brands in identifying animals, some Chinese cities try to utilize RFID tags to store simple information necessary for pets and build pet identification systems. Thus once a pet is lost, the person who finds it can easily figure out who it belongs to by reading the RFID tag.

RFID tags are also applied in the pork supply chain to guarantee the product's quality. This is the first time that Chinese government requires traceability in the food supply to protect the consumer's right to know what they will buy (Xiong, Fu, Lin, Luo, & Yang, 2009).

USDA goes further to build NAIS, which enable USDA to trace a disease back to its source in short time and limit potential harm to animal agriculture (USDA, 2008).

The premises registration component is the foundation of NAIS. When a producer registers his premise, a unique premises identification number (PIN) is assigned and his contact information is recorded, which ensures that the producer is notified quickly when an animal disease outbreaks (USDA, 2008).

The animal identification component involves assigning an animal or a group of animals a unique animal identification number (AIN), which gives animal health officials a clue for epidemiologic investigations (USDA, 2008).

The animal tracing component allows a producer to choose an animal tracing database (operated and maintained by private industry groups or States) and report certain animal movements that might pose a significant risk of disease transmission (USDA, 2008).

NAIS is a State-Federal-industry partnership, the responsibility for implementing and administering NAIS is shared among State animal health authorities, USDA, and the animal agriculture production industry (USDA, 2008).

The Electronic Pedigree

FDA specifies that the drug pedigree is the statement of a drug's history in the pharmaceutical supply chain. According to the Prescription Drug Marketing Act (PDMA), the drug pedigree should record the drug name, dosage, container size, number of containers, drug lot or control number, names and addresses of all partners in each previous transaction, and transaction dates. But maintaining such a drug pedigree is overwhelming (Koh, Schuster, Chackrabarti, & Bellman, 2003).

EPCglobal specifies an open document model complying with PDMA, which defines two XML schemas. One is about the standard electronic pedigree format; the other is about the standard electronic envelope format to package multiple electronic pedigrees. The great benefit of these schemas is that they provide standardization for the exchange of electronic pedigrees as they pass down the supply chain (EPCGlobal, 2007).

The electronic pedigree is created using the first XML schema and the new shall always be started from an intialPedigree element, which is the innermost component of the electronic pedigree and includes serial number, product and item information. Each partner engaged in the pharmaceutical supply chain is required to provide signed electronic pedigree to the recipient who authenticates each previous transaction in the electronic pedigree and add its own certification of receipt and signature to the electronic pedigree (EPCGlobal, 2007).

The open document model does not identify exactly how electronic pedigrees must be transferred between partners, and the RFID technology is not mandatory (EPCGlobal, 2007).

SOLUTION TO THE LIFE-TIME TRACEABILITY OF ANIMALS

Current Problems

The life-time traceability of animals involves collaboration among government authorities, individuals and organizations of the industry, which store information in their own databases or paper-based filing systems. So in this collaborative environment, the most significant challenge is to provide standardization for data exchange and apply modern technology to integrate information systems of partners (USDA, 2008).

RFID and the Electronic Pedigree

In this paper, we suggest that the electronic pedigree be used to record an animal's movements as it does in the pharmaceutical supply chain. In EPCglobal's design, parts of an electronic pedigree are distributed across different information systems; one can collect these parts into a complete electronic pedigree through a query (EPCGlobal, 2007). But FDA sees an electronic pedigree as a complete electronic legal document directly transferred from one partner to another (EPCGlobal, 2007).

There are several mechanisms which are likely to be utilized for this transfer. For example, many existing information systems could be augmented to include the electronic pedigree (EPCGlobal, 2007). In this paper, we propose that the electronic pedigree can be stored in the RFID tag and transferred with the animal.

RFID is a technology used to identify, locate and track assets. Each RFID tag has a unique number which is called EPC. EPC is an expansion of UPC-like codes, allowing for identifying a specific item (not just their broad classes) (Stapleton-Gray, 2004).

For example, a national standard of animal identification was introduced in china on December 1, 2006, in which the animal's EPC is composed of 64 bits, and is classified into three fields: the first 16 bits are for control, then the 10 bits from 17 to 26 represent country or region, and the rest is serial number (Liu & Shao, 2007).

Now RFID tags have enough memories that allow them to store the electronic pedigree. So in this paper, we suggest that the RFID tag be used to identify an animal, and the electronic pedigree be used to trace its history. Next a CIS is developed to integrate information systems of partners and ensure the animal's movements to be recorded correctly.

Moreover, the electronic pedigree only contains important information about an animal's movements, while other information, for example those about vaccinations, be distributed in information systems and collected by the CIS.

Collaborative Business Process Modeling

Complex systems (such as the CIS) require the development of models as a help to better understand the business domain and as a basis for integrating information systems (Rajsiri, Lorre, Benaben, & Pingaud, 2007).

The Business Process Model is a representation that tries to capture the business process which is essential to the organization's functions (Martins & Soares, 2006). A lot of business processes modeling techniques are developed, from data modeling to behavior modeling techniques (Martins & Soares, 2006), which are in high levels and easy to understand. At the same time there are some low-level ones, such as BPEL4WS, WS-CDL, BPML, WSCI, WSFL, XLANG and WSDL, which are XML based languages (Martins & Soares, 2006).

Business Process Modeling Notation (BPMN) positions itself as a bridge between these two groups and between people who run the business and people who implement the system (Martins & Soares, 2006). Next we will introduce a BPMN-based methodology combined by methods of Rajsiri, Lorre, Benaben, and Pingaud (2007) and Chaari, Binnier, Favrel, and Amar (2006). The objective of this methodology is to build the collaborative business process model and then to develop a CIS. This methodology includes 6 steps, which are shown below.

Step 1: To collect the details about partners.

This step addresses to the definition of partners who collaborate around a product (an animal in this paper). Partners shall be interviewed individually to collect their information, especially their relationships with others. These relationships can be described with a matrix where the rows represent the partners and the columns also represent the same set of partners. If there is an interaction between partner i and partner j, matrix entry (i, j) is assigned a specific value that defines one kind of relationship; and 0 otherwise. It is recommended to investigate more similar products, which will help better understand the business domain.

Step 2: To define roles and their relationships.

When analyzing relationship matrixes in step 1, we will find that many partners are similar. If two partners connect with others in the same way, we would say that they have the same role (Hanneman & Riddle, 2005). Thus we can abstract a few roles from partners.

After defining roles, we continue to analyze relationships between these roles and describe them in a new relationship matrix. Since roles are usually connected for multiple objectives simultaneously (Hanneman & Riddle, 2005), it is suggested that one matrix be created for an objective to avoid complexity.

Step 3: To specify the collaborative business process model using the objective.

If the objective is general, it should be divided into smaller detailed ones, and for each of them a collaborative business process model will be defined. We get one matrix for a smaller detailed objective in step 2, so the collaborative business process model can be analyzed from it.

Step 4: To analyze activities one by one in the collaborative business process model.

Activities are associated with enterprise business functionalities, and must be analyzed one by one. They can be broken down into a finer level of detail, such as tasks, using BPMN as the business processes modeling technique. In previous step, we also use BPMN.

Step 5: To translate the collaborative business process model into a SOA model.

Activities in the collaborative business process model correspond to a set of business components which are made of business objects. Web services can be created from these business components and exposed to be invocated by roles (or partners) in the collaborative environment (Chaari, Binnier, Favrel, & Amar, 2006). A SOA model is an architecture which consists of a set of web services that can be invoked through standard protocols.

Step 6: To use orchestration and choreography for integration.

One can orchestrate and choreograph web services to fulfill an organization's goals (Arsanjani, 2004). Partners can continue to use their own information systems, while a CIS is used for managing the collaborative business process (Rajsiri, Lorre, Benaben, & Pingaud, 2007).

CASE STUDY

In this section, we will apply our solution to the life-time traceability of pets, since many problems in the pet's management are associated with movements of pets, such as dishonest behaviors in transactions.

First we design the electronic pedigree for pets, and then analyze the collaborative business process model and develop a CIS.

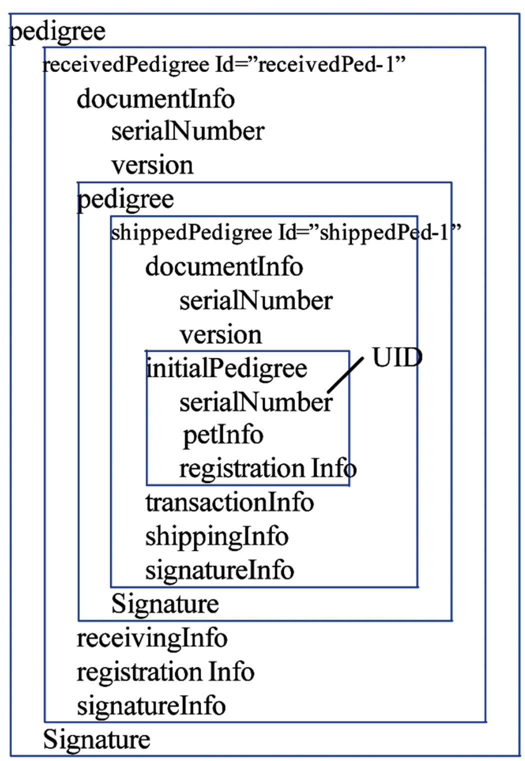
The Electronic Pedigree for Pets

Except for UID, the information recorded in the electronic pedigree for a pet includes:

- PetInfo, such as the specie, sex, birth date and its parents;
- RegistrationInfo, such as ID, name and the owner's information;
- TransactionInfo
- ShippingInfo
- ReceivingInfo
- SignatureInfo

An example of such electronic pedigree is shown below (Figure 1). This example describes a scenario in which a pet is sold from a producer to a customer. Before the sale, the producer must register the pet's birth in a police station; and after the sale the customer has to transfer the pet's ownership in that police station. If one studies the example in detail, he will see that the electronic pedigree can record the registration and transaction, shipping, receiving information in this scenario and help us "see" movements of this pet.

Figure 1. An electronic pedigree



The Collaborative Business Process Model and CIS

Next we will show how to develop the collaborative business process model and CIS step by step.

Step 1

Before survey, we studied Chinese laws and regulations about pets and browsed websites of animal protection associations to understand problems in the life-time traceability of pets. Then we investigated some typical pets in their experiences. Through interviews with their related people, relationship matrixes can be got, from which we can draw networks. Because these networks involve government authorities, individuals and organizations which surround pets, we call them pet-centric networks (Figure 2).

In Figure 2, partners collaborate to better achieve the common objective - the management of a pet.

Step 2

Defining roles can simplify issues that we address to. We can abstract such roles as the producer (A), customer (B), animal clinic (C), animal protection association (D), police station (E), industrial and commercial administration department (F), and animal health authority (G) from partners in pet-centric networks.

Table 1 shows relationships among such roles as the producer (A), customer (B), animal protection association (D) and the police station (E).

Figure 2. A pet-centric network

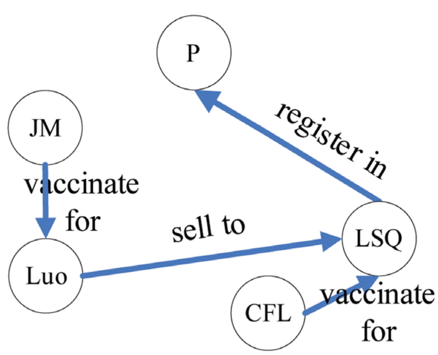


Table 1. Relationships between the police station and other roles

	A	B	D	E
A	0	2	0	1
B	0	2	0	1
D	0	3	0	1
E	0	0	0	0

1-Registration of birth/transfer/year check/missing report/rescue report
2-Sell
3-Adopt

Step 3

The common objective (the pet's management) can be divided into some smaller detailed ones. The most important of them is the life-time traceability of pets, for it we specify a collaborative business process model shown in Figure 3.

Step 4

In Figure 3, the "Register" activity is central in the collaborative business process model, and it can be divided into five smaller activities - register the birth, transfer ownership, yearly check, report missing and report rescue. In this step, we choose the "Register the birth" activity to analyze. This activity runs when a producer brings his or her pet to register the birth in a police station.

After applying RFID tags to identify and electronic pedigrees to trace, the "Register the birth" activity is different from before (Figure 4). First the producer (A) input petInfo and registrationInfo of his or her pet in a blank request. Suppose that the pet has already vaccinated in the animal health authority (G), so a temporary ID which is same as that in vaccinationInfo is filled in registrationInfo. Before approving the producer's request, the official of the police station (E) must inquiry the pet's vaccinationInfo from the animal health authority's information system.

If the producer's request is accepted, his or her pet will be embedded a RFID tag and has a new ID which will replace previous temporary ID in registrationInfo. This change must be reflected in vaccinationInfo in the animal health authority's information system too. The pet's electronic pedigree will be created as initialPedigree and stored in the RFID tag. At the same time it is also stored in the police station's information system. From now on, this electronic pedigree will act as standard data elements transferred between partners, and new information will be continually added to it when the pet moves on.

Figure 3. A collaborative business process model

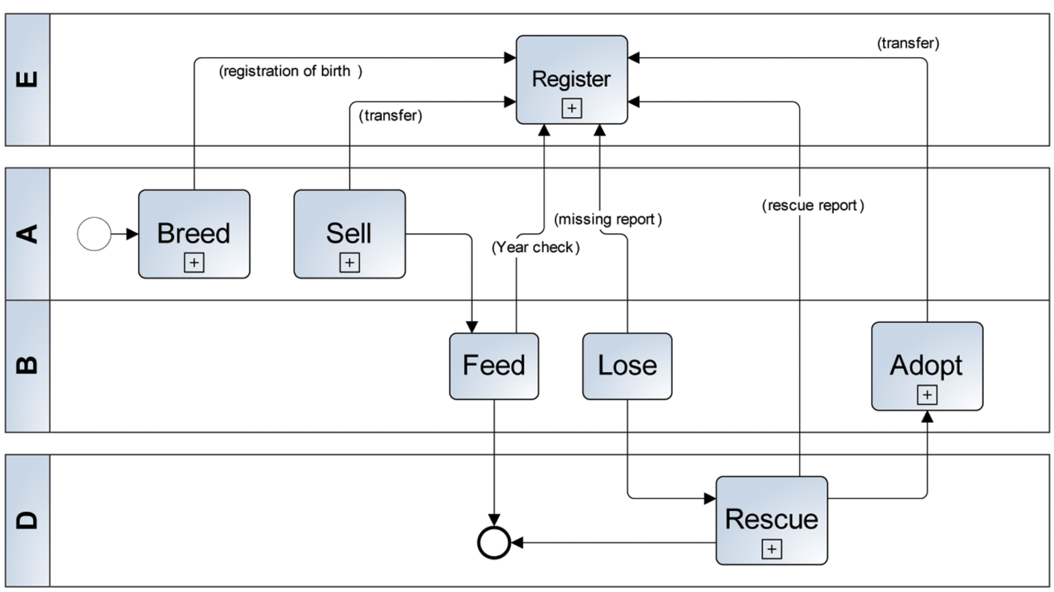
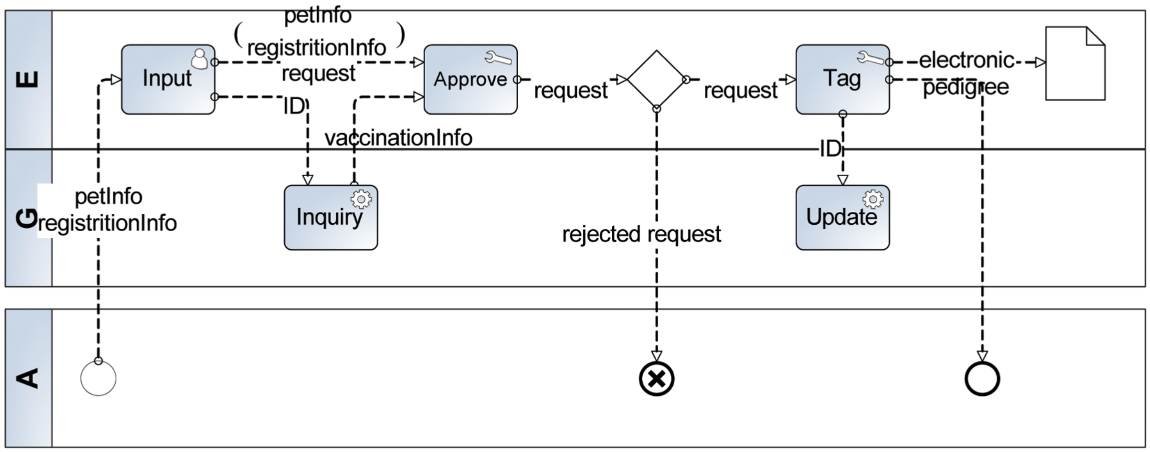


Figure 4. The "Register the birth" activity



Step 5

An important functionality of the police station in the life-time traceability of pets is to provide all kinds of registration activities which respond to business components and can be exposed to the public as web services such as registration of birth, transfer, year check, missing report and rescue report. These web services are part of the SOA model, which are shown in Figure 5.

Step 6

The "Register to birth" activity in Figure 4 is orchestrated from a set of tasks and executed with BPEL. It is run in the police station's information system and must invoke VaccinationInfo web services exposed by the animal health authority's information system.

A CIS is needed to provide access to web services in Figure 5 so that different roles in the collaborative environment can orchestrate web services into their own business processes. Figure 6 is such an example. After finishing the "Sell" activity, we can get the same electronic pedigree as Figure 1.

Based on the SOA model, it is easy for us to develop a CIS to integrate information systems of partners and help realize the life-time traceability of pets efficiently and effectively.

Figure 5. The SOA model

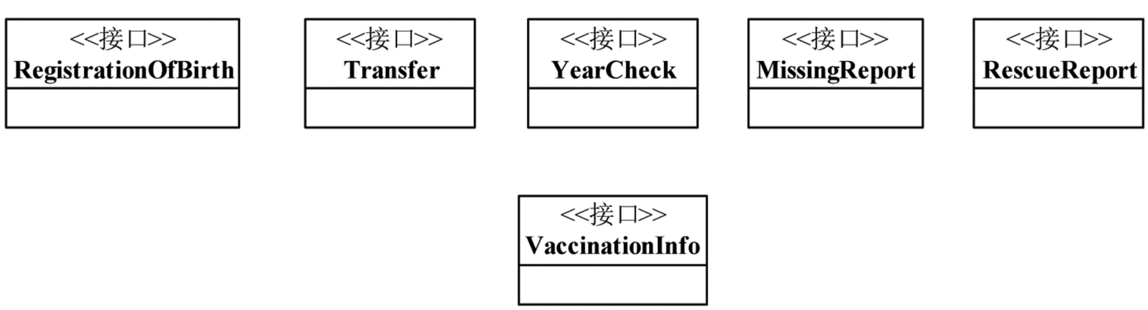
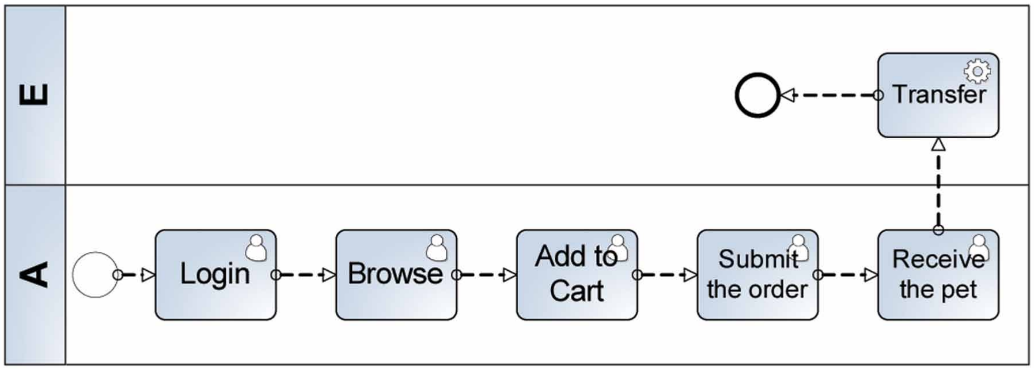


Figure 6. The "Sell" activity



DISCUSSION

In the life-time traceability of animals, the base is to create complete and correct records of animal movements. In order to save these records, some ways are used:

- To store them in RFID tags;
- To distribute them in different information systems. Then in the help of EPCglobal Network Architecture, one can collect parts into a complete electronic pedigree through a query.
- To store all records in a centralized data center.

The latter two must use EPCs as glues to establish connections between records and animals.

Different from above three ways, this paper suggests that the electronic pedigree, which describes important information about an animal's movements, be stored in the RFID tag, and other information, for example those about vaccination, be distributed in information systems and collected by a CIS. Thus in the help of RFID tags to identify and the CIS to integrate information systems of partners, the electronic pedigree can record an animal's history and realize its life-time traceability.

In the case study, we demonstrate that the application of the RFID technology in the life-time traceability of pets help fulfill two important objectives. First, RFID tags can better protect pets from being lost than traditional eartags, tattoos and brands. Second, the electronic pedigree enables the process of breeding, selling, feeding, losing, rescuing and adopting completely visible and helps government authorities to manage pets. For example, if there is an outbreak in a premise, one can trace down and find those sold, sick pets; and if a lost pet is rescued, one can trace up and help it go home.

Our solution has such advantages as the following:

- Reliable

Since the electronic pedigree is stored in the RFID tag, our solution can establish reliable connections between records and animals.

- Convenient to query

Our solution can provide a fast query by reading the electronic pedigree which contains important information about an animal's movements.

- Easy to understand and use

The electronic pedigree complies with the open document model specified by EPCGlobal. For partners in the collaborative environment, such standard data elements are easy to understand and convenient to use for adding their own information.

- Compatible

Our solution is compatible with existing information systems, only requiring the CIS to provide access to some web services.

There are still some weaknesses in our solution. For example, in order to store the electronic pedigree, the RFID tag should have a bigger memory, but this leads to cost increase.

FUTURE RESEARCH DIRECTIONS

While RFID tags and electronic pedigrees facilitate the life-time traceability of animals, it is possible to trace a disease back to its source in short time as NAIS. What we want to do in the CIS is to define affected boundary quickly and notify individuals and organizations in the boundary if there is an outbreak.

Moreover, information about vaccinations is important in prevent spreading of diseases. Because an animal may be vaccinated many times and in different places, its information could be stored in several information systems. So the problem we must resolve in the CIS is to collect this distributed information into a document through a query.

CONCLUSION

This paper proposes a solution to realize the life-time traceability of animals. First, the electronic pedigree can record movements of animals in their lives. Being stored in the RFID tag in an animal's body, the electronic pedigree links with the animal reliably and makes the query of information easier. Moreover the electronic pedigree is based on the open document model, and it acts as standard data elements to be transferred between partners. Second, the development of a CIS ensures movements of animals to be recorded correctly.

With the cost declining of the RFID tag, our solution will become more affordable. In the near future, while the RFID tag has bigger memory and can store more information, it will become easier to record all movements of an animal in the electronic pedigree. Our solution is applied to the life-time traceability of pets in this paper, but it can also be extended to other animals, even to animal products.

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Chapter 3
Image Quality Assessment and Outliers Filtering in an Image-Based Animal Supervision System

Ehsan Khoramshahi
University of Helsinki, Finland

Juha Hietaoja
University of Helsinki, Finland

Anna Valros
University of Helsinki, Finland

Jinhyeon Yun
University of Helsinki, Finland

Matti Pastell
University of Helsinki, Finland

ABSTRACT

This paper presents a probabilistic framework for the image quality assessment (QA), and filtering of outliers, in an image-based animal supervision system (asup). The proposed framework recognizes asup's imperfect frames in two stages. The first stage deals with the similarity analysis of the same-class distributions. The objective of this stage is to maximize the separability measures by defining a set of similarity indicators (SI) under the condition that the number of permissible values for them is restricted to be relatively low. The second stage, namely faulty frame recognition (FFR), deals with asup's QA training and real-time quality assessment (RTQS). In RTQS, decisions are made based on a real-time quality assessment mechanism such that the majority of the defected frames are removed from the consecutive sub routines that calculate the movements. The underlying approach consists of a set of SI indexes employed in a simple Bayesian inference model. The results confirm that a significant amount of defected frames can be efficiently classified by this approach. The performance of the proposed technique is demonstrated by the classification on a cross-validation set of mixed high and low quality frames. The classification shows a true positive rate of 88.6% while the false negative rate is only about 2.5%.

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1. INTRODUCTION

Controlling the welfare of individuals, or a group of animal, is the main responsibility of an image-based animal supervision system (asup) (Khoramshahi et al., 2013). An asup, as an intelligent routine, seeks to provide an agricultural decision-support system (ADSS) with animal's status information by analyzing diverse sources of inputs including image data. Image processing is gradually finding its rule in an asup as a result of decreasing in the processing cost. The state of the art image processing algorithms brings this opportunity to be more feasible and reliable than any other time. Many methods have been developed to use the power of image processing to measure the animal related parameters (such as the image-based movements) in order to give an estimation about a behavior coding (such as aggression, or farrowing).

Although the progress in the concepts of image-processing solutions, that are often acceptable for a controlled situation, is impressive, there is still a remarkable gap between controlled conditions, and real capturing settings that are under the effect of noise and many unwanted factors such as inconsistency in lightening condition or unwanted moving particle, which makes it a good target for developing methods that are more robust to noise, and less dependent on their training conditions.

Digital images, in a real capturing situation, are exposed to a variety of non-physical distortions during acquisition, such as the moving particles, or the poor-lighting condition, as well as the distortions during the processing, compression, storage, transmission, and the reproduction stages. Many of these factors can degrade the visual quality of an image (Wang et al., 2004).

The aim of a quality assessment (QA) research is to propose an algorithm to formulate the effective parameters in order to measure the quality of an image automatically and robustly (Sheikh et al., 2005), and take care or remove a LQ case from an image sequence.

According to the approaches that are employed to quantify the quality of an image as a numeric value, the QA methods are categorized into the following main groups:

- The full reference (FR) methods, which a set of reference images are processed to find the standards for checking the quality of an image.
- The non-reference (NR) methods, that try to find the quality measure with an unsupervised scheme (such as maximizing non Gaussianity by a tool such as kurtosis).

Between the parameters that affect the quality of a surveillance image, the effect of artifacts and the exposure change is covered in this article. The FR-QA methods for the effect of other factors, such as, sharpness, contrast, distortion, and exposure can be found for example in Sheikh et al. (2004), Saad et al.(2012), and Eckert et al.(1998).

The main physical factors, in an asup, that degrade the quality of an image can be considered according to the following categories:

- Changing and fluctuating in the lighting condition (e.g. changing a light switch).
- Small moving particles (e.g. mosquitoes, flies, and bugs).
- Unexpected movements in the borders. (e.g. opening/closing a pen's door).
- Unwanted objects inside the scene (e.g. human worker).

In this study, only the first three groups will be addressed, so the forth group is remained for further studies. The percentage of the frames, that are affected by the first three groups, are relatively low (in many experiments less than 5%), but even this small percentage negatively affects the accuracy and the precision of the consecutive processing routines (such as movement estimator), so within the preprocessing step of an image processing routine, they should be accurately recognized and filtered.

The recognition of the LQ cases from HQs is an easy task for a human operator. One main reason is that the set of common structures between LQ cases could be easily conceived by a human, so a causal mechanism would be form which will lead to detection of LQ cases based on a set of logic. This property makes the problem interesting for a research. Therefore, based on our understanding, the causal line of our cognitive system is carefully followed in this article to mathematically construct a solution for this problem.

During recent years many researchers significantly push the boundaries of the image QA. A comprehensive literature review can be found in Chandler (2013). We only compare two studies that have a similar structure to our implementation. The structural similarity measures have been first proposed by Wang et al. (2004). Accordingly, a structural similarity metric (SSIM) is defined to capture the loss of image structure. In this paper, unlike our approach, structural distortions are assumed to be treated differently from non-structural distortion like variation in lighting or contrast, whereas in our proposed method both distortions are treated in the same way by defining a joint distribution over all parameter. Unsupervised visual quality assessment was recently proposed in Saad et al. (2012). In their article, a perceptual quality of the image based on image feature extraction was studied. Moreover, this paper showed that parameters derived from a generalized statistical model of DCT coefficients could be employed to predict a perceptual image quality score.

Although the recent works are very useful for the general image QA and many special settings, there is still demand in agricultural systems for further development of current trends by analyzing and considering the common causes of quality degradation in a simple way, in order to create customized models that are able to more efficiently work under the noisy supervisory conditions of the asups.

In this paper, we first carefully analyze the set of common causes that affects the quality of frames. We formulate them in a simple way, which makes it possible to judge about the correctness of the model in a close way to our understanding, and then we progressively build a probabilistic model for the set of proposed indexes. For random variable (R.V.) definition, LQ cases are categorized based on their similarities and the common causations. A set of simple R.V.s are introduced for each catalogue of similar images. We demonstrate that our R.V.s beside the probabilistic framework enable the system to gradually achieve an acceptable accuracy level. The probabilistic model, which has been made upon a naive structure, represents the joint distribution of R.V.s in a very simple and efficient way, and provides the asup with a numeric value that represents the probability of a frame to be LQ. Using a more complex structure with a higher likelihood in the probabilistic modeling phase is remained for another study and is not covered in this article. Despite the false assumptions that has been made to make the modeling phase as simple as possible, the proposed framework is capable of recognizing the majority of the LQ frames. Finally, an important application of our model in recovering an original movement signal of a sow's movement from a noisy measurement will be demonstrated.

In the first part of this article, the set of proposed indices are listed and described, then our probabilistic model is proposed, and finally the results are presented.

2. MATERIAL AND METHOD

A data base consists of 7 days/sow of purely indoor surveillance for 7 sows for 24 h during the day and night was recorded, to develop an alerting image-based system which will be used to predict the farrowing moment of sows for the farmers. Each single recording consists of a video of a sow kept in farrowing crate of (220 x 75 cm). In each farrowing session, 8 surveillance cameras (Tracer TS 6030PSC IR), with a capture rate of 12 fps, were connected via cables to a central recording unit (Philips SAA7130HL) at the height of 2.5 m. All the cameras were equipped with IR emitters, to monitor in poor lighting conditions, and were configured to capture frames with a resolution of 352 x 288 pel2 (MPEG-4 codec). The video dataset was preprocessed in order to extract frames with a 20-second time shift, and filtered with a Gaussian kernel. We filtered a total of 2,890,163 frames. Among them, we selected a total number of 1000 frames from 5 different random sows with dissimilar lighting conditions and color content as a training database for the training step. The data set was divided into three parts: a training, test, and cross-validation set with 70%, 20%, and 10% contributions, respectively. In order to make a supervised classification, the low-quality and noisy images has been marked by a human operator and categorized. Similarities between each category have been analyzed in order to define the set of R.V.s.

The recognition phase is performed according to the following steps:

- A modified version of the Kohonen self-organizing map (K-SOM) has been employed for the discretization step.
- A light-weight and optimized C++ implementation of a singly/multiply connected probabilistic graphical models has been developed and employed for FFR and RTQS tasks.
- For the inference phase, Pearl's message passing algorithm has been developed and deployed. Based on the development simplicity, and the ease of inference, a Naive Bayes model has be chosen as the graphical structure for our joint distribution model. Dirichlet conjugate prior has been considered as the distribution for model parameters. Non-informative Jeffrey prior has been selected, and updated according to Bayes rule, in order to calculate the family of posterior distributions.
- The posterior means of the model parameters have been calculated and employed in the final model development.

3. PREPROCESSING

In this section, the mathematical foundation of the processing phase is developed. It is a common practice in many agricultural image processing routines to calculate the image-based movement by calculating an average image over a period of time and subtracting the current frame from it in order to estimate the total movement. The number of bright pixels in the resultant image will be consequently counted as the estimate (see for ex. Viazzi et al. (2011)).

Suppose that I(x,y,i) represents the gray value of i^{th} frame in location (x, y) where x and y are integer values in range (0;W] and (0;H] respectively, and (t) is integer variable with values in range [1; Frame count], where two consecutive frames has 20 sec. time delay, then the local mean image at time (t) with an interval of (n) is defined as:

$$\bar{I}_n\left(x,y,t\right)=\frac{1}{n}.\sum_{i=t-n+1}^{t} I\left(x,y,i\right) \tag{1}$$

Afterward, the movement image at time (t) with interval (n) is defined as:

$$M_n\left(t\right)=abs\left(I_t-\bar{I}_n\left(t\right)\right) \tag{2}$$

Accordingly, the resultant movement image is filtered to reduce the effect of the Gaussian noises by convolving with a Gaussian kernel with parameter σ :

$$\begin{aligned}\overline{M}_n\left(t\right)=M_n\left(t\right)*G\left(\sigma\right)=\\ \iint_{x,y} M_n\left(x-\tau_1,y-\tau_2\right).G\left(\tau_1,\tau_2\right)d\tau_1.d\tau_2\end{aligned} \tag{3}$$

which in a discrete setting is expressed as:

$$\begin{aligned}\overline{M}_n\left(t\right)=M_n\left(t\right)*G\left(\sigma\right)=\\ \sum_{n_1=F_w}^{W-F_w}\sum_{n_2=F_h}^{H-F_h} M_n\left(x-n_1,y-n_2\right).G\left(n_1,n_2\right)\end{aligned} \tag{4}$$

Finally, In order to reduce the effect of outliers and unwanted movements, the gray values that are higher than a threshold are saved:

$$\hat{M}_n\left(t\right)=\begin{cases}0, & If\,\overline{M}_n\left(t\right)<Thteshold\\ \overline{M}_n\left(t\right), & Otherwise\end{cases} \tag{5}$$

At this moment, the resultant movement image is a suitable input for any further analysis which leads to the definition of the R.V.s for QA and RTQS.

4. COMMON-CAUSE CLUSTERING AND R.V. DEFINITION

According to our analysis of a human visual and cognitive understanding about the LQ cases, we grouped them into the following categories, each of which has one or more common causes:

- **Sudden Changes in a Lighting Condition:** Turning the lightening on/off is the main reason for this group. The parameter (C_{mv}) will be developed to formulate the common cause.
- **Sudden Movements:** A recording noise is the main reason for this group. The parameter (AND_l) will be defined to describe the common cause.

- **Flying Particles:** Flies and air particles are the main reasons for this group. The parameter (D_l) will be defined to formulate the common cause.
- **Marginal Movements:** Opening/closing the pen's door as well as the marginal movements are the main reasons for this group. (C_{mg}) will be defined to capture the main reason for this group.

Beside the above R.V.s, an additional set of them will be defined that are shared between all the above groups.

A common flag for detecting a noisy frame is an unusual high number of moving pixels. We consider the cases with this common cause as the first group of affected LQ frames. The bright pixel count of a filtered movement image is defined as the first R.V. according to the following definition:

$$C_{mv}\left(I_t\right) = \sum_{x=F_w}^{W-F_w} \sum_{y=F_h}^{H-F_h} (\hat{M}_n\left(x,y,t\right) > 0 \ ?1 : 0) \tag{6}$$

In Equation (6), if the conditional of $\hat{M}_n\left(x,y,t\right) > 0$ is satisfied then (1) will be added to the summation, otherwise (0) will be added.

A sudden movement can be formulated as the considerable change between two consecutive movement frames, so the pixel count of logical ''AND'' Operator between the current and the previous movement image is defined as the second R.V., and represented by (AND_l), which has the pixel unit. In order to define (AND_l), the result of logical ''AND'' Operator between the current and the previous movement image is calculated according to the follows equation:

$$I_{AND_l}\left(t\right) = \overline{M}_n\left(t\right) \wedge \overline{M}_n\left(t-1\right) \tag{7}$$

Consequently, AND_l is defined as the pixel count of Equation (7):

$$AND_l\left(t\right) = \sum_{x=F_w}^{W-F_w} \sum_{y=F_h}^{H-F_h} \left(I_{AND_l}\left(t\right) > 0 \ ?1 : 0\right) \tag{8}$$

Another indicator which captures an unusual sudden movement is the absolute difference between the current and the previous movement's pixel count (D_l). This parameter is considered to as the third R.V., which is able to describe some illegitimate movement cases that seems to be legitimate based on AND_l. Specifically, D_l is an indicator for a sudden bright movement with low AND_l value that is occurred in the movement sequence. Therefore despite the fact that the cause is similar to AND_l, the modeling effect is different. This R.V. is defined according to the following equation:

$$AND_l\left(t\right) = \left|\sum_{x=F_w}^{W-F_w}\sum_{y=F_h}^{H-F_h}\left(\hat{M}_n\left(x,y,t\right)>0\ ?1:0\right) - \sum_{x=F_w}^{W-F_w}\sum_{y=F_h}^{H-F_h}\left(\hat{M}_n\left(x,y,t-1\right)>0\ ?1:0\right)\right| \tag{9}$$

In order to take into account the second order changes, a set four parameters: AND_{sl}, D_{sl}, AND_{tl} and D_{tl}, are defined with a similar structure, for the previous frame.

The parameter (C_{mg}) is the next R.V. in our modeling phase, which is the number of pixels in the marginal clusters. In order to calculate (C_{mg}) connected clusters are specified by applying a component labeling on the following binary image:

$$\overline{\overline{M}}_n\left(t\right) = \begin{cases} 0, & If\,\overline{M}_n\left(t\right) < Thteshold \\ 1, & Otherwise \end{cases} \tag{10}$$

Figure 8 shows the result of component labeling on a sample LQ case. In this figure, each cluster has been painted by a color that is selected from a wheel. After the clustering, regions, which have intersection with borders, have been marked, so C_{mg} has been accordingly calculated:

$$C_{mg}\left(I_t\right) = \sum_{x=F_w}^{W-F_w}\sum_{y=F_h}^{H-F_h}\left(\left(\begin{array}{l}\overline{\overline{M}}_n\left(x,y,t\right)>0\ \ \& \\ IsBorder\left(C\left(x,y,t\right)\right)\end{array}\right)?1:0\right) \tag{11}$$

In Equation (11), the $C\left(x,y,t\right)$ is the cluster assignment for the pixel $\left(x,y\right)$ in the frame (t). The function $IsBorder\left(c\right)$ returns (true) when the cluster $\left(c\right)$ has an intersection with the image borders. The number of the clusters $\left(N_c\right)$ is also considered as a new R.V. which can take care of the cases that the number of clusters is considerably high.

Another factor that our causal cognitive system uses to detect an outlier is the size of the biggest cluster. After the component labeling, the biggest cluster can be easily specified, so its bounding box is calculated, and accordingly, the width and the height of the box are considered to be the next two R.V.s: BB_w and BB_h. Afterward, the pixel count of this biggest region also has been considered as an R.V. to capture the cases that a dense pattern with relatively small bounding box is a source of error. These R.V.s improve the modeling accuracy by taking into account the cases that BB_w and BB_h are logical, but the number of the bright moving pixels is not usual.

Finally, the borders of an image are the target for the definition of the last R.V. . The parameter (C_{br}) is the number of bright bordering pixels in the movement image ($\overline{M}$), that is calculated according to the following definition:

$$C_{mv}\left(I_t\right) = \begin{array}{l} \sum_{x=F_w}^{W-F_w}\sum_{y=F_h}^{H-F_h}\left(\overline{\overline{M}}_n\left(x,0,t\right)>0 \ \ ?1:0\right)+ \\ \sum_{x=F_w}^{W-F_w}\sum_{y=F_h}^{H-F_h}\left(\overline{\overline{M}}_n\left(x,H,t\right)>0 \ \ ?1:0\right)+ \\ \sum_{x=F_w}^{W-F_w}\sum_{y=F_h}^{H-F_h}\left(\overline{\overline{M}}_n\left(0,y,t\right)>0 \ \ ?1:0\right)+ \\ \sum_{x=F_w}^{W-F_w}\sum_{y=F_h}^{H-F_h}\left(\overline{\overline{M}}_n\left(W,y,t\right)>0 \ \ ?1:0\right)+ \end{array} \quad (12)$$

Table 1 shows a sample measurement for all of the features from the test LQ case movement of Figure 2.

5. FFR AND RTQS BY NAIVE STRUCTURE

Probabilistic graphical models (PGMs) have a successful history of deployments in a variety of practical systems, from genetic analysis to financial system. Based on the flexibility and the abilities that a PGM provides, it is employed for creating a probabilistic classifier. The aim of the FFR and RTQS step is to calculate the probability of a frame being LQ. Graphical models are the family of probabilistic models that can be also expressed as both directed and undirected graphs. In this graph, nodes represent the R.V.s, while edges show the dependencies between them. This graph can basically represent the conditional independences that exist between the R.V.s. Despite the fact that finding the hidden structure of the graph is a desirable task, but using it makes the modeling phase and inference step so difficult (Koller & Friedman, 2009).

Table 1. List of the measured R.V.s for a sample LQ case

Parameter Name	Parameter Value	Parameter Name	Parameter Value
LQ Index	1	C_{mv}	18626
AND_l	2834	D_l	9998
AND_{sl}	1508	D_{sl}	16224
AND_{tl}	1866	D_{tl}	15669
C_{mg}	11205	N_c	33
BB_w	167	BB_h	214
C_{br}	12780	C_{bt}	10730

Naive Bayes Model is one of the simplest structures that can be employed to build a PGM. It has been successfully employed in many classification tasks. The conditional independencies entailed by this model are based on the false assumptions. These assumptions are required to keep the modeling phase and inference simple. The main advantage of using a Naive structure is the relatively small number of parameters and a handy algorithm for the inference (Neapolitan, 2003).

By employing a Naive structure, we assume that the joint distribution between the underlying variables follows a simple format as below:

$$\begin{aligned}&P\left(C, C_{mv}, AND_l.C_{sl}, AND_{tl}, \ldots\right) = \\ &P\left(C\right).P\left(C_{mv} | C\right).P\left(AND_l | C\right).P\left(AND_{sl} | C\right).P\left(AND_{tl} | C\right) \times \ldots\end{aligned} \tag{13}$$

In this study, the R.V.s are adjusted to take more than two values (different settings between the rage (4 to 7) has been considered) during the discretization phase, so the conjugate prior for parameters should be selected from a Dirichlet family. Although a suitable informative prior could be very beneficial for many practical problems, a sample size of one is considered in order to create a uniform non-informative prior distribution. The posterior distribution is accordingly estimated by applying the Bayes rule, and updating the conditional distribution tables, as follows:

$$P\left(\theta | X\right) = \frac{P\left(X | \theta\right) P\left(\theta\right)}{\sum_{\theta} P\left(X | \theta\right)} \tag{14}$$

Based on the Bayes formula (Equation 14), during the training phase, the prior distribution is transferred to estimation about the family of posterior distribution, by considering the list of the observations. One of the main advantages of using PGM over other approaches, such as neural network, is that the RTQS by PGM is possible even in the conditions where an incomplete set of observation exist. This capability in some cases improved the overall capability of the system. Despite the fact that the Naive Bayes model provides acceptable results for FFR and RTQS, we should logically expect to see better classification accuracies and more logical inferences by employing the most probable structural relationship.

6. RESULTS

Figure 1 demonstrates an example of the effect of a sudden change of the lighting condition on the calculated movement image. The effect of turbulence in lighting on the movement image is demonstrated in Figure 3, which caused a sudden aperture change in the camera. Figure 3 depicts the negative effects of different types of flies on the movement images, which in some cases can be also observed as a sudden change in the aperture of the camera.

Figure 4 and Figure 5 depicts the distribution of the HQ and LQ frames with respect to the proposed R.V.s, whereas Figure 6 and 7 demonstrate the cumulative performance metrics after defining a specific SI index.

As Figure 4 shows, the concentration of HQ cases is around two linear parts that are close to the center. The distribution of HQ and LQ frames with respect to the rest set of proposed R.V.s. is demon-

Figure 1. Light change effect on movement image. The First row contains the original images; the second row contains the movement images.

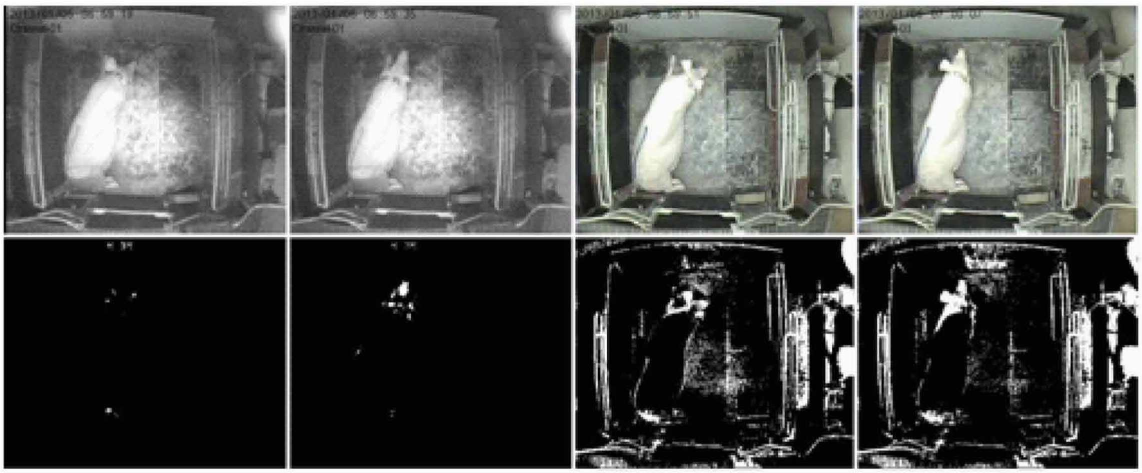


Figure 2. The effect of flies on the movement images. In each group, the first row contains the original images, and the second row contains the corresponding movement images.

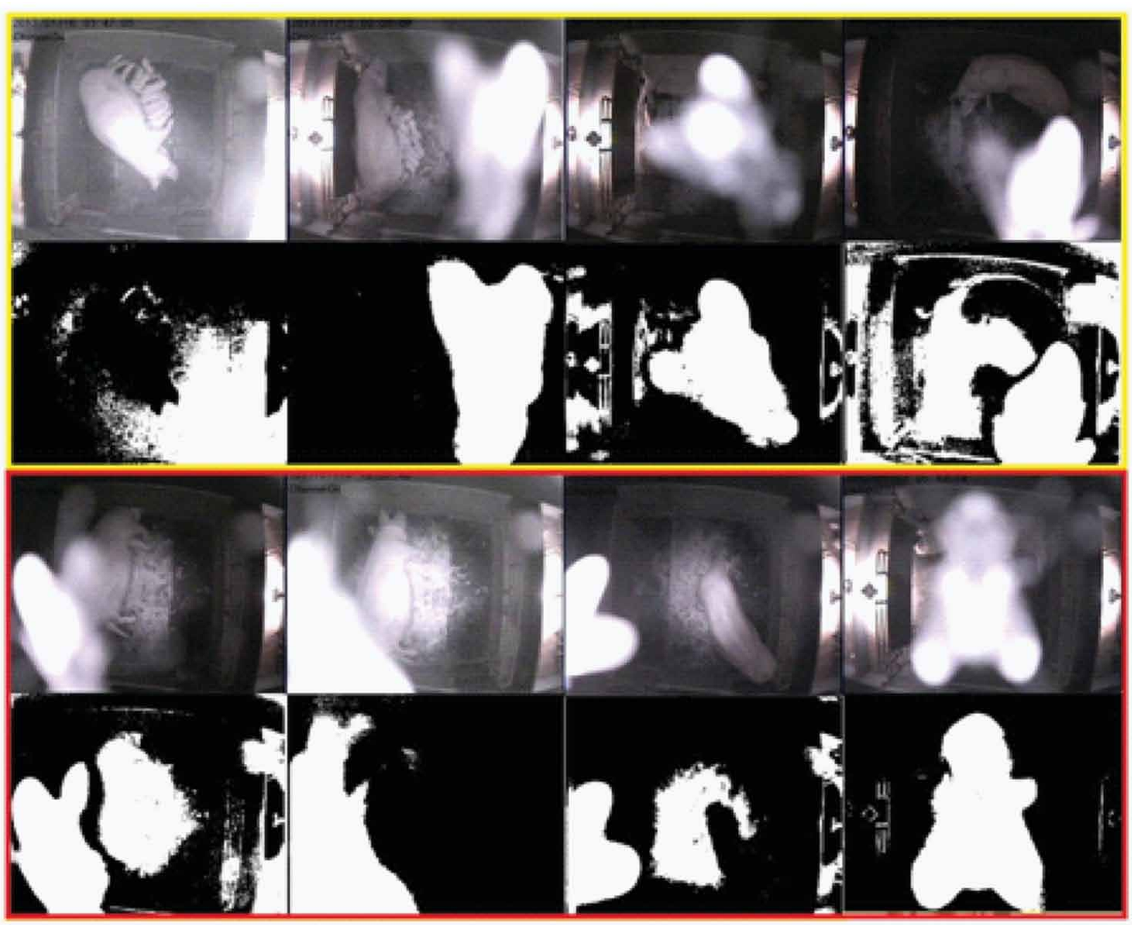


Figure 3. Light fault effect on movement image. The First row contains the original images; the second row contains the movement images.

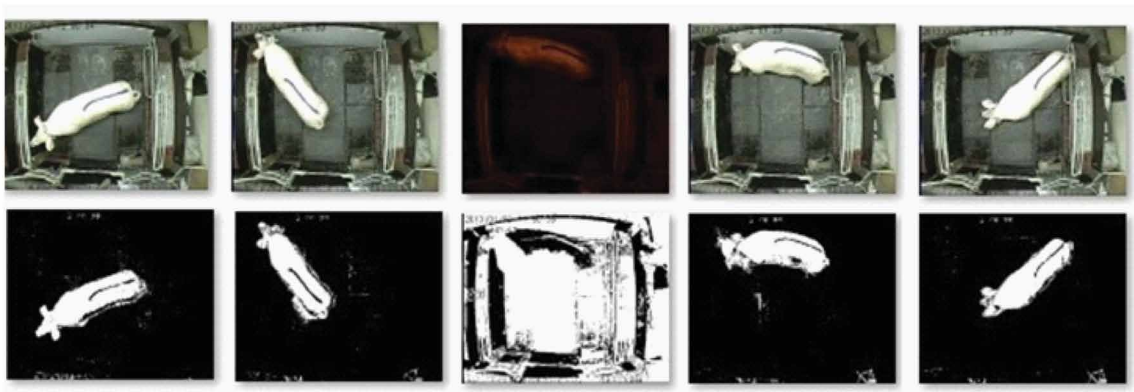
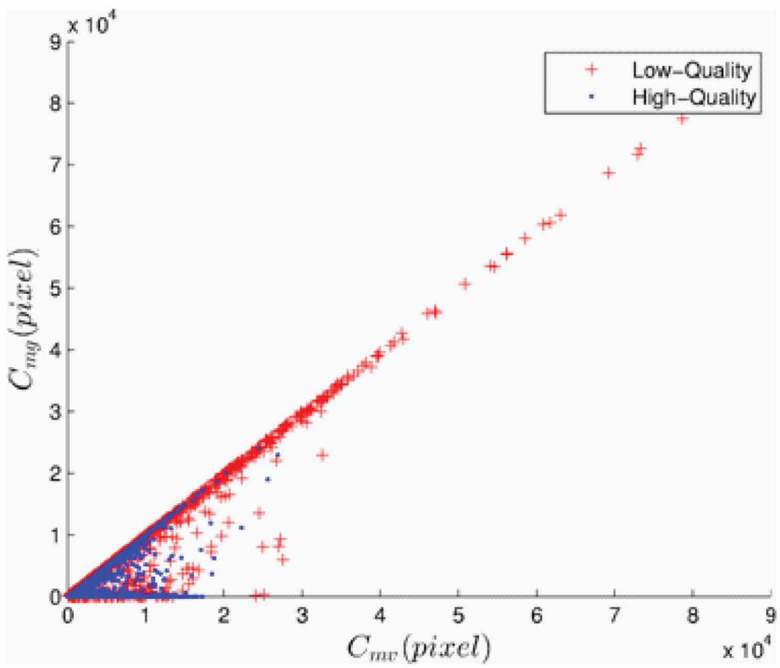


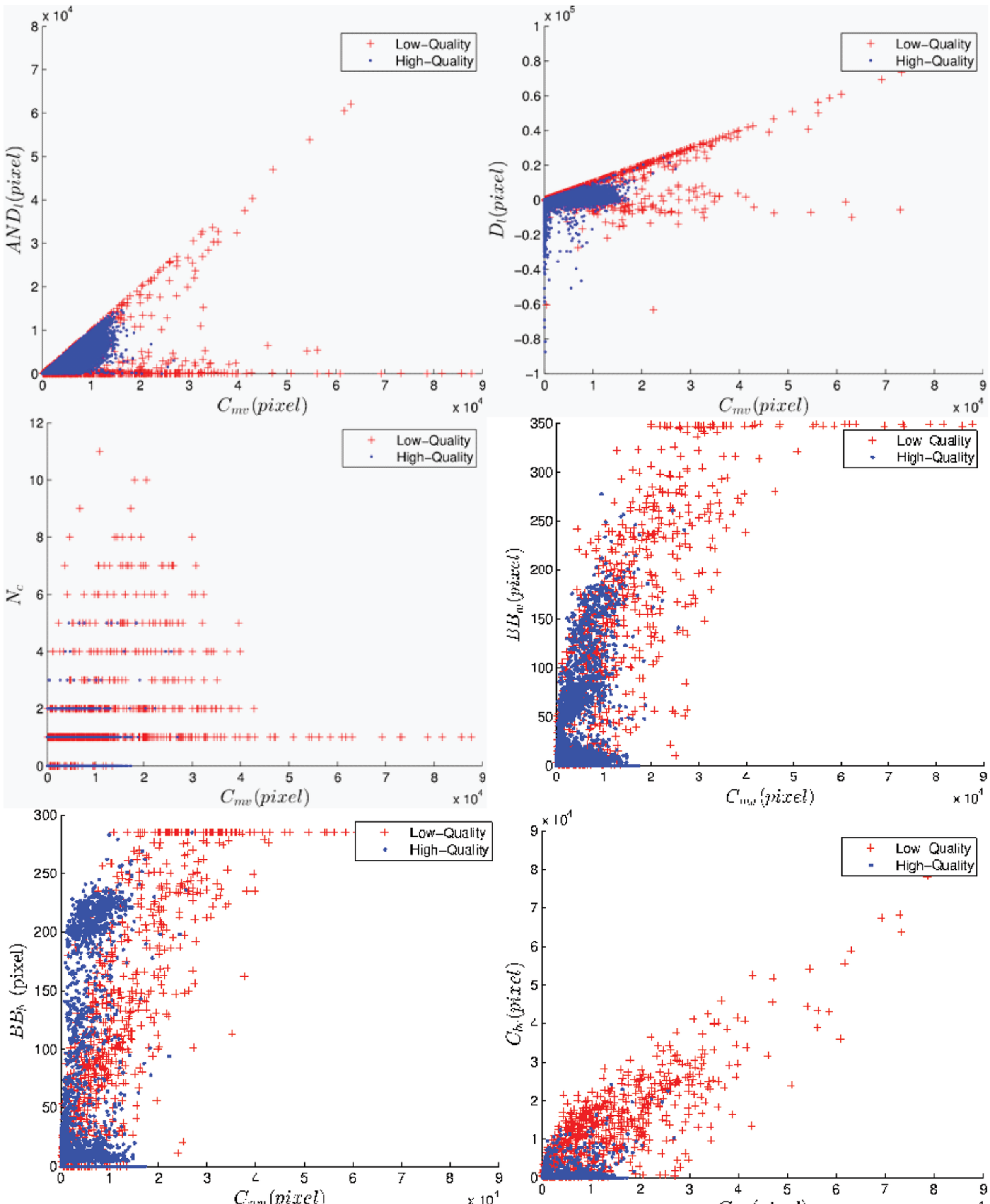
Figure 4. The distributions of the positive and negative cases with respect to C_{mg} and C_{mv} in the training database



**For a more accurate representation see the electronic version.*

strated in Figure 5. In part (A) of this figure, the distribution is shown according to (AND_l) and (C_{mv}). Obviously, the concentration of the HQ cases is mainly at a triangular area bounded by two linear boundaries on the central region, while a noticeable part of LQs are distributed closely at the borders, and also far from the central triangular region. Part (B) depicts the distribution in terms of (D_l) and (C_{mv}). Discrete concentration of the HQ cases is illustrated in Part (C), that depicts the distribution of LQ and HQ

Figure 5. The distributions of the positive and negative cases with respect to AND_l, C_{mv}, N_C, *and* BB_h *in the training database*



**For a more accurate representation see the electronic version.*

Figure 6. The cumulative performance metrics. The model complexity is increasing from left to right.

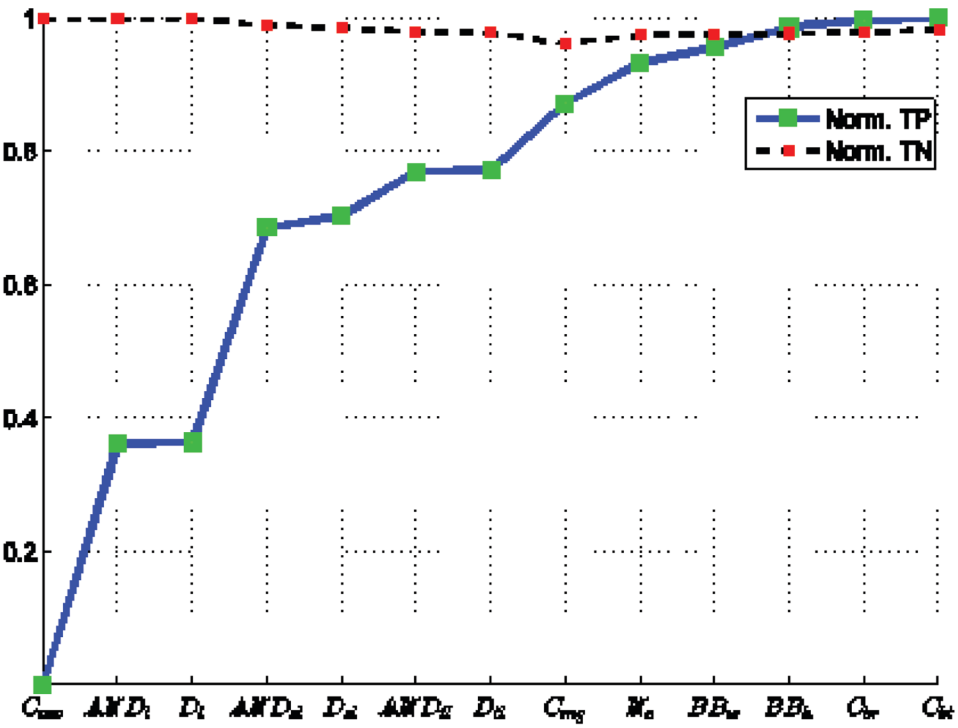
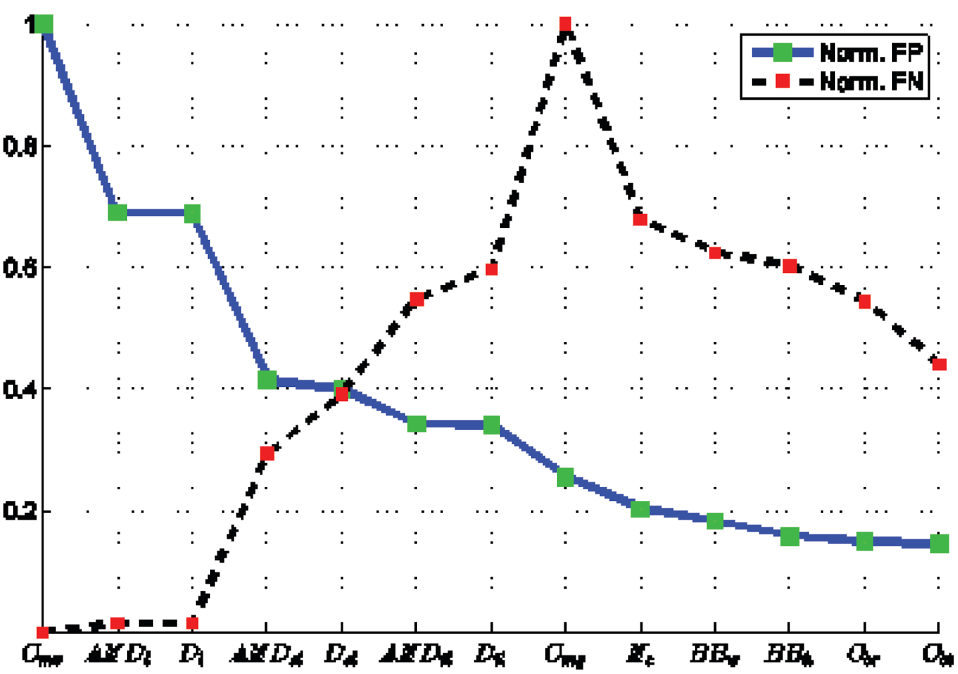


Figure 7. Cumulative normalized FP and FN curves. The model complexity increases from the left to the right.



frames with respect to the (N_c) and (C_{mv}). As expected, HQs are mainly concentrated around the central region, while the LQ cases, that have larger number of clusters, are spreading far from the origin. Part (D) and (E) shows the distribution of the HQ and the LQ cases regarding to (BB_w) and (BB_h). In both figures, a similar pattern for a decision boundary could be imagined to recognize the positives from the negatives. Finally, Part (F) demonstrates the distribution of the HQ and the LQ cases regarding to (C_{br}) and (C_{mv}). Obviously, the high concentration of HQ cases is around the center, while the optimal decision boundary is different from the other R.V.s, which confirms the different behavior of this index.

In Figure 6, as we move from left to right, higher numbers of R.V.s are contributing in the resultant model. As we expected, performance metrics are almost constantly improving after defining most of the R.V.s.

Figure 8 shows the result of the compound labeling on a sample movement image. A measurement for this sample frame has been made, that is demonstrated in Table 1.

In Figure 9, the movement signal of a sow during 7 hours has been measured by using Equation (5). The FFR and RTQS have been automatically done by the proposed model, and also by a human operator. Part (2) of this figure shows the resultant signal after automatic removal of the defected list of frames, whereas Part (3) demonstrates the filtered signal after supervised filtering.

7. DISCUSSION

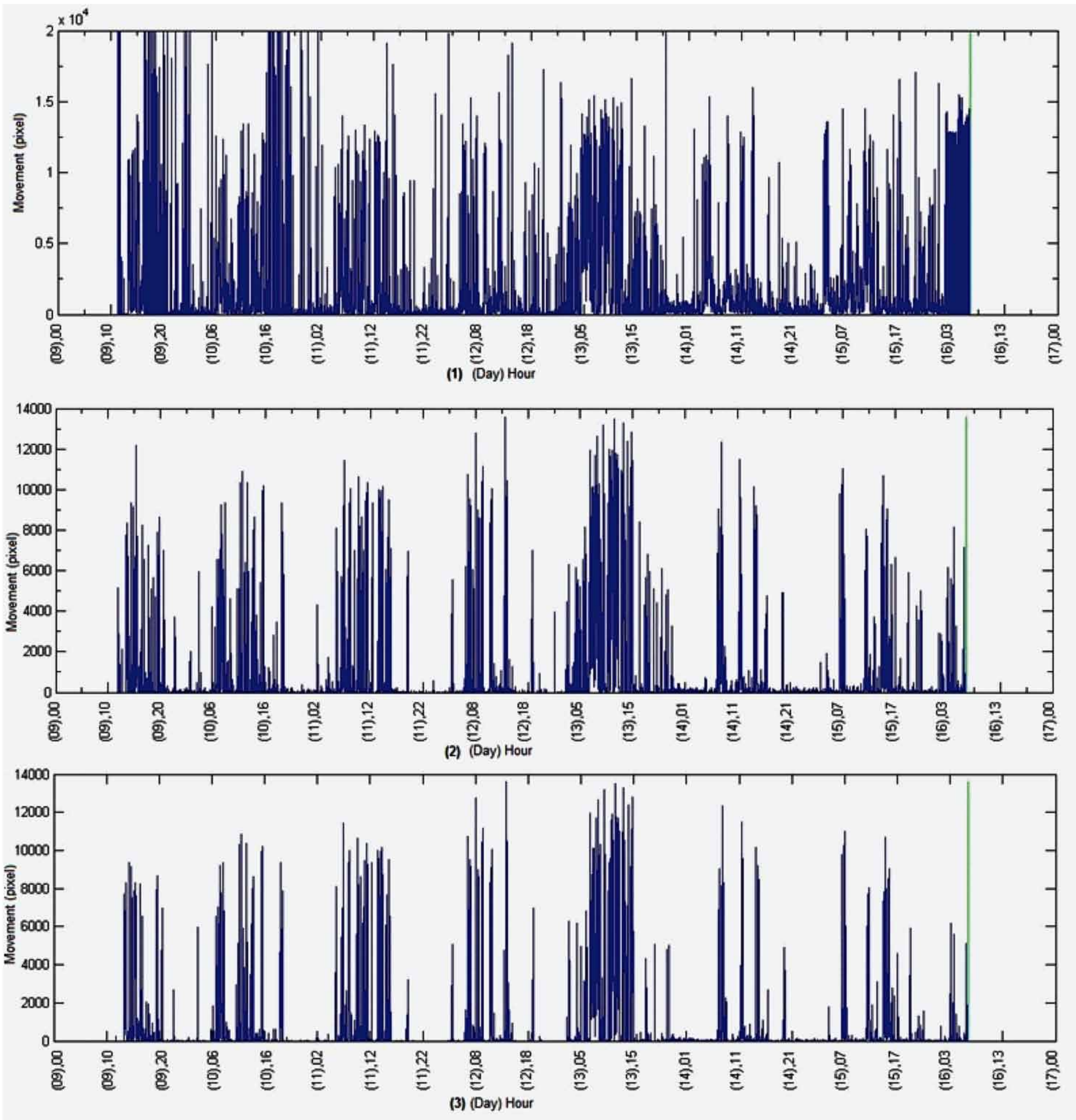
Our model is demonstrated to be elegant in detecting the majority of LQ cases. The model accuracy is consistently increasing by employing higher number of SI indices.

A main pitfall of the PGMs is the requirement for discretization of continuous variables. The Modeling phase of discrete R.V.s with large number of permissible values with PGMs are problematic, because it will increase the number of model parameters, and makes the inference step unstable, specially for the cases that a network is trained by using small datasets.

Figure 8. Left: a movement image; Right: the result of the compound labeling on the filtered movement image. Each cluster is painted by a color from a wheel.

**For a more accurate representation see the electronic version.*

Figure 9. (1) Movements before noise detection, (2) Movements after FFR and RTQS, (3) Movements after visual filtering.



Clustering is a required preprocessing step to make the number of permissible values (for each RV) limited. K-Means is the easiest and the most common clustering technique than can be employed, but the resultant clusters of the K-Means are unconditionally free, and could be far from each other without a limitation, so the resulting cluster centroids, in many settings, couldn't be suitable representatives of the whole range of the values. Self organizing map (SOM), on the other hand, brings the possibility of calculating a set of cluster centroids that are connected together by a topological structure. In this study, we used a one-dimensional topology with a dynamic connections mechanism, that unlike the classic SOM which each cluster centroid was calculated by a mean over its own and its neighbors assigned members, our modification has extended the use of the neighboring cluster points by employing a coefficient proportional to the distance between the neighboring cluster centroids, so our modification made a connection to acts in a similar way to a spring, the force of which is proportional to the geometric distance between two neighboring cluster centroids. The classification performance metrics show a slight improvement of 2% by employing our modification.

The acceptable slope of (C_{mg}) in Figure 6 (28% model improvement) confirms the positive effect of C_{mg} on improving the model. As depicted in cumulative performance metric (Figure 6), the definition of C_{br} improves the model accuracy by detecting new set of LQ cases. The slope of cumulative model, after defining BB_w and BB_h, also shows their positive effects, which are slightly at the same level.

In Part (B) of Figure 5, the HQ cases tends toward negative side, whereas the LQ cases are distributed with a different pattern which mostly tends toward the positive side. The cumulative model, concerning $\left(AND_l\right)$ and (D_l), resulted in 38.5% accuracy. As depicted in Figure 6, the largest pick in model accuracy is related to the definition of $\left(AND_{sl}\right)$. The cumulative accuracy after defining this index led to 67.5% classification accuracy. The same correlation between (AND_{sl}) and (D_{sl}) like their ancestor causes the (D_{sl}) to be the least effective between model parameters.

Progressive model metrics (Figures 6 and 7) shows that definitions of RVs are constantly improving the model ability in detecting the LQ cases. By adding more RVs, despite the progressive decrease in FP rate, FN rate is increasing up to the definition of (C_{mg}), but then the normalized FN rate shows rapid decrease (Figure 7). According to the fact that the FN cases in movement analysis are at a lower level of importance than FP cases, we can safely ignore the side effect of the small increase in the FN rate.

Despite the positive effect of adding (D_l) to the model, the progress rate is not as efficient as the other variables. The reason for this negligible improvement in model accuracy is related to considerable positive correlation between (D_l) and (AND_l), which means that (D_l), (D_{tl}) and (D_{sl}) probably could be replaced with more efficient R.V.s in the future. The cumulative performance metrics showed that after defining all the R.V.s, the model accuracy reaches to an acceptable performance level. The total movement, as depicted in Figure 9, has been clearly improved by detecting and removing LQ cases.

Despite the fact that the Naive structure has acceptable performance, a better probabilistic structure among the R.V.s is still expected to result in a better accuracy, so the structural learning and its effect on the classification task is remained for our further studies.

Our proposed probabilistic framework has been proved to work well as a noise filtering engine of an asup where the LQ frames should be detected and removed.

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Chapter 4
Microchip-Induced Tumors in Laboratory Rodents and Dogs:
A Review of the Literature 1990–2006

Katherine Albrecht
CASPIAN Consumer Privacy, USA

ABSTRACT

This chapter reviews literature published in oncology and toxicology journals between 1990 and 2006 addressing the effects of implanted radio-frequency (RFID) microchips on laboratory rodents and dogs. Eleven articles were reviewed in all, with eight investigating mice and rats, and three investigating dogs. In all but three of the articles, researchers observed that malignant sarcomas and other cancers formed around or adjacent to the implanted microchips. The tumors developed in both experimental and control animals and in two household pets. In nearly all cases, researchers concluded that the microchips had induced the cancers. Possible explanations for the tumors are explored, and a set of recommendations for policy makers, human patients and their doctors, veterinarians, pet owners, and oncology researchers is presented in light of these findings.

PROBLEMS WITH MICROCHIP IMPLANTATION: AND WHY THEY MATTER

Since their introduction in the late 1980s, implantable microchips have become the industry standard for identifying mice and rats used in laboratory research. Animal shelters and veterinarians now routinely inject microchips into dogs and cats. More recently, there has been a push to implant microchips into people for security and building access, to manage medical records, and to identify elderly patients.

American workers at the now-defunct CityWatcher surveillance company (VeriChip Corp., 2006) and officials with the Mexican Attorney General's office (Applied Digital Solutions, 2004) have been microchipped. Concern that the practice could spread has raised the specter of Big Brother and prompted lawmakers in three states to pass laws preventing the forced or coerced implantation of microchips in human beings. California, Wisconsin, and North Dakota have all passed laws banning forced or coerced microchip implantation in human beings. See: California SB 362 (2007), Wisconsin AB 290 (2005), and North Dakota SB 2415 (2007).

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There is now an ongoing debate regarding the safety of the chips. As a result of lobby pressure combined with heavy advertising by Schering Plough for its HomeAgain pet recovery system, close to 5% of the United States' estimated 164 million dogs and cats have now been chipped (Banfield the Pet Hospital, 2005). Animal shelters around the United States are routinely chipping dogs and cats before releasing them for adoption, and governments, including those of Portugal, Singapore, Bangkok, Los Angeles County, and El Paso, Texas, have passed ordinances requiring that all dogs under their jurisdiction be microchipped. El Paso has extended the chipping mandate to cats and ferrets.

In addition, horses around the nation are also being chipped, and the USDA recently approved the use of equine radio-frequency identification (RFID) injectable transponders as part of the National Animal Identification System (NAIS). The National Animal Identification System (NAIS) is a national premises registration, animal identification, and animal tracing program for owners of livestock. NAIS is a national program run by the United States Department of Agriculture (USDA), but is being implemented primarily at the state level.

As for human beings, an estimated 300 Americans and 2,000 people worldwide have been implanted with microchip transponders. This chipping apparently proceeded with the full consent of the implantees until early 2007, when the VeriChip Corporation began implanting Alzheimer's patients and their caregivers with microchips as part of a research study. These patients have reduced mental capacity and are unlikely to understand what is being done to them.

It appears that few people undergoing microchip implantation have been told about the potential health risks associated with the device. In fact, up until September 2007, almost three years after FDA approval, no mention had been made by the company or the FDA in relation to the well-established, though generally under-reported, finding that the microchip caused cancer in laboratory mice and rats.

Microchip-Induced Cancer in Mice and Rats

In at least six studies published in toxicology and pathology journals between 1996 and 2006, researchers found a causal link between implanted microchip transponders and cancer in laboratory mice and rats. The tumors were typically sarcomas, including fibrosarcomas. Other cancers found included rhabdomyosarcoma, leiomyosarcoma, malignant fibrous histiocytoma, mammary gland adenocarcinoma, malignant schwannoma, anaplastic sarcoma, and histiocytic sarcoma.

In almost all cases, the tumors arose at the site of the implants and grew to surround and fully encase the devices. In several cases the tumors also metastasized or spread to other parts of the animals, including the lungs, liver, stomach, pancreas, thymus, heart, spleen, lymph nodes, and musculature of the foreleg.

The tumors generally occurred in the second year of the studies, or after half a lifetime's exposure to the implant. At the typical time of tumor onset the animals were in middle to advancing age. The exception to this was the Blanchard (1999) study, in which genetically modified mice developed fast-growing cancers well before six months.

The percentage of mice and rats developing microchip-induced tumors in the six studies reviewed ranged from 0.8% to 10.2%. Several researchers, including Elcock et al. (2001), Le Calvez et al. (2006), and Tillmann et al. (1997) suggest that the actual rate of tumor formation may have been higher than was reported in their studies, since they examined only visible lesions and thus may have missed microscopic changes that signaled the onset of additional tumors around the implants.

Elcock et al. (2001) write, "It should be noted ... that these tumor incidences only approximated the potential incidence of microchip-induced tumors for these studies. The original intent of the studies was to characterize the toxicological profile of the chemical test substance in question, therefore tissue surrounding the animal-identification microchips was not examined microscopically unless there was a gross lesion. Thus, small pre-neoplastic or neoplastic lesions may have been missed" (p. 488).

A similar observation was made by Le Calvez et al. (2006). In their study 4.1% of animals developed visibly detectable tumors. However, researchers suspected the actual incidence of cancer may have been higher, had they looked at tissue samples. Tillmann et al. (1997) also write that "only implantation areas with macroscopic findings have been examined microscopically, so that possible pre-neoplastic lesions could have been missed" (p. 200).

Microchip-Induced Cancer in Dogs

In addition to the six studies that identified cancer in rodents, two studies evaluated cancerous tumors (fibrosarcoma and liposarcoma) that developed in dogs at the site of microchip implants. In one case, the tumor was attached to the implant. In the other case, the tumor completely encased the microchip.

Microchip Studies in Which No Cancer Was Found

Included in this review are three studies, one involving dogs, one involving rats, and one involving mice, in which none of the animals developed cancer from the microchip implant. Though these studies were originally presented as evidence that implantable microchip devices were safe, they suffer from methodological limitations that call their statistical validity into question. These limitations include the small number of animals used and the short duration of the studies. Those issues are discussed at further length in this document.

Overall Cancer Incidence

Tables 1 and 2 summarize the results of the 11 studies reviewed in this Chapter. Table 1 lists the cancer incidence from eight studies where cancer was found in connection with a microchip implant. Table 2 lists details from the three studies in which no cancer was found.

Table 1. Studies that found microchip-induced cancer

Author(s)	Species	# of Animals	Length of Implant Exposure	Developed Cancer
Le Calvez et al., 2006	mice	1,260	2 years	4.1%
Vascellari et al., 2006	dog	N/A	7 months (at age 9)	1 dog
Vascellari et al., 2004	dog	N/A	18 months (at age 11)	1 dog
Elcock et al., 2001	rats	1,040	2 years	0.8%
Blanchard et al., 1999	mice	177	6 months	10.2%
Palmer et al., 1998	mice	800	2 years	2.0%
Tillmann et al., 1997	mice	4,279	lifespan	0.8%
Johnson, 1996	mice	2,000	2 years	~1.0%

Table 2. Studies that did not find microchip-induced cancer

Author(s)	Species	# of Animals	Length of Implant Exposure	Developed Cancer
Murasugi et al., 2003	dogs	2	3 days	none observed
		2	3 months	
		2	1 year	
		2	3 years	
		1	6 years	
Ball et al., 1991	rats	10	2 weeks	none observed
		10	3 months	
		10	6 months	
		10	1 year	
Rao & Edmondson, 1990	mice	10	3 months	none observed
		10	15 months	
		74	2 years	
		39	< 2 years	

Animals Used in the Research

Toxicology and carcinogenicity researchers rely on laboratory animals to help determine which substances are safe and which are potentially harmful. Since most substances that cause cancer in humans also cause cancer in mice and rats, these animals can serve as an early indicator that a substance may not be safe for use in humans.

Several different strains of laboratory mice and rats were evaluated in the rodent studies reviewed in this report and several breeds of dog were included in the dog studies reviewed. A listing of the animals involved in each research study has been provided in Table 3.

Table 3. Animals examined in the studies, identified by breed or strain

Author(s)	# of Animals	Type of Animal Studied	Developed Cancer
Le Calvez et al., 2006	1,260	B6C3F1 mice	4.1%
Elcock et al., 2001	1,040	Fischer 344 rats	0.8%
Blanchard et al., 1999	177	*p53*+/- transgenic mice	10.2%
Palmer et al., 1998	800	B6C3F1/CrlBR VAF/Plus mice	2.0%
Tillmann et al., 1997	4,279	CBA/J mice	0.8%
Johnson, 1996	2,000	B6C3F1 mice and CD1 (“albino”) mice	~1.0%
Murasugi et al., 2003	9	Beagle; mixed breed dogs	none observed
Ball et al., 1991	40	Sprague-Dawley rats	none observed
Rao & Edmondson, 1990	140	B6C3F1 mice	none observed
Vascellari, 2006	1	French bulldog	1 dog
Vascellari, 2004	1	Mixed breed dog	1 dog

Animals in the first group of prior studies developed microchip-induced tumors. Animals in the second group did not develop tumors. The third group of studies pertain to dogs that developed cancer around or attached to microchip implants.

Rodents used in laboratory studies are specially bred for uniformity and hardiness. They are utilized in cancer studies for their ability to respond to carcinogenic substances while remaining relatively free from spontaneous tumors that are unrelated to carcinogenic test substances.

The B6C3F1 mouse was the most commonly used mouse in these studies, appearing in four of the eight rodent studies. The Handbook of Carcinogen Testing (Milman & Weisburger, 1994) states that National Toxicology Program studies use the B6C3F1 mouse almost exclusively for cancer research because of its desirable characteristics. The Handbook describes the mouse as "hardy, easy to breed, disease resistant, and [having] a low spontaneous tumor incidence at most sites" (p. 353).

The p53+/- mouse contains a genetic mutation in the p53 gene which normally sends protein to help repair damaged cells. In these mice, one allele, or portion of the gene has been deleted, thus increasing their susceptibility to cancer caused by genotoxins, or substances that damage genetic material. p53+/- mice are not known to develop spontaneous cancers in the first six months of life and are expected to only develop cancer in the presence of genotoxins. The high rate of cancer development around the microchip implant in p53+/- mice at less than six months suggests that the implant may have genotoxic attributes.

The CBA/J mouse is an inbred strain that is widely used as a general purpose laboratory animal. It suffers from hereditary blindness, making it of interest to vision researchers, and it is often selected for other studies because of its low incidence of mammary tumors (The Jackson Laboratory). The CD-1 (albino) mouse is described as a "general multipurpose model [for] safety and efficacy testing, aging, surgical model, [and] pseudopregnancy" (Charles River Laboratory, 2007, p. 15).

The Sprague-Dawley rat is described as "a general model for the study of human health and disease" and an "excellent model for toxicology, reproduction, pharmacology, and behavioral research areas." They have a life span of 2.5 – 3.5 years (Ace Animals, Inc., 2007).

The Fischer 344 rat is described as the "most widely used inbred rat strain, particularly for toxicology and teratology" studies (Simonsen Laboratories, 2007).

Microchips Used in the Research

The glass used to encapsulate the microchip is known as "bioglass," a material widely used in animal studies due to its insolubility and apparent biocompatibility (Vascellari et al., 2004). Bioglass is comprised primarily of "silicon, sodium, calcium, potassium, magnesium, iron, and aluminum" and has been classified in the silicon sodium group (Vascellari et al, 2004, p. 188; citing Jansen et al., 1999).

The microchip transponder comes prepackaged in a sterile 12-gauge injection needle attached to an implantation device supplied by the manufacturer. Once the transponder is embedded in the body, it can be interrogated by a reader device that emits radio-frequency energy. This energy stimulates the embedded transponder, causing it to emit a signal that is captured by the scanner and translated into an identification code.

The microchips used in these studies were obtained from several distributors, including BioMedic Data Systems, Inc., Destron Fearing, and Merial, as indicated in Table 4.

Table 4. Microchip implants used in the studies, identified by brand name or supplier

Author(s)	Microchip Used	Developed Cancer
Le Calvez et al., 2006	BioMedic Data Systems Inc.	4.1%
Elcock et al., 2001	BioMedic Data Systems Inc.	1.0%
Blanchard et al., 1999	BioMedic Data Systems Inc.	10.2%
Palmer et al., 1998	Unspecified	2.0%
Tillmann et al., 1997	BioMedic Data Systems Inc.	0.8%
Johnson, 1996	BioMedic Data Systems Inc.	~1.0%
Murasugi et al., 2003	LifeChip; Destron Fearing.	none observed
Ball et al., 1991	BioMedic Data Systems Inc.	none observed
Rao & Edmondson, 1990	BioMedic Data Systems Inc.	none observed
Vascellari, 2006	Merial Indexel® (Digital Angel)	1 dog
Vascellari, 2004	Merial Indexel® (Digital Angel)	1 dog

REVIEW OF STUDIES: MICROCHIP-INDUCED CANCER IN LABORATORY RODENTS AND DOGS: EIGHT STUDIES FROM 1996 TO 2006

Le Calvez et al., 2006

Subcutaneous microchip-associated tumours in B6C3F1 mice: A retrospective study to attempt to determine their histogenesis. -Experimental and Toxicologic Pathology. 2006; 57:255–265.

Most of the animals with microchip-associated tumors died prematurely ... due to the size of the masses [or] the deaths were spontaneous and attributed to the masses. (p. 258)

One of the most potentially serious disadvantages of the microchip implantation is the possibility that foreign-body-induced tumours may develop ... (p. 256)

Summary

Microchips were implanted into 1,260 experimental mice for identification purposes. Two years later, 4.1% of the mice had developed malignant (cancerous) tumors at the site of the microchip implantation (Table 5). The cancers were directly attributed to the microchips. In one subgroup, the cancer rate among the chipped mice was 6.2%.

Table 5. Le Calvez et al. 2006 study summary

Author(s)	# of Animals	Species	Study Length	Developed Cancer
Le Calvez et al., 2006	1,260	mice	2 years	4.1%

Study Design and Key Findings

1,260 mice were separated into groups for use in three oral carcinogenicity studies. The first study involved 550 mice, 110 of which received only a microchip implant. The other 440 received a microchip implant along with a low, medium, or high dose of a chemical test substance in their feed.

Two years later, 34 of the mice (6.2%) had developed malignant (cancerous) tumors around or adjacent to the microchip. These tumors occurred across groups, appearing in control mice as well as mice that had received the ingested chemical. Researchers plainly identified the microchip as the cause of the tumors.

The second study involved 600 mice. 120 received only a microchip, while the other 480 received a microchip combined with varying doses of a chemical compound in their feed. Two years later, 14 out of the 600 mice (2.3%) had developed cancerous tumors related to the microchip. For the test group of 480 mice, these tumors were determined to be unrelated to the ingested compound.In the third study, 110 mice were implanted with a microchip and received no other intervention. Four of these animals (3.6%) developed a tumor around the microchip.

The researchers suggest the actual cancer rate may have been higher than reported, as they tested for cancer only when visible abnormalities were seen in the mice. Smaller tumors in the early stages of development that were not yet visible to the naked eye may have been missed. According to the authors, "as these were only sampled and examined histologically when gross abnormalities were noted, it is possible that early reaction could have been missed. These incidences may therefore slightly underestimate the true occurrence" (p. 258).

Additional Findings

- All the cancerous masses found either contained the microchip or were adjacent to it. An empty capsule where the microchip had been was frequently identified as the origin of the tumor. The researchers wrote:

All sarcomas were characterized by a poorly delineated, non-encapsulated, densely cellular mass, located in the subcutis but frequently infiltrating the panniculus muscle and various layers of the skin with occasional ulcerations. A round-to-oval empty space of 2 mm diameter corresponding to the cast of the microchip was frequently seen and associated with a vestigial fibrous capsule and/or a focus of necrosis. (p. 261)

- Tumors were initially identified by morphology as fibrosarcoma (17 cases), rhabdomyosarcoma (12 cases), leiomyosarcoma (2 cases), malignant fibrous histiocytoma (3 cases), mammary gland adenocarcinoma (2 cases), and other sarcomas (16 cases). Researchers later redefined the tumors as "sarcomas not otherwise specified (NOS) with a large myofibroblastic component" (p. 255) after additional testing. A sarcoma is a malignant tumor of soft tissue that connects, supports or surrounds other structures and organs of the body.
- Once initiated, the tumors grew rapidly. Most of the animals that developed microchip-associated tumors died prematurely as a result of the tumors.
- Four microchip-related cancers metastasized (spread) to the lungs, liver, stomach or pancreas.

- Many of the implants migrated from the original implantation site on the back of the mice to cause cancer at other locations in the body. Nineteen percent of the cancers found involved microchips that had migrated from the back to the limbs, abdomen, or head of the mice.
- A test procedure known as desmin staining found that the tumors often infiltrated nearby muscle tissue and that there was "an extensive cavernous network of capillaries within the tumour, especially around the hole left by the microchip." (p. 261)

Study Details

- The study was conducted at MDS Pharma Services in L'Arbresle, France.
- Animals used in the study were B6C3F1 mice from Charles River Laboratory.
- Microchip implants were from BioMedic Data Systems Inc. and were described as "hermetically sealed in a cylindrical inert glass capsule measuring 12 mm in length and 2 mm in diameter and partially covered on a length of 5 mm by a porous polypropylene polymer sheath as an antimigration measure." (p. 255)

Vascellari, Melchiotti, and Mutinelli, 2006

Fibrosarcoma with typical features of postinjection sarcoma at site of microchip implant in a dog: Histologic and immunohistochemical study. -Veterinary Pathology. 2006; 43:545–548

Reports on adverse reactions to vaccination and microchips are strongly encouraged to deepen the current knowledge on their possible role in tumorigenesis . . . the cause and effect relationship between exposure (injection) and outcome (sarcoma) is still to be defined and is a matter of discussion for experts. (p. 547)

Summary

A 9-year-old bulldog developed a cancerous tumor (fibrosarcoma) adjacent to a microchip implant approximately seven months after being implanted with the device (Table 6). Researchers attributed the tumor to either the microchip or to vaccinations at the site, and called for better reporting of adverse reactions to microchip implants and vaccinations.

Overview

In September 2003, Leon, a 9-year-old male French bulldog was implanted with a microchip for identification purposes. In April 2004 (8 months later) Leon's owner detected a lump measuring 3 cm x 3 cm (1.2 x 1.2 inches) in the implant area. The mass was surgically removed and subjected to laboratory

Table 6. Vascellari et al. 2006 study summary

Author(s)	Animal Involved	Chip Exposure Time	Cancer Developed
Vascellari, et al., 2006	9-year-old French bulldog	7 months	Fibrosarcoma

analysis whereby it was identified as a high-grade infiltrative fibrosarcoma – a malignant and fast-growing form of cancer. It was found attached to the microchip. Leon later died from complications that his owner attributes to the cancer.

The microchip is implanted into dogs through an injection procedure involving a 12-gauge needle. The researchers suggest the tumor may be a form of post-injection sarcoma, involving an inflammatory reaction around an injection site that predisposes the tissues to tumor development. The researchers note that "irritation, inflammation, and/or wounds [promote] tumor development. Virtually anything that causes a local inflammatory reaction may potentially be responsible for neoplastic initiation [i.e., abnormal proliferation of cells]" (p. 546).

The authors attributed the cancer to either the microchip or to vaccinations the dog had received at the same site. They wrote: "It is difficult to establish which was the primary cause of the neoplastic growth, because the dog had received several rabies vaccines and the microchip was detected close to but not included in the mass" (p. 547).

The investigators conclude by stating that "reports on adverse reactions to vaccination and microchips are strongly encouraged to deepen the current knowledge on their possible role in tumorigenesis [causing tumors]," calling it "a matter of discussion for experts" (p. 547).

It should be noted that a complete physical exam found nothing other than the detected lump to indicate that Leon had developed cancer. No evidence of inflammation or sepsis were found at the site of the implant. Had Leon's owner not insisted on a microscopic evaluation of the unusual growth, his cancer might never have been detected.

Study Details

- The evaluation was conducted by Dr. Marta Vascellari of the Instituto Zooprofilattico Sperimentale delle Venezie at Viale dell'Universita in Legnaro, Italy, with associates Erica Melchiotti and Franco Mutinelli.
- The microchip was manufactured by Digital Angel, the parent company of the VeriChip Corporation, and distributed by Merial under the Indexel® brand, through Lyon, France. Digital Angel's website states: "Digital Angel manufactures implantable RFID chips used in pets around the world ... In Europe, our product is distributed by Merial in some countries under the Indexel® brand. For more information, visit merial.com." (Source: http://www.digitalangelcorp.com/dac_pets.asp. Accessed July 23, 2007.)
- Merial's website states: "Merial is a world-leading animal health company. We are a forward-looking company with a proven track record, producing pharmaceutical products and vaccines for livestock, pets and wildlife." (Source: http://www.merial.com/our_company/index.asp. Accessed July 23, 2007.)

Vascellari et al., 2004

Liposarcoma at the site of an implanted microchip in a dog. -The Veterinary Journal. 2004; 168:188–190

The intact microchip was found completely embedded within the mass . . . [and] a diagnosis of low-grade liposarcoma was made. (p.188)

Veterinary surgeons are . . . encouraged to check the microchips that have been implanted in pets at least annually, such as when they come in for vaccinations, and report any adverse reaction. (p. 190)

Summary

An 11-year-old dog developed a cancerous tumor (liposarcoma) around a microchip that had been implanted approximately 19 months earlier. The tumor was removed and the dog recovered (Table 7).

Overview

In April 2000, a male mixed-breed dog was implanted with a microchip for identification purposes. In November 2001 (19 months later) the dog's owner detected a firm, painless lump at the implant site measuring 10 x 6 cm (approximately 4 x 2.5 inches). The lump was examined by a veterinarian who determined that the microchip was completely embedded within the mass.

In April 2003, the tumor was surgically removed under general anesthesia. Upon microscopic examination, it was identified as a malignant liposarcoma, an aggressive and invasive type of cancer that can metastasize to the lungs, liver, and bone. The researchers note that liposarcoma is uncommon in dogs. Prior to the surgery, the dog had shown no visible signs of cancer other than the unusual lump. Blood tests run on the dog, including a complete pre-operative blood count and serum biochemistry analysis, did not detect that the mass was malignant. Thoracic radiographs (chest X-rays) were also normal. Had there not been a microscopic evaluation of the unusual growth, the cancer might not have been detected.

Study Details

- The evaluation was conducted by Dr. Marta Vascellari and Franco Mutinelli of the Instituto Zooprofilattico Sperimentale delle Venezie, Histopathology Department, in Legnaro, Italy, together with veterinary surgeons Romina Cossettini and Emanuela Altinier of Porcia, Italy.
- The microchip was manufactured by Digital Angel, the parent company of the VeriChip Corporation. It is distributed by Merial under the Indexel® brand. Researchers state that the implant "consists of a sealed glass capsule containing a chip and a coil . . . [and is] equipped with an anti-migrational capsule, located in the anterior part of the microchip."

Elcock et al., 2001

Tumors in long-term rt studies associated with microchip animal identification devices. -Experimental and Toxicologic Pathology. 2001; 52:483–491

Table 7. Vascellari et al. 2004 study summary

Author(s)	Animal Involved	Chip Exposure Time	Cancer Developed
Vascellari et al., 2004	11-year-old mixed breed dog	19 months	liposarcoma

Electronic microchip technology as a means of animal identification may affect animal moribundity and mortality [i.e., illness and death rates], due to the large size and rapid growth of microchip-induced tumors as well as the occurrence of metastases. (p. 491)

Most tumors arising from foreign bodies are malignant . . . and have a rapid growth rate, killing the animal in a matter of weeks. (p. 491)

Summary

Microchips were implanted into 1,040 rats for identification purposes. After two years, just under 1% of the rats developed malignant tumors (malignant schwannoma, fibrosarcoma, anaplastic sarcoma, and histiocytic sarcoma) surrounding the implants. The researchers attributed the tumors to the presence of the microchip, and referred to them as "microchip-induced" (Table 8).

Study Design and Key Findings

A group of 1,040 rats was implanted with microchip transponders and then divided into two random groups. Half were exposed to an ingested chemical compound at high, medium, and low doses; the other half received no compound. By the end of the second year, eight of the rats that received the compound, or 0.77%, had developed malignant tumors at the site of the microchip implant.

Though the affected rats had all been dosed with a test substance, the tumor incidence was distributed across dose groups and showed no test-substance-related trends. Stated slightly differently, higher levels of chemical compounds in the animals' feed did not correspond to higher tumor rates.

Further clarifying that the tumors had arisen in response to the microchips, not the test compound, the investigators wrote: "the process of differentiating microchip-induced tumors from suspected compound-related tumors was fairly easy in the cases described here, for all contained the embedded microchip device" (p. 491).

Additional Findings

- The microchip-induced tumors were identified as malignant schwannoma, fibrosarcoma, anaplastic sarcoma, and histiocytic sarcoma. All diagnoses were confirmed with immunohistochemistry.
- All masses were confined to the area of microchip implantation and contained embedded microchips.
- Some masses were extremely fast-growing, enlarging as much as 1 cm per week. Several tumors metastasized to regions including the lungs, thymus, heart, lymph nodes, and musculature.
- Five of the eight affected animals died as a direct result of the microchips.

Table 8. Elcock et al. 2001 study summary

Author(s)	# of Animals	Species	Study Length	Developed Cancer
Elcock et al., 2001	1,040	rats	2 years	0.8%

- All tumors occurred in the second year of the study. The average age at tumor onset was 585 days, or approximately one year and seven months. (The average life span of a rat is two to three years.)
- The researchers write that: "Although the resulting tumor rate was observed to be low, the overall health of the affected rats was compromised due to tumor size and the occurrence of metastases, leading to early sacrifice" (p. 484). In other words, the animals' health was so poor due to large, malignant tumors spreading through their bodies that researchers were forced to kill them prematurely.

Study Details

- The study was conducted by Laura E. Elcock of Bayer Corporation in Stilwell, Kansas. Other investigators were Barry Stuart, Bradley Wahle, Herbert Hiss, Kerry Crabb, Donna Millard, Robert Mueller, Thomas Hastings and Stephen Lake. The results were peer-reviewed by an independent pathologist.
- Animals used were Fischer 344 laboratory rats.
- Microchip implants were from BioMedic Data Systems Inc.

Blanchard et al., 1999

Transponder-induced sarcoma in the heterozygous p53+/- mouse. -Toxicologic Pathology. 1999;27(5):519 -527

There was an unequivocal association between the [microchip implant] transponder and sarcoma that was unrelated to drug treatment. (p. 526)

The presence of the foreign body [microchip transponder] may elicit tissue reactions capable of generating genotoxic byproducts. (p. 526)

Summary

177 genetically modified mice were implanted with microchips for identification purposes as part of a chemical compound study. After six months, 18 of the mice (10.2%) had developed malignant tumors ("undifferentiated sarcomas") around the microchip (Table 9). The tumors occurred in both experimental and control animals. The researchers reported an "unequivocal association" between the implants and the cancer.

Table 9. Blanchard et al. 1999 study summary

Author(s)	# of Animals	Species	Study Length	Developed Cancer
Blanchard et al., 1999	177	mice	6 months	10.2%

Study Design and Key Findings

A group of 177 transgenic p53+/- mice were implanted with microchips as part of a six-month study to investigate the toxicity of various chemical compounds. After six months, 18 of the mice (10.2%) developed malignant tumors ("undifferentiated sarcomas" p. 520) around the microchip. The tumors occurred in both control animals and animals that had received the test compound. The authors wrote that "these masses were not related to test substance administration; they were observed in controls as well as dosed animals" (p. 520).

Of the 177 total mice studied, 56 died before researchers made a link between the microchip and the tumors. The tissue surrounding the implants in the remaining 121 mice was microscopically analyzed.

Researchers discovered that the tumors arose at the microchip's plastic anchoring barb and then expanded to eventually surround the entire microchip. They state: "It appeared that tumor(s) arose in the mesenchymal tissue surrounding the polypropylene component of the transponder, initially involving the barbed area and then in some cases extending completely around the entire transponder site" (p. 523). Further, mass development was often observed to begin at the glass-polypropylene interface (p. 521).

The mice used in this study were transgenic p53+/- mice, specially bred to lack part of the tumor suppressor gene known as p53. In normal mice, p53 regulates cell growth and causes potentially cancerous cells to destroy themselves. Missing a part of this gene makes mice more susceptible to cancer from genotoxins, or toxic substances that affect genetic material. Despite their greater tendency to develop cancer when exposed to genotoxins, p53+/- mice typically do not develop spontaneous tumors in the absence of genotoxins. When they do develop tumors, it is generally an indication that a genotoxin is present.

The researchers write that:

[D]eletion of a single allele of this tumor suppressor gene in mice appears to be without effect on the development of spontaneous tumors, at least during the first year of life, but it imparts exquisite sensitivity to the mutational and carcinogenic effects of genotoxic chemicals. (p. 524)

The glass and polypropylene components of the BioMedic transponder device used in the study are generally assumed to be free from genotoxic materials (mutagenic and/or cytoxic components), so an observation of no tumors would be predicted by this model (p 525). Because the glass capsule and polypropylene sheath around the microchip implant are generally considered not to be genotoxins, the mice should not have responded to their presence by developing cancers. Researchers did not expect this outcome, writing: "the observation of transponder implantation site sarcomas in 18/177 (10%) of the animals studied was surprising."

Additional Findings

- "Membrane endothelialization, inflammation, mesenchymal basophilia, dysplasia, and sarcoma were considered unequivocal [unmistakable] responses to the transponder" (p. 523).
- The masses increased in size rapidly. One mass measuring ½" wide in the fifteenth week of the study grew to 2" just ten weeks later (p. 520).

- The researchers “have subsequently replicated this finding in 2 separate studies with the p53+/- mouse where transponder implantation site sarcomas were also observed.” Their article does not indicate whether these studies have been published.

Study Details

- The study was conducted by Kerry Blanchard, Curt Barthel, Henry Holden, Roger Moretz, Franklin Pack, and Raymond Stoll of the Department of Toxicology and Safety Assessment at Boehringer Ingelheim Pharmaceuticals in Ridgefield, Connecticut, along with John French and Raymond Tennant of the Laboratory of Environmental Carcinogenesis at the National Institute of Environmental Health Sciences in North Carolina..
- Animals used were transgenic p53+/- mice, specially bred to lack part of the tumor suppressor gene known as p53. These mice have an increased susceptibility to cancer from genotoxins (compounds which affect genetic material) but are not known to develop tumors spontaneously in the absence of a carcinogen.
- Microchips used were IMI® implants from BioMedic Data Systems. The microchip is described as encased in a glass capsule and partially encased in a polypropylene sheath.

Palmer et al., 1998

Fibrosarcomas associated with passive integrated transponder implants. -Toxicologic Pathology. 1998;26:170

All tumors were observed . . . at or near the implantation site . . . [the tumors] were attached to the implant or partially or totally encased the implant. (p. 170)

Summary

800 mice were implanted with microchips for identification purposes. After two years 2% of the mice had developed cancerous tumors (malignant fibrosarcomas) around the implants (Table 10).

Study Design and Key Findings

The article is a short, one-page writeup, around 350 words in length. The following is known based on the information provided:

800 mice were implanted with a microchip transponder for identification purposes as part of “a 104-week dietary study” lasting two years. Between weeks 79 and 105, 16 of the mice developed “sub-

Table 10. Palmer et al. 1998 study summary

Author(s)	# of Animals	Species	Study Length	Developed Cancer
Palmer et al., 1998	800	mice	2 years	2.0%

cutaneous tumors associated with the implanted transponder." The tumors occurred in both control and treated animals and were judged unrelated to the test material. The tumors were identified as malignant fibrosarcomas.

All of the tumors occurred at or near the implantation site and were "attached to the implant or partially or totally encased the implant." The larger tumors commonly had areas of necrosis and hemorrhage with inflammation, and some of the tumors invaded adjacent skeletal muscle. In addition, two of the mice developed metastases in which the cancer spread either to the lymph nodes or to the lungs.

Study Details

- The study was conducted by T. Palmer, J. Nold, M. Palazzolo, and T. Ryan at Covance Laboratories, Inc. in Madison, Wisconsin.
- Animals used were B6C3F1/CrlBR VAF/Plus mice.
- Microchips used are identified as "passive integrated transponder implants used for identification." No additional information is provided.

Tillmann et al., 1997

Subcutaneous soft tissue tumours at the site of implanted microchips in mice. -Experimental and Toxicologic Pathology. 1997; 49:197 – 200

The neoplasms induced in the present investigation are clearly due to the implanted microchips. (p. 200)

Further information on [tumors] induced by microchips, e.g., experiments on their chemical components (glass and polypropylene cap), or the physical presence of the implant alone are necessary. (p. 200)

Summary

4,279 mice were injected with microchip implants for identification purposes. Of these, 36 developed malignant tumors (fibrosarcoma and malignant fibrous histiocytoma) that were "clearly due to the implanted microchips" (p. 200). Control animals as well as experimental animals developed the tumors (Table 11).

Study Design and Key Findings

4,279 CBA/J mice were implanted with microchips for identification purposes as part of a study examining the influence of X-ray radiation and chemical carcinogen exposure on offspring. A sample of male mice was exposed to these carcinogens once or twice, then mated with untreated females. Their offspring were then studied to see if they had increased cancer susceptibility.

Table 11. Tillmann et al. 1997 study summary

Author(s)	# of Animals	Species	Study Length	Developed Cancer
Tillmann et al., 1997	4,279	mice	lifespan	0.8%

By the conclusion of the study, 36 of the mice had developed tumors around the microchip. Implant-related tumors were identified as fibrosarcomas with "extensive local invasion of the surrounding tissues" and malignant fibrous histiocytoma with "zones of necrosis and high mitotic activity" (p. 198).

Significantly, twice as many females developed cancers as male mice, though the females had not been exposed to the experimental treatment. 1.2% of the females and 0.5% of the males developed tumors in the chip implantation area. The authors wrote that "the different generation and treatment groups showed no influence on tumour incidence," meaning that the tumors were unrelated to the x-ray treatment or other experimental factors.

The authors caution that the study may have underestimated the actual rate of tumor formation, since only tumors that were visible to the naked eye were examined microscopically. Tumors at an earlier stage of development may have been missed.

Study Details

- The study was conducted by Thomas Tillmann, Kenji Kamino and Ulrich Mohr at the Institute of Experimental Pathology at the Hannover Medical School in Hannover, Germany. Other researchers included C. Dasenbrock, H. Ernst, and G. Moraweitz of the Fraunhofer Institute of Toxicology and Aerosol Research in Hannover, Germany; E. Campo and A. Cardesa of the Department of Anatomic Pathology at the University of Barcelona in Barcelona, Spain; and L. Tomatis of the Instituto per L'Infanzia in Trieste, Italy.
- An acknowledgment at the end of the article states: "This study was supported by the European Union: EV5V-CT92-0222."
- Animals used in the study were CBA/J mice.
- The implants used were "glass-sealed devices with a polypropylene cap" obtained from BioMedic Data Systems, Inc. (European distributor PLEXX BV, Elst. The Netherlands).

Johnson, K., 1996

Foreign-body tumorigenesis: Sarcomas induced in mice by subcutaneously implanted transponders. -Toxicologic Pathology. 1996; 33(5):619. Abstract #198

Investigators using ... implanted devices need to be aware of foreign-body tumorigenesis [cancer development] when evaluating the results of long term studies using mice.

Summary of Study

A two-year Dow Chemical study of 2,000 mice found an approximately 1% incidence of sarcomas surrounding microchip implants used for identification purposes (Table 12). The tumors appeared in both control and experimental animals. This was consistent with a diagnosis of foreign-body-induced sarcoma.

Table 12. Johnson 1996 study summary

Author(s)	# of Animals	Species	Study Length	Developed Cancer
Keith Johnson, 1996	2,000	mice	2 years	~1.0%

Study Design and Key Findings

This report was based upon a series of five oncogenicity (cancer) studies involving 2,000 B6C3F1 mice and CD1 (“albino”) mice. Each study consisted of 400 mice that had been implanted with a microchip for identification purposes: 300 of the mice received test chemicals in their feed at low, medium, and high dose levels, and 100 control mice received no test chemical. After two years, just under 1% of the mice developed “incidental” subcutaneous sarcomas that incorporated the implanted microchip. Both treated and control animals developed the tumors at approximately the same rate, ruling out the test substance as the cause of these tumors.

The tumors were identified as connective tissue cancers, or fibrosarcomas, and appeared typical of foreign-body-induced sarcomas. The tumors typically appeared after more than one year post-implantation. Only gross lesions were examined.

In a telephone interview, Johnson (personal communication, October 13, 2007) also reported occasional adverse events related to the microchips, which were implanted between the shoulder blades. “Occasionally some would be inserted too deep, the needle that put them in was probably held at the wrong angle. We had a few early in the studies that would migrate out if the wound wasn’t healing properly, and we had a few that gave up functioning, but those were all pretty rare events,” he said.

Study Details

- The research was conducted at the Toxicology Research Laboratory, The Dow Chemical Company, Midland, MI by Keith Johnson.
- Animals used in the study were B6C3F1 mice and CD1 (“albino”) mice.
- Microchip implants were from BioMedic Data Systems Inc.

MICROCHIP STUDIES IN WHICH NO CANCER WAS FOUND

Murasugi et al., 2003

Histological reactions to microchip implants in dogs -The Veterinary Record. 2003 (Sept 13); 328

As the mean lifespan of dogs as companion animals increases, long-term evaluation of the safety and biological stability of implants is necessary. (p. 328)

Summary

Nine dogs were implanted with microchips and observed for adverse outcomes over periods of three days to three years. One dog was exposed to the implant for six years. The chips and surrounding tissue were removed and examined microscopically (Table 13). Inflammation and encapsulation had occurred, but no tumors or cancerous changes were found.

Table 13. Murasugi et al. 2003 study summary

Author(s)	Species	# of Animals	Length of Microchip Exposure	Developed Cancer
Murasugi et al., 2003	dogs	6	≤ 1 year	none observed
		3	3–6 years	

Study Design and Key Findings

Nine dogs (one female beagle, six female crossbreeds, and two male crossbreeds) were implanted with Destron Fearing LifeChip microchips. At selected time periods, the implants and a surrounding 2x2x2 cm cube of tissue were surgically removed from each dog and microscopically evaluated. The evaluations took place on the following schedule (Table 14).

After three days, a rim of inflammatory cells, blood congestion, and newly formed capillaries had developed around the implants. At three months, a capsule composed of connective tissue, elastic and collagen fibers had surrounded the implant. At twelve months, the encapsulation was complete and no inflammation was observed. The evaluations at 36 and 72 months were similar to those made at 12 months.

The researchers summarized these findings as follows:

a foreign body reaction to the subcutaneously implanted microchips was observed [initially] . . . followed by . . . the development of a thin capsule in close contact with the microchip. The inflammatory reactions disappeared three months after implantation, and enclosure of the microchip by a capsule consisting of fibroblasts, collagen fibres and elastic fibres was complete after 12 months. No marked difference was observed . . . 36 or 72 months after implantation, compared with those 12 months after implantation. (p. 329)

The researchers concluded that "[t]hese findings suggest that implanted microchips are likely to function safely throughout a dog's lifetime, without causing further histological [microscopic] changes".

Concern Over the Statistical Validity of the Study Findings

Although the authors conclude that "implanted microchips are likely to function safely throughout a dog's lifetime", the absence of cancerous changes in a small sample of dogs exposed to microchips for a limited period is not sufficient evidence to conclude that microchip implants are safe for long-term

Table 14. Key findings in Murasugi et al. 2003

# of Dogs Evaluated	Length of Microchip Exposure
2	3 days
2	3 months
2	1 year
2	3 years
1	6 years

use. Problems with this study include the small number of dogs examined and the short time of their exposure to the microchip.

A small sample size of just nine dogs lacks the statistical power to detect an effect that may be *in the order of a percentage point or less. Statistical validity* is the degree to which an observed result, such as a difference between two measurements, can be relied upon and not attributed to random error in sampling and measurement (National Women's Health Resource Center). *Sample size* is what gives a study statistical power, or accurate and valid predictive ability.

Dr. Elise Whitley and Dr. Jonathan Ball (2002), experts on medical statistics, explain the importance of sample size in medical studies designed to prove the safety of a device and rule out an adverse effect. They write:

The ideal study for the researcher is one in which the power is high. This means that the study has a high chance of detecting a difference between groups if one exists; consequently, if the study demonstrates no difference between groups the researcher can be reasonably confident in concluding that none exists in reality. The power of a study depends on several factors, but as a general rule higher power is achieved by increasing the sample size.

It is important to be aware of this because all too often studies are reported that are simply too small to have adequate power to detect the hypothesized effect. In other words, even when a difference exists in reality it may be that too few study subjects have been recruited . . . the erroneous conclusion may [then] be drawn that there is no difference between the groups. *This phenomenon is well summed up in the phrase, 'absence of evidence is not evidence of absence'. In other words, an apparently null result that shows no difference between groups may simply be due to lack of statistical power, making it extremely unlikely that a true difference will be correctly identified. [Emphasis added]*

In this case the "difference" described is the difference between the rate of cancer formation in dogs that have and have not been microchipped. The present study assumes that the difference between these populations is zero or non-existent, but the sample size lacks the statistical power to draw that conclusion.

To determine whether microchips are safe in dogs would require the statistical power of a much larger sample, in the order of hundreds or even thousands of dogs. Although such studies have not yet been conducted, researchers could draw on the existing population of microchipped dogs in the United States to reach more statistically valid conclusions about the implant's safety and long term effects.

In addition to the small sample size used, a further problem with this study is the short duration of time the dogs were in contact with the implants. Of the nine dogs studied, six had the implant removed within a year or less and only one dog retained the implant for six years. The researchers do not state the age of the dogs at the time they were implanted.

In mouse and rat studies, the onset of microchip-induced cancer typically did not occur until the second year after implantation. Very few tumors were seen in the first year of the study when the animals were in adolescence and early adulthood; most tumors arose during middle age and older for those animals. If dogs develop adverse microchip reactions at a comparable rate, we would not expect to see an onset of tumors in dogs until they, too, reached middle age and beyond. This would correspond to roughly six years of age, given that the average life span of the domestic dog is 12.8 years. When looking at dogs, it is important to take into account the wide variation in life span across breeds, with the average bulldog living just nine years, while the average chihuahua has a 15 year life expectancy (McCullough, 2007).

The two microchip-induced cancers reported in dogs (Vascellari et al., 2006, 2004) occurred in 9-year-old and 11-year-old dogs after exposure times of seven months and 19 months, respectively. Given the small number of reported cases, it is difficult to draw conclusions about the development of microchip-induced tumors in dogs, but it could be that older dogs are more susceptible to the possible cancer-inducing effects of implants than younger dogs. Future research could help determine the role of an animal's age and the duration of microchip exposure.

Study Details

- The study was conducted by E. Murasugi, H, Koie, M. Okano, T. Watanabe, and R. Asano, of the Department of Veterinary Medicine, College of Bioresource Sciences at Nihon University in Fujisawa, Kanagawa, Japan.
- An acknowledgment at the end of the article states, "We would like to thank Dainippon Pharmaceutical for providing the microchips".
- Microchip implants were described as "LifeChip injector; Destron Fearing. The microchips were approximately 2 mm in diameter and 11 mm long and contained an IC recording a unique identity number . . . [the microchips] are made of biocompatible glass and polypropylene".

Ball et al., 1991

Evaluation of a microchip implant system used for animal identification in rats. -Laboratory Animal Science. 1991;41(2):185—186

Summary

40 rats were implanted with subcutaneous microchips and evaluated for adverse reactions. The tissue surrounding the implants was evaluated after periods ranging from two weeks to one year. No palpable masses or visible tissue reactions were observed (Table 15).

Study Design and Key Findings

This was one of the original studies undertaken to evaluate what was then referred to as "a new microchip-based animal identification system" being marketed to laboratory researchers by BioMedic Data Systems, Inc. The goal of the study was to evaluate the safety and effectiveness of implanted microchip transponders for laboratory animal identification.

Table 15. Ball et al. 1991 study summary

Author(s)	Species	# of Animals	Length of Microchip Exposure	Developed Cancer
Ball et al., 1991	rats	10	2 weeks	none observed
		10	3 months	
		10	6 months	
		10	1 year	

For this study, 20 male and 20 female Sprague-Dawley rats were injected with microchip implants and observed for adverse reactions. At weeks 2, 12, 26, and 52, five rats of each sex were sacrificed (killed). The microchips and surrounding tissue from each rat were examined macroscopically and through histopathologic examination.

Although the researchers reported the development of "thin rims of immature fibrous connective tissue with occasional subacute inflammatory cells present in the subcutis 2 weeks after implantation" (p. 185-186) and later found that "very thin rims of mature fibrous connective tissue were seen surrounding the implant sites" (p. 186) they did not find any cancerous changes. They concluded that the implant was a "reliable, easy-to-use, nonadverse identification system" (p. 186).

Concern Over the Design and Statistical Validity of the Study

Although the authors conclude that the implanted transponders "produced no adverse clinical or histopathological side effects in the rats," the findings must be evaluated in light of the short time span for which the rats were implanted and the small sample size used.

Of the 40 rats used in this early study, none were in contact with the implants for longer than one year. Later researchers, however, found that cancerous tumors generally occur in the second year of exposure. When Elcock et al. (2001) examined a much larger sample of rats (n = 1,040), for example, they found a nearly 1% incidence of microchip-induced cancer, all of which occurred during the second year of the study. The average age of the animals at tumor onset in that study was 585 days, or approximately one year and seven months. Johnson (1996) similarly found that tumors in mice develop during the second year of exposure. The only exception to the late onset of tumors in the studies reviewed here was the Blanchard et al. (1999) study in which 10.2% of mice developed cancer within six months of implantation. These findings were atypical, however, and may be attributable to the type of genetically altered mouse used in that study.

The absence of cancerous tumors in the present study — in which animals were examined after only 2 weeks, 3 months, 6 months, and 1 year of implant exposure — is in accord with the findings of other researchers. It is neither surprising nor anomalous, nor does it rule out the possibility that microchip-induced tumors may develop in rats after a longer exposure period.

Another problem with this study is the small number of animals that were evaluated. A sample size of 40 rats lacks the statistical power to detect a small effect. This was the case in the Murasugi et al. dog study discussed earlier, and the same discussion of sample size and statistical power is applicable here.

When Elcock et al. (2001) conducted a subsequent study using a much larger sample of Fischer 344 rats (n = 1,040), they found a nearly 1% incidence of tumor formation. Due to the larger sample size, those results have greater statistical validity than those of the present study.

Study Details

- The study was conducted by D.J. Ball from Boehringer Ingelheim Pharmaceuticals, Inc. in Ridgeford, Connecticut, and associates. Additional authors include G. Argentieri, R. Krause, M. Lipinski, and R. I. Robinson from the Sandoz Research Institute of East Hanover, New Jersey; R.E. Stoll from Cetus Corporation of Emeryville, California; and G.E. Visscher from Roche Dermatologics in Nutley, New Jersey.

- The researchers thanked BioMedic for contributing to the study: "We would like to thank BioMedic Data Systems, Inc. of Maywood, N.J. for the implants and associated electronic equipment".
- Animals used were Sprague-Dawley rats.
- Microchips used were from BioMedic Data Systems, Inc., Maywood, New Jersey. The chip was described as a miniature transponder hermetically sealed in an inert glass capsule with a polypropylene sheath that covered one end of the transponder.

Rao and Edmondson, 1990

Tissue reaction to an implantable identification device in mice. -Toxicologic Pathology. 1990; 18(3):412–416

Summary of Study

140 mice were implanted with subcutaneous microchips and evaluated for adverse reactions. The tissue surrounding the implants was examined after periods ranging from three months to two years. No neoplastic (abnormal tissue growth) reactions were observed (Table 16).

Study Design and Key Findings

The study was published in 1990, when implantable microchips were first being introduced to laboratories for animal identification purposes. The goal of the project was to "determine the tissue reaction [from the implant], especially its potential to cause subcutaneous sarcoma, and the stability and reliability of a glass-sealed permanent identification device" implanted in mice (p. 412 – 413).

Researchers implanted 140 B6C3F1 mice with a microchip at approximately six weeks of age. Ten mice of each sex were evaluated at 3 months and at 15 months. The remaining animals were evaluated either as they died or upon being sacrificed at 24 months.

Histologic examination presented a connective tissue capsule of variable thickness around most of the implants, especially in the area of the glass surface of the chips. Around the polypropylene cap of the transponder, inflammatory reactions were detected but no neoplasms observed. From a summary of the Rao & Edmondson study included in Tillmann et al. (1996), p. 200. The capsule that formed around the polypropylene cap of the device contained minimal to mild inflammatory reaction with lymphocytes, macrophages, and a few plasma cells and neutrophils. Researchers noted that "Chronic granulomatous inflammation . . . was also observed around the polypropylene cap of 2 implants" (p. 414).

Table 16. Rao & Edmondson 1990 study summary

Author(s)	Species	# of Animals	Length of Microchip Exposure	Developed Cancer
Rao & Edmondson, 1990	Mice	20	3 months	none observed
		20	15 months	
		72	2 years	
		28	Less than 2 years*	

* Evaluated prior to study conclusion due to death of the animals

Though no cancer was found, there were other problems with the implants. According to the researchers, two of the implants were "lost" and four of the devices "failed." Three of these failures were attributed to microscopic cracks in the weld connecting the antenna leads to the microchip, and one was caused by "leakage of the glass capsule resulting in fluid accumulation around the microchip" (p. 413). One device lodged in the subcutaneous tissue over the lumbar vertebrae and was pushed out slowly through the scar tissue of the injection site during the tenth month of the study.

In addition to the lost or failed transponders, seven of the transponders were discovered in the abdominal cavity of the animals rather than in the subcutaneous tissue where they should have been located. Researchers did not know whether the devices had migrated into the abdominal cavity and eventually fixed in the perirenal tissue, or whether lab technicians had accidentally injected the devices into the abdomen.

Concern Over the Design and Statistical Validity of the Study

Given the small sample of animals exposed to the microchip for a full two years, this study may suffer from similar statistical validity problems as the Murasugi et al. (2003) and Ball et al. (1991) studies previously discussed.

Tillmann et al. (1997) point out this deficiency in their writeup, stating that the lack of tumor findings by Rao and Edmondson could be explained "by the low number of 140 B6C3F1 mice used by Rao and Edmondson" (p. 200).

Study Details

- The study was conducted by Ghanta Rao and Jennifer Edmondson at the Division of Toxicology Research and Testing at the National Institute of Environmental Health Sciences National Toxicology Program in North Carolina.
- Animals used were B6C3F1 mice.
- Microchips used were obtained from BioMedic Data Systems, Inc. They were described as a glass sealed 12 x 2 mm cylindrical device with a snug-fit biocompatible polypropylene cap covering a 5 mm length of the device. There are two holes in the polypropylene cap. The purpose of the polypropylene cap is to elicit mild tissue reaction and immobilize the device at the site of the implantation (p. 413).

DISCUSSION, RECOMMENDATIONS, AND CONCLUSION

Discussion

Cancerous tumors formed around or adjacent to implanted microchips in eight of the 11 studies reviewed in this report. In six of those studies, researchers clearly identified a causal link between the implanted microchip transponder and cancer. In three studies where cancer was not found, methodological shortcomings undermined the studies' validity. Either too few animals were studied to draw a valid conclusion, or the animals were not in contact with the microchip long enough for tumors to develop, in the way predicted by other models.

The tumors generally occurred in the second year of the studies, after more than one year of exposure to the implant. At the typical time of tumor onset the animals were in middle to advancing age. The exception to this was the Blanchard (1999) study, in which genetically modified mice developed fast-growing cancers well before six months.

In almost all cases, the tumors arose at the site of the implants and grew to surround and fully encase the devices. In several cases the tumors also metastasized to other parts of the animals, including the lungs, liver, stomach, pancreas, thymus, heart, spleen, lymph nodes, and musculature.

In addition to the tumors, researchers described other adverse reactions stemming from the use of the microchips, including migration, incorrect insertion, failure, and loss. These adverse reports appeared in studies which did and which did not find cancer.

Issues related to the studies, including several proposed explanations for the cancer findings, the breed and species of animals used, the relevance of this research to implanted microchips in human beings, other adverse reactions reported in the studies, and the possible under-reporting of cancer and other adverse events are discussed in detail next.

Explanations for the Tumors

At the present time, there is no definitive, universally accepted explanation for the formation of malignant tumors around implanted microchips in mice, rats, and dogs. Among some of the explanations that have been proposed are foreign-body tumorigenesis; post-injection sarcoma; possible genotoxic properties of the implant; and the radio-frequency energy emissions from the transponder or reader. Each hypothesis is addressed in this section.

Foreign-Body Tumorigenesis

The presence of the microchip, a subcutaneous foreign body, may cause cellular changes that can lead to cancer.

It is known that implanted foreign bodies can cause cancer both in animals and humans. McCarthy et al. (1996) reported on a liposarcoma in a dog where a glass foreign body had lodged 10 years previously. Brand and colleagues (1975) observed that rodents are particularly susceptible to developing tumors in response to foreign bodies and produced a large body of research on the topic. Compelling evidence indicates that foreign-body tumorigenesis is also operative in humans (Jennings et al., 1988), as discussed later in this paper.

Foreign-body-induced tumors can pose serious threats to animal health. Elcock et al. (2001) report from their review of the literature that most tumors arising from foreign bodies are malignant mesenchymal neoplasms with a rapid growth rate, killing the animal in a matter of weeks (p. 491).

Brand's research revealed that the size and surface of the foreign body are the key characteristics affecting tumor development. Although it may seem counter-intuitive, prior research shows that foreign bodies with smooth, continuous surfaces are actually more carcinogenic than those with rough, scratched, or porous surfaces.

The surface of the foreign body determines, in part, the length of the period of active inflammation. Rough, irregular surfaces have a longer active inflammatory phase before the foreign body is encapsulated in fibrous tissue. The extended period of inflammation is associated with lower rates of tumor development. In contrast, smooth surfaces have a shorter inflammatory period and thus are more likely to lead to tumors (Elcock et al., 2001, p. 490).

The microchip implant has both a smooth, homogeneous surface in the glass capsule and a rougher portion coated in the polypropylene sheath that is "characterized by scratches, ridges, and other irregularities" (Ball et al.).

In relation to the microchip implant, Elcock et al. write: "A chronic foreign body such as the electronic microchip, surrounded by a rim of mature fibrous connective tissue with little or no active inflammation may ... be more tumorigenic than one with ongoing active inflammation" (p. 490).

On the basis of these prior observations from the literature, it might be predicted that the cancer would form around the smooth portion of the implant first. However, Blanchard et al. (1999) reported that tumors in their study arose at the microchip's "plastic anchoring barb" and then expanded to eventually surround the rest of the device. They write: "It appeared that tumor(s) arose in the mesenchymal tissue surrounding the polypropylene component of the transponder, initially involving the barbed area and then in some cases extending completely around the entire transponder site" (p. 523). Further study is needed to better understand this issue.

Post-Injection Sarcoma

Inflammation from the chip-injection procedure may cause cellular changes that can lead to cancer.

[I]rritation, inflammation, and/or wounds [promote] tumor development. Virtually anything that causes a local inflammatory reaction may potentially be responsible for neoplastic [cancer] initiation (Vascellari et al., 2006, p. 546).

The microchip implant procedure involves the insertion of a 12-gauge needle into an animal's flesh to deliver the device. That procedure alone may be problematic, as research indicates that inflammation resulting from injections can predispose tissues to developing cancer. The resulting malignancies are known in the veterinary literature as post-injection sarcomas.

Vascellari et al. (2006) suggest that the tumor they evaluated in a French bulldog may have been this type of post-injection sarcoma, caused either by the injection of the microchip or by injection of vaccines that the dog received at the same site.

In light of the potential for post-injection sarcomas to develop in dogs, it would seem prudent to reduce inflammatory injection reactions in dogs (and cats) as much as possible. Given these findings, veterinarians should identify the location of microchip implants in chipped animals and avoid using the same site for vaccinations or other injections.

Possible Genotoxic Properties of the Implant

The glass capsule or polypropylene sheath surrounding it may have carcinogenic or genotoxic properties, or its presence within the host may give rise to genotoxic byproducts. In the Blanchard study over 10% of p53+/- mice developed malignancies around the implants. This finding puzzled the researchers, as the mice they used were genetically modified to develop tumors specifically in response to mutagens and genotoxins (toxic substances that affect genetic material). However, the component materials of the transponders are "widely used in genotoxicity studies" and are not known to be mutagens or genotoxins.

This discrepancy suggested to the researchers that something other than a foreign-body reaction or an injection response may be involved in the microchip-induced cancers they found. The researchers suggest that "the presence of the foreign body may elicit tissue reactions capable of generating genotoxic byproducts." They provide technical descriptions of several processes through which this may occur on page 526 of their study.

It is unclear whether the suspected genotoxic byproducts were produced by the implant directly or through processes occurring in the surrounding tissues of the host animals – or a combination of the two. The mice used in the Blanchard study were genetically modified to lack a portion of the p53 gene that normally aids in the repair of damaged cells. The higher rate of malignancy seen in these animals may result from their inability to repair cellular damage resulting from the implant.

The Blanchard report does not evaluate the biocompatibility of the polypropylene polymer sheath, but it does note that the observed tumors arose in the tissue surrounding the polypropylene component of the transponder. (As previously noted, the tumors began at the microchip's plastic anchoring barb and expanded to eventually surround the rest of the device.) This suggests another possibility: that "leachates," or substances leaching from the implant into the surrounding tissue, may be involved in the tumorigenesis (Blanchard, et al., p. 525).

A literature review to assess the safety of the polymer sheath was beyond the scope of this report but would contribute to a fuller discussion of microchip-induced tumors.

Radio-Frequency Energy Emissions From the Transponder or Reader

The radio-frequency energy involved with the transponder may somehow contribute to tumor formation. Blanchard et al. also raised the possibility that "energy from the signal transmitted by the transponder [may be] carcinogenic" (p. 525). Though there is a tendency to think of the glass encapsulated transponders as biologically inert, the reality is that these implants are radio-frequency energy transponders designed to pick up and amplify electromagnetic radiation (EMF) within the body. The long-term effects of having a reactive, foreign-body capsule in the body designed to absorb and respond to electromagnetic energy are unknown.

Based on a review of published accounts, it appears the role that EMF radiation may play in the development of microchip-induced tumors has not been well studied. Blanchard et al. believe that "these variables warrant further examination" (p. 525).

Differences Between Species

An important factor to consider when interpreting animal studies is whether findings in one breed or species of animal are applicable to other animals or to humans. This section examines that issue.

Possible Difference in Tumor Susceptibility Between Different Strains of Mice

In studies where microchip-induced malignant tumors were found, the percent of mice affected ranged from a low of 0.8% in the CBA/J mouse to a high of 10.2% in the p53+/- mouse. This wide variation suggests that different strains of mice may have different degrees of susceptibility to cancer from the implants.

Le Calvez et al. (2006), Palmer et al. (1998), and Elcock et al. (2001) all suggest a strain difference, with Palmer and Elcock observing that no implant-induced sarcomas have been reported in the CD-1 mouse strain, for example. However, Elcock et al. suggest that it may be difficult to rule out cancer in the CD-1 mice studied, since "small pre-neoplastic or neoplastic lesions may have been missed" in the absence of microscopic evaluation (p.489).

Johnson (1996), whose study of both B6C3F1 mice and CD1 mice found a ~1% overall incidence of microchip-induced tumors, believes that CD1 mice in his study "probably did" develop foreign-body sarcomas around the implanted microchips, writing in a 2007 email correspondence: "I do not specifically recall whether or not CD-1 mice developed foreign-body sarcomas around implanted microchips. I believe they probably did, but at slightly lower incidence than B6C3F1 mice, as our experience was that CD-1 mice were somewhat shorter lived (due a disease named systemic amyloidosis) and these tumors were generally seen after a long time on study" (Personal communication, October 15, 2007).

Nonetheless, it appears that different strains of mice may develop microchip-induced cancers at differing rates.

Tumor Susceptibility Across Species

It has long been observed that different species have differing levels of susceptibility to foreign-body tumors. As reported in Rao and Edmondson (1990) who cite Brand, KG (1982), evaluation of prior research shows that mice, rats, and to some extent, dogs are more susceptible to foreign body tumorigenesis than guinea pigs, chickens, and hamsters, for instance.

The fact that rodents and dogs have developed cancer in response to implants does not necessarily mean that humans will do the same. Blanchard et al. caution that "blind leaps from the detection of tumors to the prediction of human health risk should be avoided" (p. 526). In humans, fibrotic scar formation proceeds at a much slower rate than in rodents, which might indicate that humans are more resistant to foreign-body-induced tumors than rats and mice, suggest Elcock et al. (p. 491).

Humans are Susceptible to Foreign-Body Carcinogenesis

Nevertheless, according to Elcock's summary of the literature on foreign-body tumorigenesis, any inert substance inserted into the body for long periods can produce neoplasia (abnormal tissue growth), including in humans (p. 489). Vascellari et al. (2004) note that foreign-body-induced sarcomas, including osteosarcomas, rhabdomyosarcomas, haemangiosarcomas, and liposarcomas, have been described in humans, although with a low prevalence (p. 190).

Most of the malignant, microchip-induced tumors in rodents reviewed in the present report were classified as sarcomas – soft tissue cancers that afflict the muscles, tendons, fibrous tissues, fat, blood vessels, and nerves. The following is a brief description of this type of cancer in human beings from Blake Morrison (2003) of Baylor University Medical Center:

Soft tissue sarcomas are a diverse group of neoplasms that arise in the connective tissues throughout the body. They account for approximately 1% of adult malignancies and 7% to 15% of pediatric malignancies. About 50% to 60% of sarcomas occur in the extremities [the arms and legs], and although they are rare, they are responsible for more deaths than testicular cancer, Hodgkin's disease, and thyroid cancer combined. These tumors are notorious for recurring and metastasizing—often with devastating *results—despite apparently complete resection. ...The National Cancer Institute's Cancer Surveillance, Epidemiology, and End-Result (SEER) Program in 1996 reported 6400 new cases of soft tissue sarcoma, including 3500 in males and 2900 in females (2), for a male-to-female ratio of about 1.2:1.*

Sarcomas can arise in human beings in scar tissue as a result of "foreign body implantation" among other causes, according to Kasper et al. (2004).

Jennings et al. (1988) reviewed published research involving six cases of angiosarcoma and 40 cases of sarcomas of other types associated with foreign-body material in humans. They found that these cases "provide compelling evidence that solid-state [foreign-body] tumorigenesis is operative in humans," and note that "implanted foreign material ... should be considered capable of inducing virtually any form of sarcoma in humans" (Jennings et al., 1988).

Jennings et al. describe each of the three cases investigated in their study as "a high-grade tumor, which metastasized and led to the death of the patient" (p. 2443). In commenting on cases from the prior literature, they observe that the malignancies developed between four months and 63 years after exposure to the foreign body, and that the foreign-body related sarcomas "appear to be highly aggressive, both morphologically and biologically" (p. 2443).

Other researchers have also found highly aggressive sarcomas and carcinomas developing in humans around or near implants, including pacemakers (Biran et al., 2006; Rothenberger-Janzen et al., 1998; Rasmussen et al., 1985), vagus nerve stimulators (Cascino et al., 2007), and orthopedic implants (Keel et al., 2001). Based on these findings, researchers recommend that all material near implants that is removed from patients should be carefully examined for cancerous changes.

In another case, surgical threads found within and near a malignant tumor were believed to have induced tumorigenesis (Martin-Negrier et al., 1996). The researchers cite Brand's animal studies showing that the physical presence and not the chemical components of the implant of foreign bodies may be responsible for tumorigenesis, and point out that the most critical factor in the induction of these sarcomas is the formation of a fibrous capsule around the foreign body. They note that, "in our case the persistence of a foreign body ... and the presence of large extensive fibrosis areas in the tumor seem to be in agreement with this possibility."

Brand et al. (1975), reporting on rodent studies, note that removing the foreign body may not be enough to prevent the development of cancer once the tumorigenesis process is already underway. They write:

As reported in the literature and infrequently observed in our laboratory, removal of the [foreign body] implant from the tissue capsule during the late preneoplastic period does not always abort development of tumors from the remaining empty capsule . . . However, removal of the [foreign body] left a solid collagenous, possibly even calcifying or ossifying, scar that failed to resolve and therefore acted like [foreign body] material. The latter explanation may underline the occurrence of scar-related sarcomas in man, as reported in the literature. (p. 283)

Other Adverse Reactions to the Implants

Several studies incidentally reported other problems related to the microchips, including migration (shifting location in the body), incorrect insertion, failure to work, and loss from the body.

Migration

Despite the presence of the polypropylene sheath designed to anchor the implanted microchip, chip migration appears to be an ongoing problem. Le Calvez et al. found that microchips that had migrated from the initial implantation site accounted for 19.3% of the tumors they observed. Although the devices were originally injected into the backs of the animals, the microchip-associated tumors were later found in the limbs (4/52), the abdominal region (4/52), and the dorsal head (1/52) (p. 259).

Murasugi et al. reported no cases of migration in their study of nine dogs. However, Jansen et al. (1999) found that about half of the transponders inserted into the shoulders of beagle dogs in a four-month study had migrated to some extent. Reports from veterinarians also indicate that migration is a problem in dogs. In the United Kingdom, a voluntary registry of adverse reactions to microchip implants has been maintained by the British Small Animal Veterinary Association (BSAVA) for several years. Migration is the most common problem reported to the BSAVA, with "the elbow and shoulder being the favourite locations of wayward microchips" (BSAVA, 2004). The BSAVA reports that "[i]t is surprising how quickly some microchips migrate," noting that microchips have been found in a different location as little as one week after implantation or up to ten years later (BSAVA, 2003). Over 180 cases of migration have been reported to the BSAVA since 1996.

Injection Error

Occasionally, due to technician error, implants are injected into the wrong site on animals. Rao and Edmondson reported that 5% (7 of 140) of the microchips used in their study were later found in the perirenal area (in the abdominal cavity, surrounding the kidneys) instead of in the correct implant area just under the skin on the back. They surmise that the implants either had migrated or had been injected incorrectly directly into the abdomen. Johnson reported similar problems, stating, "occasionally some would be inserted too deep, the needle that put them in was probably held at the wrong angle" (Johnson, personal communication, 2007).

Like migration, the danger of incorrect injection also poses a risk to pets. The BSAVA cautions that technicians must be properly trained to perform the implant procedure, citing a "disastrous" incident in 2004 where an attempt to implant a struggling kitten resulted in its sudden death. A post-mortem examination later revealed that the microchip had been accidentally inserted into the kitten's brainstem (BSAVA, 2004). In another case a cat suffered severe neurological damage when a microchip was accidentally injected into its spinal column (Platt et al., 2006).

Failure and Loss of Transponder

Other problems with the microchips include failure to function, in which the microchip ceases to respond to a query from the reader device, and loss, where the microchip exits the body. Rao and Edmondson reported that four of the 140 implants used in their study failed due to microscopic cracks in the weld connecting the antenna leads to the microchip or leakage of the glass capsule resulting in fluid accumulation around the microchip (p. 413).

Rao and Edmondson also reported that an additional two of the 140 microchips in their study were lost, including one microchip lodged in the subcutaneous tissue over the lumbar vertebrae that was pushed out slowly through the scar tissue of the injection site during the tenth month after implantation.

In the Tillmann study, 1.5% of 4,279 (approximately 64) implanted microchips had to be substituted with new transponders when they either ceased functioning or were lost from the body and later found in the softwood of the cages. Most of the losses occurred in the first two days after implantation, but some occurred as long as seven months later.

Johnson also reported that failure and loss was an issue with the implants, stating: "We had a few early in the studies that would migrate out if the wound wasn't healing properly" (Johnson, personal communication, 2007).

Adverse Reactions Likely Under-Reported

It is likely that the true rate of microchip adverse reactions in the studies was higher than reported, since the purpose of the articles was to discuss microchip-induced cancer, not other complications. One indication that this may be the case is Johnson's personal communication (2007) reporting failure, loss, and migration, as discussed prior. Though these events did occur, they were not reported in his original published report and were only solicited in response to a specific query. It is possible that other investigators may have likewise neglected to mention such reactions when they did occur.

Adverse reactions to microchips implanted in dogs and cats may also be substantially underreported. The BSAVA (2003) reported that

2003 saw a marked increase in the number of reports received through the Adverse Reaction Reporting Scheme. It is significant that several reports were received from some quite small practices while many larger practices filed no reports at all. This suggests that there is an element of under reporting which may be happening for a variety of reasons.

Anecdotal evidence supports the proposition that adverse reactions are underreported in the veterinary and oncological literature. A review of Internet discussion boards reveals the following posts by dog owners who believe their pets have suffered adverse reactions from implants (Dogster's, 2007):

My mothers dog "Buddy" actually lost his life to a "large" malignant sarcoma that was located on his back by the chip. It was removed once, but aggressively grew back and quickly took his life. I strongly believe this Chip is what took his life.

My cocker spaniel, Cooper ... has two microchips in him. The first one quit working, so he was implanted with a second one.

My dogs problem with microchip - swelling area around microchip, even to about 4 cm big, it goes away after a course of AB.

Jack was microchipped at his first vet visit when we got him - oh so many years ago ... I'm wondering - now that he is a senior citizen, I feel a small lump where the microchip was implanted - I am assuming it's only scar tissue and my vet has backed that up ...

... when Myrl was microchipped, the vet was very rough and he bled a LOT. She kind of stabbed him with the injector and he yelped and his white fur turned red. It was horrible.

None of these incidents appears to have been formally reported to any agency or decision-making body, and a review of the literature indicates that none has been investigated or written up by the academic veterinary community. Similarly, although reports of chip-related neurological damage and infection in horses have begun to appear on the Internet (see, for example, Dutch Group Nijhof.), few, if any, reports of adverse microchip reactions in horses have been written up in the literature.

Even when pet owners contact veterinarians and researchers to report their adverse experiences, they often find it difficult to get a response. Jeanne, the owner of Leon, the bulldog whose chip-related tumor is described by Vascellari et al. (2006), reports her frustration at how difficult it was to get anyone to pay attention to what had happened. Her quest to tell Leon's story became almost a full-time endeavor as she searched the globe for a veterinary oncologist willing to look at the evidence and investigate the tumor (McIntyre, 2007; "Jeanne," personal communication, September 2007). Jeanne has maintained an updated file of articles that can be found at http://www.noble-leon.com/resourcesAdvanced/microchips.html. In the Additional References section are some of the articles she cites that have been published since this paper was originally written.

It is clear that a better mechanism for reporting adverse effects is needed and that veterinary oncologists and others need to open a better dialog with members of the public around these important issues.

What Do These Findings Mean for People?

As discussed previously, it is known that humans are susceptible to foreign-body carcinogenesis, though they appear to be less susceptible than rodents. As a foreign body, the microchip implant could potentially give rise to tumors within human beings.

The long-term effects of implanted microchips in human beings are presently unknown. Although the VeriChip implant received FDA approval for use as a medical device in October 2004, when the VeriChip Corporation became a publicly traded company in early 2007, its SEC registration statement disclosed that only 222 people in the United States had been implanted with its product. (Source: VeriChip Form S-1 Registration Statement (Amendment No. 7) see: http://www.sec.gov/Archives/edgar/data/1347022/000119312507024937/ds1a.htm p.92)

With only a few years of data available on a very small number of people, it is difficult to draw definitive conclusions about the safety of the device. If humans follow a similar pattern of microchip-induced cancer development to that observed in mice and rats, we would not expect to see implant-induced malignancies until half a lifetime's exposure, or approximately 30-40 years.

This researcher is aware of no formal follow-up procedure to evaluate the health effects or long-term safety of implanted microchips in human patients. The lack of a formal evaluation procedure and a means of publicly reporting adverse reactions that is well-understood by patients and other implantees means that such reactions could be occurring and yet be unreported to the public or to the FDA.

There is a further consideration in this day of increasing carcinogen exposure. Recent research indicates that exposure to multiple carcinogens, even within safe levels, can result in cancer development at rates that exceed what would be expected from the individual carcinogens alone. This has been called the "toxic cocktail" effect. For a discussion of research regarding this effect see Trivedi, 2007.

The microchip-induced tumors observed in the Elcock et al. study described in this paper may have been an example of the toxic cocktail effect. In that study, only rats exposed to a test chemical developed malignant tumors around the microchips. However, even rats exposed to a very low dose of the chemical compound developed the malignancies. It may be that the microchip, when combined with even small doses of a chemical compound, worked together to bring about a cancerous response.

It is estimated that every day we are exposed to 75,000 artificial chemicals (Trivedi, 2007). It would therefore seem prudent to avoid unnecessary or elective exposure to additional potential cancer-causing agents – such as implanted foreign bodies – either in ourselves or in our pets.

RECOMMENDATIONS

The following recommendations are proposed for physicians, policy-makers, veterinarians, pet owners, and veterinary researchers in light of research findings on microchip implants.

For Implanted Human Patients and Their Doctors

There are many unanswered questions about the safety of microchip implants in human beings, but what we know from animal studies is disquieting. In light of the fact that microchip implants cause serious adverse reactions in animals, the practice of chipping human beings should be immediately discontinued until the tumorigenesis process is more fully understood.

In addition, all patients, members of the public, and medical volunteers who have been implanted with microchips to date (an estimated 300 people in the United States and 2,000 people worldwide) should be immediately informed in writing of the causal link between microchips and cancer in rodents and dogs. Implanted individuals should be offered a procedure for microchip removal at the expense of the facility that provided the implant, should they choose to have the device removed. Following the advice of Jennings et al. (1988, p. 2444) that "all material removed from patients in proximity to foreign implants should be examined histologically," the tissue surrounding all removed implants should be preserved for later histological analysis.

Physicians whose patients chose to retain the microchips should routinely examine the tissue surrounding the implant for swelling, inflammation, evidence of chip migration, and pain. Any unusual sensations, lumps, or other abnormalities should be analyzed for cancerous or pre-cancerous changes. All adverse reactions, whether related to cancer or other problems, should be immediately reported to the FDA for disclosure in the public record.

For Policy-Makers

Given the clear, causal link between microchip implantation and malignant tumors in laboratory rodents and dogs, it is strongly recommended that policy makers reverse all policies that mandate the microchipping of animals under their jurisdiction or control. These include ordinances passed by state and local authorities, policies implemented at animal shelters, and formal positions adopted by animal welfare, affinity, and interest groups across the United States and around the globe.

It is the opinion of this researcher that mandatory microchipping ordinances should be repealed and replaced with a voluntary system of microchipping at the discretion of pet owners. Any pet owner who chooses to have a microchip implanted in his or her animal should be fully informed of the potential risks of the procedure. No one should be forced by law or otherwise coerced into implanting an animal against his or her conscience or medical judgment.

For Veterinarians

Veterinary offices are one of the most common places where implant procedures are performed. Since veterinarians are often the primary point of contact for pet owners on the topic of microchipping, veterinarians should familiarize themselves with the research findings and carefully consider the potential for adverse reactions before recommending implants for their patients.

Pet owners should be clearly advised of the research linking the microchip to cancer in rodents and dogs when seeking advice about the chipping procedure or choosing to have it done to their pets.

In the case of animals that have already been implanted, Vascellari et al. suggest that veterinary surgeons should routinely palpate the tissue surrounding microchip implants as part of routine medical care. Any lumps or inflammation should be investigated for cancerous or pre-cancerous changes. To avoid the complicating risk of injection-related sarcoma, veterinarians should avoid administering vaccines or other injections at or near the site of an implanted microchip.

Finally, veterinarians should advise pet owners to routinely examine the site of the implanted microchip themselves and immediately report any abnormalities.

For Pet Owners

There have been no large-scale, statistically valid, clinically controlled, experimental studies involving microchip implants in dogs and cats, so we know very little about their long-term safety. However, the fact that we have not seen an epidemic of cancers in pets would suggest that only a small number will be impacted. As the chip-removal procedure is likely to be both costly and invasive, pet owners may wish to leave the implanted microchips intact within their animals unless a problem surfaces.

Owners of pets that have been implanted should regularly check the area for any abnormal lumps or swelling. If something unusual is found, it should be reported immediately to a veterinarian, and tests should be done to rule out cancer. The pet owner may be the key to detecting a problem in the early stages and saving the life of a pet. In the two cases where dogs developed tumors around and attached to implants, it was the owners' astute eye and probing fingers that found it, not the veterinarian. The only indication that there was a problem was the lump; all other laboratory tests came back within normal ranges.

If a pet is not currently microchipped, it may be best to keep it that way. It is the opinion of this researcher that all further implantation of pets should be halted until the existing population of chipped dogs is carefully assessed for adverse reactions, including cancer. There are other ways to ensure a pet is returned to its owner in the event it goes missing. A well-made collar and a clear, legible tag with the owner's contact information are effective tools that have worked for generations of pet owners.

For Veterinary Oncology Researchers

There is fertile ground for additional research in this area. Indeed, systematic study would add greatly to our understanding of the process of tumorigenesis as related to microchip implants. Other than preliminary research involving a very small number of animals (e.g., Ball et al.; Rao and Edmondson), there have been no studies to date that have systematically examined the development of microchip-induced sarcomas as a research goal in itself. Almost all of the cancers reported herein arose incidentally, in the course of other research.

One important direction for future research would be to explore the role of the electromagnetic energy received and transmitted by the transponder. This could help isolate whether the tumors stem from a foreign-body reaction to the external surface of the microchip alone (i.e. glass capsule and polypropylene sheath) or whether some characteristic of the device in its capacity as a radio-frequency transponder could be partially or fully responsible for the tumors. A study could be designed to investigate the role of radio-frequency energy by implanting some animals with intact transponder devices and others with empty capsules, or capsules filled with an inert substance of the same mass as the current contents of the glass capsule. In each of these groups, animals could also be exposed to different levels of energy from the reader. Although these studies would help to answer a number of the questions raised, for reasons of conscience the author does not personally endorse the use of animals for this type of experimentation.

Proposal to Create a National Registry

The research community and society at large should take advantage of the fact that there are already millions of chipped dogs in the U.S. Rather than conducting further, potentially painful and invasive studies on dogs and other animals, we can use the animals that are already chipped to learn more about how living creatures respond to these devices.

Doing so would require the creation of a central registry for reporting adverse reactions to microchips, including cancer. A registry could be created in one of the following ways:

- Dogs undergoing treatment for cancer could be voluntarily reported to an independent registry set up for this purpose. This could be done through a form similar to that used by the British Small Animal Veterinary Association. Their 2-page "Microchip Adverse Reactions Reporting Form" can be found at http://www.bsava.com/VirtualContent/85185/adverse_reaction.pdf. Because microchip-induced cancer may metastasize and lead to cancer in other parts of the body, it is important to rule out the microchip as the source of cancer in dogs. Veterinarians would report the chip status of all dogs with cancer under their care, and a statistical analysis could be made to determine whether chipped dogs have a higher overall incidence of cancer than their non-chipped counterparts.
- On a voluntary basis, veterinarians disposing of the remains of chipped animals could remove the microchip and surrounding tissue and send it to a laboratory for histological analysis.

Done on a large scale, these measures would provide important data that could be used to assess the safety of microchip implants in dogs. Establishing national registries for adverse reactions and evaluation of tissue samples would provide a more systematic way of assessing the risk than the current state of relying on case-by-case, anecdotal reports alone.

CONCLUSION

The body of research reviewed in this report indicates a clear causal link between microchip implants and cancer in mice and rats. It also appears that microchips can cause cancer in dogs–and that they have done so in at least one case, and quite likely in two. These findings raise a red flag about the continued use of microchips in both animals and human beings.

As the Associated Press reported, this concern is shared by some of the nation's most respected cancer researchers.

"There's no way in the world, having read this information, that I would have one of those chips implanted in my skin, or in one of my family members," said Dr. Robert Benezra, head of the Cancer Biology Genetics Program at the Memorial Sloan-Kettering Cancer Center in New York. He added, "[g] iven the preliminary animal data, it looks to me that there's definitely cause for concern."

Dr. George Demetri, director of the Center for Sarcoma and Bone Oncology at the Dana-Farber Cancer Institute in Boston, agreed. Even though the tumor incidences were "reasonably small," in his view, the research underscored "certainly real risks" in RFID implants, adding that the tumors can be "incredibly aggressive and can kill people in three to six months."

Dr. Chand Khanna, a veterinary oncologist at the National Cancer Institute, said that the evidence "does suggest some reason to be concerned about tumor formations." All of the cancer specialists agreed that the animal study findings should be disclosed to anyone considering a chip implant.

On the basis of these findings, physicians, patients, veterinarians, and pet owners may wish to carefully consider whether the benefits of implants are worth the potential health risks such implants appear to pose. It is the opinion of this researcher that further microchipping of pets or human beings should be immediately discontinued.

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KEY TERMS AND DEFINITIONS

Adenocarcinoma: A form of cancer that involves cells from the lining of the walls of many different organs of the body. Breast cancer is a type of adenocarcinoma.

Anaplasia: Reversion of cells to an immature or a less differentiated form, as occurs in most malignant tumors.

Angiosarcoma: A malignant tumor originating from blood vessels.

Cancer: A general term for more than 100 diseases that are characterized by uncontrolled, abnormal growth of cells. Cancer cells can spread locally or through the bloodstream and lymphatic system to other parts of the body. (See also: *malignant*).

Carcinogen: An agent capable of initiating the development of malignant (cancerous) tumors. May be a chemical, a form of electromagnetic radiation or an inert solid body.

Carcinogenicity: The tumor-producing/cancer cell-producing potency of an agent.

Fibroblast: Resident cell of connective tissue.

Fibrosarcoma: Malignant tumor derived from connective tissue cells.

Foreign Body: Anything in the tissues or cavities of the body that has been introduced there from without, and that is not rapidly absorbable.

Genotoxin: A toxin (poisonous substance) which harms the body by damaging DNA molecules, causing mutations, tumors, or neoplasms. A substance that can mutate and damage genetic material. (Also *genotoxicant*).

Histiocyte: Long-lived resident macrophage (immune-related cells) found within tissues.

Histiocytoma: A tumor composed of histiocytes.

Histochemical: Study of the chemical composition of tissues by means of specific staining reactions.

Histology: The study of cells and tissue on the microscopic level.

Histopathology: The science concerned with the study of microscopic changes in diseased tissues.

Immunohistochemistry: Histochemical localization of immunoreactive substances using labelled antibodies as reagents.

Induce: To bring on; to effect; to cause.

Inert: Refers to a substance which will not chemically react with anything under normal circumstances.

Leiomyosarcoma: A malignant tumor of smooth muscle origin.

Liposarcoma: A malignant tumor that may be composed of fat cells.

Macrophage: Relatively long lived phagocytic cell of mammalian tissues. In response to foreign materials may become stimulated or activated. Macrophages play an important role in killing of some bacteria, protozoa and tumor cells, release substances that stimulate other cells of the immune system and are involved in antigen presentation.

Malignant: Tending to become progressively worse and to result in death. Having the properties of anaplasia, invasion, and metastasis, said of tumors.

Malignant Fibrous Histiocytoma (MFH): A deeply situated tumor, especially on the extremities of adults.

Malignant Tumor: A mass of cancer cells. These cells have uncontrolled growth and will invade surrounding tissues and spread to distant sites of the body, setting up new cancer sites, a process called metastasis.

Mesenchymal: Relating to the mesenchyme, embryonic tissue of mesodermal origin. The mesoderm is the middle of the three germ layers and gives rise to the musculoskeletal, blood, vascular, and urinogenital systems, to connective tissue (including that of dermis) and contributes to some glands.

Metastasis: The transfer of disease from one organ to another due either to the transfer of pathogenic microorganisms (for example, tubercle bacilli) or to transfer of cells, as in malignant tumors. The capacity to metastasize is a characteristic of all malignant tumors.

Metastases: A growth of abnormal cells distant from the site primarily involved by the disease process.

Metastasize: To spread to another part of the body, usually through the blood vessels, lymph channels, or spinal fluid.

Mitosis: A method of indirect division of a cell, consisting of a complex of various processes, by means of which the two daughter nuclei normally receive identical complements of the number of chromosomes characteristic of the somatic cells of the species.

Mitotic: Pertaining to mitosis.

Morphology: The configuration or structure (shape).

Moribundity: In a dying state; dying; at the point of death.

Mutagen: An agent that can cause an increase in the rate of mutation, includes X-rays, ultraviolet irradiation (260 nm), and various chemicals.

Necrosis: Morphological changes indicative of cell death.

Neoplasia/Neoplasm: New and abnormal growth of tissue, which may be benign or cancerous.

Oncology: The study of diseases that cause cancer.

P53 Gene: A gene which encodes a protein that regulates cell growth and is able to cause potentially cancerous cells to destroy themselves.

Rhabdomyosarcoma: Malignant tumor (sarcoma) derived from striated muscle.

Sarcoma: Malignant tumor of soft tissue (tissue that connects, supports or surrounds other structures and organs of the body). Soft tissue includes muscles, tendons, fibrous tissues, fat, blood vessels, and nerves.

Schwannoma: A neoplasm [new and abnormal growth of tissue] originating from Schwann cells (of the myelin sheath) of neurons.

Teratology: The branch of embryology and pathology that deals with abnormal development and congenital malformations (i.e., the study of birth defects).

Toxicology: The scientific study of the chemistry, effects, and treatment of poisonous substances.

Tumor: An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive, also called a neoplasm. Tumors perform no useful body function. They may be either benign (not cancerous) or malignant.

Tumorigenesis: The production of tumors.

Validity: The extent to which a measurement, test, or study measures what it purports to measure.

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Section 2

Disease Diagnosis and Prevention

Chapter 5
Thermographic Evaluation of Racehorse Performance

Maria Soroko
Wroclaw University of Environmental and Life Sciences, Poland

ABSTRACT

Thermography has found a broad range of applications in equine sport and veterinary medicine. Thermographic diagnosis is useful in monitoring changes of horse surface temperature resulting from exercise allowing evaluation of the work of individual parts of the body in racing performance. Regular assessment of body surface temperature allows the detection of training overloads and identification of pathological conditions of the musculoskeletal system during the racing training cycle. The usefulness of thermography in veterinary medicine has been proved in detecting pathological conditions associated mainly with inflammation processes of the distal parts of the limbs and back. The main advantage of thermography is the detection of subclinical signs of inflammation before the onset of clinical signs of pathology, providing great value in veterinary medicine diagnosis. Thermography has also found application in detecting illegal performance procedures to improve horse performance and in assessing the saddle fit to the horse's back.

INTRODUCTION

Thermography in equine veterinary medicine was introduced in 1965 and since that time has been considered for use in a wide range of applications (Delahanty & Georgi, 1965).

Thermography enables abnormal patterns in skin surface temperatures (and hence vascularity and metabolic activity within and below the skin surface) due to injury to be detected (Turner, 1991). One of the clinical signs of inflammation is heat, related to metabolic activity and an elevated local circulation, recognised thermographically as a 'hotspot' (Ring, 1990). Other pathological conditions reduce blood circulation due to either vascular shunts, thrombosis or autonomic nervous system abnormalities and are recognised as 'coldspots' (Turner, 1991; von Schweinitz, 1999).

Therefore thermography has been used increasingly in equine veterinary practice as an efficient tool for detection of injuries of the musculoskeletal system in sport horses (Turner et al., 2001). It has been

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employed especially in the racing industry, where the physical demands put on racing horses are extreme (Figure 1). Constant overload of the musculoskeletal system due to regular training and racing can cause abnormalities associated with painful conditions or diseases, leading to loss of performance (Jeffcott et al., 1982; Rossdale et al., 1985). Injuries are mainly associated with soft tissue or bone fractures of the distal parts of limbs (Jeffcott, 1999; Parkin et al., 2004; Head, 2009). They are often variably clinically manifested, ranging from overt lameness but also pain on palpation or gait alterations (Jeffcott, 1999; Denoix, 1999; Haussler et al., 1999).

Lameness is a significant disorder for racehorses, recognized as an abnormality associated with painful conditions or mechanical injuries, which affect the horse's way of movement. Numerous reports describing lameness incidence in racehorses have been recorded in the United Kingdom. Investigations presented by Buchner et al. (1996), Ramdy (1997), Oliver et al. (1997), Jeffcott (1999), Kane et al. (2000), and Keegan et al. (2000) indicated that lameness is the main reason for training days being lost and wastage in the horse industry. In the study presented by Jeffcott et al. (1982), out of 163 Thoroughbred racehorses 53% suffered from lameness, which was the main cause of elimination of the horses from performance. A more recent study involving Thoroughbred racehorses recorded an 81% incidence of lameness (Williams et al., 2001).

One of the main problems with injuries is the long period of rehabilitation. Additionally, the reduced tissue functionality decreases the chance of the horse returning to its previous performance and soundness. It was reported that 70% of Thoroughbred horses failed to return to regular training after injury (Oikawa & Kasashima, 2002). Monitoring the impact of racehorse exercise programmes through the measurement of body surface temperature can help to detect potential injuries, maintain horse health and condition, and extend a horse's career in sport.

Figure 1. Thermogram of a racehorse with the rider from the lateral aspect

**For a more accurate representation see the electronic version.*

APPLICATION OF THERMOGRAPHY IN VETERINARY MEDICINE

Potential equine veterinary applications of thermography in identifying areas of pathology have been described (Purohit & McCoy, 1980; Bowman et al., 1983; Turner et al., 1983; Turner, 1991). These reports mostly address the detection of injuries, especially at the back and the distal parts of the limbs (Vaden et al., 1980; von Schweinitz, 1999; Turner et al., 2001; Turner, 2003; Soroko et al., 2013).

Clinical diseases of the distal limbs including tendonitis, carpal and tarsal joint inflammation and bucked shins have been recognized and characterized by thermography (Purohit & McCoy, 1980; Bowman et al., 1983; Turner et al., 1983; Turner, 1991; Soroko, 2011a). Thermography is also useful in recognizing abnormal conditions of the hoof including navicular syndrome, laminitis, sole abscesses, corns and other hoof-related structural pathologies (Purohit & McCoy, 1980; Turner et al., 1983; Turner, 1991). Thermography not only provides additional information about localizing the problem but also evaluates the degree of associated inflammation.

Thermography and radiography are complementary diagnostic tools for the study of inflammation diseases of distal parts of the limbs (Collins et al., 1976). They cooperate together in diagnosis of joint diseases, as radiography recognizes osseous changes, while thermography indicates changes associated with capsulitis and synovitis in joints. Cooperation between those two methods was successfully applied for diagnosis of osteoarthritis. The study presented by Vaden et al. (1980) indicated that thermography can be a useful tool for chronic tarsal joint arthritis diagnosis together with radiography, and also in the early stages of joint disorders, when no changes are detected in radiography examinations. Similar conclusions were indicated in the case of carpal inflammatory joint disease (Bowman et al., 1983).

Thermography and ultrasonography are also used as complementary tools for the examination of tendons in the distal parts of the limbs. While ultrasonography evaluates morphology of the tendonitis (the size and the shape of the injury), thermography localizes the injury. Moreover thermography can be useful to follow the healing process. As the tendon heals the thermal pattern becomes more uniform, but the temperature remains abnormally elevated compared with a normal tendon (Stromberg, 1972; 1974). Later in the recovery process, as the scar tissue is deposited, the skin over the injured area may actually show a decrease in temperature. According to Hall et al. (1987), ultrasonographic assessment of the structural reorganization of the tendon during healing did not correlate with the thermal changes. However a correlation between thermography and ultrasonography examinations was demonstrated at the time of diagnosis of the clinical signs of tendon inflammation (Soroko et al., 2012a).

Thermography has been shown to be useful in monitoring the healing process, being able to detect inflammation in cases with no clinical signs of injury (Bowman et al., 1983). Additionally, thermography was used to grade the significance of the inflammation during the recovery phase. In the study presented by Purohit and McCoy (1980) thermography monitored the response to anti-inflammatory drugs in the area of the front splints bones. Thermographic images confirmed the reduction of inflammation, however when no heat was detected manually at the affected area, the image continued to suggest increased blood circulation.

Other studies indicated the effectiveness of thermography in monitoring the development of cast sores in the distal parts of the limb. Thermographic evaluations of sored limbs were performed between 18-31 days after the cast. It was found that the technique was able to detect superficial and deep dermal sores. The results indicate that thermography can be useful in monitoring casts and the complications associated with them (Levet et al., 2009).

In the case of back abnormalities, thermography can diagnose muscular and spinous process inflammation of the thoracic vertebrae (Turner et al., 1996; Kold & Chappel, 1998). It has also been used to diagnose clinical cases of lumbosacral muscle tension (Turner, 1991; Turner et al., 1996). In another study thermography diagnosed the clinical signs of neuromuscular disease as caused by nerve dysfunction of the thoracolumbar region (von Schweintiz, 1999). Thermography has been compared with radiographic examination to detect an area of subluxation of the third lumbar vertebrae. The large mass of soft tissue meant that radiographic images did not detect the site of injury, whereas thermography was effective in identification of the exact site of the pathology (Purohit & McCoy, 1980). Thermography was shown to be an effective diagnostic tool in finding active or degenerative places of lesion. Another study presented by Kold and Chappel (1998), investigated the effectiveness of thermography in detecting inflammation along the spine in acute stages. Diagnoses were successful in identification of increased activity of the superficial soft tissue of the thoracic spine and symmetrically over the sacroiliac area. It has been suggested that additional thermography diagnosis can help to locate the site of pain allowing other diagnosis to work more effectively (Turner, 2003). In another study, thermography (along with ultrasonography) was efficient at detecting supraspinous and interspinous ligament inflammation, dorsal intervertebral osteoarthritis and kissing spines of the thoracolumbar spine (Fonseca et al., 2006). Thermography has also been used as a first examination tool for the detection of subclinical inflammation, before the onset of clinical signs of injury. It diagnosed subclinical signs of tendonitis and joint arthritis prior to the appearance of clinical signs of inflammation (Stromberg, 1974; Vaden et al., 1980; Bowman et al., 1983). Recent studies also report possible detection of subclinical inflammation in racehorses (Turner, 1991; Turner et al., 2001; Soroko, 2011a; Soroko et al., 2013). In the study presented by Turner et al. (2001), out of 127 specific limb problems in racehorses, 120 abnormalities were predicted 2 weeks before they became evident clinically. Thermography may therefore help to avoid future loss of soundness by applying treatment or by changing the training program.

PROCEDURES FOR THERMOGRAPHIC EXAMINATION

Internal and external factors have a significant effect on body surface temperature distribution. The proper use of thermography to evaluate surface thermal patterns therefore requires a controlled environment, and the physiological state of the horse must be considered in order to reduce variability and eliminate errors of interpretation (Head & Dyson, 2001; American Academy of Thermology, 2013; Soroko & Davies – Morel 2016).

Indoor thermography measurement standards have been established in equine veterinary practice (Purohit, 2009). To enhance the diagnostic value of thermography, the thermographic examination should be performed in an area sheltered from the sunlight, in the absence of air drafts (Palmer, 1981; Turner, 2001; Westermann et al. 2013). The ambient temperature of the examination room should be maintained between 21°C to 26°C. Slight variation in some cases may be acceptable, but room temperature should always be cooler than the animal's body temperature and free from bright lights. It is also recommended to acclimatise the horse for 15-20 minutes prior to imaging in the room where thermography will take place. A longer period of equilibration may be required in cases where the animal is transported from an extreme cold or hot environment. According to Tunley and Henson (2004), the thermographic pattern does not change significantly during acclimatization, but the time taken for stabilisation of the absolute temperature of the body surface is between 39 and 60 minutes. The major factor affecting this equilibration time is the temperature difference between the original environment and that in which the images are to be obtained. Therefore a stabilisation period of one hour is suggested after exposure to a different ambient temperature (Palmer, 1983). Another factor affecting the quality of thermograms is sweating. Therefore imaging should be performed prior to exercise (Purohit, 2009). The examimed horse must have a clean, dry hair coat and should be groomed at least one hour before the examination. Artifacts can be produced by any material on the body surface such as dirt, thick coat, scars and bands (Stromberg, 1974; Palmer, 1981). The feet should be brushed to remove external contamination. Anti – inflammatory medications, vasoactive drugs, regional and local blocks, sedation and tranquilisation should be avoided because of their effect on superficial perfusion (Purohit, 2009). Blankets should be removed at least 30 minutes before thermographic examination, and any bandages should be removed at least two hours before imaging (Palmer, 1981).

Emissivity of the hair coat is generally assumed to be 1, but a lack of precise knowledge of this value will have a small impact on accuracy of perhaps a few tenths of a degree Celsius (Soroko & Davies-Morel, 2016).

Hair coat has been shown to be an effective insulator by blocking heat emission from the skin (Turner, 1991). It has been found that clipping does not cause any change in the thermal distribution but does result in an increase in overall thermal emission. This indicates that clipping is not necessary for a reliable thermogram, however it is necessary that the hair coat be short, of uniform length, and lay flat against the skin to permit thermal conduction (Turner et al., 1983). This is important in the feet area, where some horses can have long "feathers".

The effect of the coat on thermal distribution has many considerations, because its emission presents a rough surface causing an error in reading the surface temperature. The coated animal surface seen by the camera includes some layers within the coat. Its equilibrium temperature in air is determined by the balance between the loss of heat by radiation and convection to the surrounding environment, and heat conduction through the coat, (Cena, 1974). Clark and Cena (1973) described the transmission of thermal radiation through animal coats of various colours and the related effects of environmental factors. The influence of radiant solar energy on pigmented and non-pigmented areas of the coat was also examined. There was a significant difference in coat surface temperature, up to 8°C between hotter black pigments compared to white areas. It was concluded that skin temperature differences are clearly expressed on the thermal image, but the effect of environmental factors can disturb a reliable thermal image of the animal. In a later study, it was confirmed that under direct sun exposure, black areas of the skin are significantly warmer compared to unpigmented areas. However, indoor examination did not present a significant difference between pigmented and non-pigmented areas (Palmer, 1981). It was also suggested that solar energy absorption depended on the shape and posture of exposed areas to sun (Clark & Cena, 1973). Errors of reading can also be influenced by curvature of the anatomical surface, variations in coat thickness, or pigmentation differences (Clark & Cena, 1977; Turner et al., 1983).

Notes of the thermographic examination should include age, gender and breed of the horse, type of performance and training intensity, and also information about saddle fit. A medical history is also required, including results of other veterinary examinations like radiography, ultrasonography and palpation. This is crucial because many musculoskeletal injuries can be detected by thermography not only in the acute or chronic but also the subclinical stage of inflammation (Soroko & Davies-Morel, 2016).

Thermographic examination of the horse for veterinary diagnosis should include a lateral aspect of the whole body from both sides (Eddy et al., 2001). In these views there should be equal loading of four all limbs with the lateral and medial aspects of the limbs visible. Imaging distance should be about 7

m. The distal parts of the forelimbs and hindlimbs can be imaged from a distance of approximately 2 m (Van Hoogmoed & Snyder, 2002) and should include dorsal, palmar/plantar, lateral and medial aspects. Symmetrical limbs imaged together for palmar or dorsal aspects in one thermographic image should be positioned next to each other; the horse should stand straight without lateral and medial rotation, and the limbs should be evenly loaded.

It is also important to include both lateral aspects of the head, neck, thoracic and pelvic areas, imaged from a distance of around 3 m. The thoracolumbar and sacral parts of the spine should be imaged in the dorsal aspect (von Schweinitz, 1999) from a height of approximately 1.2 m and at a distance of 1.5 m.

SURFACE TEMPERATURE DISTRIBUTION

Thermographic patterns of the healthy horse have been described, enabling improved diagnostic interpretation of equine thermography (Soroko & Davies-Morel, 2016). It was found that every horse has its own individual and reproducible thermographic pattern, which is related to the vasculature and tissue metabolism and is influenced by ambient air temperature (Purohit & McCoy, 1980; Waldsmith & Oltmann, 1994). However, a number of studies have demonstrated repeatability of body surface temperature distribution on the same areas in different horses (Vaden et al., 1980; Purohit & McCoy, 1980; Palmer, 1981). The skin overlying major vessels will appear warm, whereas areas distal to a major blood supply will appear cooler. Normally veins are warmer compared to arteries because they are in metabolically active areas and closer to the skin surface. Venous drainage from tissue with a high metabolic rate is warmer than venous drainage from normal tissue. The temperature of skin overlying a muscle mass depends on muscle activity.

Based on the above findings, some generalisations can be made regarding the thermal pattern of the horse. The midline of the horse is warm, including the back, chest, and the area between the hindlimbs along the ventral midline (Turner, 1991). Temperature over the limbs decreases from the proximal to the distal part.

Studies by Purohit et al. (1977), Purohit and McCoy (1980), Turner (1991) and Tunley and Henson (2004) has established normal thermographic patterns of the distal parts of the limbs and the back for clinical use.

The patterns obtained in the distal parts of the limbs are characterised by right and left temperature symmetry. Also the thermal symmetry was found to be identical between distal parts of forelimbs and hindlimbs (Purohit & McCoy, 1980). Variations in local blood supply determine the thermal pattern. Areas of increased temperature follow the vascular patterns, including the 3rd metacarpal/metatarsal from the medial and lateral aspects, and coronary band arteries in the dorsal aspect (Vaden et al., 1980; Turner, 1991). In the dorsal aspect joints are cooler compared to the surrounding structures, except the tarsal joint which has a vertical area of increased temperature medially corresponding to the saphenous vein. The route of the median palmar vein in the forelimb and the metatarsal vein in the hindlimb produces a warm region between the 3rd metacarpal/metatarsal and the flexor tendons (Figure 2). Therefore the medial metacarpal/metatarsal region is warmer than the lateral. In contrast, areas distant from major blood vessels appear cooler, including the 3rd metacarpal/metatarsal bone, fetlock, and pastern from the dorsal and palmar/plantar aspects (Turner et al., 1996) (Figure 3, 4).

Figure 2. Thermogram of lateral aspect of the distal part of right forelimb and medial aspect of distal part of left forelimb. Areas of increased temperature follow the vascular patterns in 3rd metacarpal region

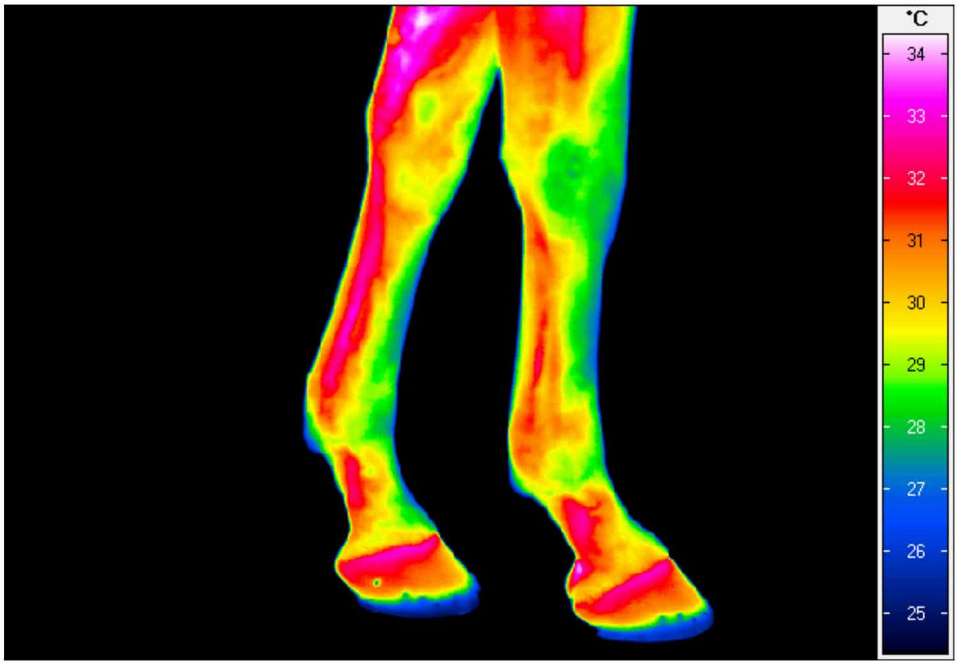

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Figure 3. Thermogram of dorsal aspect of the distal part of forelimbs. The highest temperature is in the coronary band. Lower temperatures follow the tendons

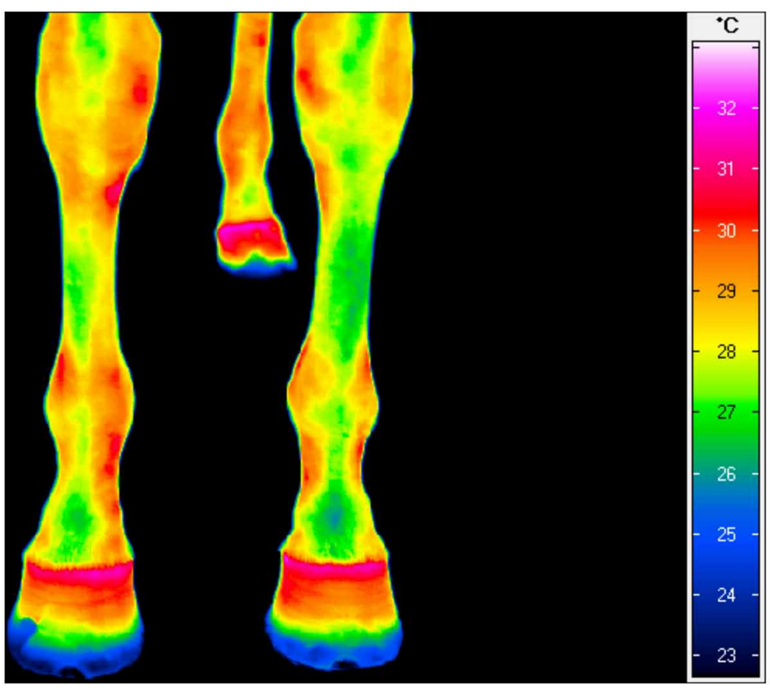

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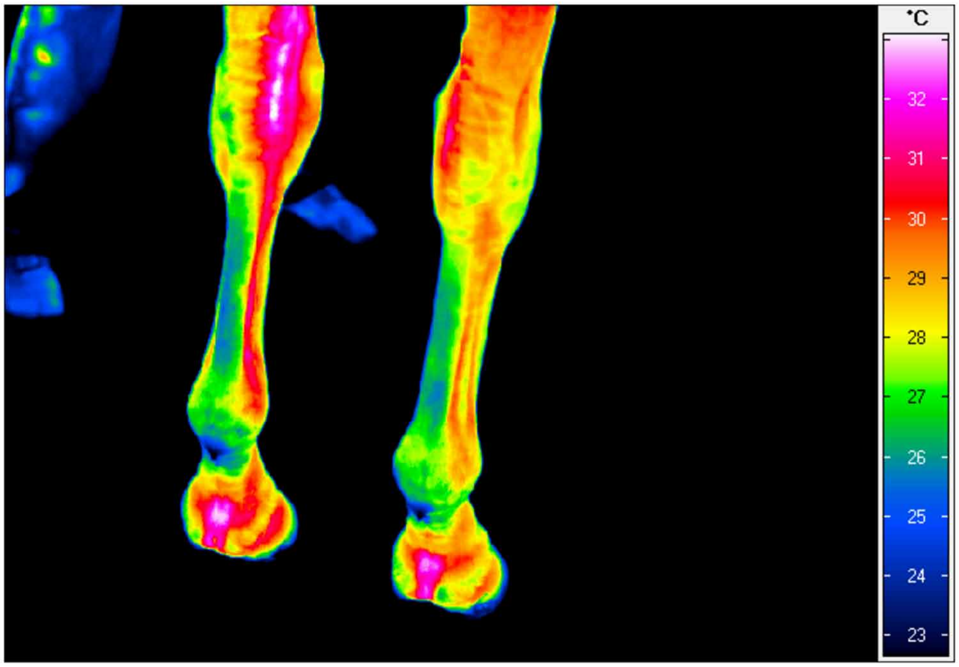
Figure 4. Thermogram of palmar aspect of the distal part of forelimbs. Increase in the heat between the heel bulbs. Lower temperatures follow the tendons



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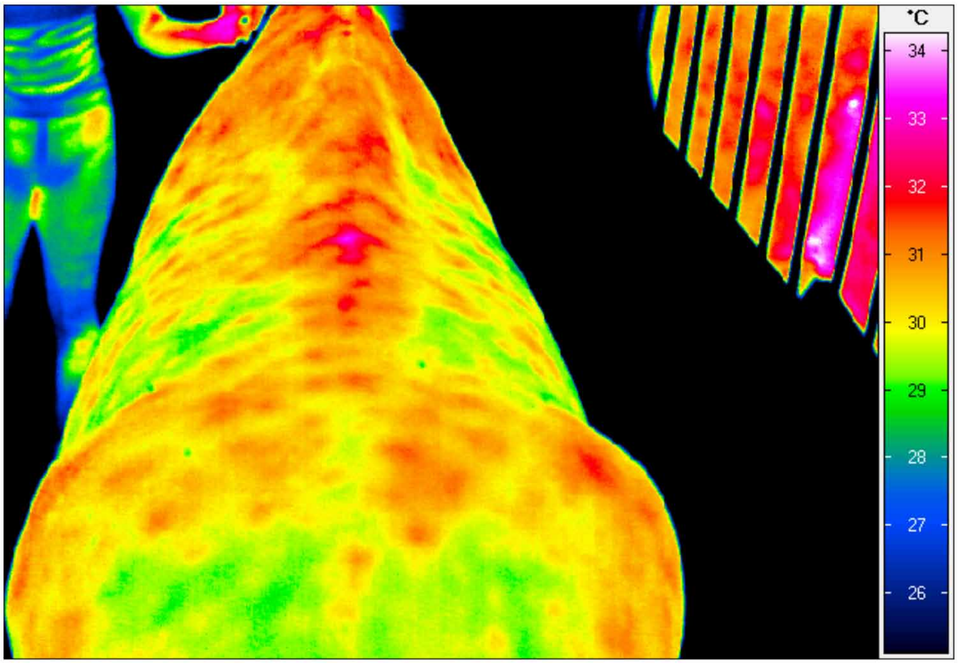
The highest temperature is in the coronary band, as it is situated close to the major arterio-venous plexus (Kold & Chappell, 1998; Turner, 2001) (Figure 3). The coronary band is 1-2°C warmer than the remainder of the hoof. The surface temperature of the hoof becomes gradually cooler towards the ground, because of the specific anatomic build of the hoof (Verschooten et al., 1997). Tendons have a low blood supply and will appear cold in the dorsal and palmar/plantar aspects because of their location far from superficial vessels. From palmar/plantar aspects, a high surface temperature is indicated in the area between the bulbs of the heels (Turner, 1991) (Figure 4).

Lateral and medial aspects of the distal part of the limb are more reliable than the palmar/plantar aspects for detecting and monitoring abnormalities in increased blood flow.

The thermographic image of a clinically healthy back presents with left and right temperature distribution symmetry along the midline of the spine (Kold & Chappell, 1998). Similar conclusions were found in another study where the thoracolumbar spine was divided into 6 horizontal lines along which the temperatures were measured. All thermograms indicated increased temperature along the midline of the spine, with a temperature 3°C higher at the midline at the thoracic and lumbar vertebrae (Tunley & Henson, 2004). A possible explanation is a high number of superficial subcutaneus blood vessels in that area (von Schweinitz, 1999) (Figure 5).

Any thermal asymmetry between compared bilateral surfaces can indicate abnormalities (Verschooten et al., 1997). However, not every asymmetry should be defined as an abnormal condition (Kold & Chappell, 1998). Temperature variations up to 1ºC between the compared limbs represents normal variation. Where there is a temperature difference of more than 1°C over 25% of the compared body

Figure 5. Thermogram of dorsal aspect of back. Increased temperatures follow the midline of the spine in the thoracic and lumbar vertebrae with temperature symmetry between right and left side of the back



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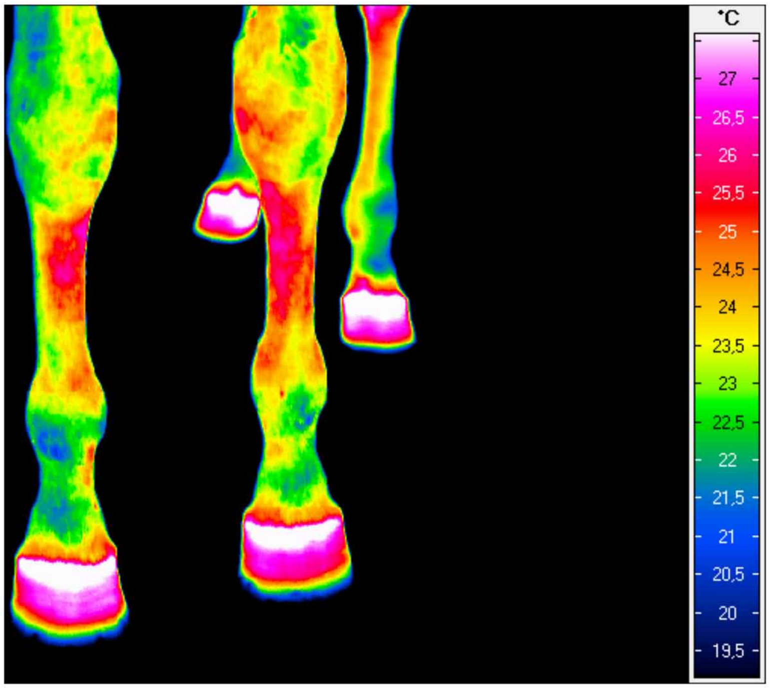
area, it is considered to be abnormal (Turner, 1991). Temperature differences of 1.25°C between the right and left distal parts of limbs indicated subclinical inflammation of the superficial digital flexor tendon and bucked shins in racehorses (Soroko et al., 2013). In another study, the early stages of bucked shins (Figure 6) were diagnosed when local temperatures over the dorsal 3rd metacarpal bone were 1°C to 2°C higher compared to the surrounding distal limb areas (Turner, 1991) .

In the early phase of laminitis, the coronary band had significantly increased surface temperature compared to the distal hoof wall and soles of the hooves (Noeck, 1997). In navicular disease, there was a reduction of the blood flow, especially in the heel region, because of vascular constriction. Affected horses presented with a lack of temperature increase in the suspected limb after exercise. The results were correlated with radiography findings, which showed an increased vascular foramina of the affected navicular bone (Turner et al., 1983). Therefore navicular disease can be recognized by thermography in the early stages, with the decreased blood flow appearing as a cooler area (Waldsmith & Oltmann, 1994).

Not every temperature asymmetry may lead to pathological conditions (Kold & Chappell, 1998). In the distal parts of the limbs, local skin temperature variations may be associated with the horse's homeostatic response to ambient temperature extremes. At low ambient temperature there is a maximal temperature gradient between the skin and the environment, because of vasoconstriction of the local vasculature in the extremities to conserve metabolic energy. At high ambient temperatures, vasodilation causes warming of the extremities, encouraging heat loss to the environment. Bilateral symmetry of the limbs is clinically valid throughout the range of ambient temperature (Palmer, 1983).

Figure 6. Thermogram of dorsal aspect of distal part of forelimbs. Subclinical inflammation of the right and left 3rd metacarpal bone



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APPLICATIONS OF THERMOGRAPHY IN RACEHORSE TRAINING

Body surface temperature distribution depends on movement, and the type of physical exercise performed, as the skin overlying muscle is subjected to an increase in temperature during muscular activity (Turner et al., 1996). Thermograms documenting the changes of horse surface temperature resulting from exercise could be useful in the evaluation of the work of individual parts of the body in racing performance (Purohit & McCoy, 1980; Waldsmith & Oltmann, 1994; Jodkowska et al., 2001; Jodkowska, 2005).

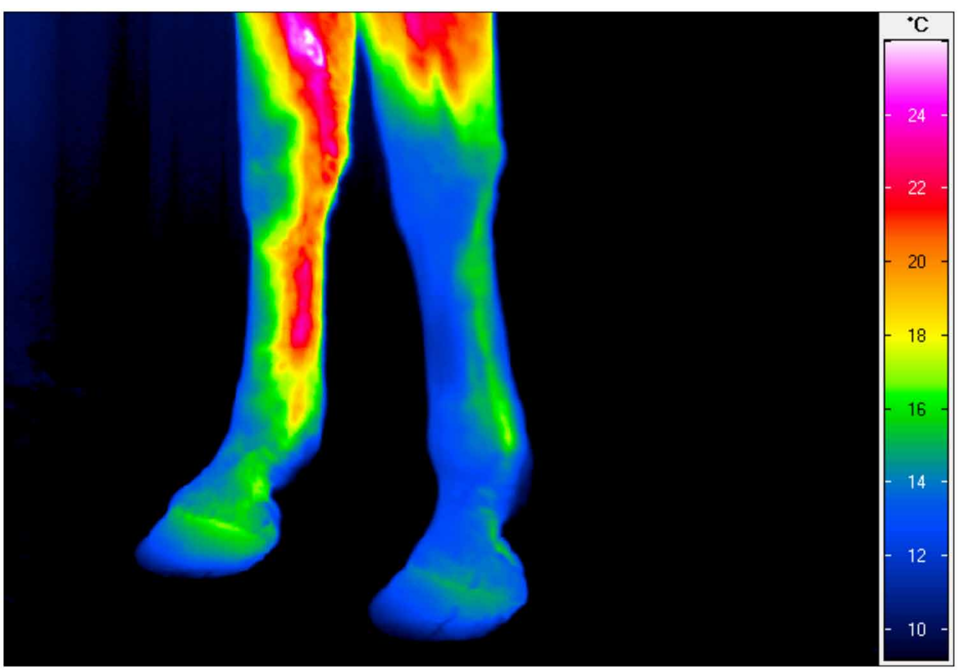
The study presented by Simon et al. (2006) highlighted the influence of exercise on body surface temperature changes in the forelimbs and hindlimbs. Thermal images of examined horses were taken before and after exercise on a treadmill. The skin temperature overlying muscle surfaces after exercise was increased by 6°C, whereas areas of distal parts of the limbs were increased by 8°C. There was a significant temperature difference during the first 15 minutes after exercise, whereas thermographic examinations performed 45 minutes after exercise were not influenced by the mechanism of thermoregulation. It was also found that muscular areas in the upper part of the body returned more quickly to the basal temperature compared to the dorsal parts of the limbs. In the study by Turner et al. (2001), racehorses had an increased hoof surface temperature for almost 24 hours after an intensive gallop.

Symmetrical temperature distribution on both sides from the front and from the back aspect should be present at rest, and also after exercise (Jodkowska et al., 2001). Any temperature asymmetry after training could be useful in the evaluation of the work of individual parts of the body in sport performance. Jodkowska (2005) determined a model of horse temperature before and after exercise. During the study the rectal temperature, pulse rate and blood parameters, as well as environmental factors were correlated with changing temperature patterns. It was concluded that body surface temperature patterns depend on exercise performance. Surface temperature examination of the distal limbs and back was helpful in assessing the quality of exercises and preparation of a horse for training. It was also found that the optimum period for measurements of body surface temperature was the time before exercise, or on the day after exercise.

Thermography was also confirmed as a valuable aid in regular assessment of racehorses by Turner et al. (2001). Thermographic imaging of the distal parts of the limbs and back at rest during the training season facilitated identification of inflammation affecting performance (Soroko at al., 2013). In the study presented by Turner et al. (2001) there was a high correlation between Thoroughbred racehorse trainers' and veterinary diagnosis supported by thermographic assessment. Additionally, in most cases subclinical inflammation was detected 2 weeks before clinical problems were noted. This finding confirmed reports in a previous paper that indicated injury of the superficial digital flexor tendon of racehorses prior to the appearance of clinical signs of inflammation (Stromberg, 1974) (Figure 7). The injured area showed increased temperature on the thermographic image even though radiogram did not show any changes. Stromberg (1974) concluded that thermography can predict tendon injures up to 14 days before clinical signs appear and can play an essential role in preventing lameness in racehorses.

The type of training has an influence on changes of body temperature distribution. Horses in training put more strain on the forelimbs, especially on the digital flexor tendons and bones (Nilson & Bjorck, 1969). Regular thermographic examination of racehorses found thermal abnormalities of forelimbs as-

Figure 7. Thermogram of lateral aspect of the distal part of left forelimb and medial aspect of distal part of right forelimb. Subclinical inflammation of superficial digital flexor tendon of right forelimb



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sociated with strains and overloads (Soroko, 2011b; Soroko et al., 2014). This confirms that racehorses are more likely to develop injury associated with the forelimb than the hindlimb (Peloso et al., 1994). The same conclusions have been presented in another study, where more signs of injuries in 4-year-old Standardbreed Trotters were recorded in the left forelimb compared to the right one (Magnusson, 1985). Possibly, as horses during racing and exercise were loaded on the right forelimb due to the clockwise race track, when resting they were overloading the opposite side.

Increased body surface temperature in the back area may indicate pathological conditions caused by intensive performance of a horse, the rider's imbalance, or an incorrectly fitted saddle (Harman, 1999; De Cocq et al., 2004; Arruda at al., 2011). The study by Jeffcott et al. (1985) proved that injuries of the paraspinal muscles and the ligaments were diagnosed in 25% of horses in intensive training. Other research indicated body temperature surface variations in the sacroiliac joint region, which were found to be typical injuries for show jumping horses with indicated abnormalities of hind limb movement patterns (Haussler et al., 1999). Racehorse back surface temperature distribution changes were characterised in response to increasing training intensity in long-term training by Soroko et al. (2012b). The study found that the spine had the highest temperature in the thoracic vertebrae compared to the lumbar vertebrae and sacroiliac joint area. Higher temperatures in the thoracic vertebrae could be associated with riding techniques in trot. Peham et al. (2010) detected the highest load on the horse's back at the sitting trot (2112 N), followed by the rising trot (2056 N) and the two-point seat (1688 N). Saddles, analysed for the pressure distribution over the thoracic vertebrae during movement, indicated the highest pressure at trot (Latif et al., 2010).

Gradual increments of training intensity in long - term training caused a decrease of average temperature differences between thoracic vertebrae compared to the lumbar vertebrae and sacroiliac joint areas in racehorses at rest (Soroko et al., 2012b). Regular thermographic examination of racehorse performance indicated an increment of the temperature at the back and the distal parts of the forelimbs at rest (Soroko, at al., 2015). In another study, the best performing racehorses were warmer than their poorer performing peers at all body sites. Differences in temperature between the groups were significantly higher at the carpal joint, 3rd metacarpal bone, fetlock joint, the short pastern bone, the tarsus joint, (although only on the left side) and also the thoracic vertebrae (Soroko et al., 2014). This temperature difference may reflect an increased physiological training impact on the best performing horses. According to Evans et al. (1992), strains and overloading of the musculoskeletal system due to physical work under demanding exercise results in increased blood circulation in a defensive adaptation process, predisposing the animal to future lameness injuries. This agrees with Estberg et al. (1995) who confirmed that training intensity and regular exercise predispose horses to fatal skeletal injures. According to Soroko et al. (2014) identification of the most reliable body regions recommended for monitoring the impact of training should facilitate the detection of pathological conditions during the training cycle. This is particularly important in racehorses, where immediate diagnosis might help to maintain their health and condition, positively influencing their further career in sport.

Thermography is able to diagnose an area of inflammation associated with superficial muscles or muscle groups. Muscle inflammation is usually identified as an area of increased temperature directly overlying the affected muscle. Although thermography measures only skin surface temperature it also reflects alterations in the circulation of deeper tissue. The most common cause of muscle inflammation is muscle strain, which can be detected by thermography, however it has not been well documented in studies. Turner (1998) detected by thermography inflammation of muscles in forelimbs including the pectoralis muscles and biceps brachialis muscles. In the upper hindlimb, the gluteal muscles and the biceps femoris muscles appeared warmer when the croup region was injured (Turner et al., 1996). In another study horses with croup and caudal thigh myopathy were diagnosed. Thermography was recommended as a tool for detecting upper limb lameness, by confirming inflammation of sore areas requiring further diagnostics (Turner, 1998). Figures 8-10 present examples of thermographically detected muscle inflammation processes in four cases of sport horses. Thermography was able to detect upper limb problems associated with: gluteus muscles inflammation (Figure 8), tensor fasciae latae muscle inflammation (Figure 9) inflammation of the semitendinosus (Figure 10) and biceps femoris muscles (Figure 11). Once abnormalities have been detected, thermography can determine the effectiveness of different types of therapeutic and rehabilitation applications (Turner, 1991; Turner, 1998).

In racing performance horses intensively trained for high level racing, musculoskeletal injures can impair the horse's ability to perform and can lead to dismissal from competition. Common areas which are frequently a source of lameness in racing horses are the distal parts of limbs and back. Therefore regular thermographic analysis will enable horseback overloads to be monitored and facilitate identification of pathological conditions during the training cycle. With the veterinarians and breeders working together, new heights in performance can be reached when training and conditional diagnosis are combined.

ILLEGALLY ENHANCING PERFORMANCE

Thermography has also found application in detecting abnormal temperature caused by chemical and mechanical abrasion of performance horses. In equestrian events intense competition promotes the use of

Figure 8. Thermogram of dorsal aspect of hindlimb. Inflammation of left and right gluteus muscles

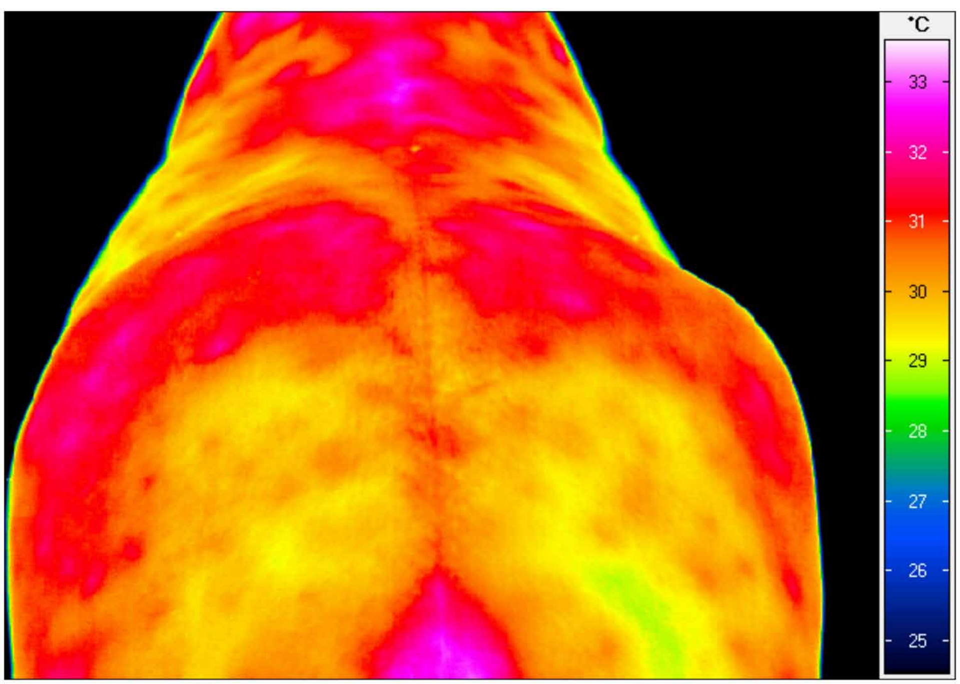

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Figure 9. Thermogram of lateral aspect of left hindlimb. Inflammation of tensor fasciae latae muscle

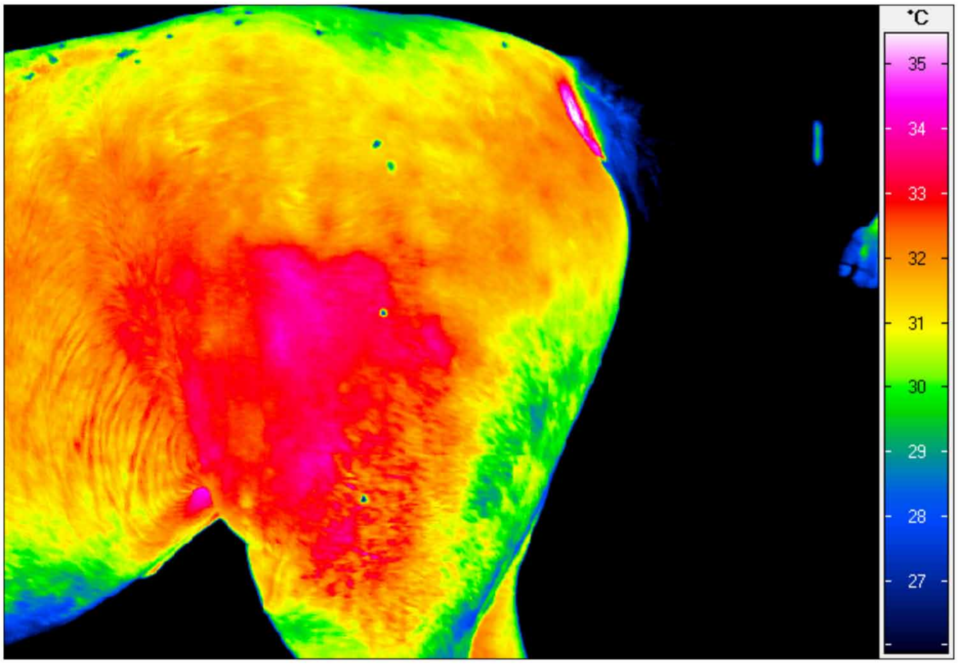

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Figure 10. Thermogram of caudal aspect of hindlimb. Inflammation of left semitendinosus muscle

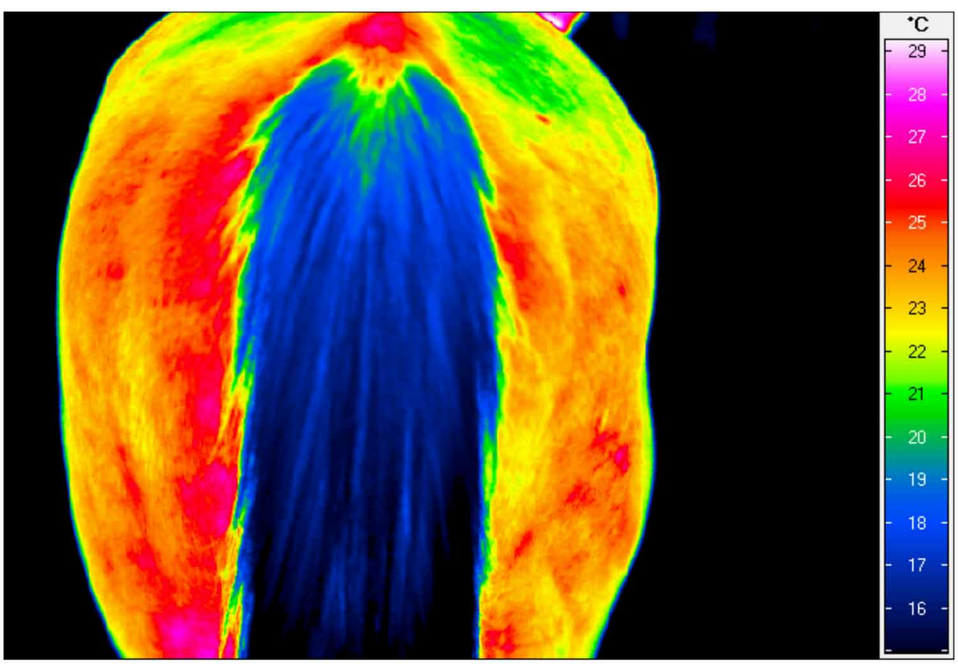

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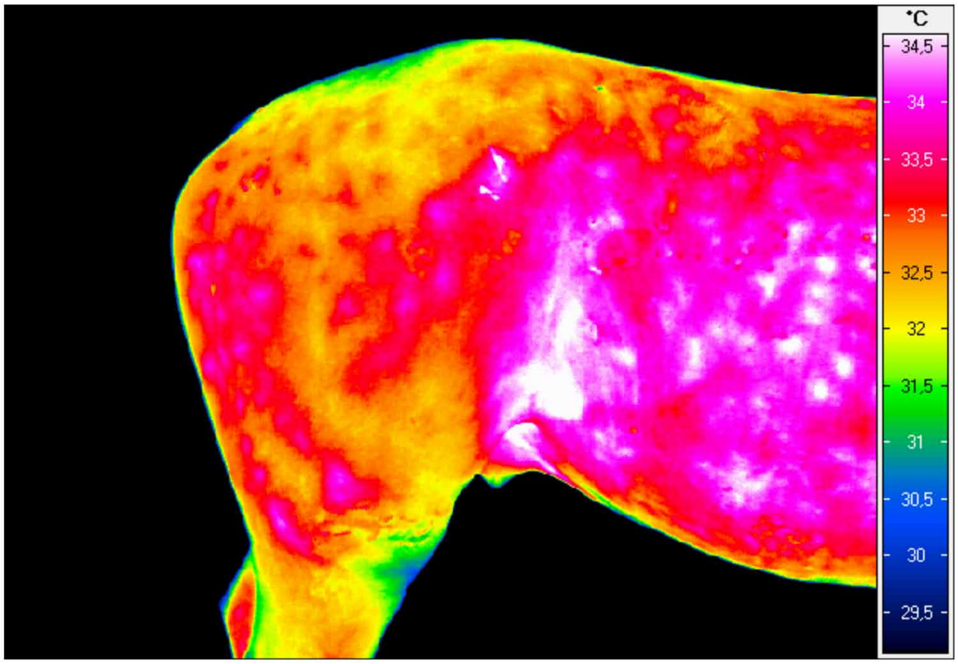
Figure 11. Thermogram of lateral aspect of right hindlimb. Inflammation of biceps femoris muscle



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procedures designed to illegally enhance performance including application of counterirritants, subdermal injections, irritants or use of regional nerve block via chemical or surgical neurectomies. The majority of these methods are an attempt either to mask lameness from veterinarians or enhance a horse's natural gait by artificially producing more action or suspension. Some techniques are not detectable, and may be difficult to prove, using conventional methods.

In 1970 the passage of the US federal Horse Protection Act put a legal ban on the use of chemical or mechanical means of soring horses. Five years later Nelson and Osheim (1975) demonstrated that chemical and mechanical soring caused definite abnormalities in the radiation emission patterns of the horse's digit. In a later publication, thermography detected illegal procedures in show horses, detecting the application of irritants to the perineal region to enhance rail evaluation (Turner & Scroggins, 1989). Therefore thermography became an appropriate tool for the detection of illegal performance procedures. Thermography successfully detected limb sensitivity, which refers to the sensation perceived by horses in their limbs. When the sensation is increased above normal limits it is called hypersensitivity, as from traumatic or surgical cutting of the nerves in that area of the limb (neurectomy). It is practiced to encourage sport horses to jump more carefully and higher. In a study presented by Van Hoogmoed et al. (2000) thermography was used to investigate the detection and duration of counter-irritants applied topically and injected subdermally, and induction of hypersensitisation using limb bandages containing metallic objects. Counter-irritations were applied to the dorsum of the pastern, and metallic irritants contained in limb bandages were applied to the metacarpal area to induce hypersensitivity of that area. Thermography images were found useful to detect and monitor the effect of changed thermal patterns after a single application of an irritant: mercuric iodine for 6 days, and the effect of metallic bottle caps within the leg wraps for 24h after application, presenting thermography as a sensitive tool for detecting hypersensitisations in horses.

Another study evaluated the ability of thermography to detect procedures used to obscure lameness, ranging from local injections of various pharmaceuticals. The injection of analgesic agents was applied to horses' limbs and backs. Thermographic images were recorded before, and 30, 60, 90 and 120 min. after the experimental procedures, until temperature differences from the opposite non-treated site were no longer significant. A single injection of neurolitic agents in the area of lumbar vertebrae and in the suspensory ligament caused an increase of temperature which persisted for 2 days. The highest temperature differences peaked at 60 min. and later declined. The study identified thermography as potential tool for detecting temperature changes in heat patterns compared to control regions. In the same study, the application of thermography was investigated for detecting and monitoring palmar digital neurectomy. Horses with palmar digital neurectomy did not show a persistent increase in temperature compared to the control limb. The significantly increased temperature was present on the first day of treatment in the limb with neurectomy compared to opposite control limb. However, no temperature differences between limbs were detected by day 6. It is suspected that nervous interruption causes a vasodilator effect, persistent for a short period of time until the vascular system compensates, influencing a return to normal circulation (Van Hoogmoed & Synder, 2002). It has been concluded that thermography is sensitive enough to detect changes in heat patterns from innervated regions, however it is not specific enough to discriminate between procedures and injury inducing an inflammatory response.

Since 2002 thermography has been recommended as a potential screening technique for illegal limb sensitivity of competition horses by the International Federation for Equestrian Sports. If the examining veterinarians observe excessively sensitive, or insensitive limbs together with abnormal thermal patterns detected by thermography, a horse can be disqualified from competition on the basis of horse welfare and fair play.

Thermography was also used for examination of the correct fit of the saddle to the horse's back (Turner, 1991). Tack related problems can be identified by the thermal patterns caused by the tack while the horse is being ridden. Thermal image assessment of the dynamic interaction between the saddle and the back of the horse showed not only the heat generated in areas of greater interaction with the saddle, but also the physiological effects of riding on the back of the horse (Turner et al., 2004; Arruda et al., 2011).

CONCLUSION

Thermography is becoming increasingly popular as an aid to assist the diagnosis of musculoskeletal and neurological injuries in racehorses. It can detect subclinical problems at least 2 weeks before they are visually detectable. It helps veterinarians to diagnose the exact site of injury and follow the response to treatment. Thermography detects training overloads and muscle strains which can lead to injury, allowing the trainer to make decisions about the horse's training programme and management. It is more sensitive than palpitation for detecting subtle temperature variations (Turner, 2001). This high sensitivity makes it useful in conjunction with other veterinary diagnostic tools that provide more specific information. Thermography, as a non-invasive tool, allows the horses to be examined without being touched, thus causing no stress or discomfort to the animal.

Infrared imaging technology has improved extraordinarily in recent years. New generations of thermographic imagers are user-friendly, portable and have a high temperature sensitivity. Current thermographic equipment is sensitive enough to detect skin temperature differences of 0.1°C.

The development of infra-red technology and better availability of this type of equipment should contribute to more extensive use of this diagnostic method, applicable not only to horses, but also to other animals.

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KEY TERMS AND DEFINITIONS

Bucked Shines: A repetitive loading injury of the third metacarpal bone. It occurs when the periosteum tears away from the front of the cannon bone. As the result of this this tear, there is bleeding with the formation of a hematoma, where new bone if forming.

Distal Parts of the Limbs: Limb from carpal joint do hoof in forelimb and from tarsal joint to hoof in hindlimb.

Laminitis: Laminitis is a crippling disease in which there is a failure of attachment of the epidermal laminae connected to the hoof wall from the dermal laminae attached to the distal phalanx.

Long Term Training: One racing training season which lasts 10 months from January till October, during which horses are regularly trained and raced.

Navicular Disease: Is an arthrosis developing on the surfaces of the navicular bone and the deep flexor tendon.

Subclinical Sign of Inflammations: Very early stage of inflammation when no clinical signs of inflammation: pain, heat, lameness, swelling and concerns of trainers are present.

Tendonitis: Inflammation of a tendon.

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Chapter 6
An Up-To-Date Review of Piglet Isosporosis:
New Insights and Therapeutic Perspectives

Vasiliki Boulaki
Academy of Athens, Greece

Dimitrios Vlachakis
Academy of Athens, Greece

Smaragda Sotiraki
Veterinary Research Institute of Thessaloniki, Greece

Sophia Kossida
Academy of Athens, Greece

ABSTRACT

Piglet isosporosis caused by Isospora suis represents a considerable problem worldwide with great economic losses and veterinary importance in pig production. So the control of this parasite is a great need. However, little is known about porcine coccidiosis concerning dynamics, pathophysiology and immunology of this disease, as well as host-parasite interactions. In addition, only few studies deal with experimental modelling of this illness with parameters such as the excretion patterns and the age-related susceptibility. However, besides natural I. suis infections occurring in pig farms, there are some experimental infections described that allow investigating accurately the course of infection. Experimental infections could contribute to a more effective control of these infections. In addition, managerial practices of farrowing facilities and piglet manipulations can contribute to this purpose. So, the description of hygiene measures, the appropriate management of farrowing facilities and piglet manipulations, as well as appropriate farm-specific environment, comprising appropriate design and materials of the farrowing pen and enough room, could diminish the occurrence and transmission of this parasite. However, unfortunately there are only very few reports documenting all this subjects that are so important for the effective control of this disease.

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INTRODUCTION

Woese *et al.* first proposed that life on earth is composed of three primary divisions, or domains to which all organisms belong. These domains are named *Archaea* (or archaebacteria), *Bacteria* (or eubacteria), and *Eucarya* (or eukaryotes), with *Eucarya* being relatives (or descendants) of Archaea (Woese & Fox, 1977; Woese et al., 1990). This proposal was based on 16S ribosomal RNA sequences and later confirmed by the comparison of many protein sequences (Pohlschroder et al., 1997; Scamardella, 1999; Woese & Fox, 1977; Woese et al., 1990) . This proposal is currently widely accepted, although some sequence features and phylogenies derived from many highly conserved proteins are inconsistent (Gupta, 1998).

Prokaryotes and eukaryotes differ from each other in many respects, with the most important criteria of their distinction being the type of their cells; eukaryotes' cells contain a membrane-bounded nucleus, while prokaryotes not (Gupta, 1998). Archaea resemble morphologically with bacteria (e.g both of them are prokaryotes), but they are evolutionary distinct from them and other prokaryotes and constitute a fundamentally different form of life (i.e., life's third domain) (Gupta, 1998; Olsen & Woese, 1993; Pohlschroder et al., 1997; Woese & Fox, 1977; Woese et al., 1990).

Eukaryotes are organisms composed of one or more cells with nuclei which have inhabited Earth for approximately 1.2 billion to 1.8 billion years (Knoll et al., 2006). Eukaryotes dominate the visible landscapes of terrestrial and marine systems and are major players in biogeochemical cycling and cause numerous global diseases (e.g., malaria, African sleeping sickness, amoebic dysentery). Eukaryotes clearly differentiate from prokaryotes as all of eukaryotes share the main features of cellular architecture (e.g the complex intracellular compartmentalization) and the regulatory circuitry (Koonin, 2010). Plants, animals, fungi and protists are the most familiar eukaryotes (Tekle et al., 2009).

The small size of some of Eukaryotes has traditionally made these groups recalcitrant to study. In addition, their evolution exhibits a vast timescale that obscures evolutionary events during their origin and early diversification. However, advances in molecular techniques (e.g., multigene sequencing, genomics) are transforming our views on eukaryotic evolution (Tekle et al., 2009).

Protozoa are single-celled eukaryotes that commonly show characteristics usually associated with animals, most notably mobility and heterotrophy (Flynn et al., 2007; Pink et al., 2005). Protozoa combine cell and organism in one (Vickerman & Coombs, 1999). The kingdom Protozoa belongs to Protists that contains also algae, and lower fungi (Corliss, 2002). The term "protist" is often used instead of "protozoa" because many protozoa have features in common with fungi or algae (Flynn et al., 2007).

They are a multiphyletic group of organisms, whose members differ in structure, morphology, biochemistry and genetics (Flynn et al., 2007; Scamardella, 1999) and their vast diversity of cellular organization provides an endless supply of material for biologists to investigate (Vickerman & Coombs, 1999). Protozoa adapt to changing environments by modifying form and function to achieve homeostasis (Vickerman & Coombs, 1999).

A few protozoa are important parasites (Pink et al., 2005) that are responsible for diseases of humans and other mammals, lower animals and higher plants (Vickerman & Coombs, 1999). Such protozoa experience devastating changes of environment during the course of their life cycles. Protozoa may leave the host to face the outside world before infecting another host or move directly from one host to another (e.g vector-transmitted parasites such as the trypanosomes, leishmanias and malaria parasites) (Vickerman & Coombs, 1999). In addition, some parasitic protozoa must avoid elimination by host defences, innate or acquired (Vickerman & Coombs, 1999).

Parasitic diseases are caused mainly by protozoa and continue to take an enormous toll on human health, particularly in tropical regions (Pink et al., 2005). Parasitic diseases also provoke crop damage and problems in livestock health (Adl et al., 2007).

EPIZOOTIC DISEASE AND ZOONOSIS

Epizootic (from Greek *epi-* upon + *zoon* animal) is a disease that occasionally occur at higher than normal rates in animal populations (in correspondence with the term epidemic applied to human populations) and it generally represent an unstable relationship between the causative agent and affected animals. High population density is a major contributing factor to epizootics (Encyclopaedia Britannica inc., 2001; Morens, 2003).

Even if both domestic and wild animals suffer from various parasites, wild animals seldom suffer massive deaths or epizootics because of the normal dispersal and territorialism of most species (L. S. Roberts et al., 2009). Domesticated animals, on the contrary, suffer from epizootics as they are usually confined to pastures or pens in great numbers year after year. This fact makes parasite eggs, larvae, and cysts become extremely dense in the soil and the number of adult parasites within each host becomes vast (L. S. Roberts et al., 2009). Coccidia, that are a diverse group of parasitic protozoa (Tenter et al., 2002), thrive under a variety of conditions in poultry flocks, in sheep (in wool) and in lambs, provoking severe economic losses (L. S. Roberts et al., 2009).

Zoonosis is the human disease resulting from the transmission of parasites of wild and domestic animals to humans. Zoonoses are quite common and consists an important hazard to public health (L. S. Roberts et al., 2009; Taylor et al., 2001).

THE PHYLUM APICOMPLEXA

The Apicomplexa are a large phylum of diverse obligate intracellular parasites (Morrissette & Sibley, 2002). These species are phylogenetically related and they constitute a major burden on human health, agriculture and economics. For example, this phylum contains parasites as *Plasmodium* spp. (the cause of malaria), *Toxoplasma gondii*, *Cryptosporidium parvum* (pathogens of immunocompromised individuals) and *Theileria* spp. *Eimeria* spp., as well as *Isospora* spp., *Neospora* spp. and *Sarcocystis* spp. that are parasites of considerable agricultural importance (Augustine, 2001; Dubey, 1999; Graat et al., 1996; Morrissette & Sibley, 2002; Wasmuth et al., 2009). The Apicomplexa phylum consists of around 6000 known species of protozoa (with potential number of species reaching 1.2–10 × 10^6 species) infecting a wide range of animals from mollusks to mammals and man (Adl et al., 2007; Cavalier-Smith, 1993; Wasmuth et al., 2009).

Apicomplexan protozoan parasites share distinctive morphological features, cytoskeletal organization, and modes of replication, motility, and invasion (Morrissette & Sibley, 2002). Apicomplexans are generally slender, crescent-shaped cells with size that range from 4-9 microns long by 1 to 3 microns wide (Sibley, 2004). Ultrastructure of sporozoites and merozoites has the typical structure of Apicomplexa (Levine, 1973). They all possess an apical complex, that is a certain combination of structures, and help the parasites to enter into hosts (L. S. Roberts et al., 2009). Their cell cortex is comprised of several membranous layers and the underlying cytoskeleton (Sibley, 2004). Apicomplexans usually have no cilia or flagella. Generally, they have cysts ("spores") that function in transmission, but in some that the cyst wall has been eliminated, the development of infective stages is completed within an invertebrate vector as sporozoites. Most apicomplexans contain an organelle called the apicoplast (Fast et al., 2001; Obornik et al., 2002; Toso & Omoto, 2007; Vaishnava & Striepen, 2006; Wasmuth et al., 2009) that is essential for parasite survival; it is involved in fatty acid synthesis and other critical metabolic pathways (Ralph et al., 2004; Vaishnava & Striepen, 2006; Waller & McFadden, 2005; Wasmuth et al., 2009). Apicomplexans are also characterized by various defining organelles involved in host cell attachment, invasion, and the establishment of an parasitophorous vacuole (that act intracellularly within the host cell) where proteins are stored and released through the apical complex at the anterior of the cell (Sibley, 2004; Wasmuth et al., 2009). Locomotor organelles in Apicomplexans are less obvious than in other protozoan phyla (L. S. Roberts et al., 2009; Sinden, 1985).

THE APICOMPLEXAN LIFE CYCLE

The apicomplexan life cycle is generally common to the phylum but there are striking differences between species, e.g some require a single host whereas others require sexual reproduction in the vector species for transmission. Coccidians, or coccidia, members of the subclass Coccidiasina of this phylum (that live in digestive tract epithelium, liver, kidneys, blood cells, and other tissues of vertebrates and invertebrates), present intracellular asexual reproduction, either as monoxenous species or oligoxenous species (according to the number of hosts required to complete their life cycles .Their life cycle is complex and may be broken down into three broad stages: sporozoite, merozoite, and gametocyte (L. S. Roberts et al., 2009; Wasmuth et al., 2009). Apicomplexans enters a host cell (infection) as sporozoites and then they becomes ameboid trophozoites that multiplie to form merozoites (merogony). Merozoites escape from the host cell and enter other cells to initiate further merogony or transform into gamonts (gametogony) that produce "male" microgametocytes or "female" macrogametocytes. Macrogametocytes develop directly into macrogametes and microgametocytes undergo multiple fission to form microgametes respectively. Fertilization produces zygotes, which after multiple fission produce sporozoite-filled oocysts (sporogony). In homoxenous life cycles all stages occur in a single host, although oocysts mature (sporozoite development is complete) in the oxygen-rich, lower-temperature environment outside a host and sporozoites are released when a mature oocyst is eaten by another host (L. S. Roberts et al., 2009). In heteroxenous life cycles, in some species merogony and a part of gametogony occur in a vertebrate host while sporogony occurs in an invertebrate and sporozoites are transmitted by the bite of the invertebrate; and in some other species sporozoites are infective to a vertebrate intermediate host, where they produce zoites that are infective to a carnivorous vertebrate host (L. S. Roberts et al., 2009).

THE FAMILIES EIMERIIDAE AND SARCOCYSTIDAE

The families Eimeriidae and Sarcocystidae of the phylum Apicomplexa represent a highly diversified group of intracellular coccidian parasites of vertebrate and invertebrate hosts (Jirku et al., 2002; Modry et al., 2001). Coccidian parasites are parasites that belongs to the suborder Eimeriina and subclass Coccidiasina (L. S. Roberts et al., 2009). They are parasites of great medical importance that's why they have attracted substantially more attention than other coccidian groups (Jirku et al., 2002). Both of these families possess two sporocysts, each with four sporozoites per oocyst (L. S. Roberts et al., 2009). They are traditionally classified based on the number of sporocysts per oocyst but they can also classified based on the small subunit ribosomal RNA gene (SSU rRNA gene) (Modry et al., 2001). They represent the taxonomically most complex groups (Modry et al., 2001; Morrison et al., 2004). However, these families differ as the Eimeriidae is consisting of oocyst-forming coccidia, while Sarcocystidae is consisting of cyst-forming coccidia (Modry et al., 2001; Morrison et al., 2004).

THE LIFE CYCLE OF SPECIES OF THE FAMILY EIMERIIDAE AND SARCOCYSTIDAE

In the family Eimeriidae, micro- and macrogametes develop independently without syzygy; microgametocytes produce many active microgametes, which then encounter macrogametes (typically located within cells of a host's intestinal epithelium). After syngamy, their oocysts develop resistant walls and contain sporocysts (one, two, four, or sometimes more), each with one or more sporozoites. Merogony and gemetogony occur within a host but sporogony typically occurs outside (L. S. Roberts et al., 2009; Tenter et al., 2002). Species of Isosporan and Eimerian genera of the family Eimeriidae have similar general life cycle (L. S. Roberts et al., 2009).

In family Sarcocystidae, the parasites are heteroxenous, with vertebrate intermediate hosts. Asexual development occurs in vertebrate intermediate hosts, whereas other vertebrates, mainly carnivorous mammals and birds, are definitive hosts. Oocysts from a definitive host sporulate and are swallowed by an intermediate host. Sporozoites released from oocysts infect various tissues and rapidly undergo endodyogeny to form merozoites, also known as tachyzoites which can infect other tissues such as muscles, fibroblasts, liver, and nerves. Asexual reproduction in these tissues (rather than in intestine) is much slower than in the original site, and the parasites develop large, cystlike accumulations of merozoites that are called bradyzoites. The cyst itself is called a zoitocyst, or simply a tissue cyst. A definitive host is infected when it eats meat containing bradyzoites or, rarely, tachyzoites or, in some cases, when it swallows a sporulated oocyst. When tissue cysts are ingested by a definitive host, bradyzoites invade enteroepithelial cells and undergo schizogony, then gametogenesis, and finally fertilization to produce oocysts (L. S. Roberts et al., 2009).

COCCIDIAN OOCYSTS AND SPOROCYSTS

Coccidian oocysts are remarkably constant in their morphology within a given species of the subclass Coccidiasina. The oocyst wall has two layers, an outer one that is electron dense and varies in thickness among coccidian genera, and an inner one that is 20–40 nm thick and not so dense. A membrane known as the veil surrounds the outer wall layer which contains mostly lipids and proteins, and is resistant to proteolytic enzymes and various chemicals (Belli et al., 2006). The oocyst wall helps the organism survive harsh conditions in the external environment. Oocysts of *Isospora* species resemble with oocysts of genera *Toxoplasma, Sarcocystis, Levineia, Besnoitia, Frenkelia,* and *Arthrocystis* (Belli et al., 2006; L. S. Roberts et al., 2009).

Sporocysts contain a sporocyst residuum that contains a large amount of lipid, an important source of energy for sporozoites when they stay outside a host. The sporocyst wall consists of a thin outer granular layer surrounded by two membranes and a thick, fibrous inner layer and an homogeneous Stieda body at one end of the sporocyst (plugging a small gap in the inner layer), which in some species is underlied by the substiedal body. When sporocysts reach the intestine of a new host, the Stieda body is digested, the substiedal body pops out, and sporozoites wriggle through the small opening thus created (W. L. Roberts et al., 1970).

ISOSPORA SPP

Isospora is an interesting genus of the protozoan phylum Apicomplexa which is consisted of enteric species that belongs to coccidian parasites. *Isospora* cause isosporosis which is a severe disease mainly in livestock. *Isosporosis* consists of an acute diarrhoea in humans and other mammals (Anantharaman et al., 2007). This genus less often infect humans; mainly infecting immunosuppressed or young individuals (Anantharaman et al., 2007; Lindsay et al., 1997; Sibley, 2011). Isosporans are known from all continents except Antarctica (Jirku et al., 2002).

Historically, *Isopora* species were considered to infect only the digestive tract of a single host species but now it is known that certain isosporans can produce encysted asexual stages in extraintestinal tissues of the host (Gardiner et al., 1989). The genus *Atoxoplasma*, homoxenous blood parasites of birds (N. D. Levine, 1982), has had a long and convoluted taxonomic history with *Isospora* but now is merged with *Isospora* (Barta et al., 2005). So the genus *Isospora* now includes species that have merogony in a variety of host cells, including a variety of blood cells as those of the intestinal epithelium, gametogony in the intestinal epithelium, and sporogony outside the host (Barta et al., 2005). These species show close affinity to the Eimeriidae, while other species of the genus *Isospora* from mammalian hosts are grouped together within Sarcocystidae (Modry et al., 2001; Morrison et al., 2004). Their current taxonomy is based on ultrastructural and life-cycle features, but also molecular evidence (based on the small-subunit ribosomal RNA gene sequence) (Jirku et al., 2002; L. S. Roberts et al., 2009). That's why coccidians infecting mammals, formerly classified as *Isospora* species, are now considered members of genus *Cystoisospora*. So, parasites as the parasite infecting humans (frequently observed in the tropics) that was previously reported as *Isospora belli*, now is named *Cystoisospora belli* (Barta et al., 2005; Fletcher et al., 2012; L. S. Roberts et al., 2009; Samarasinghe et al., 2008) etc..

THE LIFE CYCLE OF SPECIES OF THE GENUS *ISOSPORA*

The life cycle of the species of *Isospora* which are referred to as *Cystoisospora,* may involve a transport host. So, when the transport host becomes infected by ingesting sporulated oocysts, it harbours a monozoic cyst (containing a single sporozoite) in various organs which is not pathogenic in the transport host but mildly pathogenic in definitive hosts. When this host is eaten by the final host, the sporozoite initiates the intestinal cycle (Gardiner et al., 1989).

C. Belli

The parasite *C. belli* is a parasite infecting humans frequently observed in the tropics (Barta et al., 2005; Fletcher et al., 2012; L. S. Roberts et al., 2009; Samarasinghe et al., 2008). This parasite can cause severe intestinal disease with fever, malaise, persistent watery diarrhoea, abdominal cramps, anorexia, weight loss and even death, especially in AIDS patients (Barta et al., 2005; Doumbo et al., 1997; Fletcher et al., 2012; L. S. Roberts et al., 2009) and other immunocompromised patients (Gruz et al., 2010; Guk et al., 2005; Kim et al., 2013; Koru et al., 2007; Lagrange-Xelot et al., 2008; Meamar et al., 2009; Perez-Ayala et al., 2011; Reeders et al., 2004; Resende et al., 2011; Velasquez et al., 2011), but also in indigenous populations in the United States (Fletcher et al., 2012). In AIDS patients, infection may be characterized by chronic diarrhoea, acalculous cholecystitis cholangiopathy, and extraintestinal infection (Resende et al., 2011; Velasquez et al., 2011). *C. belli* is often implicated in traveler's diarrhoea, which is met in travellers to developing countries and has high levels of endemicity (Fletcher et al., 2012).

C. belli causes disease in several mammalian hosts, probably through the ingestion of mature sporulated oocysts in contaminated food or water. This infection is almost indistinguishable from cryptosporidiosis. Apart from *C. belli*, other *Cystoisospora* species are important causes of diarrhoea in domestic animals (Fletcher et al., 2012).

ISOSPORA SUIS (CYSTOISOSPORA SUIS)

Infections with intestinal coccidia are very important economically infections of intensively farmed mammalian livestock, and the costs of prevention and treatment are high (Mundt et al., 2006). Although several species of coccidia exist in pigs, only *I. suis* is recognised as a pathogen of economic importance (Fletcher et al., 2012; Mundt et al., 2006). *I. suis* was first described by Biester and Murray in 1934 (Worliczek et al., 2007). *I. suis* is a common intestinal parasite of piglets (Sotiraki et al., 2008; Worliczek et al., 2007) that can cause neonatal porcine coccidiosis (see below). Firstly, *I. suis* didn't receive much attention as a pathogen of pigs until the increase of intensive pig breeding systems (Worliczek et al., 2007).

Nowadays, *I. suis* is one of the most prevalent parasites in intensive pig production. Recent investigations have shown that *I. suis* is the most frequent parasite found in piglets aged 7–14 days and that the presence of the parasite is associated with diarrhoea in over 50% of naturally infected animals (Scala et al., 2009) that lasts for three until seven days or nine days (Mundt, Joachim, et al., 2003; Worliczek et al., 2009). A study carried out in 12 European countries confirmed the presence of *I. suis* in 26% of litters and in 69% of the herds examined (Skampardonis et al., 2012). *I. suis* is spread worldwide with high prevalences in pig-breeding facilities independent of the farm management system and the farrowing facilities (Mundt et al., 2005).

Isosporosis represents a considerable problem worldwide as demonstrated also by various field studies (Mundt et al., 2005; Mundt et al., 2006; Sotiraki et al., 2008; Worliczek et al., 2010). The prevalence of piglet *Isosporosis* in different regions varies from 1% to 90% of farms (Karamon et al., 2008). The economic loss from *Isosporosis* is mainly due to this growth retardation (which can reach 20% in terms of weight loss) and decreased daily weight gain and can be extended into the post-weaning phase (Scala et al., 2009). It is noticeable that this disease is rarely seen in organic systems (Sotiraki et al., 2008).

NEONATAL PORCINE COCCIDIOSIS

Neonatal porcine coccidiosis is a disease which affects piglets up to the age of 3 weeks, mainly in the second to third week of their life (Worliczek et al., 2007). Neonatal porcine coccidiosis caused by *I.*

suis comprises transient diarrhoea (non-haemorrhagic yellow to whitish diarrhoea) and dehydration in nursing piglets with subsequent decreased weight gain, poor nutrient absorption and poor performance (Mundt et al., 2005; Mundt et al., 2007; Sotiraki et al., 2008; Worliczek et al., 2010; Worliczek et al., 2007; Worliczek et al., 2009) and can cause significant economic losses. Affected piglets also present reduced and uneven weaning weights due to the reduced uptake of nutrients during a stage of intensive growth display, lower weight gain or even weight loss during and shortly after the period of diarrhoea (Worliczek et al., 2007). However, the disease shows a low mortality (Mundt et al., 2007; Scala et al., 2009; Sotiraki et al., 2008; Worliczek et al., 2010; Worliczek et al., 2007), except for cases with secondary bacterial infections (even though we don't know the exact importance and the mechanism of such infections) (Sotiraki et al., 2008). In addition, Isosporosis seems to predispose the piglet to other secondary infectious agents such as *E. coli*, *Clostridium* sp. and rotavirus, which could considerably increase morbidity, mortality and management costs (Scala et al., 2009).

CLINICAL SIGNS AND PATHOLOGY

I. suis is a host-specific enteric parasite inhabiting the small intestines (mainly the jejunum and ileum) of pigs that causes fibrinous enteritis which mainly affects the middle and posterior part of the jejunum, described often accompanied with villous necrosis and atrophy (when the damage to the intestinal lining is extensive) (Mundt et al., 2007; Worliczek et al., 2010; Worliczek et al., 2009). Infection leads to damage of the mucosal surface in the jejunum and ileum and to non-haemorrhagic diarrhoea (Worliczek et al., 2007). The changes in the gut morphology reflect the clinical picture of the disease (Mundt et al., 2007). Diagnosis can be done from mucosal biopsy specimens (Koru et al., 2007; Velasquez et al., 2011) or by direct microscopic observation of the oocyst in faeces using acid-fast staining as the oocysts are quite large (20 to 23 μm by 10 to 19 μm) and morphologically distinctive. However, veterinarians frequently report difficulties in diagnosing the oocysts in the faeces maybe due to the high fat content (steatorrhoea) or because samples are taken during the non-patent stage of infection (Worliczek et al., 2007). Molecular techniques can also be used to augment diagnosis and the detection is more sensitive (Fletcher et al., 2012). Changes in haematological parameters during an infection with *I. suis* are not so clear, so they can't be used as a test for this infection (Schlepers, 2010).

THE LIFE CYCLE OF *ISOSPORA SUIS (CYSTOISOSPORA SUIS)*

The life cycle of *I. suis* is completed within 5–6 days (Worliczek et al., 2010; Worliczek et al., 2007) and consists of three main phases: merogony (asexual reproduction), gamogony (sexual reproduction), and sporogony. The first two phases are located in host intestines and the third one in the environment (Karamon et al., 2008). Piglets are infected by ingestion of sporulated oocysts. After oral ingestion of them, the parasite (that is motile sporozoites released from the sporulated oocysts) invades the villus epithelial cells of the small intestines and develops intracellularly within a parasitophorous vacuole. Then it begins to reproduce asexually and sexually (Karamon et al., 2008; Worliczek et al., 2010; Worliczek et al., 2009). The meronts or gamonts are described as the pathogenic stages (Mundt et al., 2007; Worliczek et al., 2009). Meronts divide into many merozoites (with asexual reproduction) which infect next epithelial cells. Some of them transform to sexual stages (macro- and microgamonts) intracellularly and as a result of sexual reproduction, the oocysts arise (prepatent period lasts 5-7 days) (Karamon et al., 2008). Intracellular multiplication of the parasite leads to crypt hyperplasia and fusion, and atrophy and necrosis of the villi resulting in diarrhoea and reduced uptake of nutrients by the mucosa (Worliczek et al., 2010). The final stage of endogenous development is the oocyst which unsporulated exits the cell (released from the enterocytes) and is excreted with the faeces. The infectious stages (sporocysts containing sporozoites) develop in the environment within 1–3 days, depending on the temperature (Karamon et al., 2008; Worliczek et al., 2010; Worliczek et al., 2007); the sporulation rate increase with temperature, although the infective sporocyst stage was reached within 24 h at all temperatures (Langkjaer & Roepstorff, 2008). Unlike the closely related *Eimeria*, *I. suis* merogonies cannot be divided into generations, rather the meronts develop into different types (Worliczek et al., 2007).

TREATMENT AND PREVENTION

So as to control *isosporosis*, it is very important to identify the specific mixture of necessary conditions and events that are needed for the *I.suis* infection and determine the future course of the infection; such as the duration and level of exposure to the pathogen, the presence of animal- and herd-specific risk factors etc. (Sotiraki et al., 2008). Not all piglets in a litter or in a herd are equally affected (variation in the risk of occurrence of oocyst excretion, the level of excretion and the risk of diarrhoea) and this observation can also be made during experimental infections under highly standardised conditions (Mundt et al., 2006). So it can be assumed that the individual susceptibility to infection is very variable in outbred piglets and depends on their ability to respond to infection. Secondary bacterial infections or secondary infections with other enteric influence positively the morbidity of this disease, increasing the mortality. The age of the piglets upon infection also plays a role for clinical outcome under natural conditions, and this further adds to the heterogenic picture of isosporosis in a herd; younger animals are more affected than older ones (Sotiraki et al., 2008; Worliczek et al., 2009). However the mechanisms for this phenomenon are unclear (Worliczek et al., 2007). The infection dose and duration of exposure influences the intensity of the pathological changes (Worliczek et al., 2007).The factors varying at the litter level may affect the relation between the oocyst excretion pattern and clinical Isosporosis (Skampardonis et al., 2012). However, several aspects of the *I. suis* epidemiology have not been fully understood yet (Skampardonis et al., 2012) .

Control of this parasite is currently almost completely based on early routine treatment of piglets with toltrazuril, an anticoccidial triazin derivative (Scala et al., 2009; Sotiraki et al., 2008). Treatment with toltrazuril can decrease the prevalence of diarrhoea and the number of diarrhoea days. It can also contribute to a lower oocyst excretion and a higher gain than in infected pigs (untreated with toltrazuril) (Mundt et al., 2007; Schlepers, 2010; Worliczek et al., 2007). Notably, some results confirm that prophylactic treatment of piglets with toltrazuril (prevention) is the best option to control isosporosis in suckling piglets (Scala et al., 2009) as there is no real treatment versus an outbreak of isosporosis (confirming findings in experimental infections) (Scala et al., 2009; Schlepers, 2010). That means that after a pig show clinical signs of infections with *I. suis*, there are already tissue alterations, so a treatment is not still very effective (Scala et al., 2009; Schlepers, 2010). However, presently, metaphylaxis and specific therapy against Isosporosis in overt clinical forms with toltrazuril is recommended, since toltrazuril significantly reduces the shedding of oocysts and diarrheic symptoms in infected piglets (Scala et al., 2009). Certainly the correct treatment timing is very important issue so as the intervention get before the onset of diarrhoea and/or oocyst excretion which allows clinical or parasitological diagnosis and unfortunately *I. suis* has an extremely short life cycle (Mundt et al., 2007; Scala et al., 2009). The exact mode of action of toltrazuril is still not fully known (Mundt et al., 2007). It is believed that toltrazuril interferes with enzymes of the respiratory chain of the coccidian parasite and inhibits the pirimidine synthesis, without effecting the entry of the coccidians into the host cells (so there is development of immunity) (Greif, 2000; Harder & Haberkorn, 1989; Mundt et al., 2007; Schlepers, 2010).The use of sulphonamide drugs (coccidiostatic drugs for mammalian coccidia, mostly *Eimeria* spp. of cattle and rabbits) is not advisable (Scala et al., 2009).

Apart from prophylactic treatment with toltrazuril, hygiene measures are also advisable (Schlepers, 2010). Indeed, the impact of several managerial factors on the odds and the level of *I. suis* oocyst excretion are assessed. Such interventions could be used as preventing measures against Isosporosis alternatively or supplementary to medical control and that is very important because of the currently widespread use of anticoccidial compounds and the possible development of resistant parasites (Langkjaer & Roepstorff, 2008; Mundt, Daugschies, et al., 2003; Skampardonis et al., 2012) and the poor response to antibiotics of suckling piglets in the second week of life (typically infected by the scouring of farm). Unfortunately, even though hygiene measures may prevent disease outbreaks, the resistant oocysts cannot be easily inactivated (Worliczek et al., 2007). So, once *I. suis* has established itself on a farm, the infection is maintained (maybe through piglet-to-piglet transmission via contaminated farrowing pens, as sows are rarely found to excrete oocysts) (Sotiraki et al., 2008). Different approaches have been recommended to decrease the survival of *I. suis* oocysts in the environment and the risk of infection, such as changing microclimatic conditions in the farrowing pens or constructing perforated pen floors (Scala et al., 2009; Skampardonis et al., 2012). However, in large pig farms it is quite difficult to increase the days between litters and to maintain microclimatic conditions able to significantly decrease oocyst survival (Scala et al., 2009).

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Chapter 7
Thermography in Animal Models of Cancer:
A Tool for Studying Oncobiology in Laboratory Animals

Rui M. Gil da Costa
LEPABE, CI-IPOP, University of Porto, Portugal

Paula Alexandra Oliveira
CITAB, University of Trás-os-Montes and Alto Douro, Portugal

António Ramos Silva
INEGI, University of Porto, Portugal

Joaquim Gabriel
INEGI, University of Porto, Portugal

Ana Faustino Rocha
CITAB, QOPNA University of Trás-os-Montes and Alto Douro, Portugal

Ana Margarida Abrantes
Biophysics Institute, University of Coimbra, Portugal

Maria Filomena Botelho
CIMAGO, CNC.IBILI, University of Coimbra, Portugal

ABSTRACT

Laboratory animals provide important models for studying human diseases, including many types of cancer. Mice are among the most commonly used laboratory animals, allowing for the study of carcinogenic agents, cancer development and for testing innovative preventive and therapeutic strategies. Thus, monitoring angiogenesis in animal models is a major goal for cancer research. Among the currently available imaging techniques, thermography is a useful approach for studying the superficial vascularization of cancer, based on their heat emissions. At this chapter emphasis is placed on thermography and its applications on laboratory animals, in comparison with other available and applicable imaging techniques. In conclusion, thermography may be usefully applied to the study of cancer vascularization in animal models, particularly when using laboratory rodents such as mice. Care is needed in adapting existing approaches to the specificities of each animal species.

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INTRODUCTION

Among the major public health problems of our time, cancer occupies a prominent place. Cancer develops through a complex, multistage process, driven by the cellular accumulation of genetic mutations and epigenetic events (Bignold, 2003; Bignold, Coghlan, Jersmann 2006; Oliveira et al., 2007; Iacobuzio-Donahue, 2009). This process of carcinogenesis often proceeds through multiple distinguishable morphological stages as shown in Figure 1. Thus, pre-cancerous lesions may develop into benign and later malignant tumors. The term cancer is reserved for malignant lesions, while the term neoplasia (used of a tissue which has become independent of normal physiological regulatory mechanisms) applies to both benign and malignant tumors. Hence, early non-tumoral lesions are often referred to as pre-neoplastic. Environmental carcinogens are biological (e.g. human papillomavirus, HPV), chemical (e.g. nitrosamines) or physical (e.g. ionizing radiations) agents that initiate carcinogenesis by inducing genetic mutations or promote it otherwise (Oliveira et al., 2007). Genetic mutations occurring in healthy cells are, most often, successfully repaired or else they trigger programmed cell death mechanisms (as a way to prevent carcinogenesis). However, unrepaired mutations that block DNA repair mechanisms (encoded by so-called tumor suppressor genes) will promote the unchecked accumulation of further mutations (genomic instability). Mutations that activate genes (so-called proto-oncogenes) that contribute to make the cell independent from its environment (e.g. by producing its own growth factors) are also important in driving carcinogenesis. Accordingly, during the early phases of carcinogenesis, cells tend to survive and proliferate in an unregulated fashion, accumulating additional mutations (Oliveira et al., 2007) that will drive carcinogenesis further on Figure 1. As already pointed out, neoplastic tissues are not necessarily malignant. While benign tumors are well-delimited and damage adjacent tissues mainly by compressing them, malignant tumors (cancers) are able to invade adjacent tissues or event to spread to distant body parts through lymphatic or blood vessels. Progression from a benign to a malignant stage is commonly observed in many epithelial tumors. The malignant phenotype requires an ability to interact with and invade the adjacent connective tissue (called the stroma). When neoplastic cells have acquired the typical traits of malignancy, they degrade the basement membrane that separates them from the stroma, and spread into the adjacent tissues. By invading blood and lymphatic vessels (a phenomenon called intravasation) in the stroma, malignant cells may gain access to distant organs, where they may establish distant tumor foci, called metastasis. The interaction between malignant or pre-malignant cells and the adjacent stroma is highly complex.

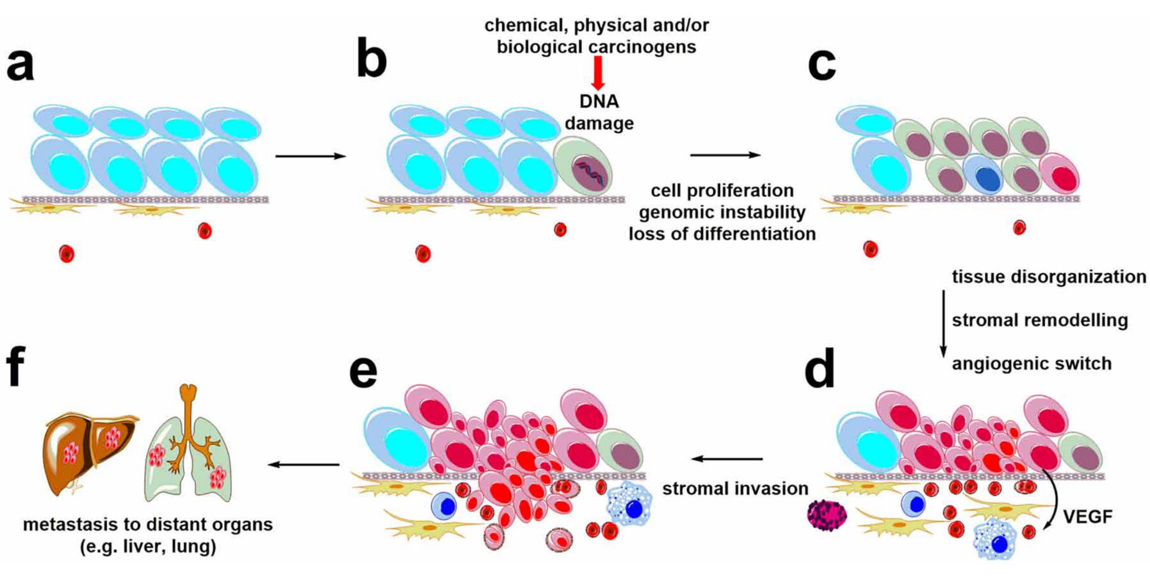
In order to study these phenomena, researchers have long resorted to employing animal models, which allow for fast and efficient experimental approaches. Thermography, as an imaging technique, is able to provide valuable additional information on the physiology and pathology of these models, namely concerning superficial inflammation and blood irrigation. The present chapter deals with laboratory animal models of cancer, followed by multiple imaging techniques available for use in these models. Special emphasis is given to the use of thermographic techniques to evaluate laboratory mice and rats.

ANGIOGENESIS IN CANCER

One key feature of the interaction between cancer cells and their adjacent stroma is the development of new, and often abundant, blood vessels, termed angiogenesis (Potente, Gerhardt, Carmeliet, 2011). Tumor-associated angiogenesis is of particular importance clinically and also from the viewpoint of thermographic analysis, as it provides the basis for temperature differences between healthy and tumoral tissues (Carmeliet & Jain, 2011).

Angiogenesis is essential to deliver nutrients to tumor cells. Tumors do not grow beyond 1 or 2 mm in diameter without developing their own blood supply. Beyond that size, oxygen and nutrients do not diffuse from adjacent blood vessels in the necessary amount, resulting in hypoxia and cell death (Potente, Gerhardt, Carmeliet, 2011). In fact, many tumors are hypoxic and necrotic areas where the blood supply is limited. A number of pro-angiogenic and anti-angiogenic factors exist, that govern the development of arrest of angiogenesis in physiological and pathological conditions. During tumor development, some tumor cells acquire the possibility of modifying the balance between pro-angiogenic and anti-angiogenic factors in favor of angiogenesis, a phenomenon known as the angiogenic switch (Shojaei, 2012). In order to achieve this, tumor cells (and, frequently, certain stromal cells) secrete a number of pro-angiogenic factors, most importantly vascular endothelial growth factor (VEGF) and basic fibroblast growth factor (bFGF). Down-regulating the expression of anti-angiogenic factors is also an important strategy, *e.g.* mutational inactivation of the p53 protein leads to decreased production of the anti-angiogenic protein thrombospondin-1 (Grossfeld, 1997). VEGF acts through its receptor (VEGFR) to attract circulating endothelial precursor cells, drive the proliferation of endothelial cells (which line the lumen of blood

Figure 1. An overview of multistage cancer development in epithelial tissues. a- normal stratified epithelium (blue), with basal cells covered by differentiated cells. The epithelium lies over a basement membrane, which separates it from the underlying stroma, containing fibroblasts (yellow) and capillaries with red blood cells. b- one epithelial cell suffers DNA mutations, triggering carcinogenesis. c- loss of normal epithelial structure, and development of multiple cellular clones harboring additional different mutations. d- an aggressive, angiogenic cellular clone develops, secreting pro-angiogenic factors and re-structuring the adjacent stroma, which shows numerous capillaries, fibroblasts and leukocytes. e- malignant (cancer) cells degrade the basement membrane, invading the stroma and blood vessels. d- cancer cells migrate through the blood and lymph vessels, establishing metastasis in distant organs



**For a more accurate representation see the electronic version.*

vessels) and their differentiation at the tumor site, as well as promoting the sprouting of new capillaries from existing blood vessels (Potente, Gerhardt, Carmeliet, 2011). The blood vessels that develop show an irregular, tortuous, abnormal architecture and increased leakiness, compared with blood vessels from healthy tissues (Shojaei, 2012). In some cases, tumor cells may line structures resembling capillaries, a phenomenon known as vasculogenesis mimicry. Besides delivering oxygen and nutrients to tumor cells, endothelial cells also provide them with important polypeptide growth factors, such as insulin-like growth factor and platelet-derived growth factor. Furthermore, the development of an extensive and accessible capillary bed facilitates tumor intravasation and metastasis.

According to the most recent GLOBOCAN data, cancer incidence rates are consistently increasing, both in developed and in developing countries, with an estimated 14.1 million new cancer cases diagnosed in 2012 (Torre, 2015). The leading causes of death by cancer are lung, breast and colorectal cancers. The rising cancer incidence is believed to reflect the increasing life expectancy and changing life habits, especially the adoption of cancer-causing behaviors such as smoking. Cancer mortality tends to be higher in developing countries, due to limited access to early diagnosis and to adequate therapy (Torre, 2015). Overall, during 2012, cancer caused an estimated 8.2 million deaths worldwide (Torre, 2015). Breast cancer is now the leading cause of death by cancer among women in developed countries. Screening and vaccination programs are good examples of how understanding the biopathology of cancer were translated into effective preventive strategies. Another highly significant example, is the development of anti-angiogenic therapies, mainly based on blocking VEGF-mediated signaling (Carmeliet & Jain, 2011). The main challenges in this area are inherent or acquired resistance to angiogenesis inhibitors, a possibly increased tumor aggressiveness during anti-angiogenic treatment, and the absence of validated biomarkers to select suitable patients and monitor tumor responses (Shojaei, 2012).

Animal Models of Cancer: General Concepts

In vivo animal models of cancer are critical tools to study the biopathology of cancer and the effects of carcinogens, as well as for developing innovative preventive and therapeutic anti-cancer strategies. In the last years, with the development of genetics, sophisticated animal models have been developed that better represent specific cancer features. Nowadays, animal models of cancer come in a diversity of forms, ranging between cancer cell lines and genetically engineered animals.

Animal models provide an alternative mean to understand the causes and to evaluate new treatments for cancer, being a resource of a great potential in oncology. The use of animal cancer models has provided a better understand of cancer's biology and, more recently, its genetics (Frese & Tuveson, 2007). Several animal species, namely dogs, large animals, rabbits, fish, guinea pigs, hamsters, rats and mice have been used in experimental protocols, the rat and mouse being most frequently used (Decker & Sausville, 2011). Rats and mice have some advantages when compared with other animal species. They are mammals, small, their accommodation and maintenance are cheap, they are easy to handle and reproduce, have a high number of offspring, their physiology and genetics are well understood and are similar to humans in various aspects, namely concerning their anatomy, physiology, genetics and biochemistry. The similarities between such animal models and humans allow their use to find new diagnostic methods, as well as discovering and testing new therapies (Oliveira, Colaco, De la Cruz, Lopes, 2006).

A wide variety of animal models of cancer is currently available. *In vivo* cancer animal models can be divided into different categories: genetically engineered, transplantation (syngeneic and xenotransplant), spontaneous and carcinogen-induced models (Table 1). Researchers may select the model according their investigation's aim.

Following the identification of many mutations responsible for the development of some human cancers, transgenic and gene targeting technology allowed the development of a large number of genetically engineered rodent strains. These genetically engineered cancer models express oncogenes or mutations in tumor suppressors found in human tumors (Hanahan, Wagner, Palmiter, 2007). In these genetically engineered animal models there is the interaction between tumor and stromal cells in their normal microenvironment, which mimics the human cancer pathogenesis better than in transplanted models. However, genetically engineered rodent strains have some limitations. Since these models usually have mutations in a single gene, they do not accurately mimic the genetic complexity and heterogeneity of human tumors. In order to overcome this limitation, mouse strains possessing combinations of oncogenic mutations have recently been developed. However, these genetically engineered animal models are expensive and not yet affordable for many research teams (Farago, Snyder, Jacks, 2012; Singh, Murriel, Johnson, 2012).

In transplantation models, tumor cell lines or a part of a human tumor, may be transplanted into immune-deficient (xenograft models) or immunocompetent (syngeneic models) animals. When tumor

Table 1. Characteristics of animal models of cancers: some advantages and disadvantages

Animal models		**Advantages**	**Disadvantages**
Genetically engineered		Tumor arise "naturally". Tumor and stromal cells interact in their normal microenvironment. Closely mimics human cancer pathogenesis.	Mutation usually only in a single gene, failing to mimic the genetic complexity and heterogeneity of human tumors. Tumors arise at different stages. Expensive models.
Transplantation	Syngeneic	Tumor cells and the host share a common genetic background. Host immune system is not compromised (immune-competent host) Mimics the normal tumor microenvironment. Rapid development of tumors. Reproducible. Low expensive.	Tumor cells are non-human In some cases, tumors are implanted in a non-natural site.
	Xenograft	Tumor cells are from human. Wide variety of tumor cell lines available.	Host is an immune-deficient animal. Longer latency period (compared with syngeneic model). In some cases, tumors are implanted in a non-natural site. Does not mimic normal tumor microenvironment. Lack of protective immune response and tumor-promoting inflammation. Expensive models.
Spontaneous		Allow the identification of cancer susceptibility genes.	Long latency period. Difficult to obtain a sample with an adequate size.
Carcinogen-induced		Short period of latency. Easily reproducible. Allows the study of carcinogenesis (e.g. mutagenesis, oxidative stress, inflammation). Allow the identification of potential targets for cancer therapy.	Non-natural tumors. In some models, induced tumors are internal and difficult to monitor. Some models simultaneously develop tumors in multiple organs.

cells are well accepted, they result in tumor formation within a few weeks. According to the aim of the researchers, there are several ways to transplant cells: subcutaneously (heterotopically) to allow the study of tumor development, intravenously to mimic the formation of metastasis, or orthotopically when the tumor cells are transplanted to their organ of origin, mimicking tumor development in its own microenvironment (Loi et al., 2011).

In xenograft models, human tumor cells are transplanted into an immune-deficient animal. These models do not mimic the natural tumor microenvironment due to a lack of protective immune response and tumor-promoting inflammation (Dranoff, 2012).

In syngeneic models, the tumor cells and the host share an inbred genetic background. The host immune system is not compromised and transplanted tissues are not rejected by the immune system of the host. This model mimics the normal tumor microenvironment. These models are rapid, reproducible and affordable when compared with xenografts and genetically engineered models (Polin, 2011).

Decades of studies in animal models allowed researchers to discover that some animal species and strains develop cancer in a certain organ or in various organs when exposed to a specific agent, under appropriate conditions, namely age of the exposure, number of exposures/administrations, dose or time of exposure. The agents that have the capacity to induce the formation of tumors are classified as carcinogen agents. These agents can be chemicals (e.g. polycyclic aromatic hydrocarbons, nitrosoureas, nitrosamines, cadmium, arsenic, tobacco compounds), virus (e.g. mouse mammary tumor virus), radiations (e.g. ultraviolet radiation, ionizing radiation) or minerals (e.g. asbestos fibers). The tumors in carcinogen-induced models have a short period of latency and are easily reproducible (Jonkers & Berns, 2005).

Spontaneous cancer animal models are animals that naturally develop cancers, these models allow researchers to identify the genes that generate susceptibility to cancer development (Hansen & Khanna, 2004). Spontaneous tumors in dogs and cats are frequently used in cancer research, as these animals frequently develop tumors with histopathologic and biologic behavior similar to those that occurs in humans (MacEwen, 1990).

Despite the limitations of each type, *in vivo* animal models of cancer are invaluable tools to study the biopathology of cancer, understand the complexity of carcinogenesis, the effects of different carcinogens and to develop innovative preventive and therapeutic anti-cancer strategies.

Imaging Techniques in Animal Models of Cancer

Medical imaging allows the creation of visual representations of the anatomy and physiology of the interior of a body. The technology, which may or may not apply ionizing radiation, is used as diagnosis tool to identify abnormalities in comparison with normal conditions. Besides this application, it is also possible to perform imaging of removed organs and tissues using pathological techniques.

The discovery of different types of radiation and its use as a diagnostic and therapeutic methods constituted a significant advance in medicine. Small animal-dedicated scanners were produced only in the late 1990s. However, the large number of research centers interested, quickly made this equipment very popular. Therefore, nowadays there are dedicated animal cameras for all the main imaging techniques, such as microSPECT, microPET, microMRI, microCT and thermography.

X-Ray Imaging

The X-rays are electromagnetic radiation similar to visible light, but with a shorter wavelength. Considering its particular characteristics, this type of radiation allows both, to obtain images, and also to be used for therapy (radiotherapy). Thus, its use as a diagnostic tool is based on the ability of the X-radiation to propagate throughout the body. The penetrating power of X-ray is inversely proportional to its wavelength, and when a volume is exposed, some portion of the radiation energy is absorbed, while the other is scattered through the matter (Lima, 1995).

The obtained image is defined as conventional radiography, and is achieved after the X-rays pass through the object and the emerging photons are able to cause fluorescence in enhancing screens. The emitted light strikes the emulsion on a film, giving rise to a latent image. Computed radiography differs from this conventional technique because the emerging photons interact with a phosphor plate, thus creating the latent image which is automatically converted into a digital image through a scanner (Gaivão, Lima, Agostinho, Oliveira, Peres, 2001).

Concerning animal applications, the X-ray is one of the most commonly used diagnostic tools, with the possibility of obtaining 2-dimensional images which are representations of 3-dimensional objects. Due to its characteristics, this technique provides a large amount of information through non-invasive and affordable means. Besides this, X-ray do not change the disease process and does not cause pain. The results obtained with X-rays imaging depend on the combination of different parameters such as the beam voltage, the number of X-rays produced and the exposure time. Besides these instrumentation characteristics, the tissue density also influences the obtained image (Lima, 1995; Gaivão, Lima, Agostinho, Oliveira, Peres, 2001).

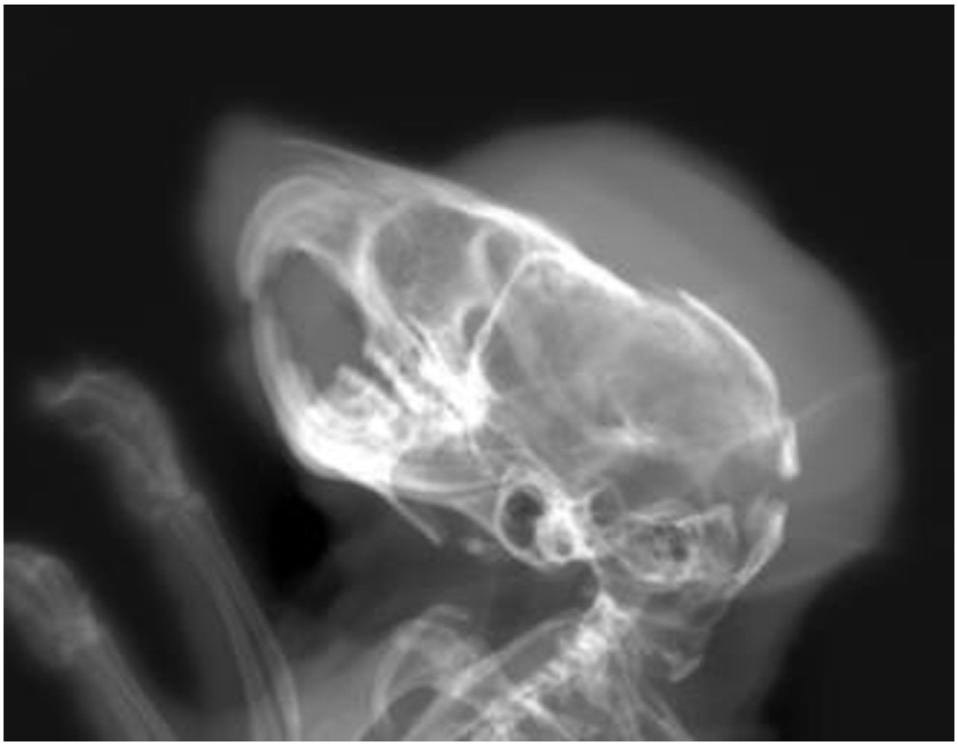
To perform animal imaging using X-ray (Figure 2), the animal must be adequately restrained and positioned to obtain high-quality radiographic images, whereby sedation or short-acting anesthesia is often necessary. Besides that, image acquisition parameters may also be manipulated in order to minimize the effects of animal motion. Specifically, these conditions are the decrease of exposure time and the maximization of the power (Merck Sharp, Dohme Corp, 2014).

Computed Tomography (CT)

Since the 1970s, CT has been established as an imaging approach which produces axial slice images using a source of X-rays. Using this imaging technique it is possible to estimate the linear attenuation coefficient of the X-rays in each pixel of slice, which are obtained around the patient considering different angles. Whereas the final images on radiographs are obtained by the compression of a volume in a 2D level, in which the radiological projection information from a three-dimensional object is represented, with CT it is possible to get a flat image of a three-dimensional object visualized in a gray scale. This imaging methodology, allows a better temporal and spatial resolution, more anatomic imaging, improved signal/noise ratio as well as a better image processing potential and a retrospective reconstruction, especially taking into account the innovations using multi-slice imaging and newly developed contrast media (Gaivão, Lima, Agostinho, Oliveira, Peres, 2001).

For animal imaging studies, all CT scanners that provide higher spatial resolution than current scanners used in clinics are named micro-CT. The spatial resolution of these equipment is in the order of a few hundred μm. In this imaging technique, anesthesia is not required for intravenous, intraperitoneal or oral administration of contrast agents. However, mice or rats are imaged under anesthesia. To perform a CT

Figure 2. Skull radiograph of the mouse in profile with changes in bone structure suggesting bone involvement by an orthotopic osteosarcoma model



study, animals are positioned within the scanner, and visually monitored during the scan (Bartling, Stiller, Semmler, Kiessling, 2007). Employing this imaging technique, it is possible to design *in vivo* research experiments allowing repeated measurements of the same animal. This approach reduces the variability associated with images coming from different animals (Bartling, Stiller, Semmler, Kiessling, 2007).

Nuclear Medicine (NM)

Nuclear medicine it is a diagnostic imaging and therapeutic technique also known as molecular medicine or molecular imaging, which allows in some situations, the performance of metabolic radiotherapy. This technique uses properties of radioactive isotopes and the energetic radiation emitted by them. This is always ionizing radiation and may be of different natures (particles or electromagnetic). Nuclear medicine uses both types of radiation for different purposes, the particles for therapy and the electromagnetic (gamma rays and annihilation photons) for imaging. Concerning the utilization of X-rays, radiology is more dedicated to morphological studies, whereas nuclear medicine enables the assessment of functional information. Nuclear medicine can be divided into single-photon emission computed tomography (SPECT) and positron emission tomography (PET), each technique associated with a specific and/or dedicated equipment. In nuclear medicine using SPECT, images are acquired after collimation of the photons, which are detected by a crystal that gives off a light signal. This is, in turn, amplified and converted into count data, planar or, after processing, 3D tomographic images. This imaging technique allied to a CT scanner can provide information about localization and function simultaneously. In SPECT imaging, Technetium-99m is the radionuclide most used. This isotope labels the majority of the molecules with different biodistributions (Lima, 2011) (Figure 3).

PET uses a short-lived positron-emitting isotope such as Fluor-18, which is the most commonly used (Figure 4). Modern scanners used in small animal imaging may integrate PET with CT and MRI, allowing the production of PET-CT or PET-MRI images. In small animal imaging equipment, these combinations are possible and can all be simultaneously present in the same equipment without physically moving the animal off the gantry. This possibility allows the generation of images that match information from different sources. The resultant hybrid image with functional and anatomical information is a useful tool in non-invasive diagnosis and provides information over time, promoting respect for the 3Rs principles of animal research ethics (Lima, 2011; Rowland, Cherry, 2008, May).

Figure 3. Nuclear medicine (SPECT) imaging using 99mTc-MIBI. Static image of an animal model with colostomy and colorectal cancer with 99mTc- MIBI uptake in tumor localization

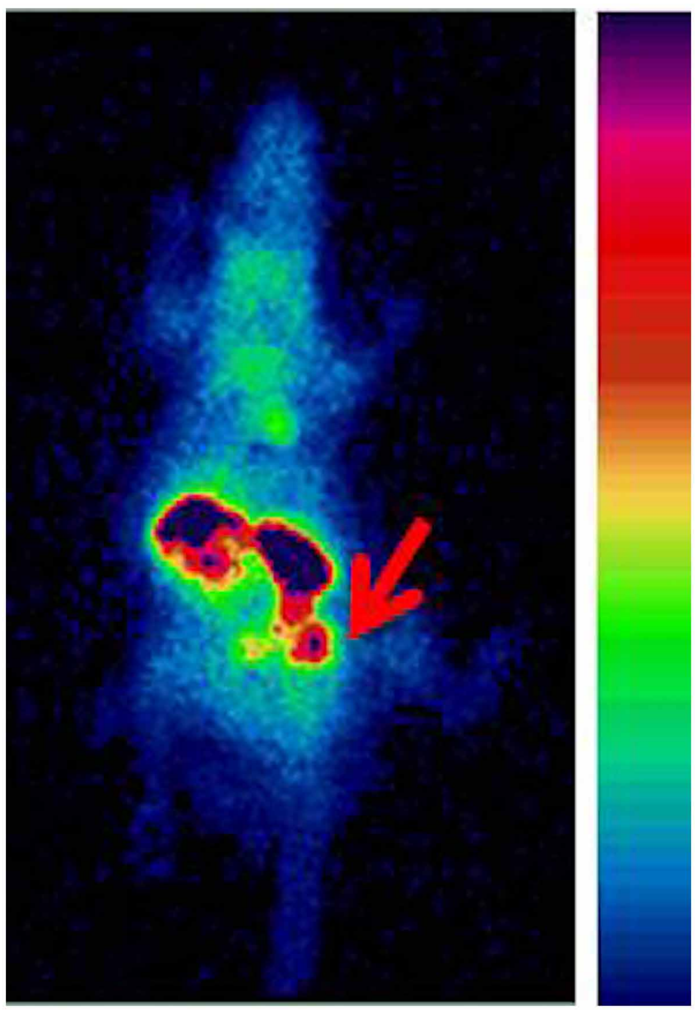


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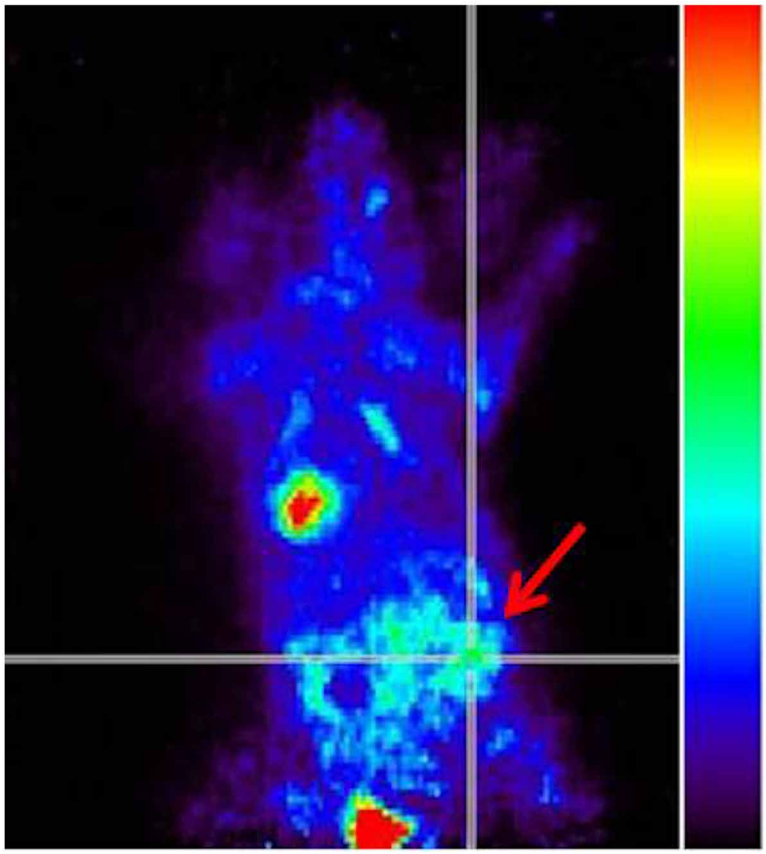
Figure 4. Nuclear medicine (PET) imaging using ^{18}F-FDG. Static image of an animal model with colostomy and colorectal cancer with ^{18}F-FDG uptake in tumor localization, 60 minutes after radiopharmaceutical administration



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Ultrasonography

Since the discovery of the piezoelectric properties of quartz in 1880 by Marie Curie until its current status, ultrasound imaging is the result of several decades of research. This medical imaging uses high frequency sound waves in the megahertz range that, once applied on tissues, are reflected to various degrees, being useful to produce 3D images (Gaivão, Lima, Agostinho, Oliveira, Peres, 2001).

Employing the transmission and reception of sound pressure waves it is possible to perform tissue characterization, using frequencies ranging from 20 kHz up to several GHz, which allow for a different medical image modality. The high frequency sound waves are applied on tissues and, depending on the composition of the different tissues crossed, the signal is differently attenuated, and the returned echo is also separated by different intervals. This imaging approach is safe, not appear to cause any adverse effects in the body. Besides that, it is also relatively inexpensive and quick to perform and the equipment does not use ionizing radiation (Gaivão, Lima, Agostinho, Oliveira, Peres, 2001). However, the final quality of the image depends on the technician skills.

Concerning ultrasonography for animals, higher frequencies are used when compared with clinical devices used in human patients. Besides that, there is the possibility to use different contrast agents in order to study specific pathologies related with cellular receptors. This imaging approach has also the advantage of enabling real-time imaging, with the possibility of capturing about 1000 frames per second and allowing the visualization of blood flow *in vivo*, which is adequate, for instance, for cardiac studies. Considering its spatial resolution, ultrasonography is also suitable to study angiogenesis related with tumor development. However, the limited depth of penetration, influences the type of pathology in which ultrasound can be used, and should be considered as an inconvenient characteristic of this technique (Gaivão, Lima, Agostinho, Oliveira, Peres, 2001; Renault et al., 2006).

Magnetic Resonance Imaging (MRI)

A magnetic resonance imaging instrument (MRI scanner), or a nuclear magnetic resonance (NMR) imaging scanner as it was originally known, uses powerful magnets to polarize and excite hydrogen nuclei (single proton) in water molecules of biological tissues, producing a detectable signal which is spatially encoded, resulting in images of the body. The MRI machine emits a radio frequency (RF) pulse that specifically tilts the magnetic moment of the hydrogen nuclei. This pulse causes the protons in that area to absorb the energy needed to make them spin in a different direction. This is the "resonance" part of MRI. The resonance frequency is called the Larmor frequency and is calculated based on the particular tissue being imaged and the strength of the main magnetic field. MRI uses three kinds of electromagnetic fields: a very strong (in the range of a few tesla) static magnetic field to polarize the hydrogen nuclei, called the static field; one or more weaker time-varying (on the order of 1 kHz) field(s) for spatial encoding, called the gradient field(s); and a weak radio-frequency (RF) field for the manipulation of the hydrogen nuclei to produce measurable signals, collected through a RF antenna (Gaivão, Lima, Agostinho, Oliveira, Peres, 2001).

As for CT imaging, MRI traditionally creates a two dimensional image of a thin "slice" of the body and is therefore considered a tomographic imaging technique. Modern MRI instruments are able to produce images in the form of 3D blocks, which may be considered a generalization of the single-slice, maintaining the tomographic concept. However, unlike CT, MRI does not involve the use of ionizing radiation and is therefore not associated with the same health hazards. On the other hand, because MRI has only been in use since the early 1980s, there is not much confidence what are the effects of long-term exposure to strong static fields. Because of that, there is currently no limit to the number of scans to which an individual can be subjected, in contrast to what happens with radiology, CT and nuclear medicine. However, the health risks associated with tissue heating due to exposure to the RF field and to the magnetic field, are well-identified, namely if there are devices implanted in the body, such as pacemakers or other metal apparatus. These risks are strictly controlled as part of the design of the instrument and the scanning protocols used (Gaivão, Lima, Agostinho, Oliveira, Peres, 2001; Chatham, Blackband, 2001).

Because CT and MRI are sensitive to different tissue properties, the appearance of the images obtained with the two techniques differ markedly. In CT, the X-rays are more attenuated by dense tissue to create an image, whereby the image quality of soft tissues is poor. In MRI, although any nucleus with a net nuclear spin can be used, the proton of the hydrogen atom remains the most widely used, especially in the clinical setting, because it is ubiquitous and returns a large signal. This nucleus, present in water molecules, allows the excellent soft-tissue contrast achievable with MRI (Gaivão, Lima, Agostinho, Oliveira, Peres, 2001; Bartling, Stiller, Semmler, Kiessling, 2007).

Pathology

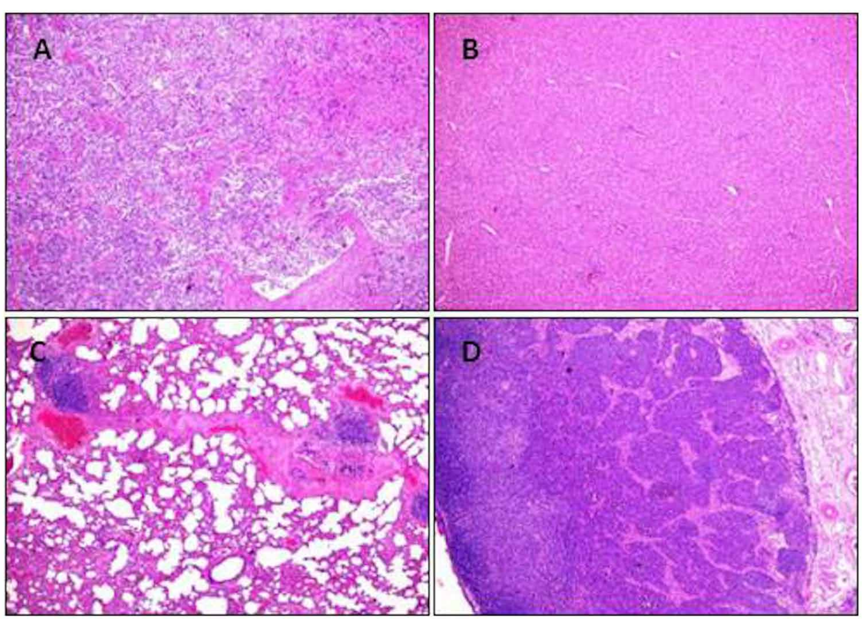
Pathological analysis is older than any of the imaging techniques already described. Using a tissue sample, it is possible to perform a morphological evaluation of tissues in search for clues concerning its histogenesis and biological behavior. Nowadays, the pathology is able not only to label diseases but also to characterize and define them morphologically as well as elucidates their underlying mechanisms (Cross, 2013; Van Middendorp, Sanchez, Burridge, 2010).

When using body tissues for pathological analysis, it is necessary first to fixate them before proceeding to histological analysis through microscopy. Fixation allows the preservation of tissues permanently in a life-like state.

Over the years, the role of pathology in medicine has benefitted from the application of specialized techniques allowing a more complete characterization of the specimen. Both, enzyme histochemistry and electron microscopy, have expanded the role of pathology from the primary microanatomical (histological) evaluation to the assessment of biochemical and subcellular structural features, exploring immunological markers and chemical signatures of cells. Over the years, advances on fixation, embedding, cutting, immunohistochemical staining, molecular methods, microscopy, as well as in image processing have improved the diagnostic ability and the research applicability of pathology (Cross, 2013; Van Middendorp, Sanchez, Burridge, 2010).

In animal research, pathological approaches have an add value, in order to obtain a complete tissue characterization in comparison with the other imaging techniques available (Figure 5). However, it is necessary to keep in mind the implications of performing a technique which involves a highly invasive procedure, i.e. removing a sample of tissue. Accordingly, pathological analysis is often performed at the end of experimental protocols or when animals are sacrificed at intermediate time points.

Figure 5. Representative images of histology specimens obtained from an orthotopic colorectal cancer animal model, stained with hematoxylin and eosin (H&E) and isolated from: colorectal cancer (A), liver (B), lung (C) and lymph node (D). Magnifications: 40x



THERMOGRAPHIC TECHNOLOGY: FUNDAMENTALS FOR ANIMAL STUDIES

The image techniques seen before can be processed in order to get some useful medical information that can support the diagnosis:

- Geometry,
- Density,
- Flow,
- Size,
- Symmetry,
- Of the organ or zone of interest.

Thermography is an imaging technique that captures infrared radiation and uses it to create a temperature mapping image. Therefore, thermography not only reads the thermal patterns of a certain zone but simultaneously quantifies the temperature in each of the image picture. This adds value to the technology but requires correct equipment, conditions and protocols to perform a rigorous and useful thermographic analysis.

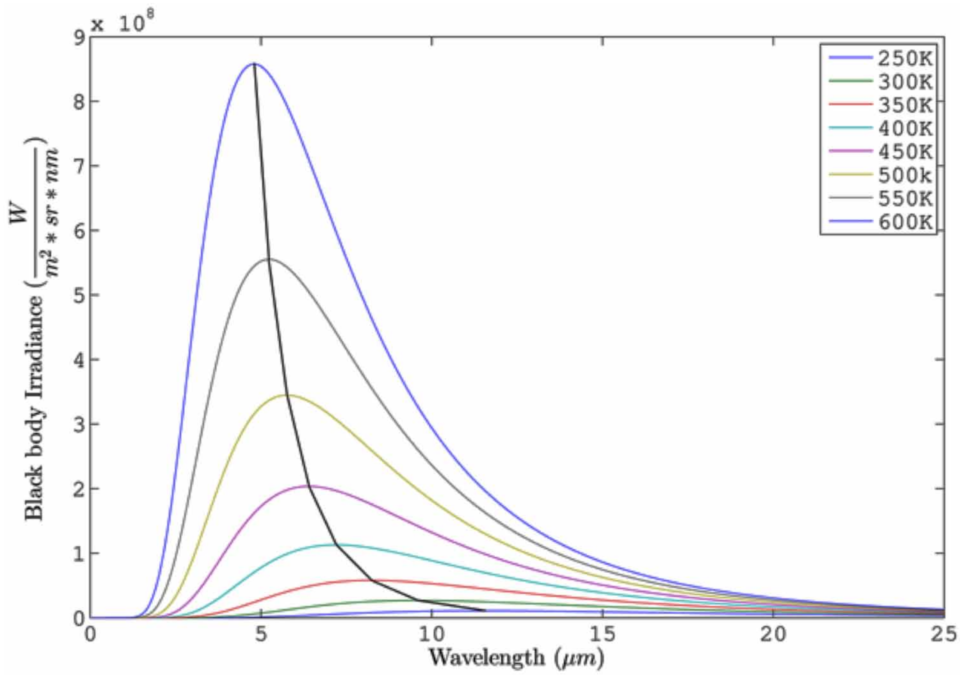
The majority of published thermographic studies tries to correlate a temperature variation (increase or decrease) with a certain pathology or physical disorder (Snekhalatha, Anburajan, Venkatraman, Menaka, 2013). In fact, since thermography measures radiation to create an image representing the temperature of objects, it is the most suitable method to assess the thermogenesis and thermoregulation in the majority of animals. However, the thermographic measurement of the body temperature is a challenging task as it depends on the environment, animal fur, and a precise protocol.

Infrared Measuring Principle

Measuring Temperature

Temperature is due to the kinetic movement of the molecules inside the objects. As this movement increases in amplitude and frequency, the object's temperature also increases, and thus the infrared radiation emission. The correlation between the temperature and the spectral radiation distribution can be described by the Plank law. This law states that the amount of radiation and the distribution peak frequency increases proportionally with the temperature. This way, it is possible to calculate the temperature of an object by measuring the amount of radiation in a specific waveband. A thermal camera captures infrared radiation and converts it into an electric signal that is then converted into a digital value. Through a calibration procedure, using a black body, it is possible to calculate the temperature at every pixel of the thermal image. A black body is an ideal physical object that absorbs all incident radiation, regardless of the incidence angle or radiation frequency. As an output, the emitted radiation follows the Plank law perfectly and is only modified by changing the black body's temperature (Figure 6). Another important aspect is that the radiation density is not dependent on the viewing angle. Even if the radiation is not isotropically distributed, this aspect is usually ignored since the camera's viewing angle is relatively small (less than 30º) and therefore their inherent errors are acceptable. The emissivity can then be seen has the "closeness" that an object is from being a black body, resulting in values from 1 (black body) to 0.

Figure 6. Black body radiation distribution at several temperatures, according to the Plank's law. LWIR - Long Wavelength Infrared (8-14 μm), represents the main waveband used in quantitative infrared thermography as it corresponds to the peak for environment temperatures



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The majority of the studies take place at room temperature (approximately between 293 and 297 K). Therefore, it is necessary to use a camera that is able to capture the maximum amount of radiation in that temperature range, in order to obtain readings as precise as possible. According with the Plank law represented in Figure 6, the majority of the emitted radiation, at the ambient temperature (approximately 300K) is located between the 7 and 17 μm of wavelength. This type of radiation is known as infrared radiation (ranging from 0.77 to 1000 μm), (Ryer & Light, 1997).

Temperature Calculation

Since thermography uses and measures radiation to calculate temperature, it is influenced by some properties of the object, the environment and the camera itself. The main factors influencing thermographic measurements are:

- Objet
  - Emissivity
  - Reflected temperature and radiation
- Environment
  - Environmental temperature
  - Relative humidity
  - Distance

The emissivity is the balance between the emitted radiation due to the object's temperature and the radiation reflected and transmitted through the object. The skin emissivity is very high, approximately 0.98, and is the most important parameter to be set when acquiring thermal images. Another important aspect is the reflected radiation, emitted by any object in the vicinity, which interferes with temperature measurements. This effect also takes place due to background radiation emitted by the room walls, especially if the room temperature is far from the recommended. Depending on the study, and mainly the animal being studied, the ideal room temperature may vary. Although the room temperature is generally assumed to be stable during the entire image acquisition process, the reflected radiation often changes (e.g., when the hands of the researcher manipulate the animals). This aspect is far more important when working with mice compared with human patients. As mice are so small, researcher's hand occupies a considerable part of the image, thereby increasing the errors and uncertainties associated with the measurements. Ideally, animals should be pictured without any handling, which often requires sedation or a light transient anesthesia (e.g. volatile anesthesia using isoflurane). Care is needed to avoid prolonged anesthesia protocols, as these interfere with body temperature regulation.

Ideally, the lenses of the thermal camera should be completely transparent to the infrared radiation. In reality, this is impossible and the lens' transmissibility should be considered in temperature calculations. Consequentially, part of the radiation received by the sensor will derive from the lenses and not from the object. This is the reason why the thermal camera should be kept at a stable temperature.

Thermography Operating Issues

One of the most important procedures when acquiring a thermal image is the focus. An unfocused image can lead to increased uncertainty or even wrong evaluation of the thermal image. If the temperature is important for interpretation, this aspect is even more important. Figure 7, shows two thermographic images of a Wistar rat presenting chemically-induced mammary tumors in an early phase. The animal was partially shaved over the tumor area, however hair scatters the emitted infrared radiation and severely affects image quality. In Figure 7a) it is possible to observe the shaved area exhibiting three hot areas and a central colder zone. However, after adjusting the focus to the central colder area, it shows up as a clump of unshaved hair, interfering with image analysis (Figure 7b). Shaving the animal may cause light trauma to the skin, with associated inflammation, thus increasing local temperature. Care should be taken to allow sufficient time for the inflammatory phenomena to abate (usually up to 48 hours should be enough).

Another important aspect is the correct distance from the object. To achieve a perfect focus, the area to analyze is expected to be as flat as possible, which is more relevant as the camera approaches the animal. However, due to the natural round form of rats and other small animals, this situation is not usually verified. In order to minimize this problem, the object to be analyzed should be positioned as far as possible, without losing the necessary detail. An example of this situation is represented in Figure 8, representing a mouse skin tumor. The lesion was imaged using a macro lens in order to emphasize the referred effect: by focusing on the tumor basis and contour, surface and center areas become blurred. The ideal situation would be to place the camera at a 90º angle from the animal's surface, which is difficult, in this case, due to the natural shape of these animals.

Figure 7. N-methyl-N-nitrosourea-induced model of mammary cancer in a female Wistar rat. a) poorly focused thermal image of the tumor, b) correctly focused of the central area of the tumor

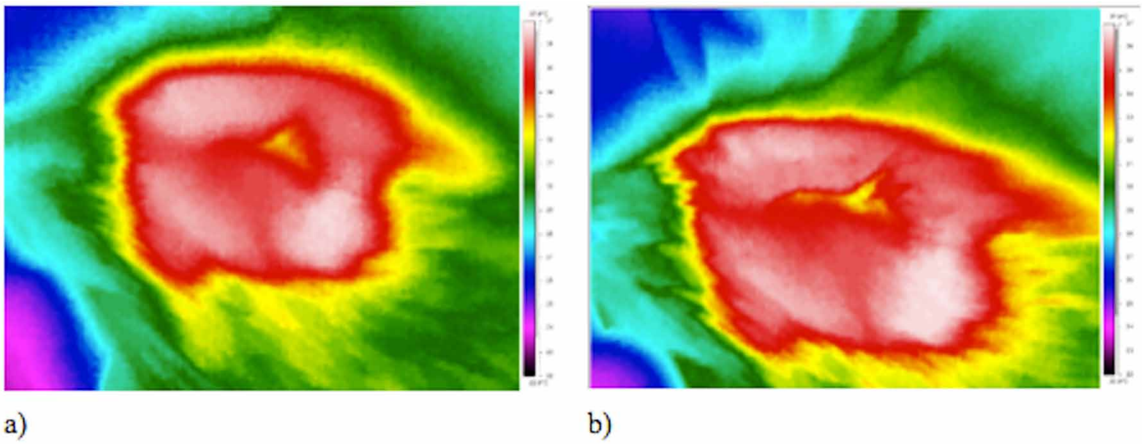

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Figure 8. Two-stage skin cancer model developed with 12-O-tetradecanoylphorbol-13-acetate and 7,12-dimethylbenz(a)anthracene in a mouse. a) Poorly focused image of the tumor, b) Correctly focused image of the tumor

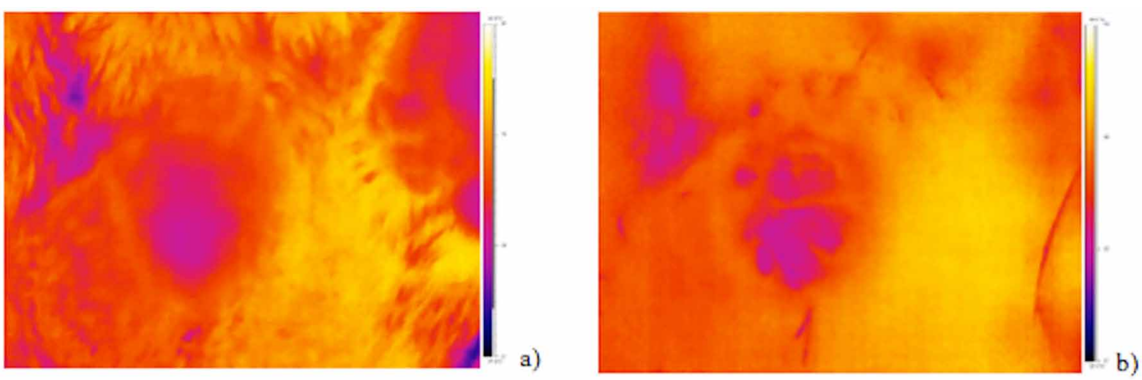

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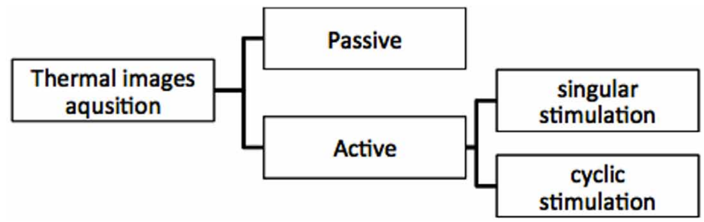
IMAGE ACQUISITION AND PROCEDURE

Image Acquisition Modalities

Thermal images may be acquired for several purposes, therefore the acquisition methodology and modality should be chosen for each case. Thermal imaging modalities can be divided into passive and active thermography (Figure 9).

In passive thermography, a single thermal image is enough to detect and characterize the object of analysis. Skin temperature changes may be detected in consequence of anomalies in the skin or in organs near the surface. For this reason, passive thermography has been the most used method in health applications, being also the easiest method to use.

Figure 9. Thermography modalities



On the other hand, active thermography uses a heat flow to induce temperature changes and thus increase the accuracy of thermal readings, or to study a particular aspect e.g. thermoregulation phenomena.

Active thermography can be divided in two modalities, singular and cyclic stimulation. In the first case, the object is submitted to a single thermal stimulation; its reaction and its recovery after stimulation are then observed. Thermal transient analysis is used for example in the evaluation of the effect of physical exercise, or the response cold stress test.

Cyclic thermography is characterized by the repetition of the stimulation along the time. In this way, it is possible to achieve an accurate time-response, even if the thermal amplitudes are very small.

Preparing an Image Acquisition Setup

To perform a good thermal evaluation, it is extremely important to use not only the adequate modality but also to have a good preparation and appropriate setup. This should include a steady support for the camera, a clean table to manipulate the animal with high emissivity and low reflection and conductivity.

Firstly, a camera with the appropriate lenses should be employed. There are two types of thermal cameras (cooled and uncooled), thus the first step is to select the appropriate technology. Cooled cameras tend to be considerably more expensive but are more precise, and their sensitivity can go up to 13 mK. However, for most applications, a sensibility of 50 mK (provided by the vast majority of uncooled cameras) is sufficient. On the other hand, a very important aspect is the spatial resolution. Since the areas to observe in rats and mice are often very small, it is important to have an image with a high spatial resolution, to allow observation of small details after image acquisition. An image resolution of 320x240 pixels or higher is advisable. The lenses are also an important detail and will determine the distance to the focus area. A lens with a wide angle will be able to view a large area but not the small details and will lead to unfocussed images, as those presented in Figure 8. On the other hand, a lens with a small angle may require a far greater working space, by requiring a higher distance to view the same area. Small viewing areas also tend to create difficulties in interpreting the image and centering the object.

A relevant aspect in a thermal image is the thermal patterns, specially the natural body symmetry. Usually relative temperature (left compared to right) usually provide more information than the absolute temperature values. Another important aspect is to consider the average temperature in small areas, instead of evaluating a single point, which will necessarily conduct to wide errors.

Thermography in Animal Models of Cancer

Over the last 60 years, thermography has been used in clinical and pre-clinical (animal) studies (Ring, Hartmann, Ammer, Thomas, Land, Hand, 2010). Temperature changes at the surface of the skin may result from several biological phenomena, like: exercise (Aughey, Goodman, McKenna, 2014), articulation disorders, tumor development (Bendele, 2001; Magnan, Bondi, Pierantoni, Samaila, 2014) and drug delivery (Snekhalatha, Anburajan, Venkatraman, Menaka, 2013).

Heat and cold in a hot-blooded mammal can be either a diagnostic tool or a treatment procedure. Typically, a temperature increment or a left/right difference higher than 0.5 K is sufficient to require a more precise and complete diagnostic (Vardasca, 2012). However, for treatment purposes, a temperature variation of approximately 12 K is usually required (Portela et al., 2013, Rodrigues et al., 2013).

The thermographic evaluation of cancer patients usually takes place in hospitals, under thermoneutral temperature at approximately at 23 ºC. In order to develop reliable thermographic animal cancer models, such comfort conditions must be mimicked. However, for mice the thermoneutrality should be achieved at temperatures between 30 and 32 ºC (Gordon, 2012), which is far above the usual temperature in animal facilities. Other factors such the gender and the menstrual cycle of animals may also affect temperature readings (Renault et al., 2006).

The dynamics of angiogenesis in cancer have been intensively studied with recourse to animal models. Different models have allowed researchers to explore many features of cancer-associated angiogenesis, as well as to develop and test anti-angiogenic drugs. However, data from animal models must be carefully interpreted and extrapolation to human patients is not straightforward. For instance, clinical results obtained with anti-angiogenic drugs are often below what could be anticipated based on animal studies (Carmeliet & Jain, 2011). Choosing - and often, creating - adequate animal models to study specific aspects of angiogenesis is a critical step for planning translational research experiments.

Monitoring angiogenesis in animal models of cancer is also challenging. *Post-mortem* evaluations can be readily performed histologically, or by employing immunohistochemical or immunofluorescent techniques to detect and quantify blood or lymphatic vessels in tissue samples. *In vivo* monitoring of cancer-associated angiogenesis presents other difficulties. In this context, thermography offers its well-known advantages as a safe and non-invasive method. Several experiments have been performed using thermography to monitor physiological parameters and pathological changes in laboratory animals. However, only a few reports refer the use of thermography to monitor tumor growth and/or response to therapy in animal models of cancer.

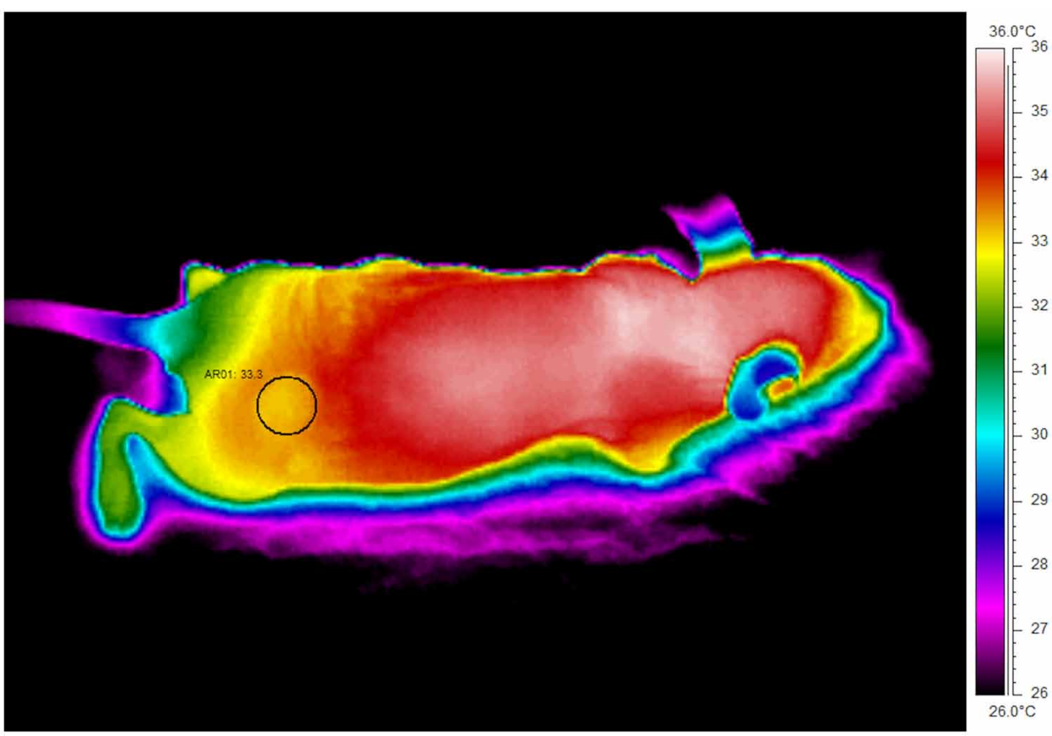
From the point of view of physiology, thermographic techniques have been used to study the effects of dietary components on thermogenesis (Smriga, Murakami, Mori, Torii, 2000) and to correlate body temperature and cage behavior in rats (Bilodeau, 2011). Recently, David *et al*. (2013) used thermography to study the effects of environmental temperature in animal facilities on the metabolic status of mice. This study pointed thermography as an ideal tool for assessing husbandry practices and manage thermal stress in laboratory animals.

Thermography has also been used to study pathological phenomena, like the effects of sciatic nerve crush on the thermal status of the affected limb (Sacharuk et al., 2011). Thermography also allowed the detection of experimentally-induced pneumotorax in rats by demonstrating the presence of cooler thoracic areas Rich et al. (2004) and was shown to be useful in studying the viability of surgical skin flaps (Shejbal, Drvis, Bedekovic, 2012). In a rat model of serotonin-induced itch, thermography was used to study the local vasoregulation in response to serotonin administration, and a negative correlation between serotonin dose and local temperature was observed (Jasemian, Gazerani, Dagnaes-Hansen, 2012). In a recent study, Snekhalatha *et al*. (2013) showed that thermography may be used to monitor the development of arthritis in an experimental rat model and that thermographic findings significantly correlate with radiographic and other clinical data.

The need for adequate animal models to develop thermographic cancer research was recognized as early as 1986 (Jochimsen, Folk, Sundell, Loh, 1986). Two years later, Konerding and Steinberg (1988), reported the use of thermography to study subcutaneous (heterotopic) tumor xenografts in nude mice (Figure 10). Nude mice are particularly attractive for thermographic studies, since even a moderately thick hair coat will produce dramatic radiation scattering effects as well as change the skin temperature. Their extensive use in cancer biology for developing heterotopic (almost always subcutaneous) tumor xenografts is another reason why these models are so promising from the point of view of thermography.

An identical approach was used by Xie *et al*. (2004) to study the vascularization of breast cancer xenografts in mice. Both studies concluded that tumor xenografts showed reduced temperature, compared with the surrounding tissues. These findings were later confirmed by Song *et al*. (2007), who reported that tumor temperature progressively decreased as they developed, reaching a minimum of 3 ºC when compared with adjacent tissues, at 14 days post-implantation. These reports are in accordance with our own findings, depicted in Figure 10. The reason why mouse xenografts showed reduced temperature when compared with adjacent tissues, in stark contrast with previous thermographic in human cancer patients, is not fully understood. Mouse xenografts do not develop through the usual multistep carcinogenesis process, but are a population of, often, highly malignant cells, cultured *in vitro* and then injected into the animal. As such, it is possible that some tumors do not adequately represent the histological

Figure 10. Nude mouse showing subcutaneous colon cancer xenograft (circle). The tumor temperature varies between 33.1 and 33.9 ºC (33.3 ± 0.1, average ± standard deviation) For the adjacent tissue, the average temperature is 34.1 ± 0.1

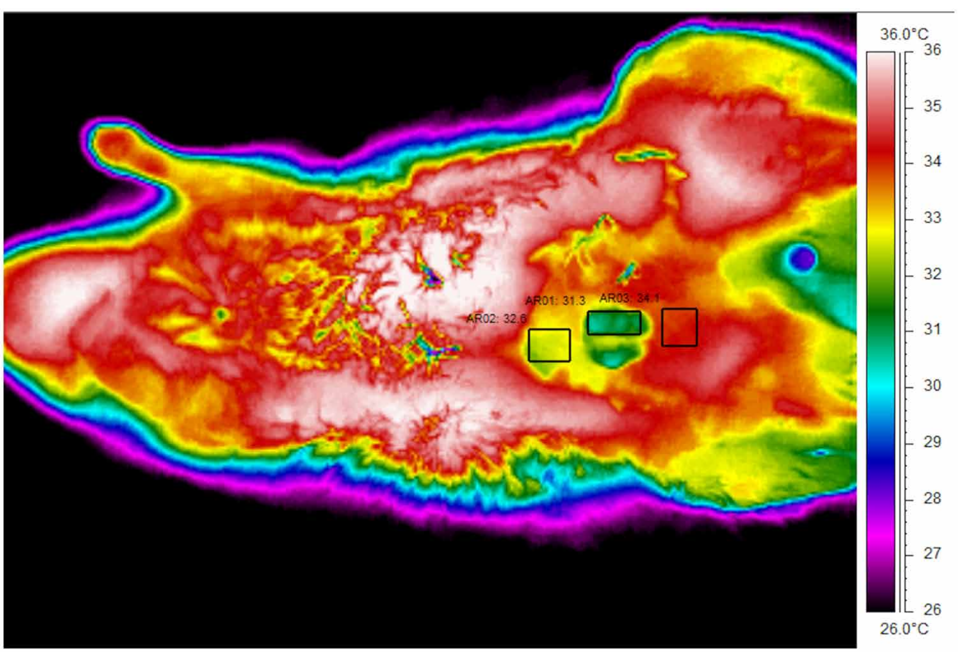


**For a more accurate representation see the electronic version.*

and, especially, vascular aspects of the original human tumors. Despite these surprising findings, early studies using mouse xenografts suggested that thermography could be a useful method to monitor tumor response to anticancer drugs in animal models (Xie, McCahon, Jakobsen, Parish, 2004; Song et al. 2007). Orthotopic rat xenografts (tumors or tumor cell lines transplanted into their corresponding organ of origin) are expected to be a more realistic model than heterotopic xenografts. One such model, mimicking colon carcinoma, is depicted in Figure 11.

However, thermography has seldom been adopted for this purpose. Recently, Rodrigues *et al*. (2013), reported on the successful use of thermography to monitor the response of mouse tumor xenografts treated with hyperthermia induced by magnetic nanoparticles. The same group also reported that thermographic data significantly correlated with readings obtained by intratumoral fiber-optic thermometers. A similar approach was successfully used by Tepper *et al*. (2013), for assessing the effects of diffusing alpha-emitters radiation therapy (DaRT) wires on subcutaneous breast cancer xenografts in mice. Intratumoral temperature differences were higher in treated *versus* untreated tumors, which agrees with the hypothesis that DaRT wires induced localized tumor destruction at implantation sites. The authors also found that tumor area estimated based on thermographic images was significantly correlated with direct visual caliper measurements. In a recent study, Hashida *et al*. (2014) successfully used a thermographic approach to monitor the thermal ablation of subcutaneous colon cancer xenografts using modified carbon nanotubes. Given the importance of nude mice xenografts in developing anti-cancer therapies, and the high costs associated with other imaging technologies, it is expected that thermography, with its inherent advantages, will attract the attention of researchers working with this kind of models in the near future.

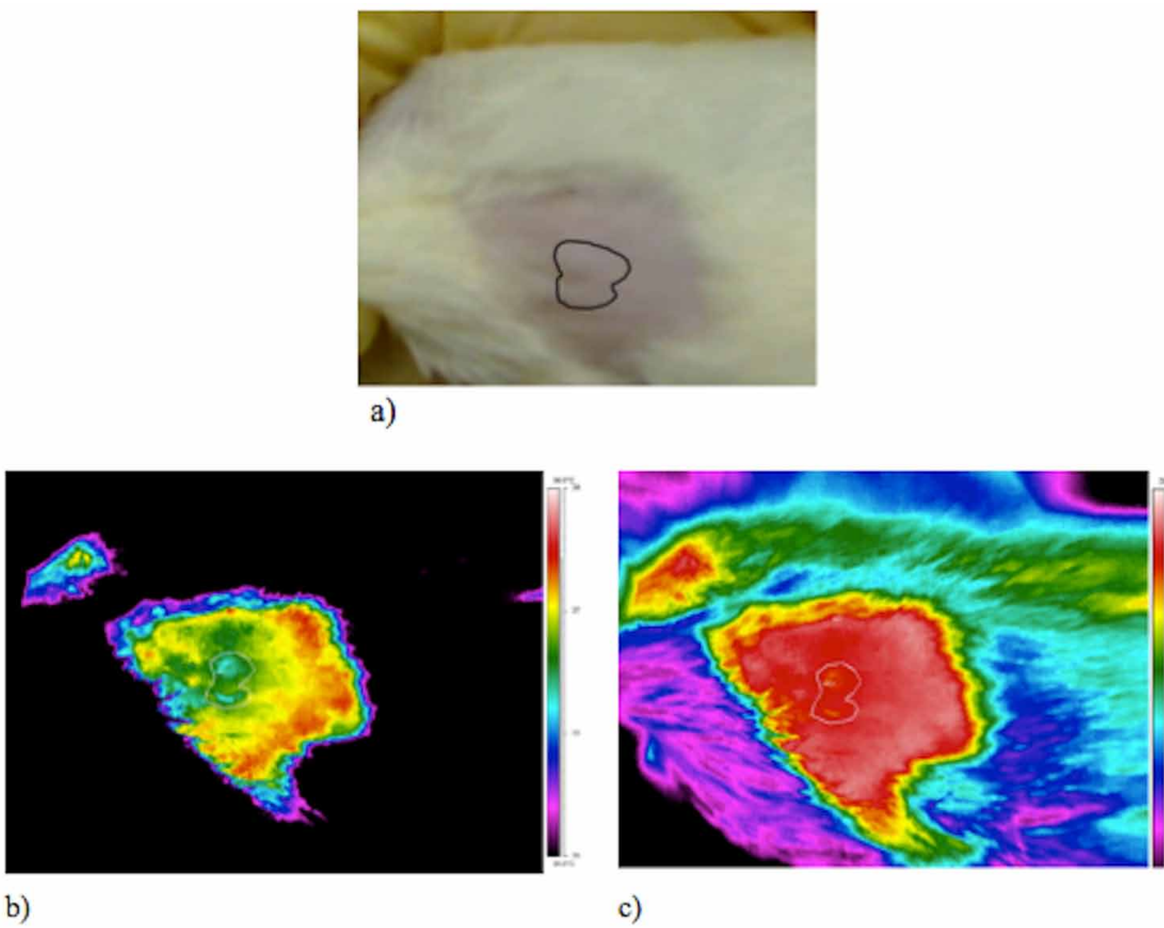
Figure 11. Nude rat with an orthotopic colon xenograft tumor. The tumor (AR01) shows an average temperature of 31.3 ºC, the subcutaneous tumor invasion area (AR02) 32.6 ºC and the adjacent tissue (AR03) 34.1 ºC



**For a more accurate representation see the electronic version.*

When using hirsute animals, clipping the hair that overlies the tumor area is necessary in order to obtain suitable readings (Figure 12). This problem is frequently encountered when employing common rat strains (e.g. Fischer or Wistar rats). Poljak-Blazi *et al*. (2009) studied thermographically the effects of experimental tumor transplantation, local inflammation and hematoma in Sprague-Dawley rats. As expected, the authors observed a raise in skin temperature following inflammation or hematoma induction. As observed in mouse xenografts, transplanted tumors (Walker 256 carcinoma) showed reduced temperature compared with adjacent tissues. However, contrary to what has been described for mice, this trend changed from day 10 post-transplantation onwards, when tumor temperature increased up to 1 ºC over adjacent tissues. The authors reported that, histologically, the tumors showed abundant vascularization, which may, to some degree, explain these findings. A more recent study addressed the relationship between thermographic findings and tumor vascularization, as detected by ultrasonography, in nitrosamine-induced mammary cancer (Faustino-Rocha, 2013). In this study, significant intratumoral

Figure 12. N-methyl-N-nitrosourea-induced model of mammary cancer in a female Wistar rat. Visible (a) and infrared thermal images using two different temperature scales (b and c) provide complementary information regarding the tumor (circled area)



For a more accurate representation see the electronic version.

thermal heterogeneity was observed. Maximum intratumoral temperature and thermal amplitude were found to correlate positively with tumor size. This may reflect tumor heterogeneity, typically found in large lesions, which partially agrees with the findings of Poljak-Blazi *et al*. (2009), suggesting that, at least in rats, long-term tumor progression leads to increasing tumor temperatures. However, the comparison between the results of Faustino-Rocha *et al*. (2013) and of Poljak-Blazi *et al*. (2009) is necessarily limited, because the previous study does not compare tumor temperature with that of adjacent tissues. Concerning the relationship between tumor temperature and vascularization, the authors reported that maximum tumor temperature and thermal amplitude were also correlated with blood vessel density, as determined using an ultrasonographic technique (power Doppler). A more recent study came to confirm these findings, Faustino-Rocha et al. (2016) show that thermal readings may be correlated with tumor vascularization, as assessed histologically and immunohistochemically (VEGF immunoexpression).

The thermal differences that have been observed between tumors in different animal models certainly reflect important differences in tumor development and biology. Over recent years, it has become evident that mouse xenografts only mimic the original human tumor to a limited extent (Eklund, Bry, Alitalo, 2013). Importantly, it has been found that anti-angiogenic agents which are highly effective in mouse xenografts show comparatively low efficacy in human patients, who present a more complex scenario. As a result, there is a search for models that recapitulate multistep carcinogenesis more accurately, including the progressive development of tumor vasculature (Eklund, Bry, Alitalo, 2013). A detailed and systematic characterization of such models is also mandatory. In this setting, thermography, with its inherent advantages over other invasive, expensive, or radiation-emitting techniques, maintains all its untapped potential to become a standard technique for monitoring tumor angiogenesis in animal models.

CONCLUSION

Thermography is a viable technique to assess the vascularization of superficial (cutaneous or subcutaneous) tumors in laboratory animals. As demonstrated by various studies, it may complement other techniques, such as ultrasound imaging and histopathology, providing relevant information on tumor biology. However, the presence of a dense haircoat on many mouse and rat strains, as well as the presence of a thick subcutaneous fat layer (e.g. in pigs), may limit the use of thermography. Other limitation of this technique when used in laboratory rodents is the frequent need for animal handling, restrainment or sedation, which may influence thermal readings. Also, it is not always possible to obtain thermal images from a 90º angle, as recommended, due to the animal's shape.

Finally, thermal cameras suppliers have recently started offering devices, which make it possible to obtain simultaneous and superimposable thermal and visible images, which will add to the potential of this technology. At the same time, the continuous development of smaller thermal cameras also offers new possibilities and applications.

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Chapter 8
Understanding Strategies for Implementing Integrated Information Systems for Rabies Surveillance

Anna Geofrey
Sokoine University of Agriculture, Tanzania

Maulilio J. Kipanyula
Sokoine University of Agriculture, Tanzania

Kadeghe Fue
Sokoine University of Agriculture, Tanzania

Camilius Sanga
Sokoine University of Agriculture, Tanzania

ABSTRACT

Rabies continues to be one of the most perilous viral diseases that affect the nervous system and remains a significant threat to public health across the globe. Available data that show that rabies claims about 59,000 human lives annually. Most industrialized countries have eliminated rabies from domestic dog populations. Conversely, in most of the developing countries, rabies remains endemic in domestic dog populations and poorly controlled. One of the challenges in eradicating rabies in developing countries is attributed to ineffective surveillance systems. Different stakeholders have developed solutions to address this problem without tangible outcomes. Estimation of the economic burden particularly in developing countries is difficult because of the inadequacy of update and reliable surveillance data. Certainly, it is very challenging even to obtain basic information on how many human lives are lost due to rabies and the economics behind preventing the disease amongst those exposed. Up-to-date, official reporting of incidence data on rabies and rabies exposures status remains desperately poor in most canine rabies-endemic countries. Consequently, there is increasingly underestimation of the true burden of the diseases. Worse still data from active surveillance studies highlight the disparities between officially

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reported and recorded and likely occurring rabies deaths. In some cases, it has been shown that there are higher mortality rates than officially reported data, especially in resource deprived areas. This calls for a need to establish an integrated surveillance system, which allows data to be shared openly among different stakeholders dealing with rabies. The paper presents the state of art of rabies in Tanzania and evaluates the application of ICT in surveillance. It also advocates for a need of a comprehensive approach to addressing the problem. Development and adoption of integrated surveillance systems for rabies and other zoonotic diseases remain a nightmare in many developing countries including Tanzania. This paper calls for the development of an integrated standard mechanism for countries to assess their rabies status and measure progress in eliminating the disease. Such a system will fill the missing link between surveillance and control measures.

BACKGROUND INFORMATION

Rabies is one of the deadly infectious diseases of the nervous system, with a case-fatality rate approaching 100% in both animals and humans. The disease is established on all continents apart from Antarctica; most cases are reported in Africa and Asia, with thousands of deaths recorded annually (Fooks et al., 2014). The World Health Organization (WHO) estimates that up to 99% of human rabies cases are transmitted by a bite of an infected dog. It is estimated that rabies causes about 59,000 human deaths every year, especially in economically disadvantaged areas of Africa and Asia where awareness and access to post exposure prophylaxis can be limited or non-existent (Anyiam et al., 2016). However, the estimated annual figures of human rabies fatalities are probably underestimated due to poor reporting system (Hergert and Nel, 2013).

The most cost-effective approach to eliminate the global burden of human rabies is to control canine rabies rather than expansion of the availability of human prophylaxis. Mass vaccination campaigns with parenteral vaccines, and advances in oral vaccines for wildlife have made it possible for several countries worldwide to eliminate rabies in terrestrial carnivores (Fooks et al., 2014). It has been postulated that in order to eliminate rabies from domestic dog population in an endemic area at least 70% of the dog population needs to be vaccinated during an annual rabies mass vaccination campaign and breaks the cycle of transmission (Coleman et al., 1996). Certainly, decreasing canine rabies automatically decreases the number of human deaths (Cleaveland et al., 2002). However, in many African countries, the proportion of dogs vaccinated against rabies is far below 70%. Treatment for human rabies is often inaccessible and expensive than the cost of programmes for control and prevention of dog rabies (Ope et al., 2013; Bardosh et al., 2014; Hatch et al., 2016).

Drawing a lesson from Kilosa district Tanzania where rabies is endemic, lack of appreciation and awareness that rabies can be prevented and controlled by massive dog vaccination schedules has remained a deadlock (Kipanyula et al., 2015). Figure 1 and Figure 2 show the number of dogs in different villages in Kilosa district Tanzania and the number of dogs vaccinated, the data were collected from users through the interview and were analyzed to determine the dog owners' response toward mass dog vaccination. Eliminating rabies require coordinated and sustainable long-term strategy supported by robust human and animal health systems. An integrated, holistic approach for information sharing is crucial for example using one health approach. This may require step wise approach allowing inter-sectoral surveillance data sharing based on participatory approach and coordinated intervention by all stakeholders. Evidence has shown that elimination of rabies in most of the developed countries was driven by: the strategic stepwise approach that focused primarily on reservoirs in conjunction with massive dog rabies vaccination campaigns, the establishment of a database for rabies surveillance and long term political commitment and resources availability. It is until when developing countries replicate this approach, otherwise rabies will continue to pose a significant human health problem. Use of ICT such as mobile phones, radios, televisions, websites and crowdsourcing to improve the communication of rabies surveillance information at different levels is likely to make a difference. This will facilitate awareness, timely reporting and response to rabies incidences (Kipanyula et al, 2015; Hatch et al., 2016).

The goal of this paper was to review state of the art literature, which contribute to the development of an effective, efficiency and low-cost surveillance system for detecting, identifying, controlling and monitoring rabies in Tanzania. Our hypothesis was that through public crowd sourcing of incidences of rabies outbreak via mobile telephones and web based system, combined with open and public reporting of such incidences in real-time through the Internet, radio and TV, will decrease the number of incidences.

PAPER BASED REPORTING SYSTEM FOR RABIES CASES

Traditionally, paper based reporting system has been in use for decades. Overtime the system has proven to be inefficient due to several factors within and beyond human control. Some of well documented challenges include: incompleteness of surveillance forms at the time of submission, difficulties to submit hard copies of the disease surveillance forms because of poor infrastructure, lost forms, large piles of reports,

Figure 1. The number of dogs in villages in Kilosa (adapted from Kipanyula, 2015)

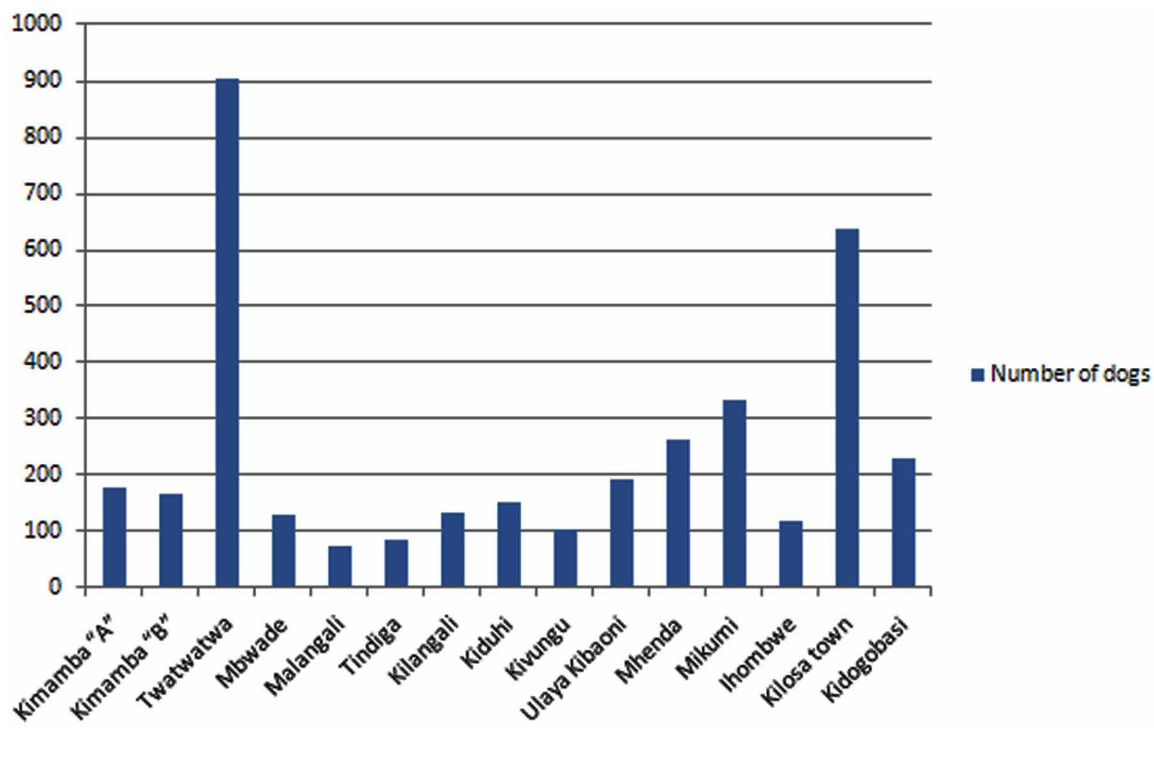
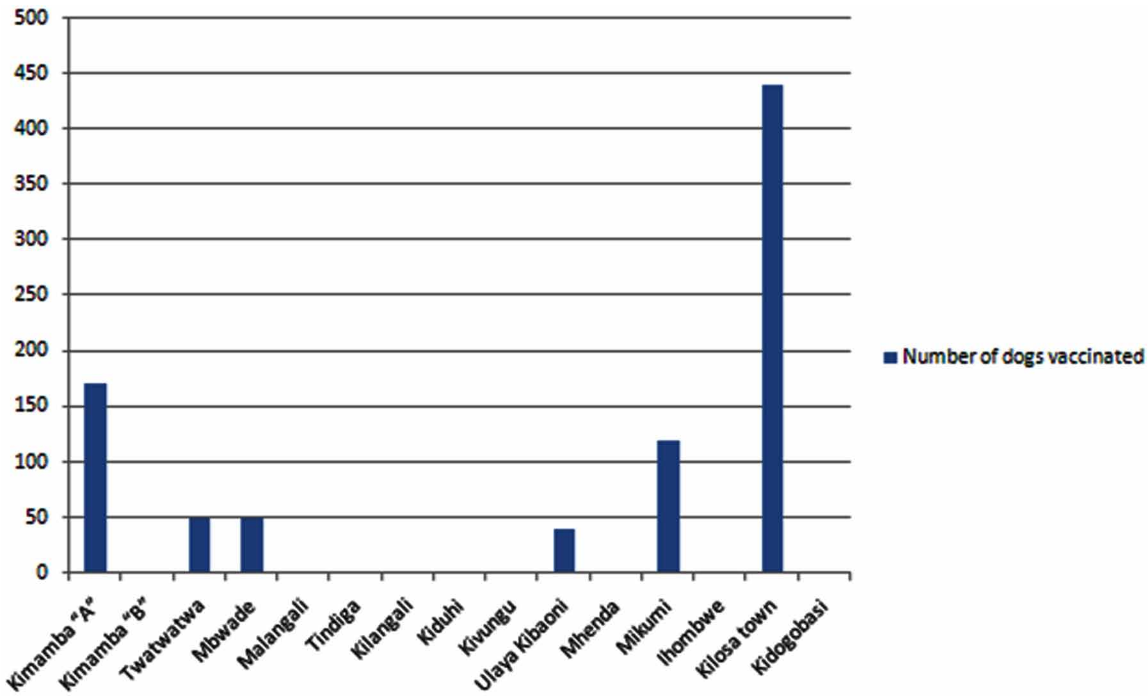


Figure 2. Number of dogs vaccinated in villages in Kilosa (adapted from Kipanyula, 2015)



difficulties in records indexing, weather conditions or challenging terrain, especially in the developing countries like Tanzania (Mtema, 2013). Following submission of forms, the system demands re-entry of the data at central data processing and analysis points. Passing data through different levels make it possible for the introduction of unexpected human errors. Considering the whole process of handling of data and given challenges highlighted above, there is significant delayed acquisition, processing and response to disease events occurring particularly in remote and resource limited areas.

APPLICATION OF ICT IN RABIES SURVEILLANCE

In recent years, we have witnessed intense research on the application of Information and Communication Technology (ICT) in integrated disease surveillance system (IDS) to help overcome the challenges in encountered in paper based reporting of rabies incidences and further expansion in hard-to-reach populations in Tanzania. This has increased the involvement of the private sector, and the use of other modes of communication like e-mail, mobile phones and voicemails. Though the use of ICT tools, it is possible to reach many people to create awareness on rabies. The ICT based rabies surveillance systems support easy awareness creation (i.e. sensitization) and a more rapid and timely reporting, and response to rabies incidences (Ncube et al., 2010; Mtema, 2013). Furthermore, ICT facilitates one health approach and improve communication between veterinary and human health services by making both Departments aware of surveillance data through the database. Furthermore, it facilitates the speed of communication which is most critical to contain or stamp out an outbreak, save lives, and prevent or minimize the detrimental effect to the communities. Although ICT appears to be simply a communication tool for sharing of surveillance data, it is challenging, however, to set up an effective communication system, and even more so in poorly established infrastructure in the developing countries like Tanzania. Future advances in ICT and wide application of human sensor web technologies minimize the above challenges (Qekwana et al., 2010; ITU, 2014). Some of the key components of the IDS include: Integration and decentralization of surveillance activities through establishment of surveillance units at national, state and district levels; Human Resource Development through training of State Surveillance Officers, District Surveillance Officers, multi-disciplinary Rapid Response Teams, and other veterinary and medical professions on all aspects of disease surveillance; Use of ICT for collection, collation, compilation, analysis and dissemination of data through a web portal and strengthening of public health laboratories (Kant., 2010). Some of the ICT application have shown tangible outputs in various settings, and are summarized below (McCall et al., 2011).

RADIOS AND TELEVISION

For rapid detection and response to any outbreak, natural or deliberate, a sensitive surveillance system is essential. It is considered that a good communication system is the 'brain' of the surveillance system. It is the speed of communication which matters most to contain or stamp out an outbreak, save lives, and prevent misery. As pointed out above it is challenging, however, to set up an effective communication system, to increase public awareness on rabies. Televisions and radios are frequently used by veterinary and public health officials or central authorities within the district to educate people on various issues. These media of communication also disseminate information on public health related matters including rabies incidences in the area (WHO, 2002). Radios are cheaper compared to televisions. They can still be used also in rural areas where there is lack of electricity thus serving as an ideal means of communication. The high costs associated with casting a program on televisions and radios has remained to be a great challenge. Thus due to un-timely communication and coordination of rabies despite the use of radio and television still the disease has continued to be a public health concern (Mazigo, 2011; Mboera and Rumisha, 2004; Sambo, 2012; Hatch et al., 2016). A novel framework for the use of radio in communicating rabies information can be adopted from Sanga et al. (2013). Radios and Televisions cannot be used for reporting isolated and emerging cases of rabies but can only be used to inform the public on outbreaks and serious public health threats.

WEB BASED INFORMATION SYSTEM

The Internet has revolutionized efficient health-related communication and epidemic intelligence worldwide (Chunara et al., 2012; Choi et al., 2016). Recent studies have shown that the increased frequency of Internet use for acquiring health information has contributed to the rise of web-based early detection systems for infectious diseases through various methodologies (Choi et al., 2016). The principal concept of this tool is that disease-related information is retrieved from a wide range of available real-time electronic data sources, which play critical roles in the identification of early events and situational preparedness by offering current, highly local information about outbreaks, even from remote areas that have been unapproachable by traditional global public health efforts (Keller et al., 2009; Choi et al., 2016).

The use of web based information system has brought opportunities and increased possibilities of community involvement in rabies cases identification, detection, alerting, monitoring, controlling, mapping and reporting (Adigwe, 2012; Mwabukusi et al., 2014). Mapping of all areas that are usually affected by the disease outbreak can be made possible by using the web-based geographical system to increase the citizen's awareness of the disease and the precautions that can be taken to prevent it. Also, the database queries can help the public health and veterinary professionals to know which areas within the district need more attention for operations such as; dog mass vaccination campaigns and stocking of health centers with sufficient PEP. The justification for advocating the use of the web-based system; the system database can provide an easy, cost effective and reliable means for reporting, monitoring and controlling of rabies (Luba, 2012). The main obstacle for a wide application of web-based diseases surveillance system is the internet connectivity.

MOBILE BASED INFORMATION SYSTEM

Although traditional pen-and-paper methods of disease reporting are not efficient or practical in complex emergencies, there are still used in developing countries. Instead, reporting formats can be provided on mobile phones, making it easy for both human and animal health professionals to enter data and send reports. Such a system will help reduce errors, decrease the time used in reporting and facilitate compliance with reporting schedules. Mobile phones facilitate real time communication, therefore, may be ideal in rabies surveillance: The ultimate result will be increased people participation in control programs such as dog mass vaccinations, communication between people and veterinary centers in case of disease outbreak and hence structural barriers, poor infrastructure, cost for transportation to access health and veterinary services will no longer be a problem (Mtema et al., 2016). Despite recent improvements, not all areas have mobile network coverage with internet capacities like 3G or 4G technology, resulting in an incomplete picture of the public health information. However, combining mobile phone service with a paper-based reporting system in areas where there is no network access is likely to give good coverage. The use of satellite phones in areas of the network would help to strengthen the system further. Even in areas where the network is working, there may be shortage of electricity supply to recharge the phone batteries; future interventions should consider the use of mobile phones with a silicon solar panel embedded into the shell of the phone. It has been advocated that wherever possible Global Positioning System (GPS) enabled mobile phones with geographic information system (GIS) capability should be used. The reporting system can be programmed to automatically generate geo-referenced data for each text message, which could help to track the disease reported with more specified locations (Snyder & Dazzo, 2011).

Information such as rabies outbreak, dog vaccination campaigns can just be sent to people through SMS or voice call within the village. Also by using a Mobile application such as SMS, mobile based systems and mobile apps, it is easy to collect data since it is automatically uploaded into a database and is available on a real-time basis. This data can be used to precisely combat the disease in specific areas, allowing the institution of appropriate interventions to target societies. With the mobile technology, data on the server can be viewed simultaneously by both the veterinary and public health centers. This helps quickly provision of services to the areas that are affected by the disease (Asangansi and Braa, 2010).

DESKTOP BASED GIS APPLICATIONS

Popular GIS applications like QGIS and Arc Map have been used to develop maps that can explicitly show health disparities along different areas. Jerrett et al., (2001) explained intersection of medical geography, environmental epidemiology, and spatial analysis and they reviewed how to apply spatial analysis in environmental health research. Emch et al., (2012) presented a case study of how social network and spatial analytical methods can be used simultaneously for disease transmission modeling. Bennett and Tang (2006) reported about agent based models of adaptive, spatially aware, and mobile entities. Rabies is carried by dogs who are spatially moving agents that can be modeled to predict future of the disease and effectiveness of the current approaches. This means that use of GIS in spatial and social network analysis can help us better understand disease transmission cycles.

Recently, some prominent geo-informatics experts have described disease map as having some prioritized properties that can help public health experts and practitioners to understand well the maps. Beyer et al., (2012) argued that as the disease map user group grows, disease maps must prioritize several essential properties that support public health uses of disease maps. They identified and described five important properties of disease maps that will produce maps appropriate for public health purposes: (1) Control the population basis of spatial support for estimating rates, (2) display rates continuously through space, (3) provide maximum geographic detail across the map, (4) consider directly and indirectly age–sex-adjusted rates, and (5) visualize rates within a relevant place context.

Integration of the shape files developed in these applications can be made available through internet. The maps can be used to develop layers that can explicitly show the relationship between economic social attributes and health centers availability and distance from most of the villages. These approaches can greatly work to combat rabies in developing countries.

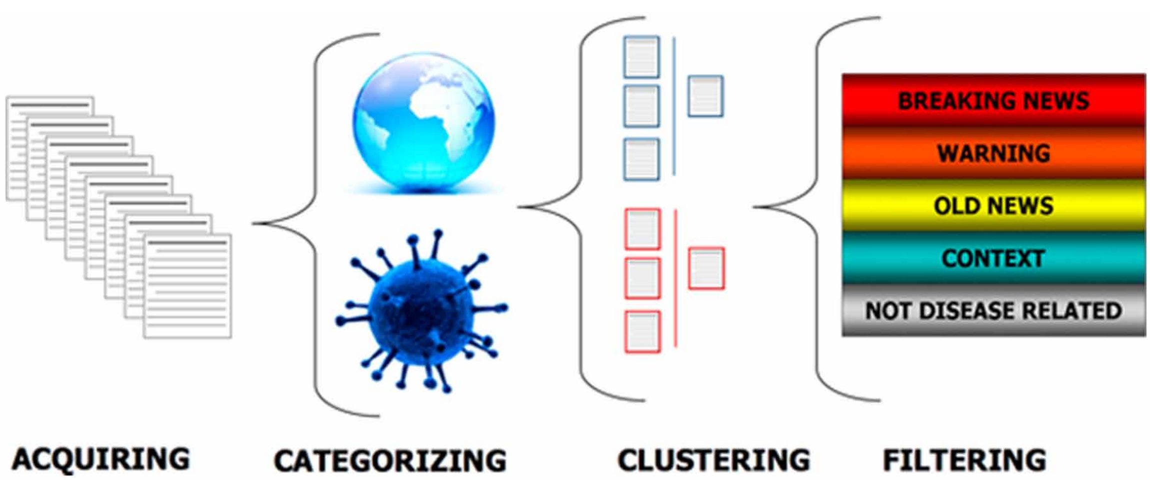
HUMAN SENSOR WEB

Human sensor web is a very effective method of rabies surveillance; it helps the veterinary and public health professionals to get real-time data on diagnosis (Trigoni and Krishnamachari, 2012). In Tanzania, this notion of human sensor web was tested and deployed to design solution on a mobile reporting system for functionality of water points in rural Tanzania under the SEMA project (Wesselink et al., 2015). If it could be applied in the context of rabies, then it would be easy to detect and timely report outbreaks in both public health and veterinary facilities. Human sensing is a method of crowd-sourcing whereby ICT devices are employed for data collection in a particular field of specialization. Human Sensor Web (HSW) is a network of people who interact with their devices in order to forward their observations to a designated receiving server in the form of messages (such as SMS and emails). The operating principle is based on the accessibility of ICT tools (such as mobile phones) by non-experts to use them as sensory nodes in order to generate useful data regarding various location-oriented phenomena. The method would allow sharing of rabies information to wider audiences (Leventhal, 2013). Studies have shown that use of rapid diagnostic kit for the diagnosis of rabies using saliva, or cerebrospinal fluid from living animals or brain homogenate to detect rabies virus antigens requires only training of veterinary and public health staff on how to use it and sharing of results could adopt human sensor notion. In brief, the rabies antigen test device is an immunochromatographic assay for the qualitative detection of rabies virus antigen in canine, bovine, Raccoon dog's secretions of saliva, and brain homogenates. The kit has a letter of "T" and "C" as test line and control line on the surface of the card. Both the test line and control line in result window is not visible before applying any samples. The control line is used for procedural control. Certainly, the control line should always appear if the test procedure is performed properly and the test reagents of control line are working. A purple test line will be visible in the result window if there are enough rabies antigen in the specimen. The specially selected rabies antibodies are used in test band as both capture and detector materials. These enable the device to identify rabies antigen in animal blood with a high degree of accuracy. Wider application of this kit may improve diagnosis and help to avoid unnecessary killing of dogs in endemic countries. This will allow early detection of dogs with rabies virus and thus allow prompt management of the disease (Nishizono, 2008). Thus, the kit is suitable for screening and surveillance of a large number of rabies-suspected animals in laboratories with proper facilities for biohazard in endemic areas because of its simple, rapid, reliable, and cost-saving properties (Nishizono, 2008). The laboratories in Kilosa health and veterinary centers could adapt the use of these human sensors that do not require expertise to use it. By doing so, the rabies diagnosis could be done promptly and at low-cost. This could change the way suspected animals with rabies are dealt and foster objective planning of rabies control strategies and dog mass vaccination schedules (Leventhal, 2013). Systems which support human web sensor web are limited in Tanzania (Pascoe et al., 2012); thus there is need of adapting existing architecture for implementing such systems (Figure 3).

CROWD SOURCING PLATFORM FOR RABIES SURVEILLANCE

The web is becoming the interface for reporting information about diseases, prevention, surveillance and control. The study by Brownstein et al. (2009) presents a seminal paper discussing how the web is being used to harness public health system globally. According to Brownstein et al. (2009), the weakness of Internet based system for diseases surveillance is information overload, false or bias reports, high cost, contributor bias, imprecise resolution, lack of specificity of signals, and sensitivity to external forces such as media interest or bias or misinformation. According to Chunara et al. (2013), mobile phone and

Figure 3. Architectural of the proposed rabies surveillance system based on human sensor web (adapted from Brownstein et al., 2008)



the Internet provide tools for collecting disease surveillance data directly from individual citizens (i.e. crowdsourcing). However, crowdsourcing is still at infancy stage in many African countries (Chuene & Mtsweni, 2015).

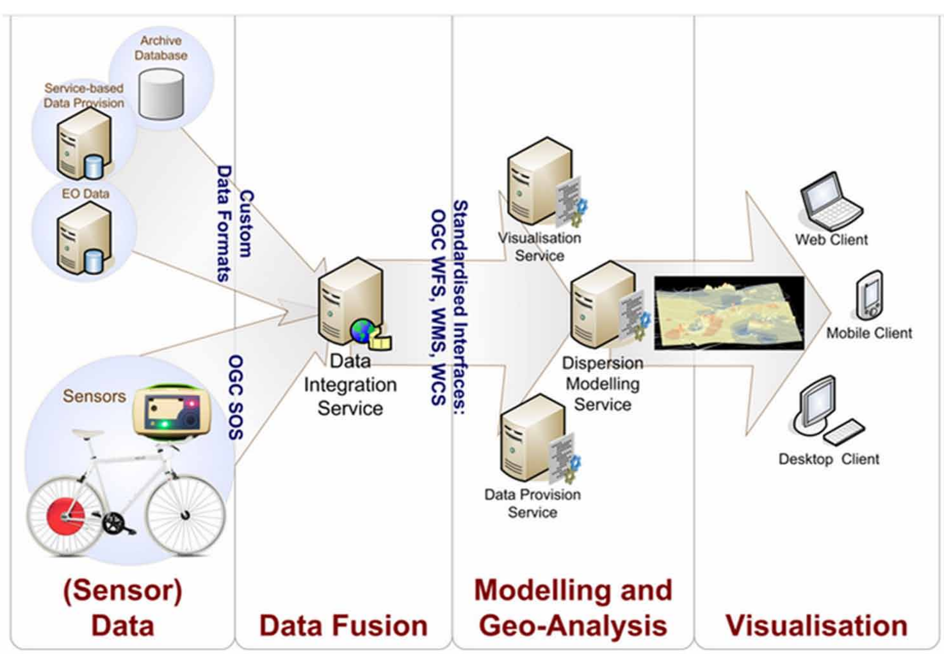
According to Chunara et al. (2013) crowdsourcing is defined as:

…the process of obtaining services, ideas, or other information via a large group from the public, rather than a specific set of people (such as government institutions or hospitals).

Boulos et al. (2009) suggested that crowdsourcing is the proposed solution to address some of the weakness mentioned by Brownstein et al. (2009). According to Boulos et al. (2009) crowdsourcing for surveillance system involves the use human (i.e. citizen or crowd) to sense and report surveillance information to a web or mobile based surveillance information system. Also, it involves the use of specialized sensor devices to send information to web or mobile based surveillance information system which aggregates or fuses information from different sources (i.e. micro blogging, mobile phones enabled by GPS, SMS). Boulos et al. (2009) Architecture can be used in implementing crowdsourcing platform for rabies surveillance (Figure 4).

Crowdsourcing platform can help control of rabies by establishing collaboration of individuals and group of individuals (i.e. crowd) to contribute their ideas in order to solve the problems. This can be done using few veterinary and health centers available in a region. Encouraging and providing responsibilities to citizens to find ways and methods to eliminate rabies in their region is the best and effective method to collect rabies data (Callaghan, 2015). Collaboration or participatory communities created especially for rabies reporting and the investigation of rabies-related incidence gives individual participants to view

Figure 4. Architectural of the proposed rabies surveillance system based on crowdsourcing application (adapted from Boulos et al., 2009)



themselves as a problem solver in a society. This is what is termed participatory citizen sensing (Boulos et al., 2009). According to Boulos et al. (2009) sensing is a process of detecting physical presence and converting that data into signal which can read by an instrument or observer (citizen). Citizen science can be done through commissioned payment or volunteer (Bonney et al., 2009). There is a developing notion of biocitizenry that being a citizen scientist, and sharing personal health information, or collaborative data collection (Swan, 2012). Thus, this act of participatory problem solving in disease surveillance using intelligence from citizens (i.e. crowd) is called crowdsourcing.

In Tanzania, crowdsourcing applications have been piloted in agriculture and health sector (Madon et al., 2014; Sanga et al., 2016, Mwangungulu et al., 2016). Madon et al. (2014) reported on the use of mobile phones for collecting health data from the field to control neglected tropical diseases. They argue that even through user generated data (i.e. crowdsourcing) can be obtained there is a need to decision support system so that there will be decentralization on the use of such data.

Mwangungulu et al. (2016) piloted crowdsourcing application in identifying areas where mosquitoes are abundant or less abundant without surveying. Community members (i.e. crowd) were trained how to report areas with abundant mosquitoes through participatory mapping using GIS. The use of crowdsourcing approach was cost effective in controlling malaria.

Sanga et al. (2016) piloted the use of a web and mobile based platform (UshauriKilimo) to all crowd to report on suspicious rabid animals, rabies disease outbreak, treatment of affected dogs. Also through UshauriKilimo veterinary and health centers and crowd can share information on rabies education, what first aid kit can be given to the rabid patient and rabies data and information generated from the crowd. Data collected from the crowd is populated in real time on map and instantly all involved users/ parties / stakeholders are notified to take appropriate measures. Examples of stakeholders are police, local communities, public health officer, community worker and law enforcement agents (e.g. local leaders – village executive officers, ward executive officers). These stakeholders can be linked by crowdsourcing application (USAID, 2013) in diseases surveillance. Thus, crowdsourcing facilitates quick response from veterinary and health centers to the areas of the disease outbreak. Also, it can increase the number of dog owners' participation in dog mass vaccination schedules.

SOCIAL MEDIA PLATFORM FOR DISEASE SURVEILLANCE

Many people are now using social networks to express their opinions regarding the vast number of topics. Most people use it to complain whenever a problem rises in the society. The geotagged tweets, Facebook status, picture updates in Instagram allow researchers to know the location of the person who writes the twit. Understanding human mobility is crucial for a broad range of applications from disease prediction to communication networks (Jurdak et al., 2015). Jurdak et al., (2015) proposed Twitter as a proxy for human mobility, as it relies on publicly available data and provides high resolution positioning when users opt to geotag their tweets with their current location.

Diseases like rabies can be combated by using big data analysis approach of reading social media status of the users and report to the disease surveillance systems. This method has been shown to be very successful in some topics already. For example, the study by Jiang et al., (2015) indicated that the filtered social media messages are strongly correlated to the Air Quality Index and can be used to monitor the air quality dynamics to some extent. So with this method, rabies surveillance can be monitored using filtered social media messages. Bosley et al., (2013) concluded that twitter can be filtered to identify public knowledge and information seeking and sharing about cardiac arrest. To better engage via social media, healthcare providers can distil tweets by user, content, temporal trends, and message dissemination. Furthermore, Nagar et al., (2014) reported the first study to stress test Twitter for daily city-level data for New York City. Extraction of personal testimonies of infection-related tweets was done and demonstrated Twitter's strength both qualitatively and quantitatively for ILI-ED prediction compared to alternative daily datasets mixed with awareness-based data such as GSQ.

This is a cost-effective method however Yang and Mu (2015) reported that these social media platforms may limit most of the information. For example, the Twitter APIs only allows free access to a one percent convenience sampling of tweets. Data acquired are restricted to users with public profiles. These may bring some bias to study results.

CONCLUSION

The paper presents the state of art of rabies surveillance and evaluates the application of ICT in as a part of the integrated approach. There is a mixture of approaches from traditional to modern approaches supported by ICTs. The shortcoming of these approaches is that they operate in in discipline related silos. This calls for Government to integrate different ICT solutions (i.e. unified approach) for surveillance of diseases developed by various organizations. The Government and other stakeholders involved in addressing zoonotic diseases like rabies should develop a framework which can guide stakeholders' participatory implementation of such blended approaches with citizens forming the center of the approach (i.e. human centred). UshauriKilimo in Tanzania is an example of a mobile based system which has been developed through involvement of user from initial phase (analysis) to final phase (implementation) (Sanga et al., 2016). This tool can be customized as (1) early warning information system for rabies (2) crowdsourcing platform for rabies surveillance (3) web based rabies advisory system (4) mobile based rabies advisory system (5) cloud based rabies advisory system. (6) e-learning and mobile learning for rabies.

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Chapter 9
Open Source Educational Initiatives to Improve Awareness of Rabies Prevention

Peter Costa
Global Alliance for Rabies Control, USA

Deborah J. Briggs
Global Alliance for Rabies Control, USA

ABSTRACT

Rabies is the deadliest infectious disease known to humans and animals and yet is almost always preventable even after an exposure has occurred. The lack of educational awareness is a major reason why over 55,000 people die of the disease every year. The Global Alliance for Rabies Control, in association with international partners in the field of public health, initiated new educational initiatives aimed at increasing global awareness for those living at daily risk of exposure to rabies. Three of the open source educational initiatives are described in this chapter, including: World Rabies Day; the establishment of a freely accessible scientifically accurate education bank; and hosting global webinars that connect public health experts interested in reducing the burden of rabies in their regions.

INTRODUCTION

Most readers of this chapter will have a specific image of fear and horror in their mind when they hear the word "rabies" and yet few people truly understand the actual disease itself including how they might be exposed to the virus causing rabies and what the current recommendations are in the event that they were exposed. Increasing awareness on these two issues could save tens of thousands of lives as a lack of true understanding of how rabies viruses are transmitted and how the disease can be prevented are the root causes of almost every human rabies death. Added to the lack of awareness about disease transmission and prevention is the fact that the majority of human rabies deaths occur in populations belonging to the lower socio-economic group where access to resources, including education and anti-rabies biologicals, are limited or non-existent (WHO, 2010). Finally, an evaluation of the highest incidence of disease per

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age group reveals that at least 50% of all rabies deaths occur in children under the age of 15 indicating that children are not aware of what rabies is, how they could be exposed to infection, and what to do if they were exposed (Rupprecht et al., 2008).

Rabies is in fact, a neglected viral zoonotic disease that is almost always transmitted from an infected mammal to a human (WHO, 2011; Wilde, Briggs, Meslin, Hemachudha, & Sitprija, 2003). Rabies has the highest case fatality rate of any disease known to infect humans and animals (Rupprecht, 2004; Rupprecht et al., 2008). There have been very few patients that have survived rabies because, once clinical signs are evident, the disease progresses rapidly and almost every patient will succumb to the disease within a few days. The World Health Organization (WHO) reports that there are at least 55,000 human deaths every year, thus one person dies of this horrific disease every 10 minutes (WHO, 2010). There are a number of different types, or variants, of rabies viruses circulating in the world and each rabies virus variant tends to be transmitted within one species of animal although 'spillover' of viral infection to other species can and does occur. In fact, it is the spillover of disease to humans that result in human fatalities. Human to human transmission of rabies is extremely rare and has only been laboratory confirmed to have occurred occasionally through organ transplantation although anecdotal transmission of rabies was reported through human bites (Dietzschold & Koprowski, 2004; Fekadu et al., 1996; Lapierre & Tiberghien, 2005). The majority of human rabies deaths, approximately 99% of all estimated global deaths, occur in Africa and Asia after being exposed to (usually through a bite) a rabid dog (WHO, 2005, 2010). Rabies viruses circulate on every continent in the world, with the exception of Antarctica, resulting in over 3.3 billion people living at risk of contracting the disease.

In North America, the circulation of canine rabies virus variants was eliminated through mass dog vaccination programs initially launched in the 1950's. However, different rabies virus variants continue to circulate within the wildlife population and unvaccinated pets, including dogs and cats, can become infected through exposure to infected wild animals. In the US, between 0 – 6 human rabies deaths are reported annually. Most of these deaths occurred after being exposed to an infected bat for which the patient did not seek prompt medical treatment (Gibbons, Holman, Mosberg, & Rupprecht, 2002; Messenger, Smith, Orciari, Yager, & Rupprecht, 2003).

Despite the extremely high fatality rate of rabies, this disease is almost 100% preventable. Rabies, unlike many other infectious diseases, can be prevented even after an exposure to the infectious agent has occurred. Post-exposure prophylaxis (PEP) consists of washing the wound where rabies virus may have entered, and then administering anti-rabies biologicals to the patient, including vaccine and immunoglobulin (WHO, 2010). In over three decades since modern cell culture rabies vaccines (CCVs) were developed, there have only been a handful of patients that have died of rabies after having received appropriate PEP thus confirming that prompt treatment after exposure could save thousands of lives (Deshmukh, Damle, Bajaj, Bhakre, & Patil, 2011; Hemachudha et al., 1999; Shantavasinkul et al., 2010). Since rabies is preventable and no one would willingly chose to die of rabies if they knew how to prevent the disease, the fact is that the lack of educational awareness on all levels of society is one of the major reasons why humans still die of this disease.

This chapter will outline the role of open source educational awareness in the prevention and control of rabies throughout the world, focusing on three specific initiatives that have used different educational platforms to promote rabies awareness and have resulted in sending rabies prevention messages to over 182 million people in over 150 countries in the past five years. These initiatives include: World Rabies Day; Global Rabies Webinars; and Open Access Rabies Education Bank.

BACKGROUND

Preventing rabies includes three basic steps: Avoiding exposure to infected animal; receiving protective immunization prior to an exposure; and/or receiving prompt PEP after an exposure has occurred (WHO, 2010, 2011). It is irrelevant as to what species of animal was involved in the exposure nor does it matter in what country the patient was exposed, the information about how to prevent rabies is scientifically identical. To avoid being exposed, humans should stay away from wild animals that may be infected with rabies, keep their pets up to date on their rabies vaccination, and understand how to avoid being bitten through treating their pets respectfully and practicing responsible pet ownership. Rabies prevention for people whose vocation puts them at increased risk of exposure to rabies should include administration of preventative immunization, or pre-exposure vaccination (PrEP) (Manning et al., 2008; WHO, 2005). This group of individuals would include veterinarians and their assistants, scientists and technicians working in rabies laboratories or in rabies vaccine production facilities, and children and other populations living in remote regions where access to rabies biologicals is difficult or not possible. Finally rabies prevention in persons exposed to rabies includes prompt wound washing and administration of anti-rabies biologicals including rabies immune globulin (RIG) and a series of rabies vaccination over two to four weeks (Manning et al., 2008; Rupprecht et al., 2010; WHO, 2005). Without prompt wound care and administration of anti-rabies biologicals, there is a high risk that exposed patients will die of rabies.

Transmitting the information about how to prevent rabies in every country across the world where rabies is endemic may seem like a daunting task, especially considering the number of different languages and various cultures involved. However, digital technology is a powerful communication tool that can provide open source access to information to communities in almost every region and when utilized correctly will deliver live-saving educational materials to those that need them. The implementation of digital technology on a global scale to improve awareness about rabies prevention and control through community based action was initiated by the Global Alliance for Rabies Control (GARC) in 2007. It began by bringing major stakeholders together to develop a strategic plan to improve awareness, followed by the selection of one specific day per year when everyone living at risk of rabies could conduct activities in their own regions to improve awareness. The date agreed upon, September 28th, was designated as "World Rabies Day" (WRD). WRD was launched as a day when all populations across the world living at risk of infection could conduct a multitude of awareness activities, based on their own culturally acceptable messaging, to highlight the ongoing tragedy of rabies and how to prevent infection (Burns, 2009); WRD, 2012).

Outdated or misinformation about how to prevent rabies is not unusual, especially in resource-poor countries where public health professionals responsible for rabies prevention and control do not have the financial resources to travel to international conferences or WHO reference laboratories to learn about new recommendations, diagnostics, surveillance techniques, reduced vaccination protocols etc. (Lapierre & Tiberghien, 2005; Mai le et al., 2010; Rupprecht et al., 2008; Zhang, Zhang, & Yin, 2008). In order to help alleviate this situation, GARC coordinated a series of open access webinars where oral presentations were conducted in 'real time' followed by an opportunity for listeners around the world to ask the speaker questions (GARC, 2012). This was the first time that local public health experts involved in rabies prevention activities, previously hampered from relating information about their own region by the cost of travel or lack of access, could provide information about the rabies situation in their own country to listeners tuning into the webinar from around the world. The only cost incurred to presenters and listeners was their own travel cost to reach a local internet connection, and their time to listen to the presentation.

One of the foremost obstacles for individuals wishing to improve educational awareness in their own country was free access to medically correct informational. Although there was a significant amount of educational material produced by reliable sources in different languages across the world, the fact that there was no central access point made it extremely difficult for individuals to find the educational material that they needed. To alleviate this situation, GARC developed a website where copyright-free educational material could be uploaded and retrieved as needed.

ISSUES, CONTROVERSIES, PROBLEMS

Previous Situation

Over the past two decades, a regional rabies prevention and control program overseen by the Pan American Health Organization (PAHO) in collaboration with experts from the Centers for Disease Control and Prevention (CDC) in Atlanta Georgia USA has been underway in Latin America (A. Belotto, Leanes, Schneider, Tamayo, & Correa, 2005; Schneider et al., 2005). PAHO has driven the regional approach by bringing together public health ministries to work together on a regional strategy (A. J. Belotto, 2004). With most Latin American countries complying with the steps outlined in the regional plan, canine rabies control has been greatly reduced throughout the continent although a few countries continue to face challenges including Haiti and Bolivia. However, in Africa and Asia, no regional approach to rabies prevention and control exists, rabies prevention is not a priority and therefore, canine rabies continues to take a heavy toll on human lives. The inability to implement a regional plan in Africa and Asia could be a result of many factors including the existence of multiple languages and the wide variety of cultures present in the regions. In Latin America, there are fewer major languages to contend with although the problem of providing messaging sensitive to some indigenous populations continues to be a challenge.

In general, prior to the global educational initiatives initiated by GARC, the approach from international public health agencies in Africa and Asia has been to use a "top down" approach where recommendations were developed and passed along to the national governments to implement. When countries have many other diseases to contend with and have limited budgets for public health, financially investing in rabies prevention is often low on the priority list of countries combating HIV, tuberculosis, childhood infectious diseases, poor sanitation, etc. Clearly, the rabies prevention and control recommendations developed by the experts at the international level continue to be important in the overall development of regional and national rabies control strategies. However, understanding how to implement these recommendations at a local level, where citizens live at daily risk of exposure to rabies, required a new strategy.

Outdated Information and Attitudes

Going global with innovative programs to improve rabies awareness had some initial controversial issues and an array of different types of oppositions to overcome. A quick review of history reveals that the disease of rabies has been with mankind since antiquity and has had an impressive past. For example, rabies was the third disease in history (after smallpox and chicken cholera) for which a vaccine was produced (Wu, Smith, & Rupprecht, 2011). It was Louis Pasteur and his colleagues that finally developed a means by which people exposed to the disease could be saved thus rabies and Louis Pasteur are inextricably linked (Teigen, 2012; Vignal, 1886). In fact, the contribution of Pasteur to rabies prevention is immortalized forever in the beautiful mosaic work depicting a rabid dog on the wall of his crypt beneath what was his home and is now part of the Pasteur Institute in Paris France. The achievements that Louis Pasteur and his colleagues made regarding the development of a rabies vaccine that included multiple injections of a crude preparation into the abdomen to save lives, is so famous that most people do not realize that modern human rabies vaccines are administered into the upper arm, similarly to other modern vaccines. Additionally, the rabies vaccine developed by Louis Pasteur and his colleagues in 1885 was always administered *after* an exposure occurred, as PEP, and was never administered *before* an exposure occurred as a preventative measure, as PrEP. This historical precedent has in fact hampered the extended use of PrEP as one of the valuable tools for governments to use to prevent rabies in populations living in high risk areas with no access to vaccines, or in children the population at highest risk of dog bites and rabies. Changing the attitude of medical professionals to promote the use of PrEP as a means to save human lives was a challenge.

Building Partnerships

Rabies is a zoonotic disease, meaning that rabies virus circulates within one or more animal species and is almost always transmitted from an infected animal to a human. Human to human transmission rarely ever occurs. Thus human rabies could be greatly reduced or eliminated totally if rabies was eliminated from circulating within animals, the source of human infection. Since dogs are the main source of infection currently causing more than 99% of all human rabies, mass vaccination of dogs would eliminate 99% of the present number of human deaths. The complicated issue to overcome is that the responsibility for monitoring and enforcing dog rabies control is not clearly established in most resource poor countries. Since rabies is not a notifiable disease in most countries in Africa and Asia and few diagnostic laboratories exist, rabid dogs and dog bites often go unreported and not treated. There is a disconnection between animal health institutions responsible for animal health issues and human health institutions responsible for purchasing and administering PEP to prevent human rabies. There are other ministries that also need to be involved in rabies prevention and control, including the legislative branch, responsible for passing and enforcing laws regarding rabies prevention; waste control, responsible for reducing the amount of garbage and food sources available to dogs; finance departments, required to fund rabies prevention projects; etc. Bringing diverse groups together to discuss common issues of importance and how interrelated programs could save money and lives is not easy and required innovative strategies to overcome obvious communication problems. Bringing the global stakeholders together to work toward common solutions presented a unique opportunity to utilize the time, talent and treasure of various individuals and groups in the field of rabies prevention and control. However, initially it was a challenge to find common ‘talking points’ and to agree on an overarching strategy that was not biased toward one particular stakeholder.

Logistics

To physically go to every locality, or even to visit one location in each country to promote rabies prevention and control is a daunting task, and the cost and time required to undertake such a mission is not feasible. Additionally, translating rabies educational messages into each language required to reach people living at risk of dying of rabies in different countries (keeping in mind the need to be sensitive to the local culture) using the expertise of a small team that did not comprehend more than five languages between them was not possible. Therefore, GARC needed to develop a different strategy in order to make the educational messages about rabies prevention freely available to the millions of people that needed them to save their lives. An additional logistic challenge was that of how to conduct real-time webinars aimed at connecting people living in every time zone around the world and having access to different types of internet connections.

SOLUTIONS AND RECOMMENDATIONS

World Rabies Day

In 2007, World Rabies Day (WRD) was coordinated by GARC and supported by numerous international partners with the single mission of increasing global awareness about rabies and its prevention because all stakeholders agreed that by increasing awareness about rabies, lives could be saved. It was understood that one of the most important reasons why people continue to die from rabies is because they are not properly informed about what constitutes an exposure to rabies and what they need to do after an exposure has occurred. Additionally, lingering challenges as old as the disease itself continued to hinder the implementation of effective prevention measures including linguistic, religious and cultural barriers, pervasiveness of traditional and ineffective therapeutic practices by local healers and generational inheritance of false local myths, inaccuracies and superstitions. WRD was launched as a health communications campaign and has been the single largest and most successful rabies awareness effort ever conducted. The WRD Campaign is a unique example of a fully functioning One Health effort and has been included as one of the 'annual awareness events' on the United Nation's calendar of international observances (United Nations, 2012). WRD has involved collaboration by and between every leading human and animal health organization in the world including the World Health Organization, World Organization for Animal Health (OIE), Food and Agricultural Organization of the United Nations (FAO), Centers for Disease Control and Prevention (CDC), and numerous other governmental, private, non-profit and charitable organization partners. WRD has united all of these organizations towards the common goal of human rabies prevention through improved educational initiatives including eliminating rabies at the source of infection.

By inviting everyone across the world to join in the fight against rabies, WRD has helped restart previously abandoned rabies control programs, build new organizational and societal partnerships and strengthen existing collaborative efforts in nations that formerly thought nothing could be done to stop rabies. Much of what has been accomplished through WRD is attributed to the incorporation of health communications to a field that was vastly dominated by scientists and researchers. Increasingly recognized as a necessary element to improve public health, health communications is critical for people's accessibility and exposure to health information and their resultant ability to make positive health behavior changes (US DHHS, 2003). With the single mission of educating everyone, and especially young people about rabies, WRD sought to convert the endless amounts of relatively stagnant technical data about rabies into freely downloadable, dynamic and intuitive information for lay person utilization. As a grassroots movement needing to quickly surmount numerous and varying behavioral, cultural, demographic and physical barriers to health behavior change, WRD focused on leveraging electronic communications through its own websites and through websites of multi-national partners to reach its target audience members. Sign-ups to the WRD website led to the creation of a global rabies network allowing for instant global communication to more than half a million people in a moment's notice. Additionally, with a focus on 'One Health', WRD eyed intersectoral collaboration from its inception and focused heavily on collaborative engagement by Ministries of Health, Agriculture and Education. This approach not only led to increased participation but illustrated to the world that rabies was a disease that everyone could work together to prevent and the support and dedication of numerous governmental sectors in a single effort signified a united front against a disease of both humans and animals.

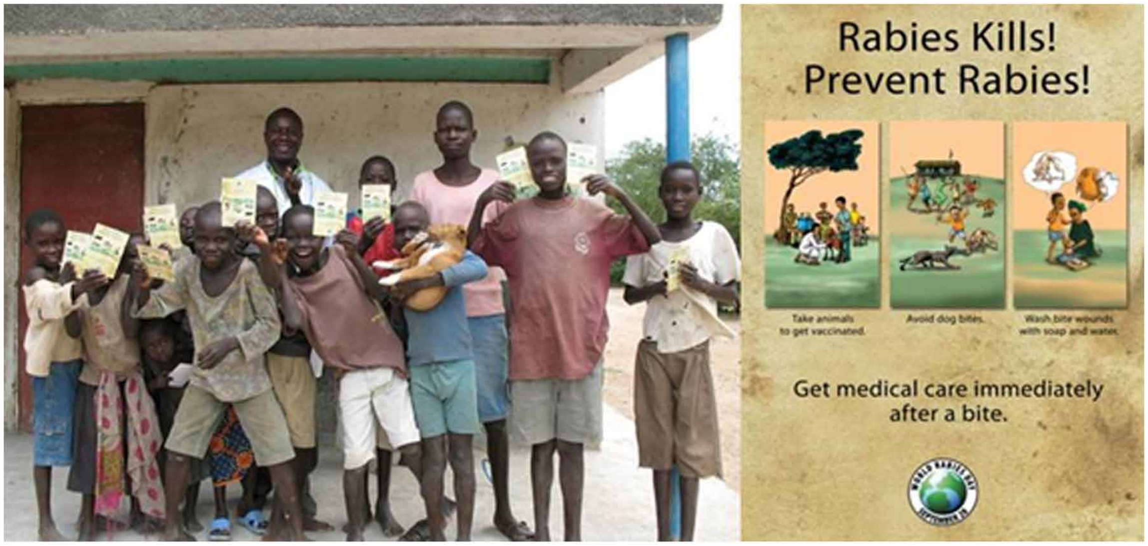
The momentum created by WRD has increased the number of global participants involved in improving educational awareness at all levels of society. In the five years since the campaign was launched, 182 million people in 150 countries have received educational messages about how to prevent rabies and close to 8 million animals have been vaccinated against rabies.

Multi-national resolutions to observe WRD each year have been implemented by organizations such as the Association for Southeast Asian Nations (ASEAN), World Organization for Animal Health (OIE) and Rabies Expert Bureaus in Africa, Asia and the Middle East (AfroREB, AREB and MEEREB respectively); recognizing WRD as an opportunity for member countries to pool resources, share expertise and work together in a common concerted effort. WRD has revitalized national programs in numerous countries (Cleaveland, 2010) Governments that had previously abandoned national rabies control efforts are now focusing on understanding the rabies situation in their own countries by self-identifying core capacity deficiencies and requesting technical support and training in areas such as pathology, diagnosis, surveillance, post exposure prophylaxis and communications. New animal vaccination programs have also emerged and with renewed vigor in nations such as Haiti, catalyzed by a mass donation of 500,000 doses of animal vaccine from Brazil in honor of WRD (Schneider et al., 2008) and in Mozambique where previous to WRD it was forbidden to vaccinate dogs as local folklore told that a vaccinated dog was not a good watch dog. World Rabies Day has been instrumental in helping to dispel such myths and make the case for renewed efforts towards controlling rabies in dogs. In absence of WRD, it is unknown how long local customs and beliefs would have endured resulting in additional human deaths, all due to the lack of correct information. Finally, it is worth mentioning the influx of new and novel partnerships that have been established to help address the need for rabies education. Organizations once separated by now seemingly trivial constraints such as geography or health specialty are now beginning to see the added benefits of working together. One such example is the multi-agency collaborative poster outreach initiative to Africa for WRD; involving participation by seven organizations on three continents and delivering more than 30,000 posters to 22 African nations. Posters were made available in numerous sizes, languages and formats and in many African villages serve as the only means for rabies education (Figure 1).

Education Bank of Materials

A major focus of World Rabies Day is to increase free access to scientifically accurate rabies prevention educational materials to as many people as possible. For decades, the information to prevent rabies has been understood at higher organizational levels but has not necessarily reached individuals 'on the ground' who are often most at risk and least informed. This has led to the chronic misinterpretation and delivery of erroneous rabies prevention information by ill-informed citizens; conceivably contributing to needless human deaths. Often times materials are simply not in the appropriate language, are culturally

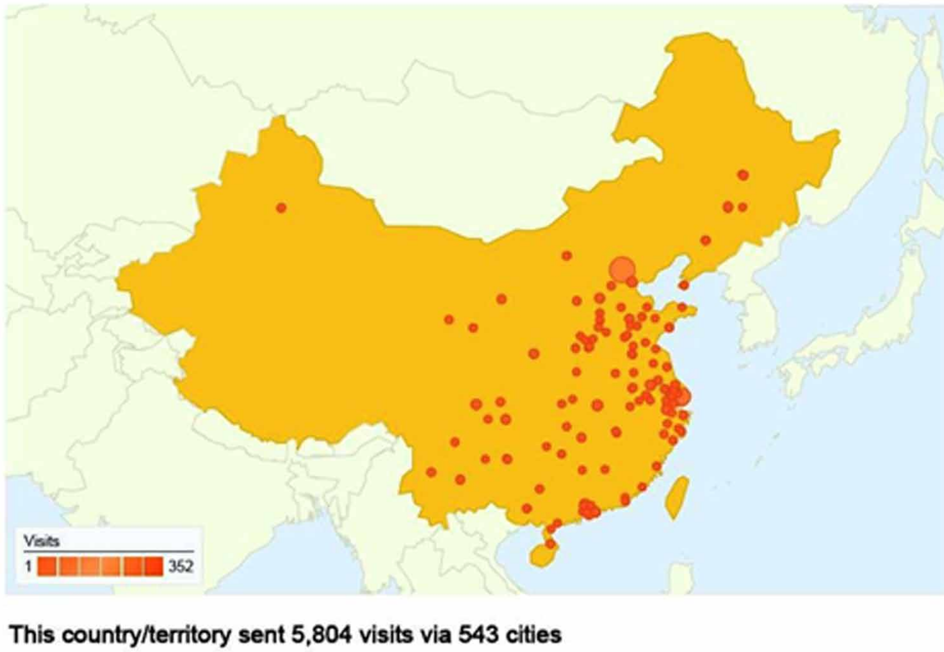
Figure 1. African posters distributed by the Global Alliance for Rabies Control and its partners including the Centers for Disease Control and Prevention, the Food and Agricultural Organization, University of Pretoria, Washington State University, and Veterinarians without Borders



or pictorially inaccurate, are inaccessible or limited in their distribution, or may otherwise be rendered unavailable due to funding or copyright constraints. To increase access to educational materials about rabies, an education resource library was constructed and embedded within the WRD website. The WRD website (www.worldrabiesday.org) serves as the campaign's communication hub and has been visited by nearly half a million visitors from over 210 countries and territories since 2007. Since the educational messages to prevent rabies are basically the same all over the world and with so many countries and cultures working individually to control rabies locally, the campaign focused not on working with every community separately but rather to serve as a point source for accurate information and guidance on what material is freely available and helping to create new materials as needed (Wunner et al., 2010). Rabies educational materials, including the WRD logo have been translated into over 40 languages and placed in the public domain.

Educational materials continue to be the most sought after resource on and subsequently the most visited section of the WRD website. Site visitor data is collected through the implementation of an analytics program. Website analytics uses unique internet provider addresses to track visitors coming to the WRD website in a non-identifiable manner. Statistics collected include but are not limited to: pages viewed, length of visit, and keywords and referring sites leading visitors to a particular webpage. In addition to providing insight into who is visiting the WRD website, analytics, perhaps more importantly, allow for a greater understanding of who is not visiting the website and thus provides an opportunity to compare and contrast those populations with their overall risk of rabies exposure. For example, by looking at website analytics from China (Figure 2), it is clear to see that web visitors from western China are nearly non-existent. Given that rabies is one of the top three most important infectious diseases in China, one would expect visitation to the WRD website, even from poorer, more rural areas of China. To better understand where additional rabies educational efforts may be needed, a physical map of China

Figure 2. Web visitors to www.worldrabiesday.org originating in China, 2007-2011



could be compared to the website analytics visitor map to help define locations for enhanced, targeted rabies education efforts.

Global Webinars

More than half of the world's population lives at daily risk to rabies (WHOa, 2011). In order to reach these individuals en masse, health educators need to move beyond traditional approaches to public health education and begin to leverage electronic communication facilities. Webinars, or web seminars, have evolved over the last decade as an open source solution to educate nearly limitless numbers of people and to reach populations traditionally unable to access accurate and culturally correct health information in a timely manner. Placing information online, for example, on a website, has significantly increased access and helped educate more people but is a static process requiring health information seeking behavior. Therefore, if someone is not actively looking for health information online, the resource may likely be un-utilized or under-utilized and therefore rendered ineffective. Clearly there is a need to not only develop and place information on the world-wide-web but also to actively promote and incentivize its availability.

Historically, online education programs developed for distance learning opportunities at colleges and universities targeted busy students with demanding schedules that wanted to advance their skills and training but were not able to attend traditional, time-fixed classroom learning environments. The provision of online courses offered an alternative for students to learn and earn course credits in a self-study, self-paced manner. Akin to other great digital discoveries during the last decade, the use of this technology gained immediate popularity. Recently, these online platforms for information dissemination have evolved beyond academia and have been embraced by additional sectors, becoming the most cost effective tool for interacting with customers (Monaghan, 2009). For example, private for-profit companies now advertise their products and services via monthly webinar offerings and public health institutions are marketing healthy behavior by hosting regularly scheduled programs on various topics such as diet and nutrition, preventing occupational injuries, cancer prevention and infectious diseases just to name a few. For many public health professionals, participation in webinars offers the opportunity to learn about a variety of new subjects while gaining continuing education credits without having to leave the workspace.

Given the extreme need for rabies education and the fact that most of the population at risk cannot afford to attend expensive international conferences, GARC began experimenting with ways to best leverage its ever growing online community. Realizing that internet communications through WRD had clearly led to a sea change in the delivery of rabies information, planning began to implement a freely accessible worldwide rabies webinar. In 2010, in observance of WRD, GARC and CDC coordinated the first intercontinental rabies webinar. The motivation behind the webinar was simply to provide information about rabies to as many people as possible over the internet and at no cost to attendees. As a young non-profit organization, GARC was not positioned to host a physical conference. So in line with its mission to educate the world about rabies, GARC leveraged its global network of advocates and available webinar technology to deliver open source rabies education en masse. Instead of hefty registration fees and travel considerations, webinar participation from anywhere in the world required only a computer with an internet connection. After downloading the webinar software and logging in to the online meeting, individuals across the world were instantly connected with rabies subject matter experts in real time.

Similar to a traditional in-person conference, much advance planning is necessary to successfully execute a webinar. Considerations include content, speakers, technology, timing and promotion (Monaghan, 2009). For a global webinar, it is also vital to consider speakers' familiarity (or lack thereof) with the webinar platform, who will facilitate and moderate the webinar and how, when and by whom the webinar will be advertised across different communities, cultures and languages. Similar to any health intervention, formative evaluation measures should also be considered at the outset of webinar planning to assess both the process and impact of the webinar meeting amongst facilitators, speakers and attendees. Similar to traditional meetings in any physical space, the first task is to set a date for the planned webinar. The first intercontinental rabies webinar coordinated in 2010 was held on World Rabies Day (September 28) as GARC's contribution to the annual observance. However, upon evaluation it was discovered that many individuals could not participate in the webinar because they were involved in their own local WRD events. Unlike most traditional meetings, however, webinar meetings can be recorded, depending on the software and technology used. Therefore, those who were unable to attend the live broadcast were still able to listen and learn from the archived recording.

After receiving numerous accolades from the 2010 webinar, GARC and CDC decided to organize and host a second webinar in September 2011 to be conducted over two days with more speakers and timed one week prior to WRD so that more people could attend. Two separate webinars were coordinated over 16 hours at times convenient for each respective target audience to participate. The first webinar ran overnight (Eastern, US) to accommodate participation from the far-East. Speaker assignments were also aligned by location and time zones. For example, at the outset of the webinar, speakers joined from Australia, Philippines and Japan. As the webinar progressed, speakers joined from India, Nepal, Ghana and the UK, slowly moving westward over an eight hour period until finally reaching the last presenter, located in the United States. Timing of message delivery is a vital component to effective health communications. In order to successfully execute a global webinar, particularly when targeting rabies-vulnerable populations in Asia and Africa, precise timing must be considered for the webinar organizers and speakers but most importantly for the anticipated attendees. When handled correctly, appropriate and precise webinar timing, especially during a time of heightened awareness such as WRD, will result in capturing a much larger portion of the intended target audience. (Table 1).

Though run entirely via internet, an open source webinar resulting in a positive experience for end users requires the focused support and constant attention of numerous organizers working synchronously to ensure seamless speaker and participant coordination, facilitation and moderation and technical functionality. Given the virtual nature of webinars, organizers can opt to be located in the same physical space or connected to the webinar system remotely yet working cooperatively side-by-side in cyber space. The global webinars run by GARC and CDC for example were coordinated by US organizers located 1000 miles apart (Scranton, Pennsylvania and Atlanta, Georgia) from each other. Throughout the webinar, organizers stayed in constant communication via phone, email and text message and also by using the private chat option available within the webinar system. This communication is vital, for example to make sure speakers that are in-line to present are logged into the webinar system, their audio is working and that they are available and ready in advance of their assigned time.

During the webinar, questions continually come into the chat window and require dedicated support staff for timely response. Question and answer sessions that allow live voice broadcast by participants with audio input devices also require a great deal of coordination. Participants' microphones must be manually 'opened' by the webinar staff and they must be congenially addressed and informed that they may now ask their question. Once their question is finished, their microphone may have to be re-muted by the webinar organizers to limit any background noise whilst the speaker is responding to their question. Facilitators must also be cognizant of time constraints and help keep presentations and question and answer sessions 'on time'. Moderation may be required if conflicts arise between speakers and listeners and must be handled delicately given that hundreds to thousands of logged-in participants are also listening. During webinars, technical issues among participants and those attempting to join the webinar are not uncommon. Dedicated staff support is required to handle these inquiries as webinar organizers cannot take their attention away from the running webinar to assist others. Complete contact information for accessing technical support and guidance on how to handle the most common technical issues should be addressed by the lead organizer at the beginning of each webinar and also provided ahead of time as part of the webinar registration information.

It is well known that many people are hesitant to engage in domains of which they are not knowledgeable. Webinars are still a relatively new concept to most people, especially speakers who are used to conducting presentations to and gathering non verbal cues from a live audience. Webinar organizers must take into account that many speakers will not have any knowledge about how to present information for or log into a webinar and may be slightly intimidated about the idea of participating. For this purpose, a

Table 1. Example of the calculation of the most appropriate timing for a rabies webinar targeting the Eastern Hemisphere. Taken from the World Rabies Day Webinar, Sept. 21, 2011

	New York, United States	Maputo, Mozambique	Istanbul, Turkey	Bangalore, India	Manila, Philippines	Sydney, Australia
Start Time	0000	0600	0700	0930	1200	1400
End Time	0800	1400	1500	1730	2000	2200

trial run of the webinar should be conducted with each speaker prior to the actual on-line presentation. This process not only familiarizes the speakers with the process but enables organizers to simultaneously conduct an internet connectivity test and an audio test of the speakers' equipment to ensure his/her voice is projecting clear and uninterrupted. Generally once the test run is complete, speakers are much more confident about their ability to participate as a presenter during a webinar. It should also be noted that while webinars offer tremendous access to teaching and learning opportunities in a more time and cost effective manner by harnessing the power of the internet, there are limitations and consequences to such dependence. First, not everyone has access to the internet nor may they have a reliable electrical connection and although the digital divide is becoming narrower with internet access being upheld as a basic human right in many countries (Meredith, 2010) and technological advancements such as the proliferation of web enabled smart phones, those without internet will not be accessible by webinars. Given their dependence on technology, the most significant downfall of webinars is their reliance upon electricity and the risk of power failures and internet connectivity.

FUTURE TRENDS

Though rabies largely remains a neglected disease, the field of rabies has evolved dramatically as a whole over the past five years. The founding of the non-profit Global Alliance for Rabies Control and its flagship initiative World Rabies Day has most certainly brought new attention to an old disease. The concept of tackling rabies using a 'One Health' approach has prominently and rightfully re-emerged, giving rise to new organizations, initiatives and opportunities for partnerships and fundraising. Multi-national resolutions have been enacted, giving way to aspirations of 'rabies-free' status amongst border-sharing endemic regions through the incorporation of planned mass animal vaccination campaigns and novel information and education programs. Perhaps most important, communities are now taking ownership of addressing local rabies issues using effective and sustainable strategies. Building on this momentum moving forward, the following future trends in rabies prevention and control are expected.

'One Health' Approach

Rabies is a disease that circulates in animals but can be transmitted to humans. It is therefore imperative to control rabies in animals that tend to expose humans to the disease (Zinsstag, 2007), most notably the domestic dog. It has become increasing clear in many countries that organizational responsibilities to manage dog populations, including licensure and rabies vaccination, bite confinement and exposure quarantine/euthanasia are undefined or unenforced and oftentimes unfunded. For example, Ministries of Health are accountable for human health and are not necessarily mandated to focus on animal health. Similarly, Ministries of Agriculture are less focused on human health and may see little value in tending to dogs as they are generally not viewed as a commercially viable consumer product. The end result is that the well-being of dogs slips between the cracks. In most countries, there is no one single entity mandated by legislation to ensure dogs are vaccinated against rabies (Lembo et al., 2011). Hence dogs continue to roam, reproduce unchecked, remain unvaccinated and ultimately expose humans to rabies. Future rabies prevention efforts will involve horizontal integration of numerous stakeholders and subject matter experts from both the human and animal sectors.

Targeted Webinars

The global webinars held during 2010 and 2011 have shown great promise in effectively delivering accurate and credible rabies prevention information to the masses, reaching more than 600,000 listeners in 83 countries. Post webinar evaluations indicating that 98% of respondents would attend a future webinar illustrates the great interest in webinars as an open source technology, particularly for rabies education, and have resulted in numerous requests for topic and or country specific webinars. Health communications increasingly need to meet intended audiences at their level of technology (Rimal et al., 2009) and webinars are a time efficient and cost effective way for any type of organization to reach its target audiences. Given that so many nations are in need of rabies education and it is simply not feasible to visit every one of them in a timely manner, the webinar provides an alternative to participating in person whilst allowing for audio and video integration alongside a presentation for a more personal experience for the end user. Future efforts through use of webinar technology for rabies education will include training on laboratory methods, surveillance techniques and communications training. These fundamental elements can be delivered to countries in need via internet, in real time and by subject matter experts, providing a unique opportunity for individuals across the world to learn from renowned rabies experts.

Rabies Educators

Although the messages to prevent rabies are the same all over the world and the concepts are fairly straightforward, there are very few people dedicated to delivering rabies prevention messages to communities living at daily risk. Currently, the Global Alliance for Rabies Control fields numerous inquiries on a daily basis that arrive by web, email, phone or text message. Most originate in Asia and each question is unique. However despite efforts to date the wrong information about how to prevent rabies is still prominent in communities around the world as has been described previously in this chapter. Clearly given the number of visitors to the WRD website and listeners on the global webinars there is a desire for further rabies education opportunities. Future efforts for rabies education therefore will include the development of a rabies educator training program to increase knowledge and country capacity for rabies prevention. The Rabies Educator Certificate training program is envisioned to be delivered via webinar and cover all principles of rabies prevention over two days, culminating in an online assessment and awarding of a certificate to those successfully achieving a passing grade. The Rabies Educator Certificate program is predicted to help increase and play a vital role in the sustainability of local rabies efforts in countries still battling canine rabies.

CONCLUSION

Over the past seven years, GARC, a registered not-for-profit organization has changed the face of rabies by leveraging open source technology and dramatically increasing the number of people that have received life-saving educational messages about how to prevent contracting the disease. GARC was the first global not-for-profit organization focusing solely on preventing rabies in humans and animals and began by bringing all stakeholders together to work on finding new solutions to improve rabies control. Initially, there was little funding available for promoting rabies prevention and therefore GARC utilized the strengths of its partners, both public and private, to deliver educational materials where they were needed. Additionally, GARC built a web-based education bank that was freely accessible to those that needed information. GARC requested and received donated educational material from public health experts working in over 50 countries around the world. The website soon became the foremost site for anyone seeking rabies educational information and receives approximately 10,000 visitors every month. WRD was promoted by all international public health organizations and member countries of WHO and OIE were encouraged to participate in WRD activities. WRD continues to gain momentum and after five years, over 182 million people have been educated about how to prevent rabies and close to 8 million animals have been vaccinated against the disease.

Overcoming obstacles including translating educational materials into multiple languages was approached by initially turning the situation around and providing simple messages in very few languages, mainly English, and encouraging individuals to translate the material as needed and then provide the translation back to GARC for posting on the website. Additionally, material that was already available in different languages was invited to be posted on the GARC for free access to others.

Encouraging rabies experts and other stakeholders to work together was initially difficult due to the perception of competition for funding and research etc. However, by providing a neutral venue for meetings and discussing commonalities among experts in the field, progress was quickly made and stakeholders began to work jointly on new projects that were freely available and beneficial to all. For example, a *Blueprint for Canine Rabies Control and Human Rabies Prevention* (www.rabiesblueprint.com) was organized and developed by public and private entities and has served as a global template for those wishing to develop strategies to tackle the issue of human rabies prevention and dog rabies control (Lembo, 2012). Modern communication methods, including web-based tools, enabled GARC and its partners to overcome logistic problems including personnel living in different continents with varying time zones.

Changing attitudes about the approach to improving educational awareness was tackled by involving experienced educators in development of new curricular material focused particularly on children, the most vulnerable population at risk of exposure to rabies. In the Philippines, for example, the Ministry of Education was involved as a partner in the initial strategic meetings to develop new strategies to reduce the burden of human rabies. Workshops were hosted for teachers to produce new curriculum materials where rabies information was incorporated into various subjects including English, mathematics, and science.

New web-based communication tools were used to provide public health experts, organizations and individuals with freely accessible and accurate educational material and the WRD campaign provided the platform for everyone living at risk of rabies to join together on one day to highlight rabies prevention activities. After five years of WRD, more than 500,000 visitors have logged onto the websites hosted by GARC to review rabies educational information and download the material that they need to improve awareness in their own countries.

Empowering communities to take responsibility for their own rabies prevention activities was one of the biggest accomplishments of WRD activities and the establishment of the free education bank. By providing these materials to 'local champions', they were able to educate their own villages. Individual stories from countries around the world were hosted on the GARC websites and published in the GARC Newsletters. Thus local champions were honored for the educational initiatives that they were conducting and were often emulated in other localities as examples of how to improve awareness and save lives.

The success of the GARC indicates that by empowering communities to take responsibility for improving their own rabies prevention educational programs and by utilizing free-access web-based educational tools, millions of people can be protected against the most deadly disease known to mankind.

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KEY TERMS AND DEFINITIONS

AfroREB: African rabies expert bureau.
AREB: Asian expert rabies bureau.
ASEAN: Association for Southeast Asian Nations.
CDC: Centers for Disease Control and Prevention.
FAO: Food and Agricultural Organization.
GARC: Global Alliance for Rabies Control.
MEEREB: Middle East rabies expert bureau.
OIE: World animal health organization.
PAHO: Pan American Health Organization; a branch of the World Health Organization.
PEP: Post-exposure vaccination after being exposed to rabies.
PrEP: Pre-exposure vaccination for prevention of rabies prior to an exposure.

RIG: Rabies immune globulin; administered into and around the wound site after exposure to provide passive immune treatment that will help to inactivate rabies virus deposited in a wound after exposure.

WHO: World Health Organization.

WRD: World Rabies Day September 28^{th}.

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Section 3
Equine and Livestock Care

Chapter 10
Enhancing the Daily Routines of Equine Veterinarians Using Mobile Technology:
The m-Equine Case

Sonja Leskinen
Åbo Akademi University, Finland

ABSTRACT

The goal of this paper is to introduce and understand the equine veterinarians' needs in their daily routines and develop a web-based support system to promote their work. An equine veterinarian works in both clinic and stable environments, which requires resilience and smart functionality from the support system's interfaces. Especially when horse treatment is in the stable environment, a mobile interface is required. The development of the system must also take into account the needs of the other stakeholders around horses. This paper introduces the requirements to develop a mobile interface for the web-based support system, m-equine. The trial of m-equine will start with an influenza vaccination protocol that is used by veterinarians, horse owners and riders as well as competition organizers. In conclusion the future developments and added values of the system are introduced.

INTRODUCTION

Currently veterinarians work on unnecessary and often repeated routine paperwork, that is time consuming and not part of the core business, i.e. helping patients. At horse clinics information can naturally be inserted and stored in a computer, but this cannot be done as easily when the veterinarian is on a "house call" i.e. visiting a stable. Paper work can get misplaced or illegible because of the non-sanitary environments. In the worst cases, the information has to be input several times into various programs, such as the veterinarian's own practice software, database and billing software. Yet after all this work, if the owner decides to use another veterinarian to treat their horse the next time, all the same work has to be done again and the previous veterinarian's findings can be difficult to acquire. All of this extra work takes time and money, not only for veterinarians, but also for other stakeholders within the equestrian world.

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The problems have been noted for some time and even Fédération Équestre International (FEI), the international body governing equestrian sport, is trying to find a logical, long term solution how to store and verify a competing horse's medical information. In Denmark a recent study also discussed the potential of a medical database for horses (Hartig, Houe, & Andersen, 2013). Horse identification is also somewhat lagging behind from e.g. bovine animals. Many countries have a database where all bovine animals are registered and can be traced with the help of their ear tags (Trevarthen, 2007; Trevarthen & Michael, 2008). In the European Union since July 2009 all member states have to identify new equidae (horses amongst other) with a microchip or a branding + dna sample (European Commission, 2008). With a reliable medical history, and proper identification methods, a competition horse's travel between countries could be made easier. One of the first problems to get tackled in a horse's medical information is to get a uniform vaccination database for all competing horses. Vaccination regulations for competing horses are not only a problematic area for veterinarians but also for horse owners, riders, competition organizers and state officials.

Within the small animal practice industry the competition is growingly larger, and therefore not only the quality of treatment matters but also good customer service when potential clients choose the clinic they are going to use. Within the equine practice, the same trend is likely to occur in the future. Digitalization of healthcare, whether it is for production animals, pets or humans seem to be today's trend. With horses the problem is that a horse can have several uses; production animal, companion animal and athlete. Depending on which category a horse falls under, it will have significantly different medical needs and requirements. One of the problems to implement a medical database for horses' which is connected to an IT and mobile service is the adoption willingness of veterinarians and other stakeholders around the horses. Security and privacy will naturally play an important role in the development of such a system, as in human healthcare (Weitzman, Kaci, & Mandl, 2010). Some of the problems introduced in this paper have been tackled and researched within human healthcare digitalization (Hoffman & Podurski, 2008).

M-equine is a system that will be built to support stakeholder's daily routines around horses. It is to be a web-based support system for veterinarians, with both a mobile and web- interface. In time this will include medical, vaccination, stable and competition information as well as other relevant data of the horse. Depending on the user's "access level" he/she would only see parts of the information, i.e. a veterinarian with permission from the horse's owner can read and write treatment information into the system, whereas an outsider would not be allowed to read this information. The specific focus of this paper will be on the *m-equine* system's solution for equine veterinarians using mobile devices. For this research it was not necessary to make a difference between mobile phones and various tablet solutions, but all are presented as mobile devices. Within the mobile devices the only distinction done is the difference between basic phones and smart phones. Here within the smartphone category all phones with internet availability are included, thus also phones that could be categorized as "feature phones". The mobile technology and IT requirements have been established with the help of veterinarians and other stakeholders within the equestrian sports.

Since the goal is to build a system that supports veterinarian work with the help of web- and mobile interface, the question is; how to build a web-based system, that has the potential to expand and support the daily routines of veterinarians? A large obstacle to overcome is the veterinarians' possible reluctance to use new technical innovations. The system however would give benefits to the equestrian sports, the veterinarian profession in general and for other stakeholders around horses. Furthermore, the *m-equine* system could serve as a model for other applications and research fields.

The paper is structured as follows. The research domain is introduced, followed by a brief state-of-the-art summary of the current mobile solutions within health industry as well as IT solutions in the meat and milk industry. Thereafter the methodology for this research will be discussed. The design and building processes of the mobile service including the systems conceptualization and design follows thereafter. The paper is concluded with a discussion of the design and upcoming testing of the service with stakeholders.

RESEARCH DOMAIN

Every county in Finland has to provide a veterinarian on call at all times, to care for local animal needs including production animals, horses, cats, dogs and even more exotic pets. The county appoints the county veterinarians in accordance to the Finnish Law of Medical Services for Animals 16 § (Ministry of Agriculture and Forestry, 2009). There are approx. 2,100 licensed veterinarians in Finland, 30% work as county veterinarians and others mostly work at private practices or clinics (Ammattina eläinlääkäri (veterinary as an occupation).2011).

Equine medicine veterinarians specialize in treating hoofed animals, which in Finland is primarily horses. The veterinarians treat and/or inspect all kind of horses: leisure, harness sport, equestrian sport and horses going to slaughter. According to Suomen Hippos (the Finnish Trotting and Breeding Association), there were approx. 73 000 horses in Finland in 2010 (Soini, 2010). Horses must have a national passport and unique life number when traveling since this is the official identification method at racetracks, equestrian competitions and border control (Skarra, 2009) and (European Commission, 2008). Today, horses are increasingly seen as companion animals and used as sport animals; therefore equine medicine, and particularly treatment methods have been developed further than e.g. production animal medicine. Production animals are seldom treated to the extent as horses, since their worth is more likely to be attached to the production value of e.g. milk and meat or to the breeding value of the animal. A horse's value is connected e.g. to the horse's age, breed, training level, quality as an athlete but also to its value as meat.

According to EU regulations and Finnish food legislation, all animals slaughtered in EU for human consumption need to have proof of identity and a logbook stating what medications and feed the animal has received during its lifetime (Maa- ja metsätalousministeriö, 1.1.2012). Some medications that are used for horses are considered dangerous for humans. If the horse has been treated with these medicines during its lifetime, the meat cannot be used for human food consumption. Since horses can be sold many times during their lifespan, the medical history that, in most cases, is in paper format does not necessarily move along with the horse. Veterinarians today usually have their own patients' records on file and according to Finnish laws are required to do so for a minimum of three years, (Ministry of Agriculture and Forestry, 14.4.2000). In 2009 there were 25 equine medicine veterinarians in Finland (Venäläinen, 2009). The problem tough is to find all the medical information of a horse. Apart from equine veterinarians, county veterinarians (over 600 county veterinarians, during 2009) might also have treated the horse and if the horse had been imported from another country, it is virtually impossible to be 100% sure that all medical data is intact (Ammattina eläinlääkäri (veterinary as an occupation).2011).

For Equine disciplines, according to FEI rules, a horse has to be vaccinated against horse influenza and in some countries also against other diseases. This information has to be marked on the horse's international passport, if the rider/driver wishes to compete with the horse in international competitions

(Article 137) (Fédération Equestre Internationale (FEI), 2013a). In Finland at district and national level equestrian competitions, the horse's vaccination rules differ a bit form the international ones (Suomen Ratsastajainliitto ry (The Equestrian federation of Finland), 2012). Vaccination information is checked from the passport at every competition, and this takes much time. Suomen Hippos has launched a vaccination database, mainly for harness racing horses, but there is no underlying program to support the database, and therefore the only difference is that instead of checking the vaccination information from the horse's passport it has to be checked from the database.

In 2010, FEI (Fédération Equestre Internationale) started the "clean sport" program against anti-doping, which requires that horses competing internationally must have a medical logbook (currently paper based) that includes the horse's medical history, article 1026, 3§ (Fédération Equestre Internationale (FEI), 2013b). The logbook includes information on what and when the horse has received medication. E.g. some horses have to be mildly tranquilized for shoeing. If trace elements of this tranquilizer remain in the horse's blood, beyond the pharmaceutical company's safe date, then a positive doping test may result.

The *m-equine* system would be developed to support a veterinarian's daily routines. The web-based system with both a web and mobile interface would help solving some of the main problems that have been identified within the research domain. Standardized electronic identification of horses, combined with an underlying medical database would ease the identification of the animal and its medical care. Different stakeholders need different information, and not all of these stakeholders know horses. The information a border control officer needs is vastly different from what e.g. FEI's doping control, veterinary examination or pre-slaughter examination needs. The *m-equine* system would allow different users to access different information, so that the information is relevant and useful for the user in hand.

RELATED RESEARCH

In recent literature, the digitalization of human healthcare has been much discussed (Boulos, Wheeler, Tavares, & Jones, 2011; Hansen, Gurney, Morgan, & Barraclough, 2011; Michael & Michael, 2009; Ngai, Poon, Suk, & Ng, 2009). The development of mobile technology has enabled mobile phones to be used not only as personal devices but also as work tools in one's profession. Already in 2010 there were over 7000 documented cases of mobile phones being used in healthcare (Kailas et. al cited in (Boulos et al., 2011)). The introduction of smart phones has opened up much more possibilities for various applications that the previous mobile devices did not have. In many of the papers mentioned above security and privacy issues have been mentioned as an important factor that should be addressed when dealing with mobile healthcare.

In her 2005 published doctoral thesis, Han discusses the mobile technology usage and adaption among Finnish physicians. In this study, once the physician started to use mobile technology (in these cases the content of the service was basically a Nokia communicator that included the whole Pharma Fennica, i.e. the Finnish medicine encyclopaedia) he/she was positively inclined towards the technology's usefulness and usage (Han, 2005). This dissertation gives a picture of the physicians' attitudes towards mobile services, which can, to some extent, be related to veterinarians' attitudes. For both professions the core business is mostly diagnosing and treating a patient. Any mobile or IT service will therefore have the role of a support tool. One of the large differences between physicians and veterinarians, from the viewpoint of their IT and mobile needs, is that they have very different working environments, especially if the veterinarian is working in the horse stable environment. Even in the not-so-sanitary horse stable environment a mobile device could be used by a veterinarian to enter treatment information, which physicians would not need since they usually work in offices with computers. Therefore, in this paper the research question has been taken a bit further than Han's dissertation.

In a more recent study, by Choi et al (2011), the research focused on how doctors use smart phones and the "Dr Smart" mobile application. This study was conducted in the end of 2010 and the results showed that younger residents in their 20s and 30s were more likely to use the application. In this research one reason why some doctors did not use the app was because they did not know how to download the app onto their smart phone (Choi et al., 2011). This same kind of problem was also already discovered in Han's dissertation (2005). A notable amount of physicians never even tried to use the mobile phone and the medicine encyclopaedia within it, since they did not want to try something new, which could possibly be difficult to use and take time to learn to use (Han, 2005). Many of the same problems that were discussed in the "Dr Smart" research by Choi et al (2011) and Han's (2005) study have to be solved, so that a working mobile service for veterinarians will reach a high penetration rate within the field. Users should be trained to use the system and with their experiments, the system can be developed in such a way that it is easy to use and take into use.

One of the problems that need to be addressed is the ideal way to identify the animal the veterinarian is treating. For livestock, the industry has already stipulated the need for clear identification, thus e.g. ear tags on bovines and swine. Often the identification today is RFID-based, as in the studies by (Trevarthen, 2007; Trevarthen & Michael, 2008; Voulodimos, Patrikakis, Sideridis, Ntafis, & Xylouri, 2010; Wallace et al., 2008). In these studies, apart from the aforementioned article by Wallace et al (2008), the studies have been about the need for bovine identification in business management and the importance of traceability. The main issue in these studies is that via the id-tag of the bovine animal, information about the animal can be traced. Whether with RFID-tag technology a cow's milk production or a heifer's movements across the country from various owners can be monitored, the information should be traceable and used from the farm to the slaughterhouse to your table. Since, a horse might end up as a meal for people, the same level of monitoring is required.

Both FEI and harness racing sports have strict rules about medication usage and vaccination requirements. Accurate identification of the animal is one of the key features that are needed to gain trustworthy information. Inserting a microchip identifies horses, but often the standards of various microchip companies vary, so the veterinarian needs more than one reader to be able to identify the horses. In the Australian bovine monitoring systems, the key concept is that the animal can be tracked by their ear tag (Trevarthen, 2007; Trevarthen & Michael, 2008). In this way the animal's identification can be read from even a larger distance, which is of value when working with animals that might be shy towards people. Today a horse's microchip is inserted into the neck of the horse, which can be difficult for the veterinarian to read, because some horses get very nervous when a strange person handles it or they might just be skittish around their head. The microchip might also be unreadable, since it can have a different frequency standard than the reader. A horse's microchip cannot be hanging outside their body, as an ear tag on bovine animals, since it would impair the animal. The question is could a microchip or other identification system be available, which would have one standard, could be read by a mobile phone and be readable from a short distance? Even 1-2 meter reading range from the animal could make a huge difference. The microchips used for horses today only contain the horse's life number. There is a need to develop horse identification in the direction discussed in other studies such as Trevarthen (2007), Trevarthen and Michael (2008), Voulodimos et al. (2010). In Wallace et al., (2008), the study involved temperature measurements done in horses with RFID tags. This study shows other issues that could be raised with id-tags and veterinary monitoring. One problem that has raised much debate within all the horse sports is the opposition of inserted microchips: Can a microchip implantation cause foreign body reactions or tumour formations? These aspects are not discussed here but the ideas on how a microchip can be used in veterinarian work are presented later. The digitalization of a horse's healthcare information, as discussed in Wallace et al (2008), proved therefore to be a good basis for the research conducted here.

Since various mobile applications have become popular, and include all types of apps imaginable, there are naturally also apps for physicians. According to studies amongst physicians the most popular m-health apps for iOS devices were medical information references, educational tools and tracking tools (Liu, Zhu, Holroyd, & Seng, 2011). Their research was done in the beginning of January 2011, and can be used as a general guide to what types of m-health applications were then in use. Later in this text I will briefly explore applications that are made for veterinarians, and compare if they relate to the apps physicians prefer and how they compare to *m-equine's* web-based support system.

Liu et.al (2011) also found in their m-health research that the apps that took advantage of the smart phones unique features to bring real convenience to the users were amongst the most popular iOS device applications (Liu et al., 2011). The highest ranked m-health apps were therefore various tracking tools, such as health, calorie intake etc. This is largely due to the fact that the app is always available on the Smart phone for the user. The second highest ranked tools were educational and reference tools for medical students and practitioners (Liu et al., 2011). When comparing these results with veterinarians' needs, tracking would seem to be more of use for the owner of the animal, but reference tools could be of use for a veterinarian. In the apps market there are already a few reference and educational tools for veterinarians and veterinary students such as "Vet Anaesthesia Guide" by Guilherme Caldas, "Veterinary Terms +Plus" by Wan Fong Lam and "VetMed EQ" by FES Solutions (Apple Inc, 2013). The tracking that a veterinarian needs to do of his/her patients can be done at the veterinary office with a computer, and does not necessarily require "anytime & anywhere" access that a mobile device can offer.

METHODOLOGY

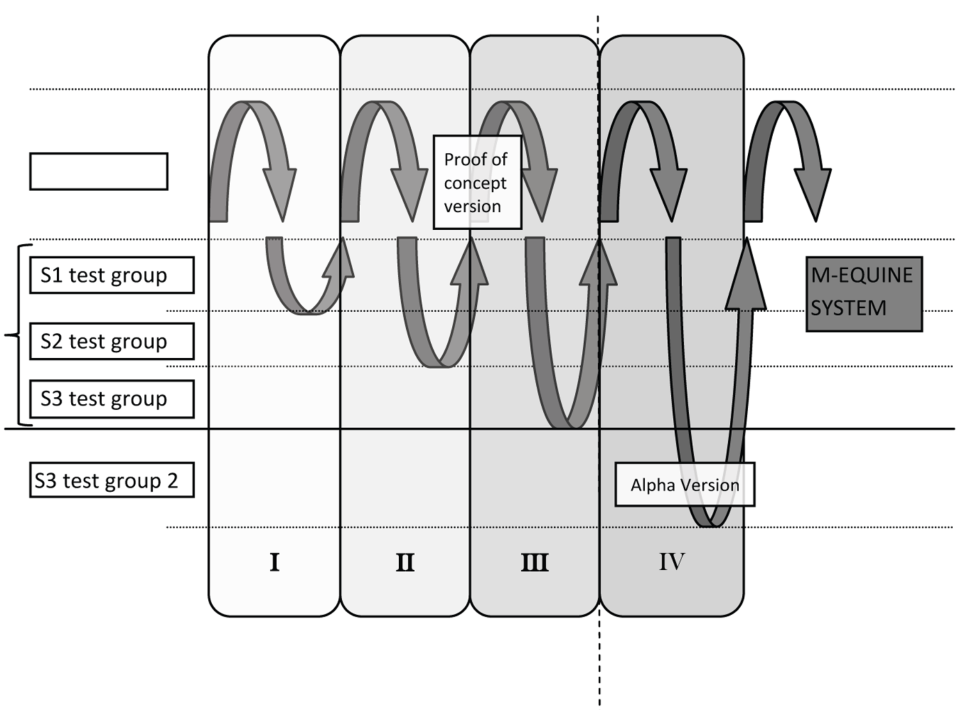
The methodology used in this research is a combination of both action research and design science research. The goal is to introduce and understand the veterinarians' needs and develop a system that would meet these needs. This will require several construction and evaluation phases, to achieve an optimal solution (Cole, Purao, Rossi, & Sein, 2005). Amongst others one definition of this type of research has been described in the article "Action Design research" by Sein, *et al.* (2011). In their paper they identify four stages that properly identify and sequence Action Design Research (ADR). Stage 1: Problem Formulation, Stage 2: Building, Intervention, and Evaluation, Stage 3: Reflection and Learning and Stage 4: Formalization of Learning (Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011).

The Problem formulation can be divided into two separate approaches, namely "the Practice-Inspired Research principle" or "the Theory-Ingrained Artefact" (Sein et al., 2011). In this research the former has been used. In stage 2, the Building, Intervention, and Evaluation (BIE) are divided into two end points; IT-Dominant BIE and Organization-Dominant BIE (Sein et al., 2011). The IT-dominant spectrum suits ADR, where practitioner and some specialists create the innovative technology. The organization-dominant BIE is ADR that is done by using, as the primary source, the organization to generate design. (Sein et al., 2011)

In Figure 1 the *m-equine* BIE schema is introduced. In this research the ADR group mainly consists of one researcher. The S1 test group consists of: one county veterinarian, three different equine medicine clinics, two FEI veterinarians and three FEI competition officials during the International dressage (CDI) and Jumping (CSI) event in Tallinn, Estonia. The individuals taking part in the S1 test group were interviewed and their daily activities were monitored and recorded. With the feedback obtained from these discussions, other stakeholders around horses could be approached. The S2 test group consists of riders and owners of competition horses. They took part in an exploratory survey summer 2009, from which the results from this survey were presented in two separate papers (Leskinen, 2010; Leskinen, 2011). With the feedback obtained from both S1 and S2 a proof of concept could be built and introduced to some extent to the S3 test group. The S3 group consisted of Finnish equestrian and county veterinarians partaking in a web-based survey during fall 2010. The following iteration now is to build and launch the *m-equine* system's alpha version in accordance to the previous iterations' collected information. Some of the participants in S3 test group voiced interest to try out the alpha version and are therefore separated to their own group; S3 group 2. After the alpha version has been launched, a new round of interviews and monitoring will be conducted, to evaluate the alpha version and record the veterinarians' opinions and suggestions. Changes will be made to the system accordingly and this will naturally lead to the next step i.e. a beta version. The final iteration ends with the launching of the commercial version. These iterations will be discussed more with the future research and development.

The three first iterations (I, II and III) are of nature IT-dominant (see Figure 1), whereas the last iteration (IV) has more trademarks from the Organization-Dominant spectrum. The Reflection and Learning stage is part of each iteration loop to learn and identify problems and processes, but also to

Figure 1. m-Equine BIE schema



reflect the problem solving and theories used. Iterations are done until the result equals the set goals of the project. Once this has been achieved, the ADR method is transferred to the fourth stage; Formalization of Learning. (Sein et al., 2011)

At the moment the fourth stage, Formalization of Learning, is presented for the alpha version in this paper. Several iterations will concur, until the *m-equine* mobile system for veterinarians is finalized, first then stage four can be fully explored.

DESIGN AND BUILDING PROCESS

The process on how the design for the system has been done follows the ADR requirements. There are various patient management systems used at veterinary practices and also some apps that have been designed for veterinarians. In Finland equine veterinarian's mostly use ProVet patient management software which has recently started to provide even a web and mobile support to its customers (www.provet.fi).

Background Information

A brief study of the current app market situation for veterinarians led me to choose to make this system web-based, since an app alone could never cover the broad area of usage and information that is required for a functioning support system for both veterinarians and other stakeholders around horses. Today's veterinary and pet related apps sold in Apple's app store and the equivalent store for Android are very similar to what Liu et.al (2011) discovered in their research with physicians. Many vet related applications – as many physician related applications (Liu et al., 2011) - were educational in nature or provided drug information or amount calculations for drug administration. With a brief study there could not be found any direct vet-horse-vaccination related apps. Liu et.al (2011) study did however rise the potentials what even a simple app could have in supporting a physician's or students work. However, simple apps cannot meet the requirements needed for such a large and complex system as the *m-equine* web-based support system will be in the future. The mobile devices have though opened up new possibilities to support different type of work, but it is evident that no mobile support system will be of use for veterinarians unless they are included into the development process. Furthermore, since other stakeholders' needs also have to be satisfied to get the *m-equine* system to work it is paramount that the developer understands these needs as well. Therefore for this system to work, the developer has to have IT and mobile system knowledge as well as knowledge in the equine sports.

Veterinarians' Needs

The veterinarians' needs are the primary basis for the IVth iteration cycle presented in Figure 1. The previous iterations state the main requirements for the system. To gather information on a veterinarian's daily routines, use of mobile devices and attitude towards new technological innovations, preliminary interviews were conducted in Finland with a few veterinarians (see Figure 1, group S1). Research on veterinarians' usage of mobile services to support their work had not been previously done in Finland. After the personal interviews and observations with group S1 and the survey done with the test group S2, three Master's students (Jorge Lucic, Valentina Muñoz and Luis Rubén Rodríguez) and I conducted an Internet survey with Finnish veterinarians (Figure 1, group S3). These survey results are a basis for the upcoming alpha version of *m-equine*. Some of the basic findings that will mould the alpha version are the veterinarian's need to eliminate unnecessary paperwork, improve their time management, and overall positive attitude towards a common database. Although many veterinarians voiced their reluctance towards new technology, many would be willing to try it out, if it were beneficial for their work performances.

One aspect that would be paramount for a successful web-based support system is that it works even outside the clinic environment. Many equine veterinarians as well as county veterinarians make house calls to treat horses. At a stable the environment is not as sanitary as in a clinic, and much work might have to be done outdoors, regardless of the weather. Therefore the veterinarian needs a working system for book keeping during house calls. Currently the data acquired during a house call often has to be inserted into the veterinary clinic's patient software, billing software etc.

The veterinarians found that vaccination data is something they could share and that it could be shared in a common database (Leskinen, 2012). In a Danish survey conducted 2012 veterinarians and other stakeholders around horses were keen on having a common database, to support equine veterinary care (Hartig et al., 2013). With this information and the information attained from previous studies it is apparent that the majority of all the major stakeholders accept and even desire a common database and services for up keeping and controlling horses' influenza vaccination. This also complies with the view of FEI and its attempt to facilitate competition horses' movements across borders (FEI, 2013).

Conceptualization

From the survey, literature and existing cases presented I started to work on how the mobile platform would work. The IS architecture is presented in Figure 2. Although the design and development of the mobile system is in the foreground, a working IT structure and database are equally important. Many Finnish veterinarians still use basic phones but especially the younger veterinarians are accustomed to use smart phones and other mobile devices. The Central Statistical Office of Finland stated that in spring 2011 42% of Finnish consumers in the age groups 16–74 were using a smartphone (Statistics Finland, 7.11.2012). Since the market share for smart phones have increased, it is safe to assume that also veterinarians would upgrade their mobile devices in an acceptable space of time. Therefore, at first the system would be built to work on smart phones or similar mobile devices, but if necessary have some of the functions available for basic phones so that veterinarians would be more inclined to try the system.

General Design

The *m-equine* architecture is visualized in *m-equine* system architecture Figure 2. The database and access to it play a pivotal role for a successful system. Since stables today are not necessarily within a good 3G or 4G network, there would be need for a backup system if internet accessibility is not available. All data input done in *m-equine*, regardless of the interface used, should be simultaneously updated into the underlying database.

The *m-equine* system has to be easily accessible for veterinarians and other stakeholders wherever they are. Therefore the system must have an interface for both mobile devices and computers. In the following table the key needs that must be met in the alpha version are listed. The requirements, security and interface options for *m-equine* have been stated for the main stakeholders, i.e. veterinarian, owner, rider/driver and competition organizer in Table 1.

Figure 2. m-Equine system architecture

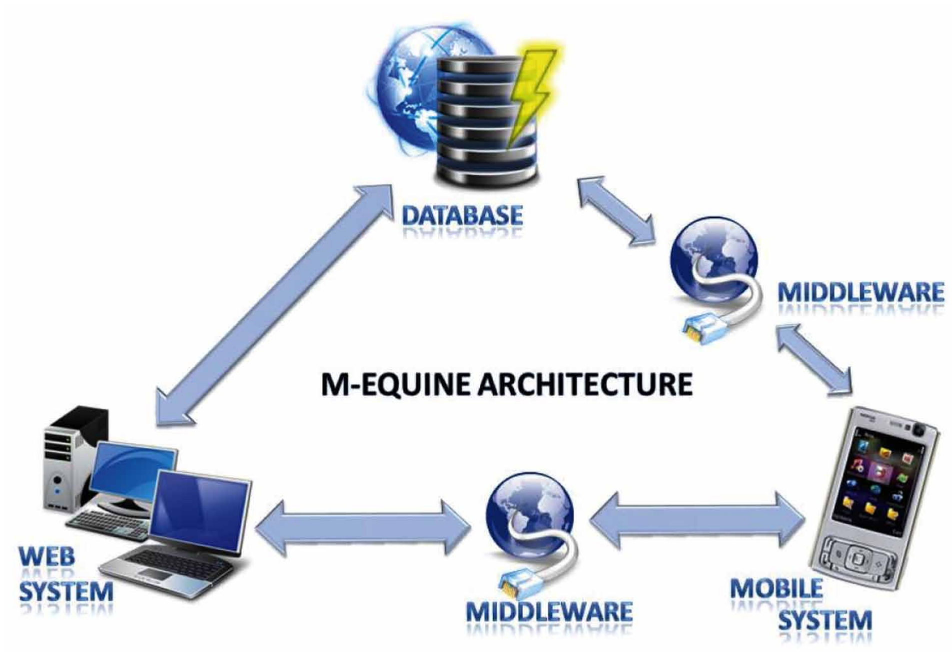


Table 1. Design requirements for various stakeholders

stakeholder	requirement	access	security	interface	
				mobile	computer
owner	list of own horses. check horse's vaccination status. reminder to vaccinate horse on time.	access to own horses' information	read allow access to horse's information	possible	yes
veterinarian	find specific horse from database with ID number or name. check horse's vaccination status. insert vaccination data	owners give access to horse's information.	read and write.	yes	yes
rider/driver	list of own horses. check horse's vaccination status. reminder to vaccinate horse on time.	owner gives access to horse's information.	read owner can allow rider to give further access to e.g. Veterinarian.	possible	yes
competition organizer	check that a list of horses are vaccinated according to regulations.	access to all horses in database, via search engine	read	no	yes

Veterinary Specific Design

The alpha version of the *m-equine* mobile system for veterinarians will be tested in Finland and will include the possibility to enter vaccination data only for horses that have a competition license in the Equestrian Federation of Finland (SRL). Since only the veterinarians would be allowed to change vaccination information, it is of pivotal importance that the system is such that the veterinarians want to use it. Although many respondents of the veterinary survey were rather positive to use mobile services, they would not use a service that is of any inconvenience. Many of the interviewed veterinarians self-proclaimed that they are not computer or mobile device savvy. This type of modest demeanour is typical for people who are not quite sure about their computer or mobile technology skills (V. Venkatesh & Davis, 1996; V. Venkatesh, 2000). Venkatesh and Davis (1996) also stated that it would be important to enhance and support the user's knowledge in computers, so that he/she would better accept new innovations and get a positive outlook on computers. To accept and use new mobile innovations, the user should be able to access and use it with ease (Kaasinen, 2005). With these statements in mind both the mobile and computer interface of the system would have to be easy and convenient to use, and have suitable support for users. The veterinarians would have to be guided how to use the system, so that they would get more self-assured around computers and mobile devices, and find the system beneficial.

With these conditions in mind, I started to work out the fundamental requirements that the *m-equine*'s mobile system would have for a veterinarian to input vaccination data. In Table 2 the *m-equine* system's conditions and the fundamental requirements to meet these conditions have been listed. This information has been gathered from the author's previous knowledge and interviews with veterinarians. The table represents requirements that the alpha version (see Figure 1) should meet. The table is divided into three sections; (i) Work Description, (ii) Requirements and (iii) Solutions (Table 2). The work description column has the different steps that a veterinarian would have to go through to be able to use the system's mobile interface. To be able to go through the various steps in downloading and using the *m-equine* mobile interface, each step has various requirements that have been stated in the second column.

The work description stipulates the main actions the veterinarian would come across and/or use in the *m-equine* mobile version. Requirements state what is needed that an action would be successful. The solutions have to meet the work description and the requirements stated to ensure a successful action.

Veterinarians, who took part in the survey by Leskinen (2012), mostly agreed that too much time is used on paperwork and that they should have a better system in book keeping when on house calls. Veterinarians would therefore need a web-based support system that works on mobile devices and supports their bookkeeping during house calls. The information that is entered on the mobile device, should automatically also be uploaded into the veterinarian's patient management system or similar, so that he/she does not end up entering the same information all over again at the office after a long day driving around the countryside stables. Although at this point it is suggested that the *m-equine* web-based support system would only have vaccination functionality, this would not be directly beneficial for veterinarians, but more beneficial for the horse's owners, riders and competition organizers. As a possible improved stable routine, the veterinarian could insert all necessary treatment and medical data on a mobile device. This would be possible since the treatments that a veterinarian can perform in a stable environment are limited. If the system could also include an automated travel expense monitor and billing opportunity, it would significantly reduce the time a veterinarian has to use on paperwork after a "house-call".

Table 2. Fundamental requirements

Work Description	Requirements	Solutions
Download m-equine on smart phone or mobile tablet device	m-equine mobile interface should be easy to download onto mobile device (one-click-principle)	Access and downloading of software for both mobile and web interface automatically when user subscribes to the system
	Updates should also be easy to download and take into use (one-click-principle)	Automatic search for software updates
	Devices with internet connection availability	Smart phones and at least Wi-Fi enabled computers used for interface.
Login into m-equine system	Security, so that nobody else can use the system if mobile device is lost	Username and passwords are individual for every user.
	The m-equine icon should be easy to find on the mobile device’s menu and opens directly to the login page.	Design of icon has to be memorable for users.
	Preferably user recognition available, to ease usage	Smart programming needed
Overall usability	Logical and simple menu	Find optimal menu order during alpha test
	Lucid style of text	Easily accessible option for increasing text size.
		Optimize colour choices to ensure good usability
	Understandable and easily accessible choice options	Large enough choice “buttons”
	Anywhere and anytime usability	The system should be able to contact the database. If there is no internet availability, store new information until connection to database is possible once again.
		Possibility to beforehand download some horses’ information if it is known that internet connection will be poor at stable.
Security	No risks of doing errors a/o errors easily repairable	Help menu a/o help pop-up when user has done a mistake.
	No risk of misinterpretation.	Security questions to make sure that the user is aware of his/her choice
	Digital fingerprint	All changes made into horse’s information must include information on who did it.
Entering horse’s data	Fast confirmation that the horse or the ID number is in the database	If several options for a name, “ask” user which one is the correct one.
Finding a horse in the database		Predictive text input
Entering vaccination info	Fast & easy input of vaccination batch number	Large number “buttons” for input. Copy/paste option, if several vaccinations are from the same batch
	Date for vaccination	Automatically propose current date.
Verification	Check that horse’s vaccinations are according to the International or national regulations.	Access to database, and previous vaccination information.
		System has “knowledge” of the current regulations

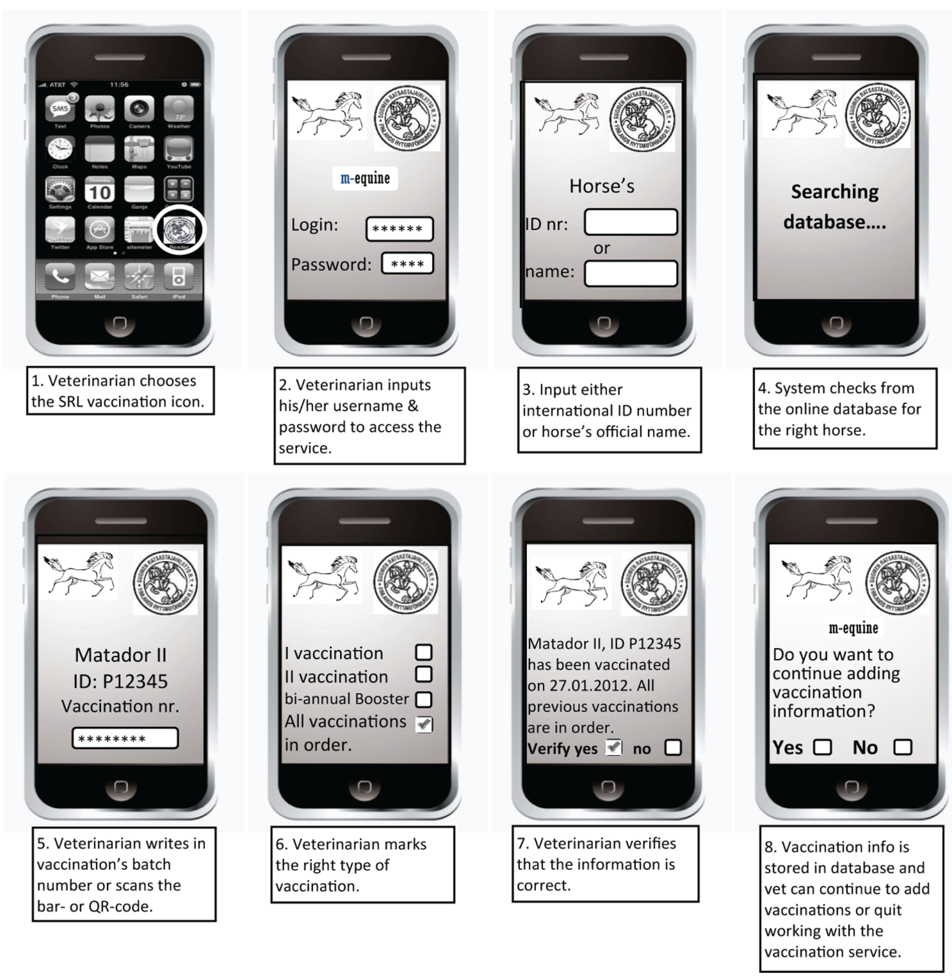
Input Model for Veterinarians Using Mobile Devices

For better understanding how the *m-equine* vaccination support system on mobile devices would work, the general idea on what it could look like, and what functionalities it would have is presented below. The still-pictures of *m-equine*'s mobile system below are done, assuming that the underlying database would be SRL's database of horses with national competition licenses, since this would ultimately be one of the major target groups for the *m-equine* system.

The process pictured in Figure 3 has eight steps, which displays how a veterinarian would use the *m-equine* system with his/her mobile device to record an equine influenza vaccination for a horse. Here is a brief description what the various steps are for, and how they work.

Steps 1-2 and 8 are self-explanatory and will not be discussed further. Competing horses have to have an identifying passport, and competition license from their national federation, and/or an international competition passport from FEI. Every passport has a unique identifying code for the horse, and it also has a unique competition name. In step 3 and 4 the veterinarian is given an option to search for the horse

Figure 3. Veterinarian inputs vaccination information with a mobile device: ADR group



from the underlying database by either its name or its ID code. In step 5 the system has found the horse and shows both the horse's name and id number. For horses competing in national or international level (in Finland and other European countries) they must have their vaccinations in order, according to FEI or national regulations. The veterinarian can confirm that he is vaccinating and adding the new vaccination record to the right horse in step 6. Today the equine influenza vaccination vials have a batch number that has to be inserted into the passport for monitoring reasons. Here the same batch number has to be inserted into the *m-equine* system, but hopefully in the future the batch number identifying the vaccination vial can be scanned directly into the system with the help of either bar-, QR-code, RFID tag or similar. In the next step the veterinarian choses the right vaccination option, depending on the horse's previous vaccination record. Step 7 is just a precaution to make sure that the veterinarian is inserting the right information to the right horse.

In this example the horse Matador II has been competing for some years already, and is now inserted into the system for the first time. So that the veterinarian, or other officials, does not have to copy all the old vaccination records into the system, he can simply check that the vaccinations so far have been done according to regulations. Now when he enters the new vaccination, that is a continuum to old vaccination records, he simultaneously verifies that all vaccination records so far, including the one he has inserted is according to regulations. This option would have to be available for the few first years that the *m-equine* system is in use. New horses entering the system, that start their vaccination records directly in the *m-equine* system, never been in the old paper based system would not need this option. Their vaccinations would be inserted as I vaccination, then 21-92 days later, II vaccination, and thereafter bi-annual booster vaccinations. Since the system has time awareness, it can "count" that the vaccinations are done within regulation parameters.

The benefits of such a system would be that a veterinarian could save time using this system, in comparison to writing the information into the horse's passport. Since the information would be saved into the database, the vet would not have to enter the same information again into another IS system, as is the situation with the current vaccination system Suomen Hippos is offering. Furthermore this system would know the vaccination rules, for international and national competitions, and thus automatically state if all vaccinations are according to regulations for the horse. The veterinaries do not have to worry nor even know what the current regulations are, since the system has the parameters for them, except in the beginning, if the veterinarians verify the old vaccinations as well, as has been done in this example.

DISCUSSION AND CONCLUSION

I have studied and analysed how to develop a web-based support system for veterinarians, which would have both a mobile and web interface. As the action design methodology suggests the next step is to build the working prototype of *m-equine*, and test it with veterinarians. From user experiences I then further develop the system, so that it can be taken into commercial use. At the same time mobile and IS systems have to be developed to support riders, owners and competition organizers, so that the value of using *m-equine* is maximized. It is also important to develop, in an early stage, more functionality for veterinarians, so that they have visible benefits from using *m-equine*.

As with various m-heath applications previously studied, also here it is important to recognize the stakeholders and the users, and distinguish their different needs. Users have to be properly educated so that they understand how the mobile solution supports their work and what benefits they can gain with it (Boulos et al., 2011; Choi et al., 2011; Liu et al., 2011). Some of the studies that have been done with physicians and m-health applications can be used as a basis for a mobile veterinary system. This research however provides a deeper insight on veterinary work and veterinarians' needs, in situations that are not comparable with physicians. One of the differences is that physicians mostly work in an indoor environment, where they have access to computers and internet all the time. A veterinarian who mostly works on the road and visits stables does not have this same luxury, and therefore has to rely on devices and support that he/she can bring to a horse stable environment. As could be seen from the results of various surveys, the veterinarian's recognize that they could improve the way they use time, and they are interested to try a system that would help them in their everyday work. This is why it is my belief that veterinarians can greatly benefit from the *m-equine's* mobile and web based support system, since it could assist their everyday work around horses. There is a need for a web based system, built on top of a comprehensive database of horses, that would support veterinarian work, but it has to be logical and easy to use and proper education has to be given to ensure that the veterinarian's will start to use the system.

To get a better picture of what the *m-equine* system can offer for veterinarians and its potential future developments I have chosen to do a SWOT analysis of the system. The SWOT analysis is done in accordance to the specifications introduced in Kotler and Armstrong (2009). With a SWOT analysis of *m-equine* the following properties can be identified.

The *strengths* of *m-equine* are that it can be used wherever and whenever needed. The system reduces paperwork for veterinarians and gives the horse owner a central location where to find all his/her horses' vaccination information. With the system the veterinarian can also improve customer service towards the horse owner. Competition organizers will need less workforce since vaccination control at the secretary's office is all but eliminated, thus also gaining significant time savings. Later down the road, sport horses can be better distinguished from non-sport horses that might be used in the food industry, which in turn can expand the pharmaceutical market available for sport-horses.

One of the main *weaknesses* is that since a common medical database does not exist it will take time until the build-up of information will yield positive results. It is also imperative that the stakeholders' needs are met, which can be complicated to achieve, since something is always lost in the development chain from the stakeholder to the programmer.

The system naturally opens up *opportunities* to be developed into a much broader information database. The vaccination information for horses, leads naturally to a platform for other support functions including the horse's whole medical history. It can be multi-lingual and usable throughout the world. More operations can be implemented into the system to support other stakeholders around horses such as blacksmiths, stables, breeders and betting community for both trotters and racehorses. Although *m-equine* is developed primarily for stakeholders around horses a similar system could be developed for e.g. cats and dogs that travel to other countries with their owners or for shows.

The *threats* are mainly ignorance and unwillingness to change among people who are to use the system. If the veterinarians cannot be educated properly to use the system, and have access to a well-organized support system when help is needed, they might stop using the system because of the problems they have encountered. It will also take time for the system to yield a positive outcome, as this will require a vast database. Since sport-horses are the main target initially, their vaccination information can be updated into the database relatively fast. The *m-equine* system would be used within FEI and/or national equestrian federations, where competent people can collect vaccination information into the database, during e.g. competitions. Thereafter any new information is to be input by a veterinarian. It will be natural that in the beginning people might be suspicious to the security of the system. This is why it is best to start the system's development from vaccination information since it does not have to be secure in the same sense as e.g. other medical information might need. However since many people (including horse owners) already use the Internet for many operations that require heavy security (e.g. banking) the supposed threat for security should be minimal.

Naturally anybody can develop a nice app that could have some of the basic features as the *m-equine* system, but a simple app does not cover the range of needs required for a system with so many stakeholders. An app cannot be expanded to meet the future needs of the various stakeholders, as the *m-equine* system will. Furthermore a similar system built by developers knowledgeable only in web-based support systems but lack the knowledge of the horse industry, will result in a system that stakeholders do not want to use, since it will not support their daily routines.

After the alpha version has been tested, and feedback has been attained from the users, a more in depth SWOT analysis can be made (Figure 4). At the same time, each iteration stage during the development of the system offers opportunities to improve it in such a way that weaknesses and threats are minimized.

IMPLICATIONS FOR PRACTICE

The obvious benefit from using a mobile veterinary system would be that notes and information would not be lost, and the veterinarian would not have to do double paper work after visiting a stable. From the

Figure 4. SWOT analysis

veterinary mobile solution it would be easy to build a chart from which it can be studied when certain vaccinations are most demanded and keep an inventory in accordance to this information. Vaccinations have expiration dates, and with some previous knowledge into "hi-season" the veterinarian can prevent unnecessary loss of merchandise.

By having detailed information easily at hand for when a horse has been vaccinated the veterinarian can send a reminder to the horse owner of the need for a new appointment, before the next vaccination is due. This service could even be automatic so that it will not interfere with the veterinarian's busy schedule. It is a win-win-win situation where the customer gets his/her horse vaccinated before the previous vaccination gets too old. With the customer reminder service the veterinarian can attract previous customers to once again use his/her services, by giving some nice bundle of services offer. The horse naturally can keep on living his happy life without getting the deceases the vaccination prevents.

LIMITATIONS

At the moment the upcoming alpha version of the mobile system for veterinarians is still rather limited, since it only deals with horse vaccinations. In order to get the alpha version to work successfully the other main stakeholders need to be able to access and read the vaccination information. Especially the competition organizers need the system to work smoothly and only deliver them information on the horses that do not have the vaccination information in order. One of the main benefits in this system would be lost if the competition organizers would have to go through a list of horses and their vaccination data at every competition. Therefor in *m-equine* the mobile and IT solutions have to work side by side, and have smart solutions that are user friendly.

FUTURE RESEARCH

As already has been mentioned, the *m-equine* system should be developed further from the vaccination service to include other services that are beneficial for veterinarians. The commercial system will already support the three main stakeholders, and the value of the system increases with the amount of data attained into the underlying database. Although the commercial product is the initial goal for the system and it is the final iteration in the BIE-schema introduced earlier, the system will need to be developed further after its initial launch. A continuous development ensures that the system meets future needs, and enhances all the stakeholders' lives. The system should also be developed to support other stakeholders around horses, such as the owners, riders, competition organizers, stables and FEI's clean sport program. The mobile system requires a supporting web system since for some stakeholders this would be the more natural platform to use. In the future there would be need for mobile phones or pads to be able to "read" a horse's ID tag, so that one unanimous protocol and standard are used everywhere. This type of system would considerably hasten the processes that a veterinarian has to do, help border control officials and limit frauds.

Equine disciplines are just one part of all the horse sports. Already in Scandinavia harness racing federations require influenza vaccinations for racing horses, in a much the similar way as FEI does for equine disciplines. Anti-doping and vaccination protocols, not to mention the efforts to stop various animal diseases from spreading are not only limited to horses, also cats, dogs, and other pets as well as production animals travel between countries and might carry diseases, without their owners knowledge. Vaccination protocols are also in use for e.g. dog and cat shows, and for now is mostly done the same way as for horses, namely by checking the animal's passport. Maybe one day the *m-equine* system can be a forerunner for all animal health information and why not even a basis for some human m- and e-health systems.

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Chapter 11
Improvement of Food Security Through Reforming of Domestic Veterinary Service:
Case of Russia

Anna Ivolga
Stavropol State Agrarian University, Russia

Vladimir Trukhachev
Stavropol State Agrarian University, Russia

Natalia Bannikova
Stavropol State Agrarian University, Russia

Anzhelika Baicherova
Stavropol State Agrarian University, Russia

ABSTRACT

The chapter gives an overview of current issues of achievement of food security through reforming of veterinary service in the light of the social, ecological, and economic development of the society. The authors analyze certain challenges of food security existing in emerging countries, including expansion of market relations within veterinary service. The results of organizational and economic reforms of veterinary service are assessed on the case of Russia in a form of the survey of the heads of regional veterinary centers. Such issues as governmental and public regulations of quarantine operations and the most dangerous animal diseases are also discussed. In order to improve food security, the authors justify the measures for competition and demand stimulation, smoothing consequences of market imperfections, encouraging veterinarians' efforts on reducing the negative impact of livestock breeding on the environment.

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INTRODUCTION

Livestock breeding is an important sector of the global agriculture. In many countries, this sector is more advanced compared to crop production. One-third of cropland is occupied by forage crops for the purposes of animal husbandry.

In the modern conditions, livestock breeding largely determines food security of the countries. Livestock products provide a full range of nutritional value. Namely, they are the sources of energy, bio-digestible minerals and vitamins, and high-quality animal protein containing all essential amino acids. Each person should consume above 20 grams of animal protein per day for a healthy diet. This can be achieved by annual consumption of 33 kg of meat, or 45 kg of fish, or 60 kg of eggs, or 230 kg of milk, respectively. Both production and consumption of animal products grow rapidly throughout the world. According to the forecast of the Food and Agriculture Organization of the United Nations [FAO] (2015), world meat production is expected to double by 2050, mainly owing to developing and emerging countries. The growth rate of meat production could exceed the growth rate of the world population. The possibility of advancing growth of meat sector in the developing and emerging countries was revealed. Such countries will be able to satisfy their domestic demand at the expense of their own production (FAO, 2015).

However, the growing scale of livestock is accompanied by a wide range of problems. One of the main problems is an environmental impact in the forms of degradation of pastures, irreversible changes of the local genetic resources of animals and plants, increasing water consumption, soil and water pollution with animal waste, as well as drugs used in animals breeding. Thus, ensuring animal health is one of the most important challenges of combating negative environmental impact. This is supported by ever-growing attention of scientists and experts, who consider the development of veterinary service in terms of its contribution to the sustainable development of the society and ensurance of food security (Davis, 2008; Gerber, Mottet, Opio, Falcucci, & Teillard, 2015; Ipema, Bleumer, & Lokhorst, 2011). Over the years, veterinary professionals have played significant roles not only in animal health, but also in human health and welfare, food quality, food safety, and food security (Caceres, 2012). Modern veterinary practice includes a series of activities that lead to environmental pollution, soil degradation, and contamination. The inevitable consequences of the veterinary interventions are a collection, recycling, and disposal of biological waste. The problem of biological waste disposal and destruction is relevant for a number of countries, especially emerging ones (McLean, Watson, & Muswema, 2007; Traverse & Aceto, 2015; Osipova, 2008; Popkova, Dubova, Yakovleva, Azarova, & Titova, 2014). In addition, negative impact on the environment may be caused by the veterinary treatment of cattle, disinfection, disinfestation, and deratization. This also contributes to soil degradation as a result of the chemical effect of disinfectants.

Many publications are devoted to the research of the possibilities and ways to reduce antibiotic treatments in veterinary (Trevisi et al., 2014; Mohring et al., 2009; Caruso et al., 2013). In the developed countries, much attention is paid to the issues of ensuring animal welfare as an aspect of decisions about whether animal-usage systems are sustainable (Velarde, Fàbrega, Blanco-Penedo, & Dalmau, 2015; Broom, 2010; Da Silva & Naas, 2012).

Based on the vision of "one medicine", scientists consider the role of veterinary medicine in protecting food security and safety (Pappaioanou, 2004; Sargeant, 2008; Steele, 2008). Dividing the concepts of food security and food safety, in this chapter, the authors address the food security in relation to the veterinary service understanding that the activities of veterinary services have a significant impact on food security which is relatively homogeneous over the four components: availability, accessibility, utilization, and sustainability. According to Zinsstag, Schelling, Waltner Toews, and Tanner (2011), the concept of "one medicine" should be transformed into the concept of "one health", and even "ecosystem health". Considering the intensifying processes of globalization, it should assume a global scale.

At the same time, the above-mentioned problems related to veterinary service remain relevant for the majority of the emerging countries because they have not yet found any optimal solutions of economic issues of veterinary care. In many countries, demand for veterinary services is quite low because of the low income of farmers and lack of qualified veterinarians, insufficient technical, financial, and administrative support of their work. This situation adversely affects the stability of livestock breeding, environment, and rural development.

The solution to this problem is largely connected to the reform of the national veterinary services (Ahuja, Umali-Deininger, & de Haan, 2003; Rutabanzibwa, 2011). Experts note that a flexible combination of state support to the veterinary services and active stimulation of the commercial sector of the veterinary medicine is required (Leonard, 1987; Ekboir, 1999; Turkson, Slenning, & Brownie, 1999; Rubyogo, Murithii, Agumbah, & Obhai, 2005; Bhandari & Wollen, 2008; Amankwah et al., 2014). In emerging countries, institutional reforms run at different speeds and with different efficiency. A success can be achieved through analysis of international experience, as well as regular monitoring of anticipated and unanticipated effects of privatization and decentralization to enable policy adjustment.

The main idea of the research presented in this chapter is to investigate the experience of reforming of the veterinary services in one of the emerging countries. The authors studied the case of Russia and surveyed the heads of the regional departments of the veterinary service in one of the Russian regions.

Research tasks included:

- Identification of the strengths and weaknesses of the reform, evaluation of its impact on different divisions;
- Expert survey to study the opinion of the veterinarians on the features and results of the further development of market relations in veterinary medicine, government impact on the improvement of the veterinary service, opportunities of stimulating demand for veterinary services, the role of veterinary medicine in ecosystem health improvement;
- Generalization and ranking of the survey results, theoretical justification of the level of government intervention;
- Development of solutions and recommendations for improving the work of the veterinary services departments based on the identified problems.

BACKGROUND

Russian animal breeding is one of the largest in the world. Russia takes the 5th place in the world in meat production, 6th place in milk production, 9th place in wool clipping (Khokhlov, 2014). However, during the 1990s, Russian livestock breeding was damaged by the market reforms and transition processes happened after the collapse of the Soviet Union in all post-soviet countries. The main damaging factor was the fall in purchasing power, which affected the most income-elastic meat and dairy products. In addition, the efficiency of livestock production and yield per unit of forage in Russia during the 1970-1980s were much lower compared to the developed countries. Therefore, import of meat and dairy products to the country rose sharply and created a competitive position to the Russian producers giving them no time for fundamental modernization of the industry.

Along with the sharp decline in output, significant structural changes occurred. Before the 1990s, the basic commodity production was concentrated in the large public agricultural enterprises. As of 2015, 54.7% of cattle and 53.4% of sheep and goats are produced by small-scale production units: farms and private subsidiary farms.

Such transformation required substantial changes to the system of veterinary care. Both before the market transformation and now, only a few veterinarians are responsible for the health condition of livestock at large agricultural enterprises. However, in small-scale farms, animal management required the establishment of a special service. In Russia, this service was established on the basis of public institutions – district centers for animal disease control that existed in each administrative area. Such centers became the major veterinary units engaged in rendering services to the owners of small animal farms within the territory of an administrative district, as well as in the coordination of the work of veterinarians at large enterprises and private veterinarians engaged in entrepreneurial activity.

The economic basis for the veterinary services has also undergone significant changes. In the planned economy, the cost of keeping and organizing the veterinary service was financed by the government. The liberalization of economic relations in the sphere of animal husbandry and veterinary medicine started in the 1990s along with the national market reforms. In 1991, public veterinary institutions financed by the state were allowed to render commercial veterinary services. However, for over 20 years, state veterinary authorities had no right to administer their earnings. Money obtained from the rendered commercial services was transferred to the regional budgets and then distributed centrally between all district centers for animal disease control located in the area. A number of budget allocations were calculated based on the performance achieved by the district centers for animal disease control centers during previous years. Thus, the degree of state economic regulation of the veterinary service remained high.

The situation changed in 2013 when the new model of market activities of district centers for animal disease control was introduced. The amount of budget money transferred to the accounts of the veterinary centers is determined based on the performance of the governmental plan on rendering veterinary services to small private farms, not the operational plan of the center itself. A governmental plan is developed based on livestock number on farms and smallholdings within the territory of an administrative district and is aimed at the prevention of quarantine and dangerous diseases. It includes scheduled preventive vaccinations and treatments of animals, scheduled diagnostic tests, a sampling of biological material for diagnostic studies on quarantine and especially dangerous animal diseases, as well as registration and issuing certificates of compliance of foodstuffs with the requirements of the veterinary standards of the food market.

The fact that such types of veterinary services are financed and controlled by the state is justified. Thus, both Lin et al. (2003) and Trevisi et al. (2014) emphasize the priority of preventive measures for the formation of the so-called "sustainable medicine" (SM) as one of the important components of a wide range of possible sustainable approaches to peaceful co-existence.

On the other hand, the involvement of a government in the facilitation of preventive measures for small private farms has been remaining top-priority in emerging countries for a long time (Leonard, 1987; Ekboir, 1999; Amankwah et al., 2014). The reasons for that have been low-income of farmers and lack of experience and industrial practices which both have led to underestimation of preventive measures and consequences of dangerous animal diseases to the society and environment.

The second feature of the new model of the market functioning of district centers for animal disease control is associated with the use of funds from commercial services. Previously, money earned by the veterinary centers was transferred to the regional budget. Currently, the money remains on the centers' accounts and is spent according to the centers' needs. Thus, the transition to the new finance system promoted the commercial component of veterinary centers' activities, strengthening their autonomy and financial independence.

To assess the results of the implementation of the new finance system of public veterinary institutions the authors conducted an expert survey on the case of Stavropol region of Russia. The region was selected as a case-study because of its well-developed animal husbandry industry. The share of animal production in total agricultural output in Stavropol region is 31%. Stavropol region ranks the second in Russia by a number of sheep and output of wool, the ninth by poultry stock, and the tenth by a number of cows and output of milk. At the same time, 69% of cattle and 82% of sheep are kept on small farms (Territorial Authority of the Federal State Statistics Service of the Russian Federation in Stavropol Region, 2014). Veterinary care of this livestock is carried out by the experts from the district centers for animal disease control. Each year, they complete over 640 million actions (vaccination, research, and animal decontamination), over 10 million laboratory and diagnostic studies, and 120 million of veterinary and sanitary examinations.

31 heads of district centers for animal disease control took part in the survey. 73.3% of them have more than 15 years of experience in veterinary medicine. The questionnaire forms were forwarded to them via e-mails and then completed forms were returned to the authors by post.

MAIN FOCUS OF THE CHAPTER

The transition to the new model of district centers of animal disease control pursued economic aims related to saving budget funds, strengthening financial independence of disease control centers, and stimulating demand for veterinary services. The most obvious consequence of this transition was a reduction of staff. Before the reform, the average number of staff per a disease control center was 70 people, now it is about 53 people.

One of the main hypothesis of the current study is that the results of transition are not similar for the veterinary centers in different districts. In order to prove it, the authors grouped the questionnaires by the size of animal population served by the district centers. Grouping the survey results allowed the authors to distinguish four groups of disease control centers. The first group includes large district veterinary networks that manage a large number of livestock (over 40 thousand livestock units). Over 70% of livestock is managed by small private farms. There is 21% of such administrative districts in the region. During the staff optimization, the number of employees per center was reduced by 14 persons in average, but the average total number of staff remained high – 61 persons. Veterinary centers are characterized by the high rate of government task performance (100% and more) and high level of income earned from commercial services.

The second group comprises veterinary centers where the livestock number amounts to 20-40 thousand units. Its considerable part (40-70%) is managed by small private farms. The share of such disease control centers is 24%. The staff was cut by 11 persons, and now the average number totals 52 persons. The majority of disease control centers in this group do not perform the government task in full volume.

The third group of the veterinary centers (42%) includes districts where livestock number is below 20 thousand units, but 70% of which is managed by small private farms. The average staff number of such centers is 47 persons. The reforms mainly affected this type of veterinary centers as 16 persons on average were fired. Underdevelopment of livestock in such administrative districts has an adverse effect on the volume of commercial services. The government task in not performed unevenly, the main targeted indicators are not met.

The fourth group of veterinary units includes city veterinary centers (about 13% of the total number). They do not treat livestock, but control processes of livestock products processing and sale. Their main function is to provide safety control.

The opinions of the heads of Stavropol district centers for animal disease control on the reform are very diverse. 40% of the respondents from first group mention did not find any disadvantages in the new system, whereas 25% of the respondents from the third group did not see any advantages. The analysis of the survey results shows that the main controversial issue is the most obvious result of the reform – staff optimization with an account of the livestock managed. Almost 47% of the respondents mentioned it as the main advantage, while 43% recognized it as the main drawback of the new system. Some experts explain that both the threat of dangerous disease spread and growth of livestock number result to the need of improving response activity, timely diagnostics, and veterinary care. This is the reason why the reduction of the staff number may endanger veterinary security.

The reduction of staff number also increased the load on the remained employees. On the other hand, it created conditions for the increase of salaries and incentives for specialists. The analysis shows that the largest number of staff optimization supporters is in the first group (60%) and the third group (54%). For the respondents from the third group, the main factor is saving limited means of such type of disease control centers. 87.5% of the respondents from the second group assess the staff layoff as the main drawback of the new system.

The lack of interest of disease control centers in environmental protection was considered as a disadvantage only by 7% of respondents. This highlights inadequate attention of experts to the issues related to sustainable development of rural areas. Strengthening of the financial independence of the centers as a positive result of the reform was mentioned by 43.3% of the respondents. It was particularly noted by the respondents in the second group (70%). Herewith, 51.7% of the respondents from the second group think that the new financing system enables a complete coverage of livestock with preventive measures and reveals new opportunities for the development of physical infrastructure.

Calculation of volume of state subsidies based on livestock number led to the change of the amount of state funding. In general, every fifth respondent mentioned the significant increase of budget funding after the transition to the new system. Herewith, there is a trend to decrease in state funding in 40 districts. 20% of the respondents from the first group mentioned the significant increase in state funding, 40% said it had slightly increased. That means that the new system improved financial situation in 60% of large district centers for animal disease control. Even bigger share of the respondents from the second group (71.4%) noted an increase in funding, while the situation in the third group was different. The reduced state financing was observed in 54% of veterinary centers. Every third respondent mentioned significant decrease of subsidy rates.

The volume of such preventive measures as vaccination, sample selection, and allergic response study is related to the current livestock number and the total level of livestock development in an administrative area. Herewith, over a half of the respondents mentioned the underperformance of the government task implementation. Only 13% of the centers succeeded to meet the targets. The authors believe that the main reason for that is an evasion of compulsory preventive veterinary and sanitary measures. This is connected to the underestimation of the importance of preventive measures for livestock health and environment as well as to reluctance of farmers to show the real livestock number. As a result, the governmental plan does not always correspond with the situation in the particular center. As a rule, the unaccounted livestock does not participate either in compulsory (free) or in commercial sanitary and veterinary treatment.

The threat of dangerous disease outbreaks remains relevant. It is difficult for the veterinarians to manage such diseases in the conditions of low awareness of their origin and course. Consequently, this situation can be regarded as a constraint for ensurance of food safety and food security in the area. The situation is complicated by organizational challenges. The current system of material and technical supply of the centers for animal disease control allows cases of untimely supply of vaccines and diagnostic materials. More than 53% of the respondents consider the problems of veterinary service supply with veterinary preparations as one of the most urgent ones.

The second important source of financing of the district centers for animal disease control is commercial services. Commercial services include all types of veterinary activities not included in the governmental plan. Commercial services are priced by each disease control center individually according to the guidelines developed by the regional state agency – Veterinary Authority. There is a unified mechanism of pricing, however, the guidelines do not provide any price limits or any other regulatory tools. As a result, the price of the same type of service varies from one district to another. This leads to the dissatisfaction between the owners of the farms located in neighboring areas, causes social conflicts, and reduces demand for veterinary services.

The problems related to pricing affect the amount of money received from rendering commercial services. Its volume reduced in 50% of the veterinary centers, while increased in 40% of those veterinary centers included to the first and the second groups. That means that the large veterinary centers have succeeded to strengthen their commercial component and increase their financial independence under new conditions.

The respondents note that the full list of commercial services is implemented only by a half of the veterinary centers. In most cases, this relates to the special features of veterinary network performance in a certain district. Thus, for example, not all the districts have veterinary laboratories. Another issue is a lack of legally formalized markets as it limits the opportunities for veterinary and sanitary examination of food products sold on the market. As the result, 42% of veterinary centers cannot cover their economic needs with money received from rendering commercial services. The main share of this money is spent for salaries and bonuses for employees. The other significant item is utility payments.

The same sort of situation is observed in the case of fixed assets purchase. Only 22.3% of the respondents considered equipment procurement as the main item for spending money received from rendering commercial services. According to the survey results, 13% of the veterinary centers do not spend their earnings on new equipment. As a result, in the districts with underdeveloped livestock breeding veterinary service is backward. There is a lack of own means for veterinarian vocational training.

Respondents were asked about the possible ways of solving existing problems. The majority of respondents believe that in order to improve veterinary service it is necessary to develop the system of financial incentives and bonuses in the case when a center systematically overperforms the governmental plan. Additional financial rewards of veterinarians are considered to be fair by 80% of the respondents from the first group, 71.4% of the respondents from the second group, and 38.5% of the respondents from the third group.

About 67% of the respondents mention the acute need for improving price policy of commercial services. This measure seems to be urgent for 80% of the respondents from the first and the second groups. These results are confirmed by the data obtained by Tregubov et al. (2012) carried out during the survey of Stavropol veterinarians on the procedural and institutional issues of veterinary service operation. In 2012, 74.1% of the respondents mentioned the problem of the inadequate price level.

Providing centers with modern equipment and vehicles is also considered as a significant issue. The importance of measures for equipment renovation was mentioned by 85.7% of the respondents from the second group and 61.5% of the respondents from the third group.

Many of the above-mentioned problems are typical for other Russian regions (Ilyinykh, 2013; Nikitin, Akmullin, & Trofimova, 2012), so the measures proposed based on the survey results are relevant for the improvement of the veterinary service.

Summarizing the survey results, the authors conclude that the reform of the veterinary service has undeniable positive organizational and economic results. The most significant of them are strengthening the commercial base of the veterinary service, staff optimization, financial incentives for the employees, more opportunities for earning financial resources, and use of new technologies. Undoubtedly, all those factors will contribute to the development of rural areas and environmental health. On the other hand, an extension of market relations caused further stratification of the network of district centers for animal disease control by financial and economic condition, opportunities for sustainable development, and ensurance of food security.

Generally, there is no opportunity to render commercial services in sufficient volume in the areas with a few livestock due to the low demand a lack of veterinary laboratories and laboratories of veterinary and sanitary examination. In such centers for animal disease control, possibilities of adequate salary rates are limited and technical backwardness and employees' dissatisfaction with the working conditions are observed. Those problems may be further complicated by a lack of transport in rural veterinary services, untimely provision of drugs, etc. As the result, preventive measures may be adversely affected, and the volume of medicines used in a case of animal disease outbreaks increases.

The lack of measures aimed at the adjustment of the working conditions of those centers can lead to the spiral development of adverse consequences, worsening conditions for veterinary security, and, as a result, further reductions in the number of livestock that taken together negatively affect food security in the area. Therefore, it is advisable to limit the differentiating features of the market, which can eventually become the signifying one. That is unacceptable in terms of the social, ecological, and economic importance of the veterinary service.

In the emerging economies, the need for state regulation of organizational and economic aspects of the veterinary service is caused by its affinity to infrastructure sectors. The issue of the market mechanism development and increasing its effectiveness is important and is still an unsolved problem in production infrastructure within the system of market economy in Russia. One of the main reasons is that many of the branches of production can be regarded as natural monopolies. Consequently, the rate of liberalization and its borders in various industries, as well as the resulting effect, are different.

According to Sulakshin et al. (2007), natural monopoly as an object of state regulation is the sphere of economic activity where competition is limited due to the specifics of the production process or contradicts the public interest. In order to identify the sectors that could be attributed to natural monopolies, the authors propose to allocate four types of market boundaries: economic, technological, social, and strategic.

Under such approach, it can be assumed that the veterinary infrastructure also has certain features of a natural monopoly. The leading element is the social boundaries of the market, according to which the social importance of the veterinary security relates to the issues of ensurance of food security. In this context, the economic boundaries of the market are also relevant, as competition in the field of quarantine and dangerous animal diseases prevention under conditions of market imperfection, which is usually observed in the emerging countries, could have negative economic consequences for agricultural production. Thus, competition in quarantine and dangerous animal diseases prevention is possible but requires public or government regulation in terms of creating conditions for ensurance of food security. It should be noted that in the developed countries the government always played an important role in the development and regulation of the veterinary service (Enticott, 2014; Kellar, 2012).

The degree of danger of animal diseases, which have to be eliminated by the veterinary service, can be regarded as social and technology boundaries of the market, beyond which the competition is rather effective. However, it should be noted that the concept of technological boundaries of the market is closely linked to the territorial limitation. In the field of veterinary medicine, this factor is quite important due to the territorial dispersal of a livestock. Therefore, in order to avoid local monopolies, a certain degree of state intervention and public control should be presented in the area of veterinary practice, which is not associated with dangerous animal diseases. This intervention should apply to regulation of tariffs on services, development of veterinary network entities, adjustment of differentiating and sanitizing functions of the market, i.e. those aspects that were mentioned by the respondents during the survey.

Based on the survey results, the authors formed a diagram of causes and effects in improving the efficiency of the veterinary services that reflects the importance of various factors (Figure 1).

The description of elements presented in Figure 1 and links between them is given in Table 1.

The system of factors presented in Figure 1 allows the authors to outline the priority goals and propose measures for further improvement of the new system of operation of the veterinary centers in terms of environmental and economic issues (Figure 2).

Figure 1. Causes and effects in improving efficiency of the veterinary services
Source: Authors' development

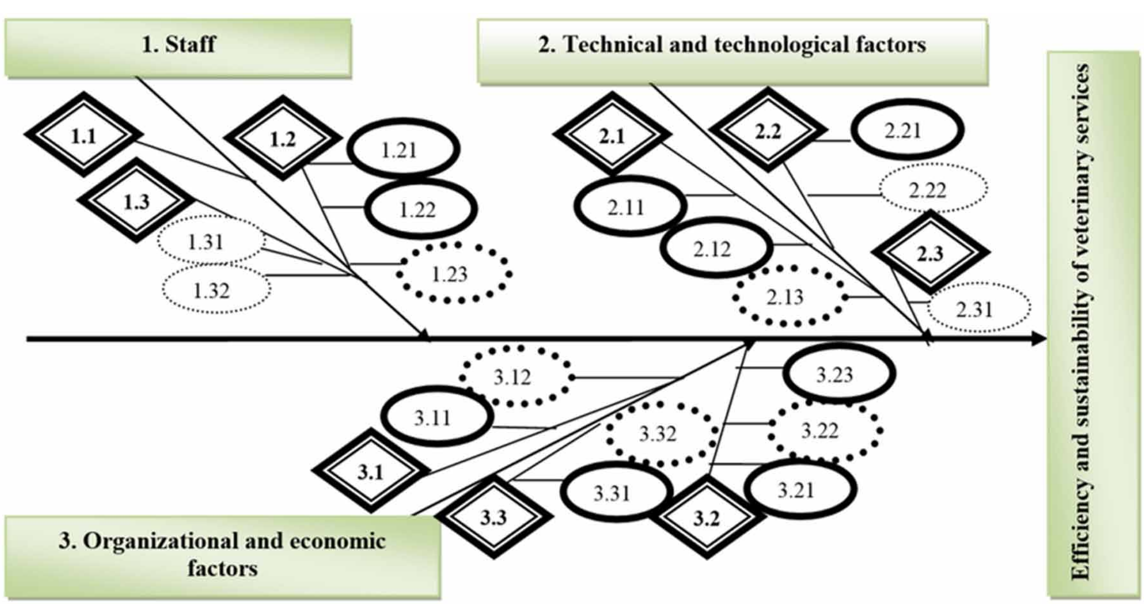
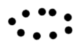
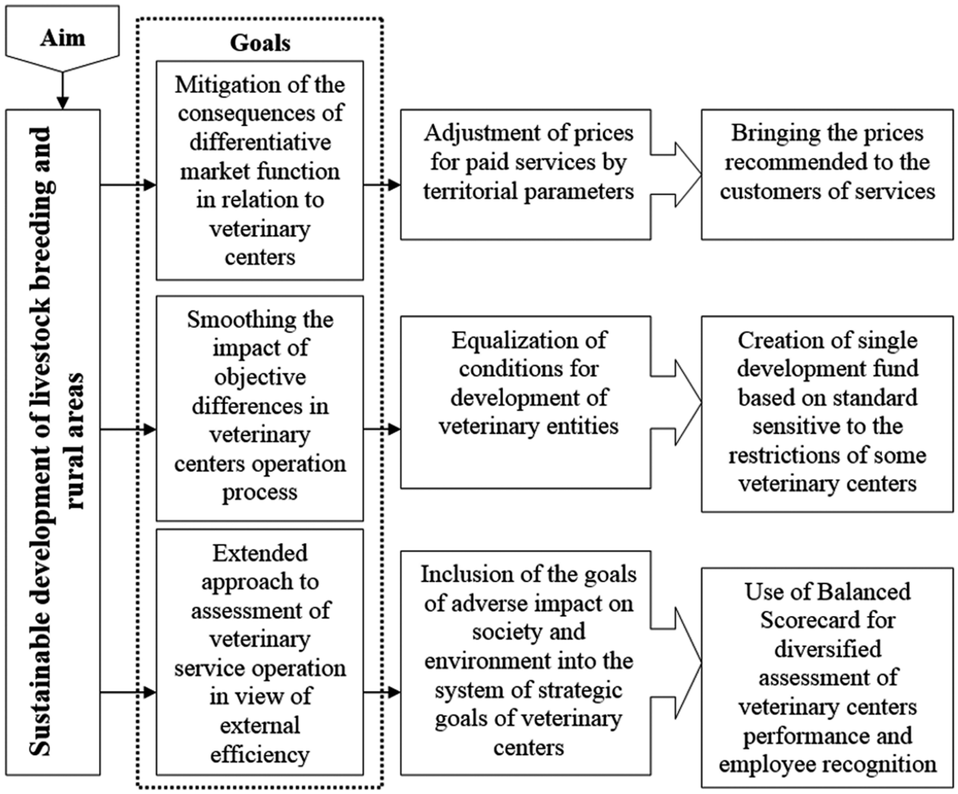


Table 1. Description of causes and effects in improving efficiency of veterinary services

Element	Description
	Resulting factors of the second level
	Resulting factors of the third level mentioned by more than 60% of the respondents
	Resulting factors of the third level mentioned by 20-60% of the respondents
	Resulting factors of the third level mentioned by less than 20% of the respondents
1.1	**Targeted subsidizing of the veterinarians in rural areas**
1.2	**Staff management improvement**
1.21	Bonuses for the veterinarians for better performance
1.22	Optimization of staff structure of the veterinarian service
1.23	Improved availability of the qualified professionals
1.3	**Advanced training of the veterinary service employees**
1.31	Entrepreneurship training for the veterinarians
1.32	Exchange of experience with the veterinarians from other regions and countries, vocational training
2.1	**Modern equipment for the veterinary entities**
2.11	Availability of modern equipment
2.12	Availability of transport
2.13	Reconstruction of buildings belonging to the veterinary services
2.2	**Availability of veterinary preparations**
2.21	Well-timed provision of veterinary preparations to the district centers for animal disease control
2.22	Improvement of medication dosing techniques
2.3	**Introduction of new technologies to medical treatment of animals**
2.31	Cooperation with scientific and research centers, universities
3.1	**Regulatory framework for veterinary service operation**
3.11	Control of prices of services
3.12	Improvement of development and control of the governmental plan
3.2	**Effective arrangements with clients**
3.21	Explanatory work on the necessity of preventive measures
3.22	Improvement of legislation aimed at reduction of unaccounted livestock number
3.23	Official formalization of unregulated markets
3.3	**Support of the veterinary centers in the areas with small livestock number**
3.31	Creation of money reserves to the support of the veterinary entities
3.32	Differentiated approach to the calculation of subsidies for the governmental plan

Source: Authors' development

Figure 2. Goals and measures for operation of the district centers for animal disease control
Source: Authors' development



The first goal is connected with mitigation of the consequences of differentiative market function. Its solution should be aimed at the balance of commercial and public interests, primarily, in the area of pricing of veterinary services. According to the survey results, the issue of regulation, dynamics, and limits of prices for the veterinary services is of particular importance. There are the following drawbacks:

- Prices of the main veterinary and sanitary services significantly vary from one administrative district to another;
- Absence of the system of price regulation taking into account the objective differences in the performance of the veterinary centers;
- Price lists have not been updated for several years.

In order to eliminate the above-mentioned drawbacks, it is advisable to readjust recommended prices of the most common veterinary services once or twice a year. Moreover, the differences in operation conditions of the district centers for animal disease control should be noted. These should primarily include a spatial dispersion of animals. One of its major parameters is a distance from the main livestock breeding units to a district center for animal disease control calculated using a size and configuration of an area, as well as a density of livestock managed in numerous small farms.

The following integral coefficient comprehensively considers all these factors:

$$К_{in} = К_f * \bullet К_d \quad (1)$$

where

$К_{in}$ – integral coefficient;

$К_f$ – coefficient of distance;

$К_d$ – coefficient of livestock density.

The cost of transport services incurred by a district veterinary service also significantly affects responsiveness to emerging livestock disease outbreaks. Thus, this factor having an indirect impact on the efficiency and stability of the veterinary services should be considered when calculating the prices of services.

In order to calculate the coefficient of distance, the authors differentiated all districts by a distance between a district center for animal disease control and the most remote settlement (the value of “transport leg”). Thus, it is reasonable to determine the value of $К_f$ for the administrative districts of Stavropol region as follows: $K_f = 1.5$ for the districts where a distance from a veterinary center to the most remote settlement exceeds 70 km; $K_f = 1.3$ if a distance is between 50 and 70 km; $K_f = 1.1$ if a distance is less than 50 km.

The coefficient of the density of livestock reflects the concentration of livestock on the territory of an administrative district. When determining K_d in the districts of Stavropol region it should be noted that the average index in the region is equal to 15.64 livestock units/square km of farmland. $K_d = 1.5$ in the areas where the density of livestock is close to the minimum value and does not exceed ten livestock units/square km; $K_d = 1.4$ – for the density index from 10 to 20; $K_d = 1.3$ – for livestock density between 20 and 30; $K_d = 1.3$ for the density index over 30 livestock units/square km.

The values of integrated coefficient adjusting the cost of the veterinary commercial services in the administrative districts of Stavropol region are presented in Table 2.

As a case, the authors studied an example of mastitis treatment in Kochubeevskii and Grachevskii districts of Stavropol region. Currently, the prices of such service in Grachevskii and Kochubeevskii districts are 105 RUB and 205 RUB, respectively. However, the price recommended by the Veterinary Authority of Stavropol region is 72.4 RUB. The value of “transport leg” in Grachevskii district is 60 km, livestock density corresponds to the district average and does not exceed 15 livestock units/square km. In Kochubeevskii district, these parameters are 70 km and 42.4 livestock units/square km, respectively. Taking into account the inflation rate in 2014 (6.7%), the base price of mastitis treatment should be 77.25 RUB. Considering the value of $К_{in}$, the prices in Grachevskii and Kochubeevskii districts should be 140.6 RUB and 110.5 RUB, respectively.

It would be reasonable for the Veterinary Authority of Stavropol region informing the consumers about the price change. In order to facilitate this process, the recommended prices should be posted on the official website of the Veterinary Authority of Stavropol region, as well as in each district veterinary center so that to be available for the consumers of veterinary services.

The second goal of improving economic conditions in the district centers for animal disease control relates to the smoothing of conditions for their development. Sharp disparities in funding of the veterinary centers of Stavropol region for the purposes of the governmental plan performance on preventive

Table 2. Value of the integrated coefficient adjusting the cost of the veterinary commercial services in the districts of Stavropol region

Districts	K_f	K_d	K_{in}
Aleksandrovskii	1.1	1.5	1.65
Andropovskii	1.3	1.4	1.82
Apanasenkovskii	1.3	1.4	1.82
Arzgirskii	1.1	1.5	1.65
Blarodarnenskii	1.3	1.5	1.95
Budennovskii	1.3	1.5	1.95
Georgievskii	1.3	1.3	1.69
Grachevskii	1.3	1.4	1.82
Izobilnenskii	1.1	1.4	1.54
Ipatovskii	1.5	1.4	2.10
Kochubeevskii	1.3	1.1	1.43
Krasnogvardeyskii	1.1	1.3	1.43
Kirovskii	1.1	1.4	1.54
Kurskii	1.5	1.5	2.25
Levokumskii	1.5	1.3	1.95
Mineralovodskii	1.3	1.5	1.95
Neftekumskii	1.5	1.3	1.95
Novoaleksandrovskii	1.1	1.4	1.54
Novoselitskii	1.1	1.4	1.54
Petrovskii	1.1	1.5	1.65
Predgornii	1.1	1.4	1.54
Sovetskii	1.5	1.5	2.25
Stepnovskii	1.1	1.4	1.54
Trunovskii	1.1	1.4	1.54
Turkmenskii	1.5	1.5	2.25
Shpakovskii	1.5	1.1	1.65

Source: Authors' development

measures and rendering commercial services should not affect the availability of necessary equipment and material resources. In order to overcome the imbalance, it is necessary to create conditions to support district centers for animal disease control, which belong to the third group, the most disadvantaged one according to the survey results. They are located in the administrative districts with small livestock number, so the possibilities of increasing the volume of services and improving financial and economic conditions are limited. Thus, all these factors can result in worsening conditions of the veterinary security and further development of adverse trends in such centers, which can have a multiplier effect and cut the number of livestock in the area. Despite the current complicated situation, those centers for animal disease control are still responsible for the veterinary safety assurance and livestock breeding. Currently, the state support in providing the centers with the basic means is carried out mainly through the targeted funding from the regional budget, but this process is now complicated due to the budget deficit.

Under such circumstances, it would be advisable to create a regional fund for all veterinary centers. Its main purpose would be the formation of a reserve to meet the needs of the centers in modern equipment and vehicles. By paying a fixed percentage of income the centers receive from rendering commercial services, they could get the necessary amount of money in priority sequence and consider the urgency of their needs. Such system of co-financing of the veterinary network would also contribute to the strengthening of relations between district veterinary centers, which are located in the areas dependent on the veterinary security.

The authors suggest differentiation of the payments made by the veterinary centers to this fund based on their technical equipment, staffing, and availability of additional income sources, such as veterinary laboratories. Therefore, the authors propose the following procedure for determining the ratio of payment to the fund for the development of the veterinary service:

$$H_s = H_b + H_d + H_a + H_t + H_p \tag{2}$$

where

H_s – ratio of subscription of a district center for animal disease control to the development fund;

H_b – basic ratio;

H_d – ratio of livestock density;

H_a– ratio related to the absence of a laboratory;

H_t– ratio related to the lack of financial and logistical support;

H_p– ratio related to the insufficient availability of staff.

The structure of the ratios was determined based on the opinions of the experts surveyed. The ratio of livestock density reflects the efficiency level of preventive measures carried out by the veterinary centers.

The ratio related to the absence of a veterinary laboratory reflects the opportunities of a veterinary center for additional income that could be received from laboratory examinations. The veterinary laboratory is an important element of the veterinary infrastructure of an area. Its availability and appropriate equipment enable carrying out timely diagnostics and possessing the relevant information on the local epizootic situation. Under the new financing system, those district veterinary centers which cannot run their own laboratories are forced to close them down and devolve the power of examinations to the laboratories in neighboring areas. It reduced their incomes and increased the timing of the diagnostic procedures.

The ratio related to the lack of financial and logistical support reflects the level of veterinary center's equipment necessary for effective veterinary practice. Availability of vehicles for the timely veterinary care, adequate equipment of veterinary centers and clinics for dangerous disease elimination are necessary to ensure the veterinary security of an area and contribute to food security and sustainable development of animal husbandry.

The ratio related to the insufficient availability of staff determines the degree of availability of the veterinary specialists for a district center for animal disease control for carrying out therapeutic and preventive measures. In the result of the staff structure optimization under the new financing system, some veterinary centers became unable to keep staff and cut it down to a minimum, which negatively affected the results of their work.

In order to determine the values of the ratios under discussion, it is necessary to define the common standards for the material and technical base renewal, which primarily reflect the amount of annual depreciation. In 2014, the aggregate amount of depreciation charges paid by the district centers for animal disease control in Stavropol region amounted to 15.2 million RUB. Corrected on the rate of inflation, the total amount of resource required to ensure the replacement was 16.2 million RUB. As the total value of income received from rendering commercial services amounted to 225.4 million RUB in 2014, the capital required for a creation of the development fund was 7.2% of the total income amount. Resources of the fund devoted for the replacement of normal assets, extended replacement, or equipment renewal.

Currently, the main source of funds covering the costs of technical equipment for the veterinary service are federal and regional target programs. Thus, using both targeted funding and reserves of the development fund, it would be possible to meet not only the most urgent needs of the veterinary centers in fixed assets but also to carry out assets replacement process in an innovative way. In order to create a fund that could completely finance the needs of the district veterinary centers, it should also receive funds allocated from the regional budget for target needs of the veterinary centers and determine the basic ratio for deductions to a fund. This ratio should be similar for all veterinary centers and should be supported by the differentiated ratios of payments presented in Table 3.

In the previous three years, the amount of the targeted funds allocated from the regional budget was 8.7 million RUB. When supplemented by the funds collected involving the differentiated coefficients (5.8 million RUB), the fund totals 14.5 million RUB, that covers 89.5% of needs. The rest of the funds can be raised using the basic ratio, which would be equal to 0.75%.

SOLUTIONS AND RECOMMENDATIONS

The ultimate goal of improving economic conditions of a district center for animal disease control should be related to the objective evaluation of the veterinary service and respective employee recognition. When assessing the performance of the veterinary service based on “ecosystem health” concept both the results of livestock breeding and social and ecological effects should be considered. It is reasonable to distinguish internal and external efficiency of infrastructure industries, which include veterinary medicine as well. The internal efficiency of an infrastructure industry is expressed in achieving its own goals. For the veterinary infrastructure, the internal efficiency means the rational use of resources and application of appropriate methods and tools for ensuring the health of a livestock.

The external efficiency is considered as a creation of economic benefits for the society, enabling sustainable development of an area. In relation to the veterinary infrastructure, such benefits include the prevention of dangerous animal disease outbreaks, reduction of human morbidity with anthropozoonosis, and mitigation of adverse environmental impact.

Table 3. Grouping of the districts by differentiated components of ratio of deductions to the development fund

1. Grouping by a livestock density		
Up to 15 livestock units/km^2 – ratio = 0.5%	15–30 livestock units/km^2 – ratio = 1.0%	Over 30 livestock units/km^2 – ratio = 1.5%
Aleksandrovskii, Andropovskii, Apanasenkovskii, Arzgirskii, Blagodarnenskii, Budennovskii, Grachevskii, Ipatovskii, Kirovskii, Kurskii, Mineralovodskii, Novoaleksandrovskii, Novoselitskii, Petrovskii, Predgornii, Sovetskii, Stepnovskii, Trunovskii, Turkmenskii	Georgievskii, Izobilnenskii, Krasnogvardeyskii, Levokumskii, Neftekumskii	Kochubeevskii, Shpakovskii
2. Grouping by an availability of a veterinary laboratory		
Not available – ratio = 0%	Available – ratio = 0.5%	
Andropovskii, Arzgirskii, Grachevskii	Aleksandrovskii, Apanasenkovskii, Blagodarnenskii, Budennovskii, Georgievskii, Izobilnenskii, Ipatovskii, Kochubeevskii, Krasnogvardeyskii, Kirovskii, Kurskii, Levokumskii, Mineralovodskii, Neftekumskii, Novoaleksandrovskii, Novoselitskii, Petrovskii, Predgornii, Sovetskii, Stepnovskii, Trunovskii, Turkmenskii, Shpakovskii	
3. Grouping by a level of financial and logistical support		
Low – ratio = 0%	Middle – ratio = 0.5%	High – ratio = 1.5%
Andropovskii, Arzgirskii, Georgievskii, Kurskii, Sovetskii, Trunovskii	Aleksandrovskii, Apanasenkovskii, Budennovskii, Georgievskii, Izobilnenskii, Kirovskii, Novoaleksandrovskii, Novoselitskii, Predgornii, Turkmenskii, Shpakovskii	Blagodarnenskii, Ipatovskii, Kochubeevskii, Krasnogvardeyskii, Levokumskii, Mineralovodskii, Neftekumskii, Stepnovskii, Petrovskii
4. Grouping by a level of staffing support		
Insufficient – ratio = 0%	Sufficient – ratio = 0.5%	
Andropovskii, Arzgirskii, Blagodarnenskii, Grachevskii, Kirovskii, Novoselitskii, Sovetskii, Trunovskii, Turkmenskii	Aleksandrovskii, Apanasenkovskii, Budennovskii, Georgievskii, Izobilnenskii, Ipatovskii, Kochubeevskii, Krasnogvardeyskii, Neftekumskii, Novoaleksandrovskii, Petrovskii, Predgornii, Stepnovskii, Shpakovskii	

Source: Authors' development

The Balanced Scorecard management system is considered to be an appropriate tool for the extended assessment of the performance results of a veterinary center (Kaplan & Norton, 2007). Many organizations worldwide adopt Balanced Scorecard as a strategic planning and performance management methodology. One of its main advantages is a transfer of focus from activities and projects on impacts when determining long-term strategy.

The authors recommend including targets of each veterinary center into a system of strategic goals in order to reduce the adverse environmental impact (including social aspects of this problem). For example, it may be a target of reducing human morbidity with such a dangerous disease as brucellosis, which is common for animals and human beings. Prevention of this disease remains relevant for many countries (Marcotty et al., 2013). According to the Balanced Scorecard concept, each target has a description (specific, measurable, achievable, realistic, and time-bound). When determining a target one should consider an area under assessment, level of morbidity, and time for achieving this target.

The second advantage of the Balanced Scorecard is an opportunity to translate strategy into action. This is implemented by involving employees into solving strategic goals by developing an adequate system of indicators. According to the survey made by the authors, veterinarians do not pay enough attention to the environmental effects. This case requires additional stimulation and cascade strategic targets for each team member. For this purpose, the system of measures for each target and metrics is developed. Thus, in the case of reducing human morbidity with brucellosis, such measures are immunization of the animals and detection of unaccounted livestock. The number of livestock examined and treated and promptness of the quarantine operations can be considered as metrics.

As stated earlier, the majority of the respondents think that improvement of the veterinary service in Stavropol region under the new conditions requires the development of financial incentives. It is advisable to pay bonuses to employees when they achieve the targeted values of the metrics, which reflect the contribution of veterinarians to the ensurance of food security and sustainable development of an area.

FUTURE RESEARCH DIRECTIONS

Veterinary care of livestock is of crucial importance for the successful livestock breeding. It also influences sustainable rural development. Scientists from all over the world study issues of a decrease in environmental pressure caused by the veterinary service including reduction of antibiotic treatments, disposal of biological waste, expansion of a variety of preventive measures, etc. However, the solution of these problems in emerging countries is complicated by a low level of veterinary medicine caused by an inadequate demand for veterinary services and lack of qualified staff and equipment. That is the reason why the further research of such issues is important in the light of their influence on food security and development of market relations in the sphere of veterinary medicine.

Another future research direction which is perspective in terms of the relations between the development of veterinary service and ensurance of food security is a link between the veterinary sector and the food chains, which is rather weak in the emerging countries. As of Bonnet, Lancelot, Martinez, and Seegers (2011), any health problems that occur in animal production have complex repercussions all the way along the food chains. That is why, in the emerging countries, the role of the veterinary service as one of the guarantors of the stability of the food chains has to be investigated.

The authors founded their research on the case of one administrative region of Russia. The methodology implemented may be spread on the investigation of the roles of the veterinary services in establishing food security in other regions of Russia, as well as other emerging countries.

CONCLUSION

Emerging countries make their first steps towards liberalization of their veterinary services. The expert survey held on the case of one of the regions of Russia demonstrated that the new system brought some positive results. However, some district centers for animal disease control faced their drawbacks. According to the survey results, veterinary medicine should be managed using the tools of competition promotion, demand stimulation, and smoothing consequences of market imperfections.

In order to improve the efficiency of the organizational and economic reform of the district centers for animal disease control, it is necessary to solve such problems as development and adjustment of prices of the commercial services differentiated according to the spatial parameters of an area. In addition, in order to smooth the conditions for manageable asset replacement process, it is advisable to create a fund for the development of veterinary medicine. A number of deductions to this fund would be calculated based on the ratio, which considers constraints of some district centers for animal disease control in the sphere of food security.

The effectiveness of a veterinary service in the broad sense should be regarded as an indicator of veterinary and food security of an area both in terms of internal and external effects. The former displays themselves in the results of the medical and health-promoting measures of reducing the livestock morbidity, the latter are reflected in the spheres which do not directly relate to the veterinary activities (public health service and environment). Practical application of the extended approach to the veterinary service assessment, taking into account its contribution to food security is possible through the use of the Balanced Scorecard. Strategic goals in the area of environmental impact can be transferred to a system of balanced targeting metrics, which promote motivation of veterinarians.

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KEY TERMS AND DEFINITIONS

Balanced Scorecard: A system for strategic planning and management used to align business activities to the vision and strategy of an organization, improve communications, and monitor organization performance.

Biological Waste: A biological material obtained because of clinical work and elimination of hotbeds of animal diseases.

Environmental Pressure: An activity that causes environmental change. It includes land use, extraction of resources, greenhouse gas emission, water use, and energy use.

Food Security: Availability of adequate food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in food production and food prices.

Sustainability: The quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance.

Veterinary Reform: A reform which objectives are to improve the quality, performance, and status of veterinary service.

Veterinary Service: A network of organizations which provide vital veterinary aid and ensure the quality of animal husbandry products.

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Chapter 12
Optimization of Dairy Feeding Models With C-SOMGA

Pratiksha Saxena
Gautam Buddha University, India

Dipti Singh
Gauatam Buddha University, India

Neha Khanna
Gauatam Buddha University, India

ABSTRACT

This chapter presents a self-organizing migrating genetic algorithm(C-SOMGA) for animal diet formulation. Bi-objective models for cost minimization and shelf life maximization are developed and objectives are achieved by combination of linear and C-SOMGA. Self-organizing migrating genetic algorithm provides exact and quick solution and an innovative approach towards successful application of soft computing technique in the area of animal diet formulation.

INTRODUCTION

Achievement of balanced ration of animals is very important from livestock as well as commercial point of view. Lack of balanced ration causes malnutrition in animals and they are not able to perform well in terms of high yields and reproductively. Therefore various mathematical models depending on different techniques have been widely used for animal ration formulation. Objective of animal ration formulation is to get a balanced ration at least cost which fulfill energy and nutrient requirements of animal. Standard linear programming technique has been extensively used for least cost ration formulation in 19th century (Deseit, 2009). Several mathematical models were formulated using linear programming method to get ration which supply required nutrients at minimum cost. A linear programming model was developed to get the least cost ration for drought maintenance of dry adult sheep. Results shows that sheep can be fully maintained at an approximate cost of one cent per head per day (Vere, 1972). A model, named the Grange Beef Model, was presented to find optimal beef production systems in Ireland. A series of

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scenarios concerning variation in beef and concentrate prices were used to explain model applications (Crosson, Kiely, Mara & Wallace, 2006). Linear programming technique was used for finding the least cost ration for broilers of age 6 to 10 weeks for the utilization of locally available and non- conventional feed stuff-Duckweed (Lemna paucicostata). The result shows the reduction of cost of feed by 20.82% with utilization of feed mix having 29.50% of duckweed and therefore improve profitability in broiler production (Olorunfemi & Temitope, 2006). A linear model was developed for the Nigerian poultry industry and data for this has been taken from a typical commercial farm. It has been observed that cost was reduced by 9% compared to the existing practice(Oladokun & Johnson, 2012).

An LP model was developed for least cost poultry ration in which elements of the tableau are stochastic. Results shows that less time and complexity is involved compared to alternative methods. The limitations imposed by lack of data and of biological minima was the largest obstacle in the examination of related problems(Rahman & Bender, 1971). An LP model with 8 ingredients and 18 constraints was developed for getting optimized shrimp feed mix. Growth tests were carried out with Penaeus japonicus over periods of more than 30 days. To determine the physiological state of shrimps after the experiment, some analyses were conducted on haemolymph. Results showed reduction in cost of nearly 30%, without any significant loss in growth performance (Barbieri & Cuzon, 1980). LP technique with the aid of an electronic computer was used to develop the models for the optimized fattening rations of weaner calves. Nutrients used in the model are digestible energy or estimated net energy, crude protein, crude fiber, calcium and phosphorus. Chemical analysis demonstrate a quite good agreement between specifications and analyses for crude protein, crude fiber and phosphorus. Animal performance data showed that estimated net energy was superior to digestible energy as a basis of ration formulation (Church, Brown & Ralston, 1963). An optimization method was used for a beef cattle fattening system to determine the utilization of food by-products under various situations. Later on reduction of feed costs and nitrogen and phosphorus excretions were also discussed in the method (Jayasuriya).

A model was developed using linear approximation of chance-constrained programming (CCP). In this model, linear codes are used to approximate the non-linear form of chance constraints (Olson & Swenseth, 1987).

The variability in the nutrient composition of the feed ingredients can have a negative impact on the growth of the animals as well as on the cost. Therefore it is essential to consider this variation during the development of the models for animal feed mix formulation. Stochastic programming models have been used to deal with the nutrient variability. These models are developed to incorporate nutrient variability. Tozer developed a model to achieve a final calving weight of 600 kg for large-breed replacement dairy heifers. A base linear program was developed and then variability of crude protein(CP) content of ration ingredients was incorporated by three methods; right-hand side adjustment, incorporation of a safety margin and stochastic programming (SP)(Tozer, 2000). A model is developed using stochastic programming technique to incorporate nutrient variability in least cost feed formulation for African catfish. The objective was to minimize the risk of not meeting the nutrient requirements through under formulation and over formulation which will result in high cost (Udo, Ndome & Asuquo, 2011).

Though standard linear programming technique is mostly used for formulating animal feed mix problems, it has the weaknesses such as optimization of a single objective function only, rigidity of the constraints etc. Goal programming is used in combination with linear programming to get better results. Numerous models were developed using goal programming technique. GP is presented as a method of achieving nutritional balance in selected feed mix. GP is used to develop the model with one hundred and fifty food raw materials to satisfy the daily nutritional requirements of Thais. Results obtained by

GP showed a marked improvement over those of LP (Anderson & Earle, 1983). Linear programming is combined with weighted goal programming to develop a non-parametric model. In this model multiple goals have been taken for optimization. The model was tested for optimization of winter and summer feed mix. Results showed that summer feed rations are more expensive but more balanced. The weighted goal programming technique has provided more practical and useful results in practice as compared to linear programming, where only one goal can be optimized at a time(Prišenk et al., 2013). A goal programming model was developed to obtain an optimal feed mix for livestock feed. The goals of meal quality and different requirements of decision makers are modeled by goal programming (Zoran & Tunjo, 2011). Romero and Rehman reported that GP applied to feed mix planning offers little improvement over standard LP techniques (Romero & Rehman, 1984). A paper was presented to develop a new model for the optimization of feed rations for active and trained sport horses. The model was structured on two different sub-models, the first submodel was based on the linear programming (LP) technique and the second on weighted-goal programming (WGP). The model was tested under two different WGP scenarios to formulate two different feed rations. It has been found that feed rations calculated with the modified WGP technique are more balanced, and the costs of feed rations are lower as compared with LP. The ration was about 10% cheaper and there were no surpluses of any nutrient (Prišenk, Pažek, Rozman, Turk & Borec Andreja, 2013).

MATERIAL AND METHODS

Animal feed mix is formulated to achieve specific objectives like minimization of cost, maximization of milk yield, maximization of shelf life etc. These objectives can be achieved by determination of optimum values of feed ingredients. Main consideration is to be given to cost of nutrient ingredients, feed quality and requirement of animal at different stages of livestock while evaluating optimum values of feed ingredients. In this paper, the research objectives are taken as minimization for different weight stages and maximization of nutritional value and shelf life of the feed blend. For the preparation of an optimal feed, following criteria should be considered: cost of the feed ingredients, nutrient required for maximization of weight gain and quantity of nutrient ingredients for maximum quality of the feed blend.

This research work is carried out to achieve two objectives:

1. To formulate a feed blend containing feed components at minimum cost for different stages of livestock.
2. To maximize the feed blend quality in terms of its shelf life.

Maximum weight gain can be achieved by maximizing the nutrient value of the feed components. It can be achieved by choosing those feed components that contain high digestibility ingredients. Higher digestibility ensures higher weight gain, which reduces feed costs. Shelf life of a feed blend can be increased by reducing the water content of water. Reduced water content allows reduced feed costs at same weight gain with a smaller feed blend quantity. Linear programming is used for the first phase of this work where both of these objectives are achieved by standard technique of linear programming. Linear programming is used to achieve these objectives for different stages of livestock. These stages are categorized as for weight gain of 200 Kg., 300 Kg., 450 Kg. and 680 Kg. To overcome the deterministic assumption of linear programming technique and to include variability of nutrient ingredient in the feed mix, stochastic programming is used in the second phase of this research work. These two weaknesses of mathematical formulations are removed by the use of stochastic programming. Results are calculated by the help of software LINGO and TORA. In the third phase of this work, a new technique C-SOMGA is introduced to evaluate and compare the results.

In this chapter a hybridized Constrained Self Organizing Migrating Genetic Algorithm (C-SOMGA) has been used to solve this problem. This algorithm is inspired by the features of Self Organizing Migrating Algorithm (SOMA). SOMA is an emergent search technique based on the self organizing behavior of groups of individuals in a social environment. Like other evolutionary algorithm, it also works with a population of solutions. The main feature of this algorithm which distinguishes it from other algorithms is that no new solutions are created during the search. Instead, only the positions of the solutions are changed during a generation, called a migration loop. The details of this algorithm can be found in many research papers and books Oplatkova and Zelinka (2005), Zelinka (2002), Nolle and Zelinka (2003), Nolle et al (2005), Nolle (2007), Zelinka et al (2004), zelinka et al (2001), Onwubolu and Babu (2004), etc.

SOMGA is a hybridized variant of GA and SOMA for solving unconstrained optimization problems, proposed by Deep and Dipti (2007), in which the features of both GA and SOMA are utilized in such a way that diversity of the search domain can be maintained by newly generated points and can be thoroughly exploited. The direction of the search can be little bit guided and competitive-cooperative behavior can achieve the global optimal solution with a small population size in less number of function evaluations. The common feature between GA and SOMA is that both are population based stochastic search heuristics. Mutation and crossover is done (but the way in which they are applied is different). Later SOMGA has been extended to solve constrained optimization problem and Constrained Self Organizing Migrating Genetic Algorithm (C-SOMGA) came into the picture. The details of this algorithm can be seen in Deep and Dipti (2008, 2009, 2012).

Before discussing the working of C-SOMGA, it is important to discuss the methodology of tournament selection used in the working of C-SOMGA. The main reason to choose this selection is that it does not require any parameter to be fine tuned for constraint handling and works with a very low population size.

TOURNAMENT SELECTION IN CONSTRAINED OPTIMIZATION

The tournament selection method seems to be more effective method while solving constrained nonlinear optimization problems. This selection picks up the better solution, in terms of function fitness, for the next generation. Thus this selection does not depend on the nature of the problem under consideration. Both maximization and minimization problems are treated in the same way because tournament selection will choose a better solution in both the cases. For a minimization problem, the solution with the smaller fitness value is selected and kept in an intermediate population, whereas for a maximization problem, the solution with a higher fitness is selected. It is also possible to transform a maximization problem to a minimization problem using the identity

$$Max\ \left\{f\left(x\right)\right\}\ = -min\ \left\{-f\left(x\right)\right\}$$

For the constrained optimization, the tournament selection method is less sensitive to the choice of the penalty function. In most cases the constant penalty method with a great value of the penalty coefficient will produce good results. Kundu and Osyczka (1996) showed that tournament selection gives better results while solving multicriteria constrained optimization problems using the distance method. Deb (1997 a) used tournament selection in his genetic adaptive search method and applied it to solve several mechanical design problems, which are also highly constrained problems. Osyczka et al (1999) showed that tournament selection gives better results while solving a constrained function minimization problem. This whole information is taken from Osyczka (2002).

In this section a tournament selection method developed by Osyczka and Krenich (1999) is discussed. This method is very effective while solving highly constrained single criterion optimization problems as well as the problems with computationally expensive objective function. Description of the method is given below:

In this method the tournament between two chromosomes is carried out in the following way:

1. If both chromosomes are not in the feasible region the one which is closer to the feasible region is taken to the next generation. The values of the objective function are not calculated for either of chromosomes.
2. If one chromosome is in the feasible region and the other one is out of the feasible region the one which is in the feasible region is taken to the next generation. The values of the objective function are not calculated for either chromosome.
3. If both chromosomes are in the feasible region, the values of the objective function are calculated for both chromosomes and the one, which has a better value of the objective function, is taken to the next generation.

The constraint violation function can be evaluated as follows:

$$\psi(x) = \sum_{m=1}^{M} \left[h_m(x) \right]^2 + \sum_{k=1}^{K} G_k \left[g_k(x) \right]^2$$

where G_k is the Heaviside operator such that $G_k = 0$ for $g_k(x) \geq 0$ and $G_k = 1$ for $g_k(x) < 0$.

It is clear that for the solutions which are in the feasible region, the value of constraint violation function equation (4.2) equals zero and for those which are out of feasible region the value of $\psi(x)$ indicates how far the solutions are from the feasible region. In the tournament selection method a comparison between violated solutions is made and the one which is less violated, i.e., which is closer to the feasible region, will be chosen for the next generation. The main idea of the constraint tournament selection method is illustrated graphically in Figure 1.

METHODOLOGY OF C-SOMGA

In this section the methodology of hybridized Self Organizing Migrating Genetic Algorithm called C-SOMGA for constrained nonlinear optimization problem has been discussed. The methodology of this algorithm is as follows:

First the individuals are generated randomly. These individuals compete with each other through constraint tournament selection method. The methodology of this tournament selection method is described in section …, create new individuals via single point crossover and bitwise mutation. Then the best individual among them is considered as leader and all others are considered as active. For each active individual a new population of size N is created. Where N=path length/step size. This population is nothing but the new positions of the active individual, proceeds in the direction of the leader in n steps of the defined length. This path is perturbed randomly by a parameter called as PRT parameter. It is defined in the range <0, 1>. A PRT vector is created using PRT parameter value, before an individual proceeds towards leader. The movement of an individual is given as follows:

$$x_{i,j}^{MLnew} = x_{i,j,start}^{ML} + \left(x_{L,j}^{ML} - x_{i,j,start}^{ML}\right) tPRTVector_j$$

$$where \quad t \in < 0, by\, Step\, to, PathLength >,$$

ML is actual migration loop.
$x_{i,j}^{MLnew}$ is the new positions of an individual.
$x_{i,j,start}^{ML}$ is the positions of active individual.
$x_{L,j}^{ML}$ is the positions of leader.

Then sort this population according to the fitness value in decreasing order. Starting from the best one of the new population evaluate the constraint violation function described in equation (4.2). If $\psi\left(x\right)=0$, replace the active individual with the current position and move to the next active individual. And If $\psi\left(x\right)\succ 0$ then move to the next best position of the sorted new population. In this way, all the active individuals are replaced by the new updated feasible position. If no feasible solution is available then active individual remains the same. At last the best individuals (number equal to population size) from the previous and current generations are selected for the next generation. The computational steps of this approach are given below:

Step 1: Generate the initial population.
Step 2: Evaluate all individuals.
Step 3: Apply tournament selection for constrained optimization as explained in Section 4.2, on all individuals to select the better individuals for the next generation.
Step 4: Apply crossover operator on all individuals with crossover probability P_c to produce new individuals.
Step 5: Evaluate the new individuals.
Step 6: Apply mutation operator on every bit of every individual of the population with mutation probability P_m.
Step 7: Evaluate the mutated individuals.
Step 8: Find leader (best fitted individual) of the population and consider all others as active individuals of the population.

Step 9: For each active individual a new population of size N is created. This population is nothing but the new positions of the active individual towards the leader in n steps of the defined length. The movement of this individual is given in equation (3.2).

Step 9.1: Sort new population with respect to fitness in decreasing order.

Step 9.2: For each individual in the sorted population, check feasibility criterion.

Step 9.3: If feasibility criterion is satisfied replace the active individual with the new position, else move to next position in sort order and go to step 9.2.

Step 10: Select the best individuals (in fitness) of previous and current generation for the next generation via tournament selection.

Step 11: If termination criterion is satisfied stop else go to step 3.

Step 12: Report the best chromosome as the final optimal solution.

INPUT DATA FOR DETERMINATION OF FEED BLEND

Let us introduce the following notations:

z objective function, c_j per unit cost of feed ingredient j, x_j quantity of jth feed ingredient in the feed mix, a_{ij} amount of nutrient i available in the feed ingredient j, b_i minimum requirement of ith nutrient, i index identifying feed nutrient components with i = 1,2,….m, j index identifying feed components with j =1,2,………n

These models consist of 16 feed ingredients and 6 nutrient ingredients for optimization of feed blend. Input data for feed ingredients with cost, water content and nutritional composition is shown in table 1.

Figure 1. The constraint tournament method

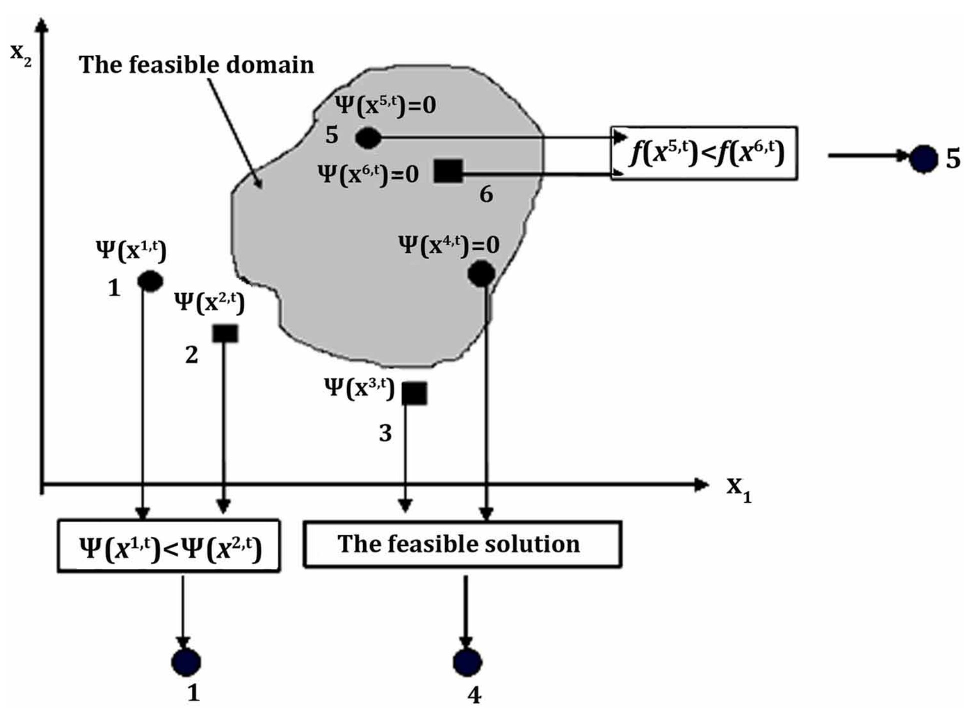

Table 1. Composition of feed ingredients

Notation	Feed Ingredient	Price (Rs./ Kg.)	Water Content (on the Basis of DM)	Metabolizable Energy(ME) (mj/kg of feed)	Crude Protein (CP)(g/ kg)	NDF (g/kg)	DM (g/kg)	Ca (g/kg)	P (g/kg)
x_1	Alfalfa hay	14	.11	7.51	163	400	894	15	2.3
x_2	Barley grain	10	.13	10.80	103	189	871	0.7	3.4
x_3	Sugarbeetpulp	15	.11	9.99	83	429	892	13.83	0.89
x_4	Cottonseed meal (high fibre, low oil)	18	.10	9.2	360	330	902	2.62	11
x_5	Soyabean meal(high protein- dehulled)	28	.12	11.98	471	97	881	3.17	6.70
x_6	Sunflower meal(solvent-extracted, dehulled or non-dehulled)	16	.11	8.10	288	400	890	3.92	10.32
x_7	Wheat bran	19	.13	9.57	151	394	870	1.22	9.66
x_8	Maize grain high moisture	23	.35	8.84	62	89	650	0.32	2.01
x_9	Sorghum grain	17	.13	11.80	94	96	874	0.26	2.88
x_{10}	Groundnut meal(solvent-extracted)	25	.11	11.16	489	217	893	1.52	5.54
x_{11}	Rice bran(fibre 11-20%)	10	.10	9.11	115	310	902	0.63	12.45
x_{12}	Oats grain	18	.12	8.70	97	314	879	0.97	3.16
x_{13}	Wheat straw	7	.09	6.19	38	706	910	4.37	0.64
x_{14}	Corn gluten feed	14	.12	10.77	192	350	883	1.41	9.01
x_{15}	Canola meal(solvent-extracted)	24	.10	10.54	351	242	901	6.67	10.45
x_{16}	Cottonseed hulls	11	.10	5.89	46	773	906	1.18	0.91

Table 2. Minimum Requirement for different nutrients at different weight of dairy cow to reach at 680 kg weight

Nutrient	200 kg	300 kg	450 kg	680 kg
ME	8.54	9.54	7.49	6.28
CP	127	123	94	155
NDF	315	315	315	300
DM	5200	7100	11300	23600
Ca	11.3	15	13	10
P	9.1	10.6	13	5

Linear Programming Model for Determination of Feed Blend for Cost and Water Content Minimization

$$Min \;\; z = \sum c_j x_j \qquad Min \;\; z = \sum c_j x_j \qquad Min \;\; z = \sum c_j x_j$$

$$s.t. \sum_{j=1}^{n} a_{ij} x_j \geq b_i \qquad s.t. \sum_{j=1}^{n} a_{ij} x_j \geq b_i \qquad s.t. \sum_{j=1}^{n} a_{ij} x_j \geq b_i$$

$$0 \leq x_i \leq 0.10 (i = 1, 2, \ldots 16) \quad 0 \leq x_i \leq 0.15 (i = 1, 2, \ldots 16) \quad 0 \leq x_i \leq 0.20 (i = 1, 2, \ldots 16)$$

$$x_j \geq 0, b_i \geq 0 \qquad x_j \geq 0, b_i \geq 0 \qquad x_j \geq 0, b_i \geq 0$$

These three models represent objective function as minimization of cost under defined constraints. In these three linear models, an additional constraint is included to the basic least cost ration model, which makes it different from the previous work in this field. This constraint is added as upper bound for the feed ingredients. This level if set as 0.10, 0.15 and 0.20 per unit. These models are developed for four different weight classes 200 Kg., 300 Kg., 450 Kg. and 680 Kg. 12 models are developed for cost minimization for different stages of livestock. Linear programming model is formulated for determination of optimum values of feed ingredients to achieve weight at different stages of livestock. This model is divided in to four sub models to:

1. Minimize the per kg cost of ration of dairy cow of weight 680 kg.
2. Minimize the per kg cost of ration of dairy cow of weight 200 kg to reach the weight 680 kg.
3. Minimize the per kg cost of ration of dairy cow of weight 300 kg. to reach the weight 680 kg.
4. Minimize the per kg cost of ration of dairy cow of weight 450 kg to reach the weight 680 kg.

These are 12 models for cost minimization by linear programming and it is associated with optimization of nutrient variables to reach different weight classes. Linear programming model is also formulated to maximize the feed blend quality in terms of its shelf life. It can be done by minimizing the water content of the feed blend. This model is sub divided in to four models. These models are formulated to obtain optimum values of feed components to

5. Minimize the water content of ration of dairy cow of weight 680 kg.
6. Minimize the water content of ration of dairy cow of weight 200 kg to reach the weight 680 kg.
7. Minimize the water content of ration of dairy cow of weight 300 kg to reach the weight 680 kg.
8. Minimize the water content of ration of dairy cow of weight 450kg to reach the weight of 680 kg.

After formulating the models by linear programming, nutrient variability is included in these models by the use of stochastic programming.

Stochastic Programming Model for Determination of Feed Blend for Cost and Water Content Minimization

$$\min \ z = \sum c_j x_j$$
$$s.t. \sum_{j=1}^{n} \left(a_{ij} - z \left(\sqrt{\sum_{j=1}^{n} \sigma_{ij}^{\ 2}} \right) \right) x_j \geq b_i$$
$$0 \leq x_i \leq 0.10 (i = 1, 2, ...16)$$
$$x_j \geq 0, b_i \geq 0$$

$$\min \ z = \sum c_j x_j$$
$$s.t. \sum_{j=1}^{n} \left(a_{ij} - z \left(\sqrt{\sum_{j=1}^{n} \sigma_{ij}^{\ 2}} \right) \right) x_j \geq b_i$$
$$0 \leq x_i \leq 0.15 (i = 1, 2, ...16)$$
$$x_j \geq 0, b_i \geq 0$$

$$\min \ z = \sum c_j x_j$$
$$s.t. \sum_{j=1}^{n} \left(a_{ij} - z \left(\sqrt{\sum_{j=1}^{n} \sigma_{ij}^{\ 2}} \right) \right) x_j \geq b_i$$
$$0 \leq x_i \leq 0.20 (i = 1, 2, \ldots 16)$$
$$x_j \geq 0, b_i \geq 0$$

Stochastic models are very much similar of LP models, but the only difference is inclusion of nutrient variability. It is introduced as nonlinear variance of each nutrient ingredient and a desired probability level. $\sigma_{ij}^{\ 2}$ represents variance of nutrient i in ingredient j and it is included with a certain probability level, rest of the variables are defined as above . This model is formulated assuming probability of 80% which takes the variability of nutritional values of feed component. This assumption implies that there is 80% probability that a ration contains the desired level of nutrients. Value of z is 2.33 for this level of probability. In this model, it is important to define a certain value of nutrient. The requested probability determines the nutrient concentration for ration formulation. This model is very much similar to the linear programming model, but the only difference is in the constraint term. Variability of nutrient is taken in to account as a nonlinear term of variance in each feed component and a desired probability level. Again eight models are formulated for sixteen feed components to obtain optimum value of variables to reach at specific levels of livestock. Water content is again minimized to increase the shelf life of ration.

Stochastic programming model is formulated for determination of optimum values of feed ingredients to achieve weight at different stages of livestock. This model is divided in to four sub models to:

1. Minimize the per kg cost of ration of dairy cow of weight 680 kg.
2. Minimize the per kg cost of ration of dairy cow of weight 200 kg to reach the weight 680 kg.
3. Minimize the per kg cost of ration of dairy cow of weight 300 kg. to reach the weight 680 kg.
4. Minimize the per kg cost of ration of dairy cow of weight 450 kg to reach the weight 680 kg.

Stochastic programming model is also formulated to maximize the feed blend quality in terms of its shelf life. It can be done by minimizing the water content of the feed blend. This model is sub divided in to four models. These models are formulated to obtain optimum values of feed components to

5. Minimize the water content of ration of dairy cow of weight 680 kg.
6. Minimize the water content of ration of dairy cow of weight 200 kg to reach the weight 680 kg.
7. Minimize the water content of ration of dairy cow of weight 300 kg to reach the weight 680 kg.
8. Minimize the water content of ration of dairy cow of weight 450kg to reach the weight of 680 kg.

In this chapter 48 models are formulated and optimized values for feed components are obtained firstly by linear programming, stochastic programming and then by C-SOMGA technique.

DISCUSSION

48 models are formed and obtained solution provides optimum values of feed ingredients for minimum cost and for minimum water content to reach different weight class of dairy cattle. 48 models are presented and analyzed by the blend of linear programming, stochastic programming and C-SOMGA. Table 3 represents minimum cost and minimum water content for different level of livestock by using C-SOMGA technique.

Table 3 is representing optimum value of nutrient ingredients for cost minimization for linear models. Similarly models are solved for maximum shelf life, which is obtained by minimizing the water content in the ration. Table 4 represents solution values for water content minimization in the ration.

Graphical view of results for values of decision variables for cost minimization and water content minimization by linear models are represented by figure 2 and figure 3 respectively.

There may be inherent variation in the nutrient composition of the feed ingredients. This variation in nutrient content can have a negative impact on the growth rate of the animals as well as on the cost. Therefore to reduce the risk of not meeting the nutrient requirements by under or over formulation, it is essential to consider this variation while developing the models for animal feed mix formulation. Stochastic programming model is an appropriate tool to incorporate nutrient variability of feed ingredients. These models have been developed to deal with nutrient variability. Using Stochastic Programming models results can be improved in terms of nutrient variability. Table 5 contains values for feed ingredients to minimize cost optimally by use of stochastic programming and table 6 contains optimum values of feed ingredients for minimum water content of the ration.

Figure 4 represents the graphical results for minimization of cost and Figure 5 for minimization of water content from feed mix for better shelf quality of meal for different stages of livestock.

Table 3. Optimum values of nutrient ingredients for cost minimization (Linear Models)

Variables	Cost 200 kg ub=0.1	Cost 200 kg ub=0.15	Cost 200 kg ub=0.20	Cost 300 kg ub=0.1	Cost 300 kg ub=0.15	Cost 300 kg ub=0.2
X_1	0.0342075	0.0676047	0.00361367	0.0544279	0.0477362	0.032699
X_2	0.0551405	0.00106444	0.000250626	0.0967256	0.0260412	0.000173378
X_3	0.0927192	0.0898489	0.045884	0.0966768	0.13331	0.0689805
X_4	0.00833407	0.0611719	0.00202694	0.006351	0.0016664	0.0291771
X_5	0.0214521	0.0311689	0.0228798	0.0128067	0.0029799	0.014694
X_6	0.00158224	0.0238093	0.0677725	3.84331e-05	0.0242156	0.000283432
X_7	0.0962783	0.105772	0.152262	0.0998876	0.147138	0.191508
X_8	0.0999954	0.149761	0.199959	0.0999578	0.149997	0.199755
X_9	0.086565	0.109345	0.0420908	0.0999972	0.149879	0.152787
X_{10}	0.0410566	0.00638624	0.00310002	0.00240555	0.0212647	0.0100994
X_{11}	0.031434	0.0115196	0.000335312	0.0581514	0.042302	4.92096e-05
X_{12}	0.0989161	0.143177	0.199869	0.0849461	0.14811	0.199098
X_{13}	0.0657946	0.00553566	0.00031929	0.032671	0.00306201	0.000565911
X_{14}	0.0628199	0.0116302	0.0536358	0.045442	0.00128274	3.01361e-05
X_{15}	0.0399842	0.00891739	0.0446789	0.0767092	0.0376963	0.0274864
X_{16}	0.0810905	0.117546	0.112316	0.0899219	0.0796585	0.104647
Objective Function Value	15.1108	16.5333	17.4498	15.4155	17.6637	18.9177
Variables	**Cost 450 kg ub=0.1**	**Cost 450 kg ub=0.15**	**Cost 450 kg ub=0.20**	**Cost 680 kg ub=0.1**	**Cost 680 kg ub=0.15**	**Cost 680 kg ub=0.2**
X_1	0.0825456	0.0442632	0.022361	0.0800332	0.0162316	0.0825456
X_2	0.0550896	0.0405055	0.000634194	1.4019e-05	0.000105858	0.0550896
X_3	0.0991122	0.091767	0.065923	0.00831052	0.0142913	0.0991122
X_4	0.00968047	0.00275717	0.00215759	0.0349037	0.00930892	0.00968047
X_5	0.0171362	0.00230284	0.0184506	0.0936927	0.104527	0.0171362
X_6	0.000160217	0.0415033	0.0197451	0.0187745	0.0254485	0.000160217
X_7	0.0998585	0.0641026	0.0738881	0.086401	0.0523074	0.0998585
X_8	0.09998	0.149831	0.199072	0.0997573	0.149998	0.09998
X_9	0.0992763	0.0988205	0.0558949	0.0010294	0.00624061	0.0992763
X_{10}	0.00928107	0.00871111	0.00390416	0.0471561	0.0577952	0.00928107
X_{11}	0.0088853	0.00015707	0.000659753	0.00069275	9.44138e-06	0.0088853
X_{12}	0.0999606	0.147486	0.184117	0.0615755	0.0444675	0.0999606
X_{13}	0.0332873	0.00317245	0.00102139	0.0192806	0.000770903	0.0332873
X_{14}	0.0059721	3.84808e-05	0.00100899	0.000343418	0.000112295	0.0059721
X_{15}	0.00615674	0.0257721	0.0350746	0.0796865	0.107438	0.00615674
X_{16}	0.0999894	0.107607	0.185243	0.042116	0.0678509	0.0999894
Objective Function Value	13.4188	14.2225	15.4314	13.5606	14.0713	13.4188

Table 4. Optimum values of nutrient ingredients for water content minimization (Linear Models)

Variables	Water 200 kg ub=0.1	Water 200 kg ub=0.15	Water 200 kg ub=0.20	Water 300 kg ub=0.1	Water 300 kg ub=0.15	Water 300 kg ub=0.2
X_1	0.0738959	0.0156073	0.0904321	0.0441485	0.0715631	0.0277567
X_2	0.0844957	0.0409464	0.0929421	0.0990306	0.142205	0.178975
X_3	0.0907998	0.0871155	0.00822621	0.0756145	0.0580329	0.016692
X_4	0.0382284	0.00591817	0.00260906	0.00463696	0.000670767	0.015511
X_5	0.0450658	0.0764982	0.0197453	0.0231754	0.0133181	0.0162571
X_6	0.00114441	0.0202054	0.0234457	0.000695134	0.00939346	0.015497
X_7	0.092794	0.0519761	0.0198694	0.0981808	0.115134	0.061756
X_8	0.0999765	0.14981	0.199472	0.0999418	0.149971	0.199663
X_9	0.0977361	0.0720591	0.0878106	0.0998439	0.129227	0.129038
X_{10}	0.0018652	0.00103784	0.00567494	0.0318	0.00867535	0.00368481
X_{11}	0.0351922	0.104873	0.0709904	0.0980447	0.0455196	0.0162258
X_{12}	0.0881292	0.114131	0.118098	0.0981462	0.14994	0.184453
X_{13}	0.0895298	0.0119516	0.118669	0.0448313	0.100221	0.0226967
X_{14}	0.0293279	0.0238728	0.0388192	0.0441783	0.00157328	0.0083458
X_{15}	0.00180035	0.0154029	0.00382443	0.0160032	0.00648051	0.000613022
X_{16}	0.0580889	0.144359	0.0684821	0.0849494	0.0287055	0.145525
Objective Function Value	0.130084	0.141388	0.156422	0.134603	0.155924	0.169868
	Water 450 kg ub=0.1	**Water 450 kg ub=0.15**	**Water 450 kg ub=0.20**	**Water 600 kg ub=0.1**	**Water 600 kg ub=0.15**	**Water 600 kg ub=0.1**
X_1	0.0478349	0.0138783	0.0860692	0.096819	0.148497	0.0786559
X_2	0.0426554	0.0488914	0.078818	0.0826429	0.00652729	0.0184784
X_3	0.0915907	0.0191461	0.0726914	0.003407	0.0034102	0.00811101
X_4	0.0180621	0.00664316	0.00930825	0.0429225	0.000944568	0.000815011
X_5	0.0199062	0.00441528	0.00949727	0.000670529	0.00060196	0.000168228
X_6	0.000370026	0.00507217	0.014011	0.0954552	0.0381795	0.0100208
X_7	0.0673689	0.0809024	0.0580617	0.0363758	0.0683169	0.0507802
X_8	0.0989412	0.149727	0.199455	0.099968	0.149908	0.199564
X_9	0.098617	0.106693	0.00500641	0.00766993	0.0759598	0.0285937
X_{10}	0.00583277	0.0293518	0.000867844	0.000289822	0.000229168	0.00198708
X_{11}	0.0602954	0.127428	0.153553	0.0260412	0.00186653	0.013974
X_{12}	0.0423991	0.0116083	0.0399065	0.0906606	0.0696716	0.139228
X_{13}	0.0996545	0.125894	0.0651911	0.0835904	0.0524038	0.0350443
X_{14}	0.0493839	0.0259541	0.00655556	0.00890923	0.00236306	0.00166016
X_{15}	0.0031291	0.0125196	0.0111666	0.00244484	0.00146771	0.00527039
X_{16}	0.0846297	0.0633217	0.0378142	0.0778945	0.147084	0.183196
Objective Function Value	0.116755	0.127926	0.141121	0.107497	0.121576	0.13384

Figure 2. Values of decision variables for cost minimization by linear models

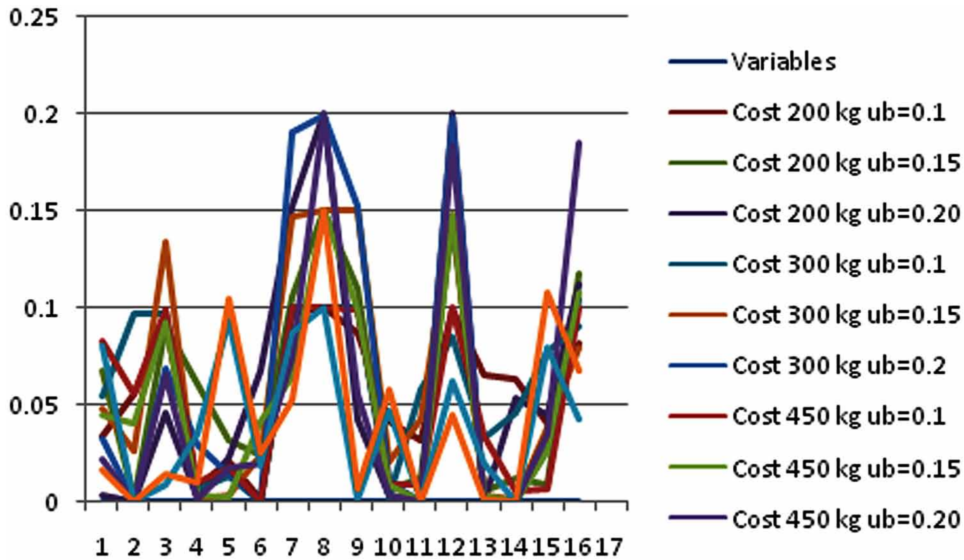

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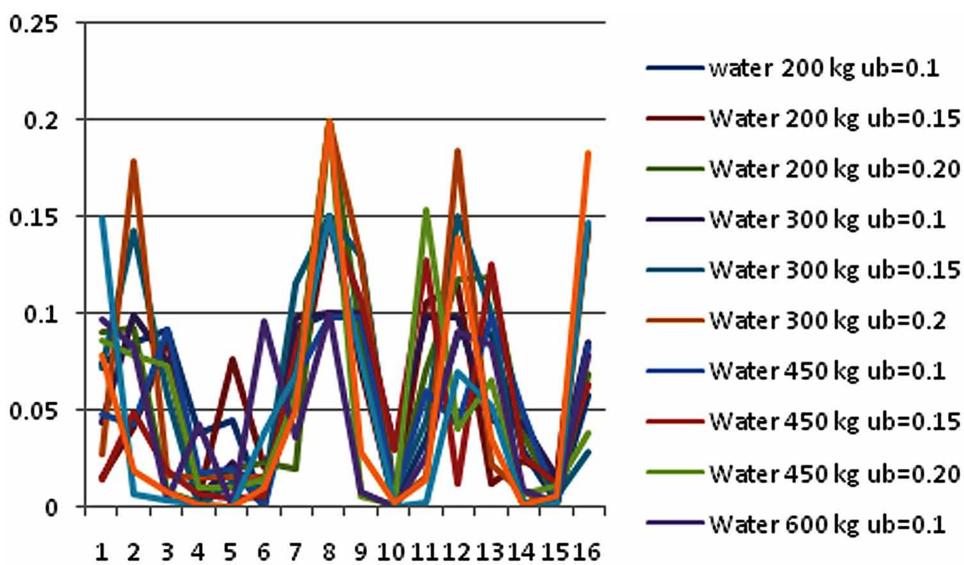
Figure 3. Values of decision variables for water content minimization by linear models



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Analysis of results obtained for cost minimization shows that value of feed components can be obtained for different weight class. Linear programming models and stochastic models are used with the constraints such that all nutrients at least achieve the NRC requirements. It is analyzed that when cost is optimized by stochastic programming technique, it is providing the better results in the sense of nutritional variability as compared to linear programming technique. It is better in the sense of variability of nutrient components at slightly higher cost. Table 3 represents the total costs for a feed blend to

Table 5. Values for decision variables for cost minimization by stochastic model

Variables	Cost 200 kg ub=0.1	Cost 200 kg ub=0.15	Cost 200 kg ub=0.20	Cost 300 kg ub=0.1	Cost 300 kg ub=0.15	Cost 300 kg ub=0.2
X_1	0.0575046	0.0575046	0.0774979	0.0221009	0.0196571	0.0735432
X_2	0.0675637	0.0675637	0.0964534	0.0998005	0.148364	0.14002
X_3	0.133783	0.133783	0.198915	0.0998877	0.146127	0.0297688
X_4	0.00985523	0.00985523	0.0197973	0.012271	0.000679494	0.0647906
X_5	0.058943	0.058943	0.0149485	0.0120235	0.0162174	0.0334626
X_6	0.00088234	0.00088234	0.000552178	0.0282353	0.00026021	0.00270367
X_7	0.0605103	0.0605103	0.0591595	0.0996277	0.149784	0.0196005
X_8	0.149999	0.149999	0.199997	0.0999988	0.149697	0.199945
X_9	0.149996	0.149996	0.188569	0.0998772	0.149991	0.197875
X_{10}	0.0207545	0.0207545	0.0128477	0.022066	9.18389e-05	0.00392266
X_{11}	0.0241222	0.0241222	0.0163019	0.095592	0.0431298	0.0582299
X_{12}	0.146574	0.146574	0.199923	0.0998588	0.149974	0.075351
X_{13}	0.0388513	0.0388513	0.000801087	0.0722028	0.025562	0.173592
X_{14}	0.00566211	0.00566211	0.00950242	0.0336768	0.0342993	0.000459099
X_{15}	0.0216264	0.0216264	0.0282252	0.0428288	0.0459179	0.00975343
X_{16}	0.107327	0.107327	0.0619164	0.0584854	0.0542452	0.0310679
Objective Function Value	17.9282	17.9282	20.3266	15.659	18.751	17.1919
Variables	**Cost 450 kg ub=0.1**	**Cost 450 kg ub=0.15**	**Cost 450 kg ub=0.20**	**Cost 680 kg ub=0.1**	**Cost 680 kg ub=0.15**	**Cost 680 kgub=0.2**
X_1	0.0660571	0.000584364	0.000359154	0.0342404	0.0115959	0.0125849
X_2	0.0577473	0.0506469	0.0161408	0.0870754	0.0554222	0.131046
X_3	0.0997235	0.141545	0.0513941	0.0999261	0.14707	0.183883
X_4	0.00490361	0.000115872	2.15531e-05	0.0858847	0.0376847	0.0024437
X_5	0.0177741	0.00774194	0.0166575	0.0208468	0.0528451	0.0275835
X_6	0.000490571	0.00464659	0.000305939	0.0349351	0.000133753	0.000995828
X_7	0.0996869	0.133399	0.110045	0.0999259	0.132598	0.0939452
X_8	0.0999861	0.14998	0.199901	0.0999902	0.149953	0.199917
X_9	0.0999903	0.149895	0.19787	0.0999953	0.149968	0.195399
X_{10}	0.000454236	0.00147629	0.000128365	0.0270594	0.00101781	0.0464879
X_{11}	0.0524993	0.019047	0.0143341	0.00815831	0.00859452	0.0228024
X_{12}	0.0999929	0.148876	0.143322	0.0999477	0.148447	0.195741
X_{13}	0.0938693	0.0555354	0.164079	0.0723414	0.0448888	0.00120697
X_{14}	0.000786305	9.67027e-05	0.000332642	0.0606112	0.0575972	0.0659833
X_{15}	0.0295818	0.0306939	0.0407412	0.0512983	0.0875617	0.0425833
X_{16}	0.0837463	0.0979485	0.0604376	0.0184071	0.022111	0.0237643
Objective Function Value	14.121	16.5747	16.9835	16.7816	19.8492	21.9112

Figure 4. Graphical view of results by stochastic models for cost minimization

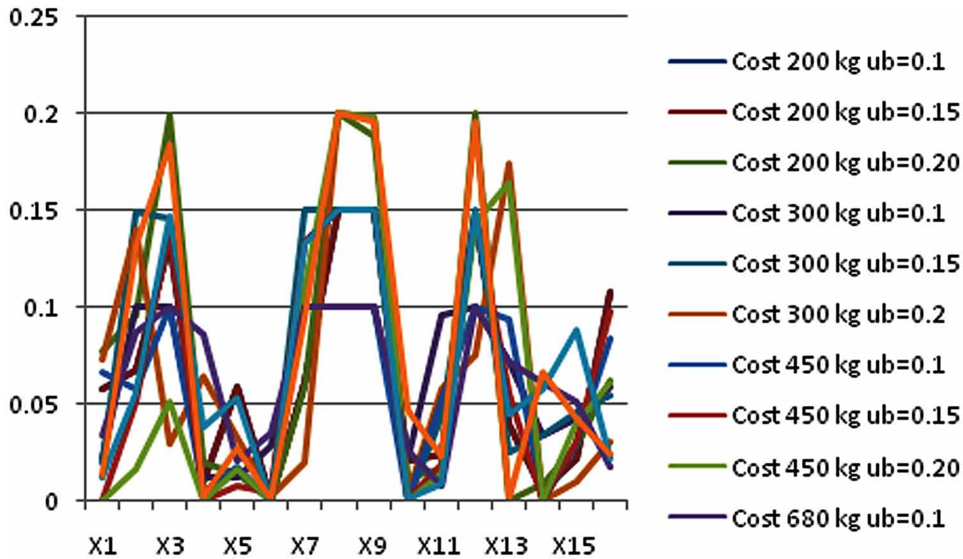

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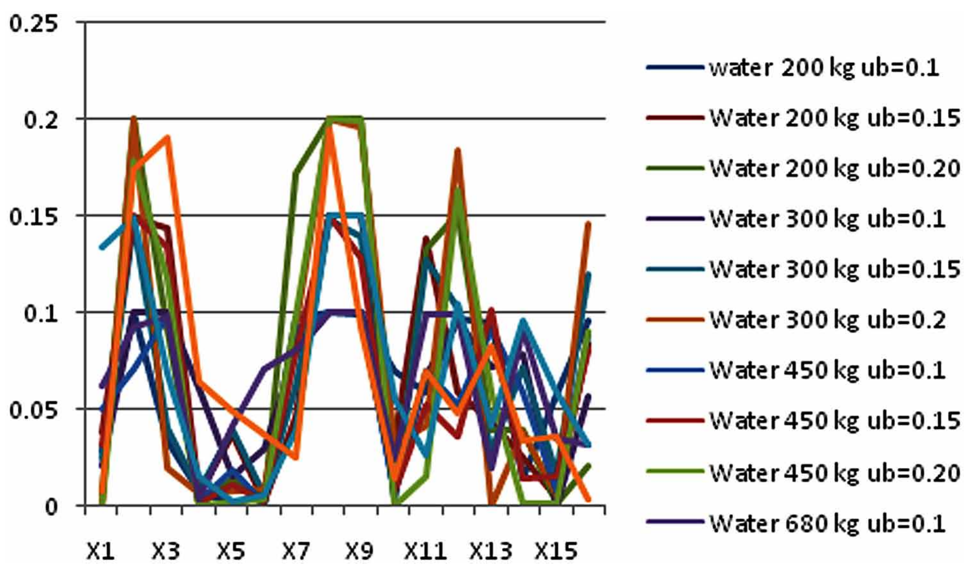
Figure 5. Graphical view of results by stochastic models for cost minimization



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reach dairy cattle through each weight class at specific growth rate. This table also provides the results for zero deviations of above defined LP and SP models. It is clear from the results shown in Table 5 that more value of variables is included in the diet, if modeled by stochastic programming technique. It should also be pointed out that marginal values of variables are also greater in this case. It is clear from the figure that both programming techniques are giving very close results for all the weight classes of

Table 6. Values for decision variables for water content minimization by stochastic model

Variables	water 200 kg ub=0.1	Water 200 kg ub=0.15	Water 200 kg ub=0.20	Water 300 kg ub=0.1	Water 300 kg ub=0.15	Water 300 kg ub=0.2
X_1	0.0280349	0.0380343	0.00675889	0.0208648	0.0256387	0.00174122
X_2	0.0994601	0.149243	0.1994	0.0996217	0.147824	0.199647
X_3	0.03372	0.14382	0.0908809	0.0998222	0.0403452	0.0196202
X_4	0.00733624	0.00651756	0.000289154	0.061385	0.00775538	0.00648633
X_5	0.00100422	0.0371616	0.0137777	0.015846	0.0395926	0.00758153
X_6	0.00554209	0.00200815	0.000155449	0.0297903	0.00550018	0.00937692
X_7	0.0970118	0.0450284	0.171584	0.0797974	0.0624302	0.0917716
X_8	0.099759	0.149981	0.199925	0.0995502	0.148625	0.199867
X_9	0.0988166	0.149906	0.199605	0.0995823	0.140082	0.196037
X_{10}	0.0692065	0.0327256	0.00326691	0.00807391	0.00329376	0.0324196
X_{11}	0.0590341	0.137762	0.133135	0.0678641	0.12792	0.0410305
X_{12}	0.0961065	0.0587308	0.151378	0.0957915	0.102952	0.18366
X_{13}	0.0943914	0.0432189	0.0388295	0.072183	0.0287918	0.000223923
X_{14}	0.0136473	0.025367	0.0387509	0.0783695	0.0717622	0.0380345
X_{15}	0.0573131	0.00432101	0.00169754	0.000557614	0.0162708	0.0061781
X_{16}	0.0952187	0.0834204	0.0211836	0.0566083	0.119814	0.145806
Objective Function Value	0.131995	0.162704	0.198861	0.136492	0.161272	0.187753
Variables	**Water 450 kg ub=0.1**	**Water 450 kg ub=0.15**	**Water 450 kg ub=0.20**	**Water 680 kg ub=0.1**	**Water 680 kg ub=0.15**	**Water 680 kg ub=0.2**
X_1	0.049772	0.0315434	0.000676728	0.0627142	0.134101	0.00801068
X_2	0.0710037	0.149695	0.178051	0.0924752	0.148502	0.173949
X_3	0.0977302	0.133401	0.117882	0.0977883	0.0685	0.19059
X_4	0.0016388	0.00130334	0.00023346	0.00396653	0.0149466	0.0640187
X_5	0.0183508	0.0108586	0.00225926	0.0417283	0.00200844	0.0491112
X_6	0.000798894	0.00235434	0.00385476	0.0703529	0.00548258	0.0368996
X_7	0.0914529	0.0789799	0.097837	0.080944	0.0389388	0.0246016
X_8	0.0994758	0.149903	0.199907	0.0999516	0.149958	0.194893
X_9	0.0999239	0.128412	0.19887	0.0994503	0.149833	0.0923852
X_{10}	0.00599309	0.00764623	0.000218392	0.0240263	0.0557037	0.0141924
X_{11}	0.0689689	0.0522147	0.0154526	0.0986636	0.0263242	0.0699517
X_{12}	0.0518027	0.0359768	0.16288	0.0988393	0.104744	0.0482405
X_{13}	0.0916021	0.101375	0.0591181	0.0206042	0.0411906	0.0828849
X_{14}	0.0580412	0.0144412	0.00131188	0.0915569	0.095039	0.0332438
X_{15}	0.00785161	0.0157228	0.0016222	0.0349246	0.0582606	0.0361178
X_{16}	0.0893076	0.0799668	0.0905578	0.0314707	0.0317767	0.00314865
Objective Function Value	0.126303	0.149529	0.181257	0.145105	0.166401	0.173955

livestock but, it can be pointed out that for better shelf life, SP models are better in terms of nutrient variability (by using table 6 and figure 4). 48 models are discussed for cost minimization and better shelf life of feed mix. Figure 2 and figure 4 represents optimum share of feed ingredients in feed mix for cost minimization by linear and stochastic programming respectively. These graphical views provide results for share of optimum feed ingredients for different stages of livestock. It shows the optimum quantity to be included in animal diet to reach the different weight classes at minimum cost, which is different from the previous work in this area that takes the objective of optimum weight gain at minimum cost. It is clear from the comparison of figure 3 and figure 4 that objective of nutrient variability is better obtained by using stochastic programming for each weight class. Different weight classes can be gained by inclusion of more variables in the feed mix by using SP models.

CONCLUSION

This chapter provides extensive study for dairy cattle with bi-criteria objectives. Cost minimization and better shelf life of ration are the main objectives of the work. The blend of linear, stochastic and C-SOMGA technique prove to be a useful procedure in determining the optimal livestock feed mix. Introduction of nutrient variability affects the cost, shelf life and ingredient content of the feed mix. It explores the blend of mathematical programming and computer programming to reach different stages of livestock which is different from the previous work in this area.

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Chapter 13
Role of Dairy Farming in Rural Development

Siraj Raja
IMT Ghaziabad, India

Sanya Sehgal
IMT Ghaziabad, India

ABSTRACT

Dairy farming is one of the growing industries. It offers multiple opportunities to people and leave a sustainable impact on society, environment and economy. In this chapter we discuss about its reach and establishment in rural areas and how this industry can play an instrumental role in rural development. The present case captures and reviews the functioning of a dairy farm situated in Ghaziabad, Uttar Pradesh, a state in India. The chapter narrates the role of various heads working at this farm and elaborates the steps involved from procuring the dairy products to its treatment and finally to its catering to the consumer, this case is developed through a rigorous literature review. To assess and establish the role of dairy farming in rural development, this chapter discusses the three tier AMUL model of Gujarat, India is also reviewed. This model by now is the most structured one and lays the foundation for dairy farming in the country. It also demonstrates that dairy farming can become instrumental in rural development.

INTRODUCTION

Dairy farming from being customary family run organizations, today has become a specialized and well established dairy industry with mechanical intrusion in all its functions. We have seen growth in dairy farming supplies which help current dairy farmers to take care of cows and buffaloes. This support in the business has made considerable contribution by generating alternative occupations for individuals. Consequently a large number of dairy farmers run dairy farms, especially in towns and supply the dairy products to expansive organizations, to be finally offered as retail product to consumers.

In the process of generating quality product, the best approach for the dairy farmer is to operate his dairy farm that gives greatest benefits to the end organization using his produce. Additionally, it should also be able to sustain the impact of dairy farms on situations and creatures for an extended period.

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DAIRY FARMING IN INDIA

As indicated by ASSOCHAM report (2010) milk handling in India is liable to achieve 190 million tons by 2015 (ref. Tables 1 and 2 for current production capabilities) with a yearly turnover of Rs.5 Lakh Cr. With planning commission focusing on 4.5 to 5% development for Animal farming in the twelfth arrangement and the World Bank's contribution of Rs1584 Cr to National Dairy plan, the division is going to witness sound development in the years to come. Further a plan of Rs17, 300 Cr. National Dairy Plan by NDDB for the next 15 years will be propelled soon. It is speculated that the first stage will have Rs 2000 Cr as opening balance.

As one of the significant hotspot for employment in rural regions, animal farming receives prime significance. To make animals division more profitable creature administration frameworks and creation efficiencies need to be moved forward. Separated from presenting new types of animal Government of AP arrangements to create grub nurseries, bund manor, lasting feed harvests and grain protection over next 4 years.

In today's mechanical world there have been numerous developments in current dairy cultivation. It is now accepted that a beneficial business such as dairy farming in India need diligent work, authentic positioning and a dynamic and extremely cautious directors and managers.

DAIRY INDUSTRY IN INDIA

The Indian dairy industry is growing rapidly, keeping pace with the technical advancements as far and wide as possible. Today, India is recognized as 'The Oyster' of the worldwide dairy industry. It offers vibrant opportunities to people around the world, who wish to explore one of the world's biggest and quickest developing markets for milk and milk products. Numerous gainful alternatives and opportunities galore for Indian dairy farmers with the expansion of this industry and its foreign operations to India. The international dairy industry may exchange engineering, sign mergers or use India as a sourcing place for local fares. The liberalization of Indian economy supports and lures MNC's and remote moguls alike.

India's dairy division is working to triple its handling in coming 10 years in perspective of growing potential for fare to Europe and the West. With anticipated WTO regulations, that will come into power in impending years, all the nations which are among enormous dairy product exporters, might need to withdraw the backing and subsidy to their domesticated milk items segment. Likewise India today is the most reduced expense maker for every liter of milk on the planet, at 27 pennies, contrasted and the US' 63 pennies, and Japan's $2.8 [National Dairy Development Board, 2013]. Additionally to exploit this least cost of milk generation and expanding processing in the nation, multinational organizations want to extend their exercises here. Some of these milk makers have effectively acquired quality standard authentications from the powers. This will help them in showcasing their items in outside nations in transformed structure.

OPERATION FLOOD

Government is heartily supporting the dairy division by actualizing different plans. Everything began with the White Revolution under the title Operation Flood (OF) Program started in 1970. By advertising

Table 1. Current production capabilities: India's Milk Production by species in tons (FAOSTAT, 2013)

Year	Country	2005	2006	2007	2008	2009	2010	2011
All Milk Production in tons	India	95619000	99348000	105712000	108618000	11493000	116904000	119444000
	USA	80254500	82463000	84189100	86177400	85880500	87474000	89015200
% Difference between India & USA		19%	20%	26%	26%	30%	34%	34%
Cow Milk Production	India	39759000	14148000	44601000	47006000	47825000	49960000	52500000
	USA	80254000	82463000	84189100	86177400	85880500	87474400	89015200
% Difference between India & USA		102%	100%	89%	83%	80%	75%	70%

Table 2. Current production capabilities: Milk production in India and the United States of America (FAOSTAT, 2013)

Year	Country	2005	2006	2007	2008	2009	2010	2011
All Milk Production in tons	India	95619000	99348000	105712000	108618000	11493000	116904000	119444000
	USA	80254500	82463000	84189100	86177400	85880500	87474000	89015200
% Difference between India & USA		19%	20%	26%	26%	30%	34%	34%
Cow Milk Production	India	39759000	14148000	44601000	47006000	47825000	49960000	52500000
	USA	80254000	82463000	84189100	86177400	85880500	87474400	89015200
% Difference between India & USA		102%	100%	89%	83%	80%	75%	70%

Anand Pattern of dairy cooperatives, OF visualized growth in resource gainfulness, acquired repute of perfection in enhanced personal satisfaction of milk makers and guaranteed supply of value milk and other dairy items to shoppers at sensible cost in a free nature's domain. Taking after the cooperative way, market turned milk handling and modernization of dairying, milk generation, preparing and showcasing grew significantly.

The goals of Operation Flood were:

- To increased milk processing ('a surge of milk')
- To augment country earnings
- To ensure reasonable costs for customers

In OF zones, the nation has more than 1 lakh composed essential town dairy cooperatives at present with a total enrollment of 1.1 Cr. Producers. These primaries are unified into 170 region helpful milk unions and further to state agreeable dairy alliances. The dairy helpful system is evaluated to have gathered near 229 lakh kilograms for every day in 2007-08 ensuing in the installment of a total sum surpassing Rs.7000 Cr. to the milk makers throughout the year. It is seen that 14 significant dairying states viz. Uttar Pradesh, Punjab, Andhra Pradesh, Gujarat, Maharashtra, Madhya Pradesh, Karnataka, Haryana, Tamil Nadu, West Bengal, Bihar, Kerala and Orissa represent 92% of India's milk creation.

IMPROVEMENT IN RURAL LIVELIHOOD THROUGH DAIRY FARMING

The sustenance of country employments is right now in question than any other time in the recent past, in the face of investment liberalization. Employment choices are contracting in rustic ranges, more so in eco-delicate areas, for example, dry spell, desert inclined mountainous zones and other immature/regressive locale. Quickly developing markets for domesticated animals items and dairy items specifically (owing to climb in for every capita earnings) are opening new roads for improving country livelihoods. Dairy farming plays huge part in supporting the rustic livelihoods, despite the fact that farmer suicides, relocation, ailing health/sick wellbeing are broadly common in India. In any case, a percentage of the dairy based dry spell inclined areas make fast strides in improving neediness by significantly helping the District/State farming economy.

EMPLOYMENT

Livestock animals segment gives job to 18 million individuals and about 70% of them are ladies. Further, dairy part is the significant wellspring of salary for an expected 27.6 million individuals. Around these, 65 to 70% are small, peripheral farmers and land-less workers. The dairy part backs around 10 million parts/ agriculturists through one lakh helpful social orders existing in the nation. Separated from livelihood created by rearing of animals, the obtainment of milk and its preparing additionally gives significant vocation. Case in point is Punjab, MILKFED, with its system of in excess of 5,000 town Milk Producers' Agreeable Societies, underpins in excess of 3 lakh Milk Producers. Further, MILKFED and its units have a work power of about 5,000 workers and offers occupation to an alternate 10,000 specialists who work for milk obtainment and specializes in segments such as include supply and delivery to retail outlets. Comparable number of workforce is utilized in all the milk leagues. Further, under SGSY (Swarnajayanti Gram Swarojgar Yojana), the main independent work program for country zones, something like 35% swarojgaries selected dairy cultivating as pay producing movement. The incremental work chart included 11 man-days for every month and the incremental net pay created was Rs. 865 for every month for every individual. (Nationwide Study, 2005).

CONTRIBUTION TO INDIAN ECONOMY

Dairying has turned into an essential auxiliary wellspring of pay for a huge number of country families and has accepted a paramount part in giving work and salary. Indian Dairying is novel in more than one ways. The extraordinary characteristic of the framework is that about 120 million rural families are occupied with milk preparation exercises as against huge specific dairy farmers in the west. Throughout the post freedom period, advancements made in dairy area has been stupendous. Milk preparation has expanded more than four folds. This noteworthy development exertion talks volume about the co-facilitated deliberations of vast number of milk generating farmers, researchers, organizers, NGO's and industry in accomplishing independence in milk handling.

Dairy industry is of urgent vitality to India. The nation is the world biggest milk maker, representing more than 13% of world's aggregate milk creation. It is the world's biggest buyer of dairy items, expending very nearly 100% of its own milk preparation. Dairy items are a real wellspring of shabby and nutritious nourishment to a huge number of individuals in India. Furthermore the main adequate wellspring of creature protein for huge veggie lover portion of Indian populace, especially around the landless, small farmers and ladies.

Dairying has been recognized as one of the exercises pointed at allaying the neediness and unemployment particularly in the provincial ranges in the sprinkle bolstered and dry season inclined areas. In India, around three-fourth of the populace live in provincial territories and about 38% of them are poor. Thus effects of Dairy Industry might be categorized into having:

- Social raise
- Economic development
- Impact on foundation
- Impact on enhanced nourishment support security

These effects can be gathered from the following existing benefits of Dairy Farming:

- Not dependent on rainfall
- Causes less pollution and is eco-friendly
- Skilled labor is not a constraint as its requirement is relatively less.
- Active Dairy product market
- Raw materials need not be stocked in huge quantities
- Shifting to a new location is relatively easier in case of any unfortunate event
- Less requirement of energy. Maximum energy can be obtained from Biogas plant fed with cow dung for daily requirements of the farms
- Fixed Selling rate of milk
- Assurance of regular income
- No control on the sale prices by the middlemen
- Increasing Demand for Milk

PLANNING A DAIRY FARM

To plan and start a new dairy farm, the following points must be considered:

a. Nourish Resources Available
   - Pasture touching area
   - Green grain accessible and deficiencies in supply
   - Availability of dry grain
   - Concentrate, sort and expense, quality, brand
   - Mineral blender

b. Classifications of Holdings
   - Land less horticultural specialists, minor, little, medium and substantial farmers.
   - Extent of usage of Natural Resources like land, human (work), capital and business endeavor.

c. Existing Infrastructure offices

- ◦ Veterinary doctor's facilities, dispensaries, and provincial veterinary dispensaries (veterinary essential wellbeing focuses)
- ◦ Semen banks – semen gathering, assessment and solidifying, offices with satisfactory offices for putting away, of solidified semen.
- ◦ Cooperatives – essential/ optional social orders for taking care of the farmers' requests and procurement of inputs comprehensive of delicate term, fleeting and medium term credits.
- ◦ Extension administrations – Animal cultivation and dairying.
- ◦ Chilling focuses – milk gathering and chilling units and transportation to preparing units.
- ◦ Feed plants – assembling of intensified food.
- ◦ Manpower accessibility.

d. Generation of Milk Products and their Demands and Supply
- ◦ Production of milk for every year for every animal and for every one thousand person.
- ◦ Facilities for storage of milk
- ◦ Actual provincial interest (utilization)

Initial Preparations: Visit to a Dairy Farm

While visiting a dairy farm, the dairy farmer should

- Focus on the aims and objectives of the farm mainly on breeding and production
- Visit to commercially based dairy farms for a discussion with experienced farm owners.
- Study feed and fodder's market and its difficulties
- Choose experienced and reliable persons as a team for the specific jobs.
- Observe animals on sale in the market
- Study the patterns on rearing of dairy animals and manufacturing of milk as mentioned by National Dairy Research Institute (NDRI), Karnal (Haryana)

DAIRY FARM: KIRPA RAM DAIRY INDUSTRY, UTTAR PRADESH

The dairy owns about 150 cows. All the cows are milked at an average of 5 minutes. Hormones are injected into them at regular intervals to increase their milk yields.

On asking the contact person, Mr. Amit Gupta, we came to know that the life expectancy of cows is about 15 years. The milk production drops to a large extent after 10 years, after which these cows are slaughtered for meat. The cows give birth to calves after nine months which are shipped to the veal industry if it is a male calf as it is of no use to the dairy industry. The cows are inseminated at regular intervals for proper milk yield.

Things that are kept in mind:

- Choosing the proper breed of animals for maximum productivity
- Construction of proper Cattle Sheds
- Proper nutrition as far as feeding is concerned and other management practices
- Adequate health Management practices for prevention of diseases in the farm

- Generation of profits by production of milk and its byproducts etc.
- Enhancement of productivity which will help farmers get more milk.

Feeding Practices (Vetbharathi, 2011)

Dairy animals need to be fed for proper maintenance of their body and production of milk. Extra feeding is required in case of pregnancy for good health of the calf.

- Mineral mixtures and fresh drinking water must be fed to the animals of all age groups and health conditions
- Fodder, concentrates (mixture of grains and legumes seeds/urea)
- The dry matter content in various foods are as follows:
    a. Concentrates: 70%
    b. Green Fresh fodder: 10%
    c. Green dried in air / sun: 20%
    d. Dry fodder / crop residues: 85%
- Dry matter requirement should be made with 1/3rd of green fodder 1/3rd from concentrates and 1/3rd from dry fodder.
- Homemade concentrates can be used: mainly leguminous seeds and food grains mixed in the proportion of 40: 60 along with oil cakes and bran in small quantity. The protein content in leguminous seeds is 20-24%, food grains is 8 – 12% and oil cakes is 24%
- To provide energy to the animals, food grains can be fed which are the best source of proteins and fats.
- Mineral mixtures are essential especially in growing and pregnant animals.

STAGES OF DAIRY FARMING (KIRPA RAM DAIRY INDUSTRY, UTTAR PRADESH)

Step 1: Rearing

Dairy cows ordinarily use their days consuming, resting, and ruminating or biting their cud. They also meander around and consume new grass (i.e. brushing). In different farms, they are bolstered grain, feed, or silage (saved search) and stay throughout the day around other people known as restricted cattle nourishing operations (Cafos), some of which house many creatures.

Farmers also use development hormones and anti-infection agents throughout the raising methodology to falsely expand a cow's milk preparation and to decline the spread of irresistible ailments around their cows.

Step 2: Harvesting

Cows are ordinarily milked at any rate twice a day. Milking time takes about five minutes for every dairy animals relying upon the kind of machine and the measure of milk the cow is transforming. Milking machines mirror the movement of a junior calf by making a throbbing vacuum around the teat, which causes the milk to be discharged from the udder.

Step 3: Storing

Milk stockpiling vats or storehouses are refrigerated and come in different shapes and sizes. Milk is normally put away on the farm at 39 degrees Fahrenheit, or colder, for close to 48 hours. Vats and storehouses are fomented to verify that the whole volume stays icy and that the milk fat does not separate from the milk. After milk has been gathered, stockpiling vats and stainless steel funnels are completely cleaned before the agriculturist milks once more.

Step 4: Transportation

Milk is gathered from the farm each 24 or 48 hours. The tankers that are utilized have extraordinary stainless steel bodies which are vigorously protected to keep the milk cool throughout transportation to the transforming manufacturing plant. Milk tanker drivers are licensed milk graders, qualified to assess the milk before gathering. Tanker drivers grade and if essential reject milk focused around temperature, sight, and odor. An agent example is gathered from each one farm pickup preceding being pumped onto the tanker. After accumulation, milk is transported to production line destinations and put away in refrigerated storehouses before preparing.

Step 5: Lab Testing

Samples of milk are taken from homestead vats before gathering and from the mass. Tests from the mass milk tanker are tried for anti-toxins and temperature before the milk enters the manufacturing plant transforming zone. Farm milk specimens are tried for milk fat, protein, mass milk cell check and microscopic organism number. On the off chance that milk does not meet quality principles it is rejected. Most farmers are paid on the quality and piece of their milk.

Step 6: Processing

Whole milk, once approved for use, is pumped into storage silos where it undergoes pasteurization, homogenization, separation and further processing.

- Pasteurization Involves heating every particle of milk to a specific temperature for a specified period of time and cooling it again without allowing recontamination.
- *Separation* Includes turning milk through an axis to divide the cream from the milk. After separation, the cream and remaining milk are remixed to give the craved fat substance to the distinctive sorts of milk being prepared.

For "entire milk," the cream is reintroduced until the fat substance achieves 3.25%. For "low fat drain," the fat substance is 1%. For "skim milk" (some of the time called nonfat milk) the fat substance is .05%.

Step 7: Packaging

Now the milk is ready to be bundled for conveyance to the stores. The milk ventures out through funnels to the programmed bundling machines that fills and seals the milk into paper containers or plastic containers. As the holders travel through the sequential construction system, a date is printed on each of them to show to what extent the milk will stay new.

RECOMMENDATIONS

To have safe, good quality milk from healthy animals, sustainable management practices can be adopted that are good for the animals from a social and economic perspective. Dairy farmers can implement the following measures to achieve the desired outcome:

- **Animal Health:** Healthy Animals that produce milk can be taken care of with effective health care programs.
- **Milking Hygiene:** Prerequisites to keep milk in hygienic conditions are proper harvesting and storing conditions. Equipment that can be used to harvest and store milk should be suitable and well maintained.
- **Nutrition (Feed and Water):** Products of suitable quality should be used to feed the animals need to be fed and watered.
- **Animal Welfare:** Animals should be kept free from thirst, malnutrition, discomfort, injuries, disease, pain and fear.
- **Environment:** Surroundings, which can balance the local environment around the farm, should be adopted for better milk production.
- **Socio-Economic Management:** Dairy farming can help by benefitting the farmers and other communities in both economic and social sector. These practices can also help to manage the social and economic risks to the enterprise.

LIMITATIONS AND CONSTRAINTS

How to Improve Dairy Farming Practices in Rural India

There is wide variety in (a) agro-climatic condition, (b) biodiversity and environment (c) socio budgetary and social foundation of individuals, (d) sorts/types of dairy cows raised. It is therefore important to get ready for dairy advancement particular to every micro level, viz., a piece, a town, a taluk and a locale. This arrangement enhances ideal use of nearby assets and guarantees better suitability of the projects and higher expense profits degree. Before defining and proposing dairy improvement programs, it is important to think about natural effect (water bodies' contamination, over munching of meadows, debasement of watersheds, deforestation). These days, saving the environment and nature is truly pushed by the private gatherings and multinational organizations while subsidizing the creature cultivation ventures. However for the healthy growth of dairy industry, the following measures are needed:

- Embrace the accompanying tips for proficient recognizable proof and plan of creature cultivation and veterinary ventures.
- Recognizing such innovations, which request less capital, less time and least operations.
- Explore the conceivable outcomes of giving advances at the most minimal investment rates with subsidies for dairy advancement exercises.
- Gradual change of existing indigenous types of animals.
- Gradual evacuation of futile stock and supplanting with high yielding predominant quality creatures.
- Gradual control in farming practice for enhancing creature benefit and reception of biotechnological mediations in food and grain, propagation and development perspectives.
- Support from Government in enhancing the supply of inputs and administration to dairy farmers/ beneficiaries at their doorsteps with least cost.
- Contribution from different nongovernmental organizations/association to straightforwardness the issues of farmers in acquaintanceship with the legislative offices.
- Create suitable agriculturist's cooperatives social orders/ leagues like, milk makers helpful social orders at town and locale levels, alliances, sheets and enterprises.
- Synchronous advancement of cool chain stockpiling and advertising offices are required, particularly for milk and milk items.
- Activation of different information administrations from various agencies.

IMPACT OF DAIRY FARMING ON RURAL INDIA

Social Impact

Since social participation interests all, absence of separation, existing doctrine, sexual orientation and budgetary status has succeeded in breaking down hindrances for those with milch creatures. Surprisingly new mindfulness has been produced and seen around the makers.

Resolving Social Inequity

Social disgrace still exists in numerous parts of country India. At all the collection centers, morning and night, many grown-ups and also the youngsters of milk makers having a place with all positions come and stand in queue to deliver their milk produce, creating a propensity of discipline. The mix of different ethnic and social gatherings twice a day for a typical reason and to their shared change has brought about lessening social inequity.

Superstitions

There were overall convictions in the greater part of the provincial ranges that drain is a sacred ware and is not intended to be sold and that certain infectious infection, for example, rudderpost ought not to be dealt with on the grounds that they are a condemnation of God. Normal pay and veterinary help through cooperatives have helped parts leave such superstitions behind.

Health Care

The benefit of gathering the milk from parts puts a commitment on the cooperatives to give inputs to build the milk handling. If required, the unions work with veterinary administrations at their doorstep to deal with dairy cattle wellbeing. Presentation to different advanced innovations and their requisitions by the veterinarians to treat their family members as well.

Impact on Infrastructure

Taking an interest farmers have gotten mindful of their obligation to the group. Consistently they liberally help a part of their agreeable benefit towards the general advancement of the town, for example,

- Improving the town approach way condition
- Providing offices to youth through making town libraries
- Contributing to instructive organizations and town essential wellbeing focuses
- Providing and redesigning regular information by putting TV sets in DCSs
- Providing a phone office to parts for better and quick correspondences
- Contributing to making the drinking water supply framework in the town.
- Cooperative dairying has in this manner demonstrated a noteworthy socio-investment sway in rural improvement.

Impact on Improved Food Aid and Nutrition

A few studies have uncovered that India is better-off now in the region of preparation of sustenance grains, then in the recent past. The genuine issue however, is that even with extra grain accessibility, lack of healthy sustenance continues on the grounds that those in genuine need have lacking acquiring power. The milk producers' associations (Mpos) do make a commitment towards producing extra pay for these poor gatherings and help manufacture an advantageous relationship between animal and crop husbandry; wage created from one makes interest for the yield of the other, as such, yield of one gets sustain for the other. The essential impacts of Mpos are to give more terrific salary to the partaking families. As every capita use expands, so does the use on sustenance items. As such, there is a proportionate expand in the utilization of sustenance as using force increments. Subsequently, extra salary gave by Mpos to families beneath the destitution line really helps them build their nourishment consumption.

Mpos gave salary at standard interims; normally every day, yet once in a while additionally when a week. Given the low buying force of provincial family units, things of crucial utilization not processed by the families themselves, for example, salt, sugar, vegetable oils, flavors, lentils and vegetables, must be acquired every day. The procurement of extra money salary day by day or week by week undoubtedly helps the families expand

Income from Dairy Farming

The ultimate goal of dairy farming is generating income and employment. Dairy farming has been able to reduce rural poverty as it ensures constant income and provides security to the family members. Selling of milk, dung, stock, milk products are the various sources of income from dairy farming.

Farmers get around 50% of the income from dairying and livestock. The price of buffalo milk is more than cow milk; hence the level of milk yield from buffalo's milk will be greater than the yield from cow's milk. Apart from this, the maintenance cost of crossbred cows is more than that for buffalos.

THREE-TIER AMUL MODEL: A BENCHMARK

The highly successful AMUL (Anand Milk Union Limited) program sets the yardstick for almost all dairy organizations in the country. It is a three-tier structure at the town level, district level and the state level. A Dairy Helpful Society at the town level is associated with a Milk Union at the District level which then is further merged into a Milk Federation at the State level. This three-level structure makes the collection, treatment and delivery of dairy products easier, thereby making the process much more systematic. The milk collection is done at the Village Dairy Society, Milk Procurement & Processing at the District Milk Union and Milk & Milk Products Marketing at the State Milk Federation. This helps in dispensing with inward rivalry as well as guaranteeing that economies of scale are accomplished. As the above structure was initially developed by AMUL in Gujarat and from that point imitated everywhere throughout the nation under the Operation Flood Program, it is known as the 'Amul Model' or 'Anand Pattern' of Dairy Cooperatives.

Roles and Responsibilities of Village Dairy Cooperative Society, District Cooperative Milk Producers' Union and State Cooperative Milk Federation

Structurally, the AMUL model comprises of collection, treatment and packaging of the dairy products. The segment wise responsibilities for each of these is given below:

Village Dairy Cooperative Society (VDCS)

The milk makers of a town, having surplus milk after own utilization, come together and structure a Village Dairy Cooperative Society (VDCS). The Village Dairy cooperative is the essential pop culture under the three-level structure. It has participation of milk makers of the town and is legislated by a selected Management Committee. This committee comprises of 9 to 12 representatives of the milk union focused around the rule of one part, one vote. The town public opinion further selects a Secretary (a paid representative and part secretary of the Management Committee) for administration of the normal capacities. It additionally utilizes different individuals for supporting the Secretary in achieving his/ her every day obligations. The VDCS is responsible for:

- Collection of surplus milk from the milk makers of the town & installment taking into account quality & amount
- Providing help administrations to the parts like Veterinary First Aid, Artificial Insemination administrations, steers nourish deals, mineral mixture deals, grub & feed seed deals, leading preparing on Animal Husbandry & Dairying, and so forth.
- Selling fluid milk for nearby buyers of the town
- Supplying milk to the District Milk Union Accordingly, the VDCS in a free element oversaw provincially by the milk makers and aided by the District Milk Union.

District Cooperative Milk Producers' Union (Milk Union)

The Village Societies of a District (going from 75 to 1653 for every Milk Union in Gujarat) having surplus drain after nearby deals meet up and structure a District Milk Union. The Milk Union is the second level under the three-level structure. It has enrollment of Village Dairy Societies of the District and is legislated by a Board of Directors comprising 9 to 18 chose agents of the Village Societies. The Milk Union further selects an expert Managing Director (paid worker and part secretary of the Board) for administration of the regular capacities. It additionally utilizes different individuals for aiding the Overseeing Director in finishing his/ her every day obligations. The principle responsibilities of the Milk Union are:

- Procurement of milk from the Village Dairy Societies of the District
- Arranging transportation of crude milk from the VDCS to the Milk Union.
- Providing information administrations to the makers like Veterinary Care, Artificial Insemination administrations, steers encourage deals, mineral mixture deals, grub & feed seed deals, and so on.
- Conducting preparing on Cooperative Development, Animal Husbandry & Dairying for milk makers and leading specific aptitude advancement & Administration Development preparing for VDCS staff & Management Committee parts.
- Providing administration backing to the VDCS alongside normal supervision of its exercises.

State Cooperative Milk Federation (SCMF)

The Milk Unions of a State are unified into a State Cooperative Milk Federation. The federation is the summit level under the three-level structure. It has participation of all the helpful Milk Unions of the State and is administered by a Board of Directors comprising of one chose illustrative of each one Milk Union. The State Federation further designates an Overseeing Director (paid representative and part secretary of the Board) for administration of the normal capacities. It likewise utilizes different individuals for helping the Managing Executive in achieving his day by day obligations. The fundamental capacities of the Federation are as takes after:

- Marketing of milk & milk items transformed/ produced by Milk Unions.
- Establish dispersion system for promoting of milk & milk items.
- Arranging transportation of milk & milk items from the Milk Unions to the market.
- Creating & keeping up a brand for promoting of milk & milk items (brand building).
- Providing help administrations to the Milk Unions & parts like Technical Inputs, administration help & consultative administrations.
- Pooling surplus milk from the Milk Unions and supplying

CONCLUSION

Apart from cooperatives, the dairy segment is still described by little scale, scattered and chaotic milch creature holders; low gainfulness; lacking and improper creature nourishing and human services; absence of guaranteed year-round gainful maker costs for milk; insufficient fundamental framework for procurement of generation inputs what's more administrations; deficient essential framework for obtainment, transportation, handling and advertising of milk and absence of expert administration. In spite of every last one of issues it confronts, the dairy division holds high guarantees as a reliable wellspring of business for the dominant part of the country poor in India. *The AMUL model of little scale dairy generation and advertising*, as it has developed and been refined in the course of the last 50 years, likewise holds high assurances for smallholder dairy improvement in India. Liberalization of world exchange dairy items under the new exchange administration of the WTO postures new difficulties and has opened up new fare open doors for the dairy business in India. It necessities to upgrade focused monetary preference in dairy items regarding both quality, expense and its validity in global markets. Milk yield needs to build in order to decline the for every liter expense of handling, quality needs to be upgraded with the selection of the most recent transforming and bundling engineering will expand fare of dairy items.

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KEY TERMS AND DEFINITIONS

Dairy Farming: A form of agriculture for production of milk for commercial purposes.

Farming Practices: The methodologies practiced in dairy farming.

Milk: Milk is a white liquid; India is the world's largest producer and consumer of milk, it has various health benefits.

Operation Flood: White Revolution under the title Operation Flood (OF) Program started in 1970.

Rural Development: The process of improving the quality of life and economic well-being of people living in villages in India.

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Chapter 14
Impact of Information and Communication Technology on Livestock Production:
The Experience of Rural Farmers in Nigeria

O. Anie Sylvester
Delta State Polytechnic, Nigeria

ABSTRACT

This chapter examines the impact of Information and Communication Technology (ICT) on livestock production by rural farmers in Nigeria. Questionnaire, interview, and personal observation methods were employed to elicit information on the impact of ICT on livestock production on rural areas of Nigeria. The study reveals the significance of personal characteristics of the respondents. The findings also reveal that rural farmers need to be encouraged by providing them with relevant ICT gadgets in order to enhance effective access to information on veterinary and extension services to improve productivity. It is therefore concluded that the establishment of internet facilities in rural communities should be the priority of the State and Federal Governments in order to encourage computer literacy.

INTRODUCTION

The Nigerian society is a social system compounded by contested demands on access to scarce resources especially information. Nigeria is naturally blessed because of the rich alluvial deposits and other natural composites. The fertility of the country makes it possible for the people to carry out fishing, hunting and animal rearing (Otolo, 2008).

Domestic animals are tamed and could be kept for commercial purposes and social means in Nigeria. Anyanwe and Ashaya (2007) opined that some of the domesticated animals such as sheep and cow can be used for meat and milk production. Herren (2004) postulated that one of the advantages of domestic animal production is the low cost of feeding. This is because most of the domesticated animals feed on grass and less expensive grains. However, Mcnit (1995) revealed that in spite of the cheap process of

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rearing domestic animals, some factors still militate against intensive and extensive livestock production in Nigeria and these include inadequate veterinary services and absence of genuine veterinary drugs. But with the advent of information and communication technology (ICT) on livestock production domestic animal rearers now find solace with the application of ICT.

Most of the rural farmers are not highly educated and most of them understand and speak their dialects only. Experience shows that the ability to acquire and use information is fundamental to the development of animal production especially in the adoption of new technologies. Poor access to information is a major constraint to domestic animal production in Nigeria, and the situation is aggravated by the high level of illiteracy among the rural farmers. It is a clear evident that the ability to acquire and use information is a sine qua non for the application of ICT and agricultural development at all levels.

Fasheun (2001) declared that computer compliance by farmers have become the most important factor for productivity and prosperity. Communication is the process of imparting or exchanging information. To expose rural farmers to a better way of animal husbandry, there is need to educate them in the language they will understand better. In view of the nature of rural farmers, which are relatively isolated and the economic activities which are predominantly agriculture oriented, there is therefore the need to bring farmers to the centre of development for the upliftment of their standard of living. It therefore, calls for a communication development strategy that is democratic, participatory and productive or result-oriented. This can be achieved with the adoption of ICT in retrieving and dissemination of information on domestic animal production (Kwesiga, 2000).

Rural farmers need a wide range of agricultural information access, especially in all areas of agricultural activities such as veterinary services, prices of drugs, diseases outbreak, processing, storage facilities and marketing. The information received helps to enlighten them on the latest species of diverse animals and current prices.

The significance of this study lies in the fact that the findings will enable the rural farmers in Nigeria to be acquainted with new ideas of domestic animal production through the application of ICT.

LITERATURE REVIEW

Ogur (2003) stressed that much efforts have been made by the Federal and State Governments to enhance animal production and other agricultural activities. Few of the programmes launched by the Federal Government were “Operation Feed the Nation and Green Revolution”, which focus attention measurably on students, civil servants, the police and army. These programs hardly favor the rural farmers especially the rural animal rearers.

Rural farmers are isolated from the dealers of agricultural produce, and therefore need a wide range of information to improve in their systems of farming. Information from the context of this study is defined as a processed data that is logically arranged and recorded in various forms, and is retrieved, stored and disseminated in the right format and at the right time with the application of Information and Computer Technology (ICT). Information could also be inform of recorded ideas, skills, feelings, experiences and research results that can be communicated for the improvement and development of others (Unegbu, 1999). Sanusi (2003) remarked that information, if well processed will serve as essential raw materials used in the realization of any objectives or goals set by individuals or group of persons. Rural farmers cannot and never obtain maximum production without adequate information on domestic animal production. Oyelaran (1996) opined that inability of the rural dwellers to access information via the internet is a major problem facing rural entrepreneurs such as rural farmers.

The impact of ICT in domestic animal production may not be felt as expected if the information needed by rural farmers is not well communicated. The most vital information needed by rural farmers in Nigeria is information on veterinary services, prices of drugs and diseases outbreak. Park (1997) posits it that communication of information to rural farmers must be characterized in the following ways for effective delivery. In the first place, it is good for the Federal and State Governments to supply drugs at subsidized rates to the rural farmers, but it is not good enough if the rural farmers are not guided on how to apply the drugs to the animals. If the veterinary is restricted to theoretical messages without practical demonstration for the illiterate farmers to see, the services are not complete and will not yield the needed result. Secondly; communication must be purposeful. The information being disseminated to rural farmers must relate to some pressing problems, and must be able to suggest solutions. And finally, in order to ascertain the validity of the questionnaire, extensive review of literature on information resources relevant to the study was consulted.

Objectives of the Study

This study aims at investigating the impact of ICTon livestock production, the experience of rural farmers in Nigeria. It also attempts to find out the effect of ICT on rural farmers and the constraints facing the rural farmers with application of ICT.

Findings and Discussions

This section presents the analysis of the collected and discussion of the findings of the study. 600 questionnaires were distributed to the political zones but only 300 questionnaires were completed and returned. There are 300 respondents from six communities representing the six political zones under survey and their distribution is as follows; Manama in North West 40; Garkida in North East 45; Osi in North Central 50; Wasinmi in South West 50; Mgbidi in South East 65; and Isele-Uku in South-South 50.

Table 1 reveals that 18 of the respondents had formal education up to National Certificate in Education (NCE), while 8 out of the respondents made it to the degree certificate level. When they were interviewed, it was discovered that they had spent years in the city searching for job appointment but could find none, so they decided to settle down for farming. And now they are on their own with an

Table 1. Educational qualification of the respondents

Educational Qualification	No. of Respondents	Percent %
First School Leaving Certificate	73	24.33
SSCE/GCE	67	22.33
NCE	18	6.00
BA/B.Sc./B.ed	8	2.67
No Certificate	134	44.67
Total	**300**	**100.00**

encouraging number of livestock. It was also discovered that 134 (44.67%) of the respondents had no formal education and most of these farmers are from the Northern part of Nigeria.

The forest and mangrove zones of the country to which Akwa-Ibom state belongs have a high concentration of chicken population in Nigeria as shown in Table 2. Recent statistics on the population of livestock in Nigeria derives from the 2007 Aerial Survey and Trotting by RIM, commissioned by the Federal Livestock Department and Pest Control Services as shown in Table 3.

From the statistics shown in Table 3, it was revealed that most of the livestock are largely produced in Northern Nigeria especially in Bauchi, Gongola, Kano, Niger, Plateau and Sokoto States. Government at all levels in the country has intensified the provision of veterinary services with the application of information and communication technology.

Table 4 reveals the information needs of the rural farmers in Nigeria. Much time was spent to get the farmers well informed about their information needs by the enlightened farmers among them. To this end, their response was on a high side hence such information will help to enhance their livestock productivity. It was revealed that rural farmers in the Northern Part of Nigeria showed more interest for the information needs due to the state government's readiness to assist the farmers.

All the respondents (100%) indicated that they need information on new breeds, veterinary services, how to get credit facilities and market strategies. This indication was supported by the findings of Aboyade (2004), Broadbent (1987). 186 (62.01%) of the respondents opined that they need information on farm implements. On the application of pesticides, 199 (66.35%) of the respondents also declared that they needed information on how to acquire and use pesticides.

Veterinary agents have been the most effective source of information on the innovations and development in livestock production. This corroborates the ascertain Otolo (2008) that the major source of acquiring information on the production of livestock is through veterinary service Agents. 300 (100%) of the respondents attested to this fact. 216 (72.00%) of the respondents revealed that their major source of information on the agricultural developments and innovations is through the extension services agents.

Table 2. Ecological distribution of livestock population in Nigeria

Ecological Zone	State	Cattle	Sheep	Goats	Pigs	Chickens
Sahel	Parts of Yobe, Sokoto and Kaduna	1,060 (7.6)	1,105 (5.0)	1,398 (4.0)	40 (1.2)	2,580 (3.6)
Sudan	Parts of Kebbi, Sokoto, Katsina, Yobe, Borno, Bauchi, Adamawa, Taraba, and Kano	6,820 (48.8)	10,965 (47.3)	12,702 (36.8)	340 (20.4)	14,448 (20.4)
Northern Guinea	Parts of Katsina, Bauchi, Kebbi, Sokoto, Niger, Kwara, Kaduna, Plateau, Taraba and Adamawa	2,580 (18.5)	2,970 (13.4)	4,025 (12.20)	415 (12.2)	5,290 (7.5)
Southern Guinea	Parts of Cross River, oyo, Ogun, Ondo, Edo and Cross-Rivers	3,260 (23.3)	4,550 (20.6)	9,550 (27.7)	1,905 (55.9)	26,002 (36.6)
Forest	Parts of Oyo, Ogun, Osun, Ondo, Edo, Delta, Amanbra, Rivers, Lagos, Akwa-Ibom, and all of Imo and Abia	317 (1.5)	2,550 (11.5)	5,920 (17.2)	580 (17.0)	78,480 (26.11)
Mangrove	Parts of Delta, Cross- River, Akwa-Ibom, Rivers, Lagos and Ondo	10 (0.7)	464 (2.1)	900 (2.6)	130 (5.8)	4,128 (7.2)
Total		**13,947**	**22,105**	**34,495**	**3,140**	**70,928**

Table 3. Statistics on the population of livestock in Nigeria

State	Cattle	Sheep	Goats	Pigs	Chickens	Duck	Guinea Fowls	Turkey	Rabbits
Abuja	156,000	63,000	144,000	16,000	280,000	32,000	12,000	-	13,000
Akwa-Ibom	2,000	516,000	816,000	89,000	3,185,000	133,000	19,000	23,000	76,000
Anambra	65,000	425,000	1,467,000	62,000	4,306,000	251,000	6,000	8,000	3,000
Bauchi	1,731,000	2,811,000	3,466,000	66,000	2,787,000	861,000	1,003,000	1,000	533,000
Benue	48,000	737,000	1,747,000	703,000	8,368,000	1,180,000	141,000	2,000	37,000
Borno	2,727,000	424,000	3,188,000	76,000	3,292,000	466,000	198,000	-	45,000
Cross-River	10,000	117,000	351,000	68,000	1,364,000	162,000	4,000	-	4,000
Gongola	1,503,000	1,324,000	1,470,000	476,000	2,975,000	953,000	409,000	2,000	74,000
Imo	13,000	495,000	1,281,000	8,000	3,008,000	147,000	3,000	5,000	18,000
Kaduna	1,007,000	557,000	967,000	250,000	2,680,000	515,000	85,000	4,000	112,000
Kano	1,014,000	2,567,000	2,736,000	-	2,947,000	579,000	374,000	25,000	217,000
Katsina	630,000	1,696,000	2,079,000	-	2,156,000	685,000	510,000	15,000	166,000
Kwara	562,000	843,000	1,132,000	81,000	2,815,000	685,000	510,000	15,000	166,000
Lagos	3,000	57,000	158,000	25,000	2,418,000	166,000	-	-	5,000
Niger	1,165,000	752,000	968,000	81,000	2,464,000	532,000	220,000	12,000	68,000
Ogun	27,000	340,000	904,000	149,000	4,310,000	318,000	188,000	-	38,000
Ondo	9,000	589,000	1,747,000	291,000	4,492,000	582,000	5,000	1,000	32,000
Oyo	296,000	861,000	1,887,000	177,000	5,647,000	536,000	72,000	14,000	310,000
Plateau	1,054,000	964,000	1,866,000	535,000	2,941,000	917,000	166,000	53,000	189,000
Rivers	3,000	509,000	670,000	66,000	2,170,000	568,000	-	-	5,000
Sokoto	1,778,000	2,566,000	2,466,000	2,000	3,432,000	801,000	1,071,000	19,000	73,000
Total	**13,947,000**	**22,104,000**	**34,495,000**	**3,410,000**	**70,826,000**	**11,789,000**	**4,679,000**	**223,000**	**1,720,000**

Source: Ibanga, 2002

176 (58.67%) of the respondents declared their neighbors and family members as their major source of productive information while 138 (46.00%) of the respondents opined that their source of information is through ICT materials such as CD-ROM, diskettes, internet, etc (See Table 5).

Table 7 reveals 259 (86.33%) of the respondents admitted that the introduction of ICT to the production and management of livestock farms has brought positive effects on farms (See Table 6). This opinion was corroborated by the findings of NERDC (1996) and Hawkins (2004). While 41 (13.67%) of the respondents are of the view that the application of ICT has no effect on their farm.

It was discovered that during the interview that the rural farmers are faced with a lot of constraints emanating from the application of ICT in livestock production. Table 7 also revealed that 261 (87.00%) of the respondents declared that the major constraint is poverty. This also is in consonant with the view of Otolo (2006), Ben (2006) and Kwesigu (2000). 196 (65.33%) of the respondents revealed that one of the major constraints is the high cost for downloaded information on livestock production. 183 (61.00%) of the respondents attributed their constraints to the inadequate provision of internet services while illiteracy and lack of computer knowledge also contributed to the major constraints as opined by 178 (59.00%) of the respondents.

Table 4. Information needs of rural farmers

Information Needs	Masama in N.W.	Garkida in N.E.	Osi in N.C.	Wasinmi in S.W.	Mgbidi in S.E.	Isele-Uku in S.S.	Total	%
New breed Livestock	40 13.32%	45 15.00%	50 16.67%	50 16.67%	65 21.67%	50 16.67%	300	100
Veterinary services	40 13.32%	45 15.00%	50 16.67%	50 16.67%	65 21.67%	50 16.67%	300	100
Farm implements	33 11.00%	42 14.00%	47 15.67%	20 6.67%	23 7.67%	21 7.00%	186	62.01
Pesticides	32 10.67%	42 14.00%	47 15.67%	20 6.67%	26 8.67%	23 7.67%	199	66.35
How to get credit facilities	40 13.32%	45 15.00%	50 16.67%	50 16.67%	65 21.67%	50 16.67%	300	100
Market strategies	40 13.32%	45 15.00%	50 16.67%	50 16.67%	65 21.67%	50 16.67%	300	100

N.W. - North West
N.E. - North East
N.C. - North Central
S.W. - South West
S.E. - South East
S.S. - South-South

Table 5. Frequency distribution of respondents in relation to the source of acquiring information on the production of livestock

Sources of Information	No. of Respondents	%
Veterinary Services Agents	300	100
Through neighbors and family members	176	58.67
Extension services agents	216	72.00
Through media e.g. Radio, TV, Newspapers, etc.	138	46.00
Using ICT materials e.g CD-ROM, Projector, Diskettes, etc.	110	36.67

Table 6. The effect of ICT on rural farmers

The Effect of ICT on rural farmers	No. of Respondents	Percent (%)
Positive	259	86.33
No effect	41	13.67

SUMMARY AND CONCLUSION

This research work was carried out to ascertain the impact of ICT on livestock production in Nigeria with concentration on rural farmers' experience. The main purpose is to identify the impact of ICT on rural farmers; to find out if there are any remarkable changes in the rural farmers' mode of operation

Table 7. Rural farmers' constraints in the application of ICT

Constraints	No. of Respondents	%
Poverty	261	87.00
Illiteracy and lack of computer knowledge	178	59.00
Lack of awareness on the usefulness of ICT in livestock production	153	51.00
Inadequate contact with veterinary services agents via internet	140	46.67
Inadequate contact with extension services agents via internet	140	46.67
Inadequate provision of internet services/ centres	183	61.00
Network problems	157	52.33
High cost of downloaded information on livestock	196	65.33

since the advent and application of ICT and to identify the sources of information and how efficient are the sources. The result of the findings shows that ICT has a positive impact on rural farmers in the production of their livestock. More so, ICT should be seen as an indispensable tool for effective animal production; also ICT would continue to serve as major weapons in agriculture, for breaking the cultural barriers that inhibit progress in the lives of rural farmers especially now that the whole world is globally a village. To this end, ICT play a key role because rural farmers have to be aware of the requirements for credit facilities, veterinary services, conditions for the application of drugs and pesticides.

RECOMMENDATIONS

The research was carried out to ascertain the impact of ICT services to rural farmers in Nigeria. And it was discovered that the extension services agents have positively touched the lives of some rural farmers through the distribution and use of ICT materials such as CD-ROM, diskettes, films, etc. Yet urgent attention of the government is therefore needed to improve the social life and the livestock production of the rural farmers.

1. Adult education and computer literacy should be emphasized among the rural farmers.
2. Establishment of cyber café or browsing centres at rural areas should be the priority of the State and Federal Government. This will help to break the yoke of monopolistic charges by the few centres.
3. The veterinary services agents and extension services agents should be motivated and well-equipped by the governments to enhance regular visit to the rural farmers to improve their productions.
4. Credit facilities should be made available and easy for rural farmers to obtain loans to improve their productions.

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Chapter 15
Mini Livestock Ranching:
Solution to Reducing the Carbon Footprint and Negative Environmental Impacts of Agriculture

Dimple Singh-Ackbarali
The University of Trinidad and Tobago, Trinidad and Tobago

Rohanie Maharaj
The University of Trinidad and Tobago, Trinidad and Tobago

ABSTRACT

The rising demand and cost of animal protein, food and feed insecurity, environmental and climatic challenges of livestock agriculture have made the option of insects as food sources a viable topic. This chapter presents existing information and research on edible insects, insect farms and value-added insect products and assesses insects as a potential source of food and feed. Mini livestock ranching where edible insect species are reared, can reduce some of the negative environmental effects of livestock agriculture as it will produce significantly less greenhouse gas emissions compared with traditional livestock and have similar nutritional profiles. Edible insect species also; have a much lower feed to meat ratio, require small areas of land and have an almost negligible water requirement. There is an untapped potential to increase access to this nutritious, climate-smart food via intensified semi-cultivation and raising insects in farming environments, developing value added products and also a potential for a significant source of income.

INTRODUCTION

World population growth has been projected to be nine billion people by the year 2015 (Gerber et al., 2013) and accompanying this projection is a prediction that the food production rate will have to double in order to feed the future population. This together with rising food insecurity, concerns of agriculture contributing to greenhouse gas (GHG) emissions and how climate change will, in turn, affect agriculture productivity, are causing experts to reassess diets and approaches for food production (FAO, 2010a

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and 2010b). Increasing food production and especially protein production in the future by increasing agriculture and livestock farming intensity, brings with it many challenges:

- There may not be land available to expand agriculture,
- If current overfishing of the oceans continues, this may deplete this resource for future populations,
- The high cost of animal feed brings with it a debate on whether grains should be used to feed animals or current human population and
- Increasing competition for scarce water resources.

Alternative solutions to conventional livestock and feed sources have led to the serious consideration of the potential for edible insects and commercial insect farming or rearing as an environmental, climate, land and water resource-friendly solution to contribute to food security, health and livelihoods (FAO, 2013). Raising insects for food would avoid many of the problems associated with livestock as they; require less land and water than livestock, they produce less waste, they do not have to be fed grains and they are not significant contributors to GHG emissions. Insect farms also do not require high resource inputs, technology or even medical services as compared to traditional livestock farms. Since insects are so different from man and vertebrate/livestock animals, risks of sharing diseases and co-infection are lower. However, there may be minor concerns of transferring microbial contaminants when feeding livestock with insect based feeds. Of all the known animal species, insects are abundant as 80% of animals walk on six legs (Dicke & Van Huis, 2011) and over 1,900 edible species have been identified by the UN so there are many different varieties that can potentially be sources of proteins for humans and animals with different flavors and potential for different value added products.

This chapter looks at the negative environmental effects associated with livestock farming including the high water and land resources needed to feed the expanding population. Rearing insects requires minimal land and water while offering an opportunity to counter nutritional insecurity by providing emergency food and by improving livelihoods and the quality of traditional diets among vulnerable people. The purpose of this chapter is to present information on edible insects and mini livestock ranching as alternative sources of food and feed; as a viable climate change strategy to combat challenges of conventional livestock farming, and that has the potential to become as important as traditional food production.

BACKGROUND

While industrialized agriculture has produced buoyant economies, it also has high external costs related to its environmental impact, climate, human health and animal welfare. The current challenge is producing food sustainably for more people, with fewer resources (particularly fossil fuels, land and water) and less environmental impact.

Current crop farming practices of land clearing and inefficient fertilizer and pesticide use, lead to significant release of GHG. Livestock production is also a major source of methane and nitrous oxide emissions from ruminant digestion and improper manure management is said to be responsible for 18% of GHS emission worldwide, more than is contributed by the transport sector (FAO, 2006b).

Potable water consumption by cattle, pigs, sheep and chickens in intensive livestock rearing has been calculated to be 103, 17, 9 and 1.3-1.8 litres per day respectively. This is exclusive of the service water requirements for the intensive rearing of these animals which is already water intensive. It takes approximately 8, 4 and 1 kg of cereal to produce 1 kg of meat from cattle, pigs and chickens respectively (FAO, 2006a). From these figures, it can be seen that chicken production is among the most energy-efficient; but it is still more energy-demanding than cereal production.

The United Nations Convention to Combat Desertification (UNCCD) has estimated that 12 x 10^6 hectares of agricultural land is lost every year and this translates to a potential loss of 20 x 10^6 tons of grain (Bai et al., 2008). This is a significant deficit/loss in grain production for human consumption and for animal feed and puts an extra strain on the remaining, limited available arable land, that now has to be split between crop agriculture, grazing and feed production for the meat industry (FAO, 2006a; 2008). Currently grazing land occupies 26% of the earth's ice-free land surface, and 33% of cropland is dedicated to the production of feed for animals, thus only 67% of cropland is dedicated to directly feeding the world's population (FAO, 2009). Although there is a portion of livestock that is grass-fed, industrialized livestock rearing depends largely on imported grains and soybean feeds. Such feeds would have been grown on land formerly occupied by forests which were cleared and then heavily treated with fertilizers and pesticides. Many small scale farmers feed their animals "human food waste" or material unsuitable for human consumption to try to offset energy efficiency and make it a more environmentally friendly farm. However, this is not the case for intensive pig and poultry production in specialized stables, where instead, an increasingly larger proportion of the production of feed crops is utilized (Keyzer et al., 2005).

To reduce the effect of agriculture on the environment, and the resultant climate change on food supplies, livelihoods and economies, we must, as an urgent priority, increase adaptive capacity in agriculture. Adaptation encompasses both long-term climatic trends, and increasing sustainability and variability in food production. Interventions at both the local and global scale are urgently needed to transition current food production patterns so that they can satisfy human needs while; reducing carbon footprint, adapt to climate change and be balanced with the planets' resources. This can be achieved through the application of science and advanced technology in several aspects of livestock production including;

- Feeding and nutrition,
- Genetics and reproduction, and
- Animal health control.

Adaptation of technology in other general animal husbandry practices such as waste and water resource management can also be used. For example, the anaerobic digestion of manure has a twofold benefit of reducing methane emissions and composting of solid manures. Composting can also lower emissions and act as organic amendments for soils. The substitution of manure for inorganic fertilizers can partially offset emissions and improve soil condition and productivity. However, in the developing world, it is difficult for farmers to improve their farming systems due to:

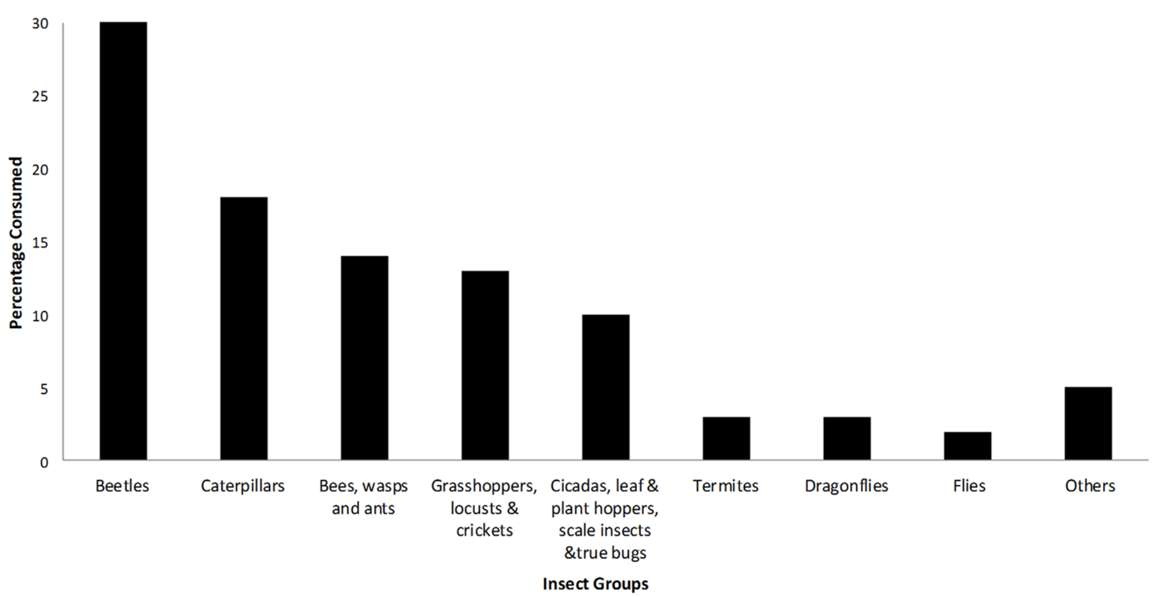
- Lack of access to new technologies,
- Outdated land tenure regulations,
- Discriminatory inheritance laws,
- Biased resource rights, and
- Extremely limited finance options.

Low profitability and poor technology access are particularly problematic for women and marginalized ethnic groups, as they generally do not have the social power or networks to overcome such barriers. With the exception of pastoralists, another common division between richer and poorer farmers in the developing world, is the ownership of livestock. Livestock requires significantly more land, labor and technical skills to manage than small holder crops. Commercial production of livestock or livestock products also requires access to veterinary services, which are often costly or unavailable in the developing world. The role of women farmers in developing countries is changing rapidly, as women become more empowered and more female-headed households are required to take on production and marketing of their agricultural goods.

A landmark, United Nation (UN), Food and Agricultural Organisation (FAO) report in 2013 recommended insects for human consumption and a viable and sustainable source of protein for human consumption and feed for animals. Entomophagy, or edible insect species for human food and animal feed, is a widespread informal practice for approximately 80% of the world's population. Insects form part of the traditional diets of at least 2 billion people according to 2013 report by the UN Food and Agriculture Organization: *Edible Insects, Future prospects for food and feed security.* Figure 1 below shows the most commonly eaten insects and was generated from percentages listed in the report.

Entomophagy is particularly popular and acceptable in countries in the southern hemisphere. Insects ranging from ants to beetle larvae are eaten by tribes in Africa and Australia as part of their subsistence diets, crispy fried locusts and beetles are enjoyed in Thailand, red and white maguay worms, moth larvae and butterfly larvae are eaten deep fried or braised, seasoned with a spicy sauce and served in a tortilla in Mexico. Aboriginal women and children in Australia eat grub either raw or lightly cooked in hot ashes. There are many reasons for the consumption of insects in these countries and are not merely a famine food eaten in times of food scarcity. Many people around the world eat insects by choice, because it is environmentally friendly, nutritious, and cheaper than meat or poultry, but most importantly because insects taste good. These insects are usually harvested from their natural habitats by women and girls. Insect gathering and rearing as mini livestock at the household level or industrial scale can offer important

Figure 1. The most commonly eaten insects worldwide
Source: (FAO, 2013)



livelihood opportunities for people in developing countries through the sale of excess production as street foods and also in developed countries through mass rearing and large scale production. There are some countries that have well established insect farms that supply insects for animal feed, human consumption and even to supplement manufacturers as main ingredients in their production. Thailand has over 20,000 registered insect farms producing around 7,000 tons of food each year (Hanboonsong et al., 2013). In recent times and after the 2010 UN report which recommended insects for human consumption, persons in the United States (US) and Universities in Northern Europe launched insect farms and meal worm farms as potential sources of protein to combat hunger in the developing world. An entrepreneur from the US developed a method of making flour out of crickets and has been able to successfully export his products internationally. Since these events, persons from across North American, Australia and some European countries, namely France, United Kingdom, Belgium, Switzerland and Netherland have been trying insect flour, other processed insect products such as bamboo worm vodka and even unprocessed edible insects such as honey roasted hornet larvae. In Europe, a small number of insect foods have been marketed. Notable UK examples include cubes of ground-up insect produced by the London Ento69 and bags of whole mealworms, crickets and grasshoppers marketed by Planet Organic. The Dutch supermarket chain Jumbo has been selling insect burgers and nuggets since autumn 2014. Research by Mintel News (2015) concluded that some consumers in non-tropical countries who had not eaten insect sourced protein would be interested in trying it. Mintel market research determined that these figures were; 21% in Germany, 26% in the US, 27% in the UK and 52% in China.

Insect specific regulations have traditionally focused on limits of insect fragments that can be accidentally included in food and not on insects as food. Insect farmers and food producers in the United States (US) have requested official guidance from regulatory bodies which has led the US Food and Drug Association (FDA) to state that, insects farmed for food, rather than fish bait or reptile feed, must be specifically bred for human consumption. Even with this US FDA statement, because there is still no regulation on the use of insects as food, there are some countries such as Germany that refuse entry of these products in their countries. However, all this may soon change as the EU will be issuing a ruling in 2015 on insects as food under their Novel Foods Regulations.

The FAO (2013) report highlights that the high demand and consequent high prices for fishmeal and soymeal, the negative environmental impacts of the production process for these feeds and the increases in aquaculture production, will drive research into the development of insect meal for aquaculture and poultry farms. Current research shows that insect meal products are comparable with fishmeal and soy based feed and, therefore, should have a similar market for these feeds (Reed Business Media, 2014; Makkar et al., 2014; Veldkamp et al., 2012). There is an increase in lobbying by the private animal feed sector in both the United States and Europe for the development of specific legislation on the use of insects as feed. The European Commission's Directorate for Health and Consumers in working on allowing insect meal to fall under processed animal proteins (PAPs) that are allowed to be fed to aquaculture species and also as allowable PAPs in pig and poultry feed.

Many insects are highly nutritious and considered healthy food sources. They are loaded with high protein, essential vitamins and minerals, and fiber that is comparable to, or higher than those in fish or meat. For example, mealworms have unsaturated omega-3 and omega-6 fatty acids that are comparable with that of fish (and higher than in cattle and pigs), and the protein, vitamin and mineral content of mealworms are similar to that in fish and meat. The nutritional value of edible insects is highly variable between different species and also even within the same group of species. The nutritional value of the insect is influenced by the metamorphic stage of the insect, the habitat in which it lives, and its diet.

Research done by Rumpold and Schluter (2013) showed the variation in nutritional content from different sources, for example - crickets, grasshoppers and locusts were found to have 64.38% to 70.75% protein and 18.55% to 22.80% fats as compared to beetles which have 10.33% to 41.69% protein and 19.50% to 69.7% fat based on dry matter content. Figures 2 and 3 show the differences in several nutritional components and also compare energy released by the different groups of insects based on dry matter content. The authors concluded that many edible insects provided satisfactory energy and protein requirements, met amino acid requirements for humans, have high monounsaturated fatty acids (MUFAs) and/or polyunsaturated fatty acids (PUFAs), and are rich in several micronutrients such as:

Figure 2. Protein bar made with insects, Photo Credit: Kickstarter/Crobar
Source: (Protein Bar Made With Cricket Flour, 2015)

Figure 3. Silk worm pancakes
Photo Credit: Tiny Farms; Source: (Tiny Farms, 2013)

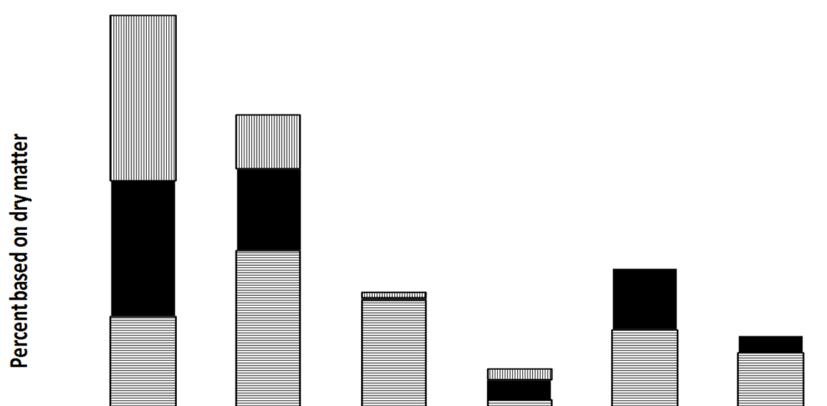
- Copper,
- Iron,
- Magnesium,
- Manganese,
- Phosphorous,
- Selenium, and zinc as well as riboflavin, pantothenic acid, biotin, and in some cases folic acid.

Insects that are collected from forest areas are generally clean and free from chemicals, and in some areas are even considered to be "health foods". FAO (2013) stated that some insect species are also reputed to have beneficial medicinal properties. A greater impetus toward insect farming or collection of insects from the wild in larger numbers is needed, however, concerns regarding handling and processing practices, hygiene and overall food safety requirements must be addressed and the public educated. Relevant standards and regulations regarding insects as food will be required to assure increasingly sophisticated and health-conscious consumers of the nutritional quality and safety of insect foods.

MINI LIVESTOCK RANCHING/ INSECT FARMING: AN ENVIRONMENTALLY, CLIMATE FRIENDLY AND HEALTHY SOLUTION TO IMPROVING FOOD SECURITY

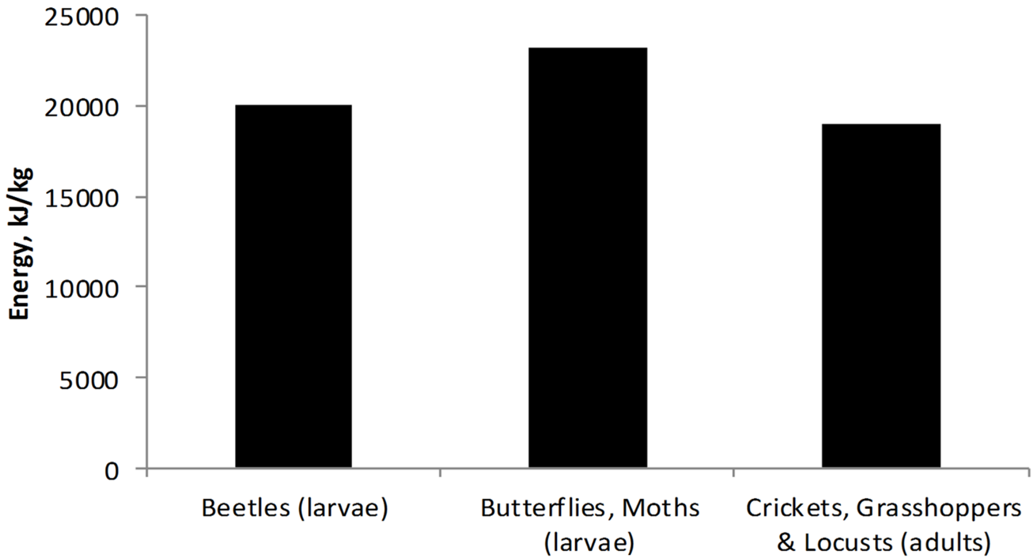
Most edible insects are harvested from their natural habitats in forested areas. However, there are some well-known domesticated insect species, such as bees and silkworms. Farming systems have long since

Figure 4. Comparison of the maximum percent protein, fats, nitrogen free extract, ash, palmitic and linoleic acid between three different groups of insects-figures are based on dry matter
Source: (Rumpold & Schlüter, 2013)



	Maximum Protein	Maximum Fat	Maximum NFE	Maximum Ash	Maximum Palmitic Acid	Maximum Linoleic Acid
Crickets, Grasshoppers & Locusts (adults)	70.5	22.8	2.6	5.1		
Butterflies, Moths (larvae)	58	35	1	8.6	26.2	7.3
Beetles (larvae)	41.69	69.78	48.6	5.7	36	26

Figure 5. Comparison of maximum energy that can be released from consumption of three different groups of insects. Figures are based on dry matter
Source: (Rumpold & Schlüter, 2013)

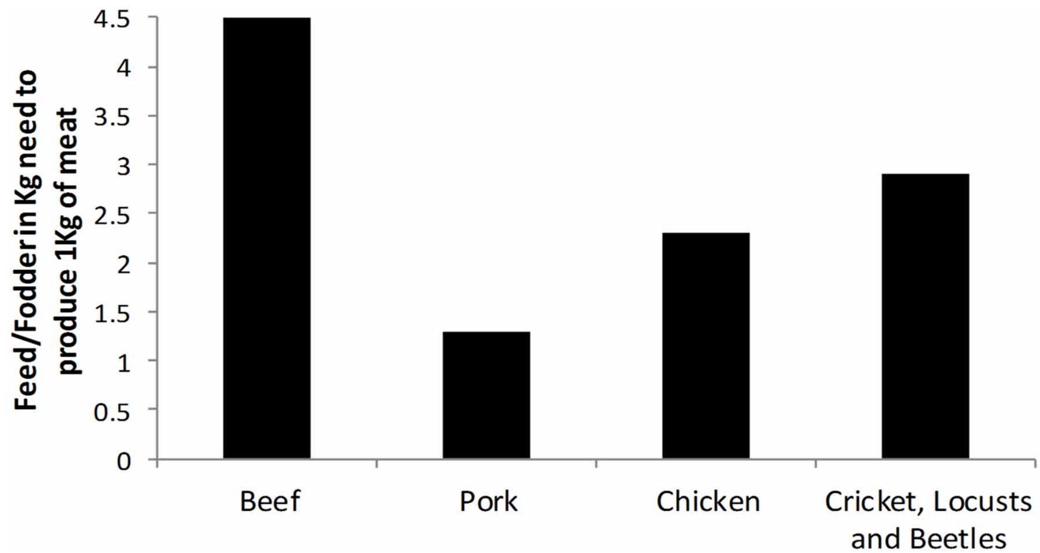


been developed for these species because of the ready market and value of their products. Other insect species are also reared in large numbers, not for their by-products but for the purposes such as:

- Biological control (for example, as predators to control disease causing organisms in plants),
- Health (for example, maggot therapy, as ingredients in medicines),
- For use in food (for example, cochineal, the red color derived from a mexican cactus insect parasite and sometimes listed on edible products as a "natural food coloring", e120)
- And also for pollination.

In temperate countries, insect farms are family-run enterprises that rear insects such as mealworms, crickets and grasshoppers in large quantities to supply as pet food or for zoos. Some of these firms have only recently been able to commercialize insects as food for human consumption and feed for animals intended for human consumption. However, the segment of their production geared for direct human consumption is still minimal. An example of rearing insects for human consumption in the tropics is cricket farming in the Lao People's Democratic Republic, Thailand and Vietnam (FAO, 2013).Insect farming offers particular benefits to those who want to reduce their environmental footprint. Insects are easier and more environmental friendly to rear than livestock; they are cold blooded and they do not need as much feed, water, space and health care as livestock. They are also exceptionally efficient at converting what they eat into tissue that can be consumed. Insects are twice as efficient as pigs and more than five times as efficient as beef cattle. Four and a half kilograms of feed yields a half kilogram of beef, one and a third kilograms of pork, two and a third kilograms of chicken and a little less than three kilograms of insect meat. Crickets, locusts and beetles, for example, require only 1.5 to 2 kilograms of fodder for every 1 kilogram of bodyweight gain or meat (see Figure 6). Factoring in their astounding reproduction rates and fecundity, the actual food conversion efficiency of insects may be 20 times that of cattle (FAO,

Figure 6. Comparison of the amount of feed/fodder needed to convert to 1Kg of meat
Source: (FAO, 2013)



2013). Insects feed on a far wider range of plants than conventional livestock and will not compete with humans for grains as feedstock. Moreover, not only do insects require less food to farm but humans and animals do not have to eat as much insect protein as compared to other animal protein to survive (see Table 1.). Insects are also an extremely rich source of essential amino acids and vitamins.

In addition, insects can be reared on organic side-streams (including human and animal waste) and can help reduce environmental contamination. A study done by Lundy & Parella (2015) determined that crickets fed the solid filtrate from food waste processed on an industrial scale via enzymatic digestion, were able to reach a harvestable size and achieve feed and protein efficiencies similar to that of chickens. However, crickets fed minimally-processed, municipal-scale food waste and diets composed largely of straw, experienced more than 99% mortality without reaching a harvestable size. Studies done by Collavo et al., (2005) and researchers Diener et al., (2009), and Offenberg (2011), found that there was an efficient conversion of feed from organic side stream to protein by crickets and other insects such as black soldier flies and ants. However, population densities in these studies were generally low, suggesting that, while the conversion efficiencies reported may be accurate on an individual basis, they may or may not apply to production environments with high-density insect populations.

Table 1. Nutritional content of insects compared with beef

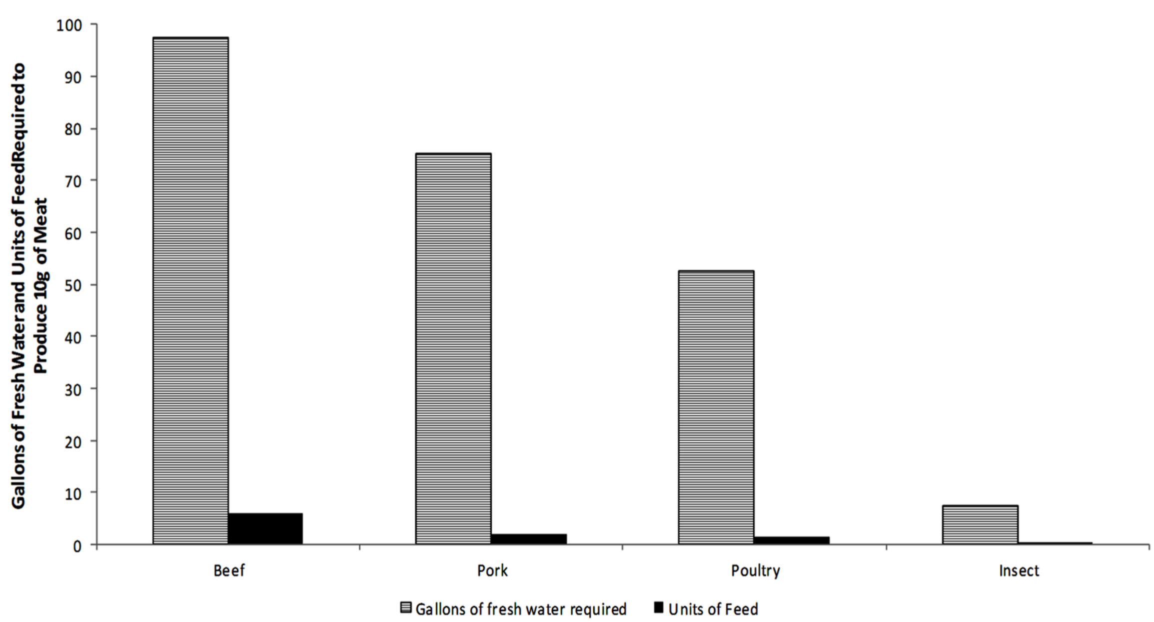
	Protein (g/kg)	Fat (g/kg)	Calories (g/kg)	Thiamin (g/kg)	Riboflavin (g/mg)
Black Soldier Fly (larvae)	175	140	1,994	7.7	16.2
House Cricket (adult)	205	68	1,402	0.4	34.1
House Fly (adult)	197	19	918	11.3	77.2
Beef	256	187	2,776	0.5	1.8

Source: (Finke, 2012, 2002)

Another side of the feed story shows insect meal as more expensive than soymeal but less expensive than fish meal fed to animals. Despite an additional positive benefit in saving of potential fisheries stock, insects do not naturally contain eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) omega-3 oils, which are essential dietary components of many fish species (e.g. salmon) and offer well-established health benefits for humans.

Traditional livestock carcasses have a high percentage of waste after processing; the proportion of livestock that is not edible or wasted after processing is 30% for pork, 35% for chicken, 45% for beef and 65% for lamb. By contrast, only 20% of a cricket is inedible and most meal worms and similar bugs have 0% that is inedible (Dicke & Van Huis, 2011). Jayathilakhan et al. (2011) had different figures for the average solid waste generation from bovine slaughter houses. They stated that 27.5% of the total live animal weight is wasted in the slaughtering of goat and sheep and there was an average waste generation of 4% of the live body weight of pigs. Insect rearing requires far less space, especially when compared to bovine and even poultry rearing. The livestock industry currently occupies 70% of agricultural land (Arkell, 2013) and according to onegreenplanet.org, raising animals for food uses up to 30% of the Earth's land mass. These figures do not consider the land needed for growing feed for these livestock animals. Breeding trials conducted by the E.U. initiative PROteINSECT have found that one hectare of land could produce at least 150 tons of insect protein per year. Questions remain over the water and energy efficiency of insect rearing, given the need for heat treatment and washing of larvae. Insect farms require minimal water, especially when compared to the production of conventional meat (it takes more than 10 gallons of water, for instance, to produce about two pounds of beef). Next Millennium Farms (@entmofarms, 2016) stated that if a family of four ate food made with insect protein at least once a week for one year, there is a potential to save 650 x 10^3L of fresh water a year. Figure 7 illustrates a comparison of the water and feed input needed to produce 10g of meat from different animals.

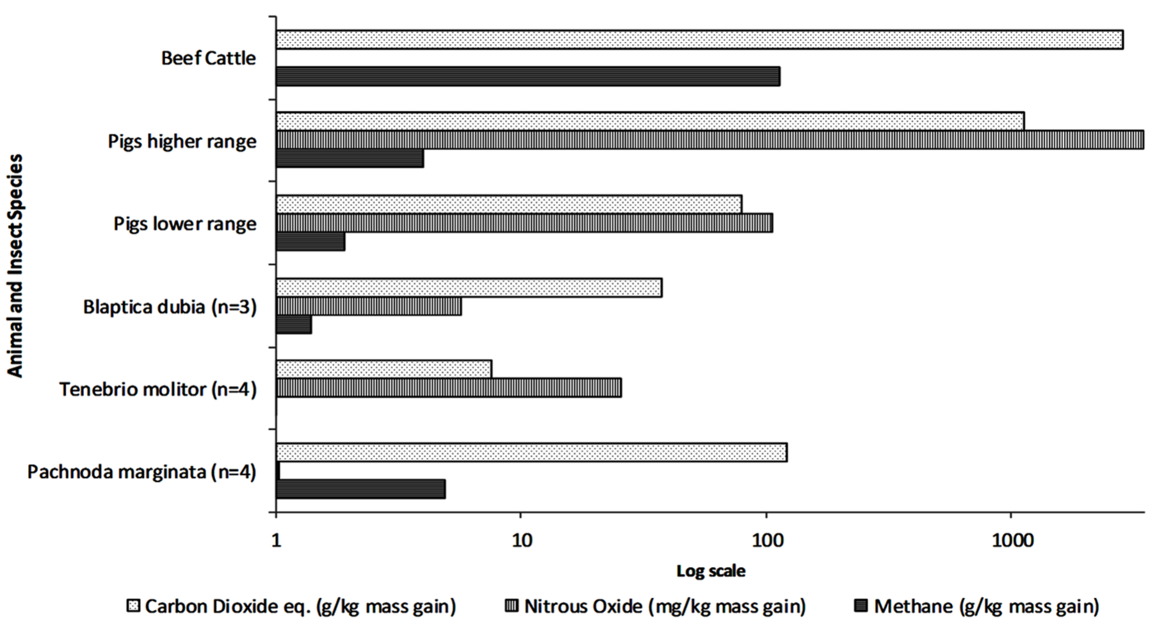
Figure 7. A comparison of water and feed resources required to produce 10g of protein from different animals
Source: (@entomofarms, 2016)



Livestock production is responsible for at least 10% of all greenhouse gas emissions (Dicke & Van Huis, 2011). However, insects produce far less ammonia and other greenhouse gasses per pound of body weight. Oonincx et al., (2010) designed a study to determine carbon dioxide, methane, and nitrous oxide produced by five insect species (only three of these species were considered edible). At the end of their study, they were able to conclude that there were large differences among the species with respect to their production of carbon dioxide and GHG. The insects in this study had a higher relative growth rate and emitted comparable or lower amounts of GHG than described in the literature for pigs and much lower amounts of GHG than cattle, as illustrated in Figure 8. The same was observed for carbon dioxide production per kg of metabolic weight and per kg of mass gain.

In the livestock sector, there can be a proliferation of pathogens due to pressures resulting from the production, processing and retail environment. Some of these pathogens result in diseases that are zoonotics, such as; foot and mouth disease and influenza A. Hazard Analysis and Critical Control Point (HACCP) planning for farms should take into account critical control points to reduce host contact rates, population size and/or microbial traffic flows into the food value chain. Insects are very different taxonomically from mammals and humans, and thus compared with livestock mammals and birds, they should pose a low risk of transmitting zoonotic infections to humans, livestock animals and wildlife. However, insects for food and feed have not been tested sufficiently and further research to determine the risk that they pose in transmitting diseases to humans, and mitigating factors must be evaluated. Intensive insect livestock facilities with proper biosecurity will prevent farmed insects from coming into contact with insects from the outside. Facilities that always handle their insects hygienically should have less risk of zoonotic infections. Additionally, heating and drying treatments during processing can reduce the risk of microbial contamination and almost guarantee that insect foods and feed would be free from viral, parasite and fungal pathogens.

Figure 8. A comparison of GHG produced by three edible insect species and pigs and cattle
Source: (Oonincx et al., 2010; Aarnink et al., 1995; Groot Koerkamp et al, 1998; Demmers et al., 2001; Nicks et al., 2003; Beauchemin & McGinn, 2005; Cabaraux et al., 2009 and Harper et al., 2009)



Mini Livestock Ranching

It is possible to rear insects using small scale cultivation methods under controlled conditions (mini livestock ranching) in order for them to develop and reproduce to have a cheap and sustainable food source. This alleviates concerns that such insects could have come into contact with pesticides and other chemical hazards when cultivated under such conditions. Some insects already farmed for human consumption, include:

- Crickets,
- Silkworms,
- Mealworms (beetle larvae), and
- Wax worms.

Insect rearing can be very simple using low-technology. Insects do not require large horizontal areas to thrive. Instead, they can be stacked vertically for maximum efficiency particularly when space is limited. Numerous species can be raised in high densities, in order to get a much higher nutritional output per unit area (Spiers, 2013). Some factors to consider with respect to rearing insects such as mealworms are now reviewed.

Equipment/Containerization: Abiotic and Biotic Factors

A minimum of three plastic containers to a maximum of ten containers stacked high and placed along the length of a room can be used to rear insects like meal worm, grasshoppers or crickets. Plastic containers or crates that have a dimension anywhere between 41 cm x 28 cm x 15 cm or 50 cm x 44 cm x 20.5 cm or 10 Liter aquarium with a screened lid can be used (Food Insects Newsletter, 1996). Containers should be cleaned thoroughly before use and not placed in bright sunlight but rather a source of radiant heat such as from a light bulb or desk light can be placed close to or even inside the container. The light can be on for up to 16 hours a day. To provide proper air circulation and prevent condensation, holes are punched in the lid and it is covered with mosquito netting or cheesecloth. For insects such as crickets and grasshoppers, moist (but not saturated) sterile sand or vermiculite can be placed in the container for egg laying. A thermostat can be used to keep the humidity as constant as possible. A common range in insect facilities is 40 to 80% relative humidity, dependent on the species and the developmental stage. Van de Ven insect rearing company has found that the ideal humidity for their meal worms is 60-70%, and a fluctuation of 5% is adequate (Erens et al., 2012).

Diets differ dependent on species. However, there are some dietary components that should be part of the nutrition of the insects. These include:

- Carbohydrates,
- Proteins,
- Lipids,
- Nucleic acids,
- Minerals,
- Vitamins, and
- Water (Erens et al., 2012).

Most of the diets are provided to the insects as a powder. For mealworms, mixed grains such as:

- Oat or wheat kernels (10 parts),
- Rolled oats (oatmeal) or whole wheat flour (10 parts);
- Wheat germ or powdered milk (1 part); and
- Brewer's yeast (1 part) are suitable.

Brewer's yeast can be obtained at health food stores. This is an important ingredient, because it provides proteins and trace elements essential to the insects' growth (Food Insects Newsletter, 1996). Kreca, an insect rearing company uses flower substrate to feed a wide range of species including:

- Mealworms,
- Wax moths,
- Houseflies,
- fruit flies,
- Cockroaches, and
- Crickets.

When using plant material, these should be well washed to remove any pesticide residue. Most insects get their hydration from their food and do not require further sources of water. Bits of vegetables (cabbage, carrots, potatoes, lettuce, and so on) or fruit (mainly apple) can be provided. Lettuce, cabbage and grass can be fed to grasshoppers and crickets. These items should be monitored daily and immediately replaced when mold growth appears (Food Insects Newsletter, 1996).

Culture Management and Maintenance

The larvae starter culture can be purchased from pet shops where they are used as food for reptiles and amphibians or bait shops or from other insect rearing companies. About 2.5 cm of the grain mixture is placed in one of the culture containers, and added to this, is the mealworm larvae, and bits of vegetables and/or fruit. As soon as the first pupae appear (this is a non-feeding and non-ambulating stage), they should be transferred to another empty box or container. This will prevent the larvae from eating the pupae. For the same reason, the adults must be separated from the pupae as soon as they emerge from the pupal 'skin' (exuviae). The adults are transferred to a third box, also containing 2.5 cm of the grain mixture and chunks of vegetables or fruit (Food Insects Newsletter, 1996). The males and females of the mealworm are indistinguishable. They mate 2-5 days after emerging, and the female lays up to 40 eggs a day. The eggs can take on average 12 days to hatch. The larvae molt several times over a period of about 10 months, until they reach 25-30 cm in length. It takes about 12 days for the pupa to complete metamorphosis into adults. The adult lives about only 2 months. At temperatures from 18 to 25°C, the insect's life cycle is about one year. However to speed up its development, the home insect 'farm' should be kept at a temperature of about 25 to 30°C. Above 30°C, there are negative effects on growth and development. Insects should be kept in a number of different containers to minimize losses due to contamination or any other problem. The pieces of fruit or vegetables should be replaced when they dry out, and any dead insects must be removed. The grain mixture must be stirred from time to time to incorporate the larval skins, so that they will also be consumed by the larvae. The mixture should be changed when it begins to look sandy and the insects are removed or separated using a sieve. Cultures must be kept in a dimly lit, dry, and well ventilated place and the mixture kept as dry as possible to avoid mold and other undesirable organisms (Food Insects Newsletter, 2009).

Yellow mealworms *Tenebrio molitor* (Family: Tenebrionidae), are some of the easiest insects to rear using the home farming system, as availability is year round through this method and with minimal cost impact. Mealworms are small, reproduce quickly and are resistant to disease and parasites. In addition, they are simple to handle and require little space and maintenance. There are four stages in the life cycle. The egg is 1.8 mm; the larva grows from about 2 to 30 mm; the pupa about 16 mm; and the adults are 16 mm. Tiny Farms, a company dedicated to increasing entomophagy in Oakland, California raises insects in bins. It has been reported that the silkworms are raised in an environmentally controlled tent and fed a prepared feed made with powdered mulberry leaves. The mealworms can be raised at room temperature in shallow plastic or metal trays in a bedding of wheat bran or another grain byproduct, and should be fed additional vegetables such as carrots, for moisture. The beetles are adult mealworms in a breeding bin, containing about 150 beetles laying over 100,000 eggs (Spiers, 2013).

Cricket farming in Thailand started in 1998 and currently around 20,000 farmers raise crickets for human consumption. Cricket farming contributes to the livelihood and nutrition base of farmers and a value chain has established through which the crickets are marketed around Thailand. The technology presented in the FAO 2013 article is aimed at small scale producers in Thailand and neighboring countries, in which these species are also available in nature. Small scale producers can be farmers, but also other people and even groups, who see a business opportunity in selling crickets. The technology describes some of the common species used, how a cricket farm is set up and further describes the daily management of the farm, including processing for sales and challenges and risks with such a venture. Challenges include the high cost of protein feed, disease and in-breeding (TECA, 2013).

PRESERVING AND PROCESSING INSECTS

Insect farming is a relatively new sector in the agri-food business. Despite the consumption of insects as food, there is limited research and information on the quality of insects that are used for food and feed. Additionally, information concerning their chemical, and microbial safety, their parasitical and allergic hazards, as well as the nutritional aspects of processed products and shelf-life are limited.

Edible insects are currently consumed in various parts of Asia, Africa and America. In developing countries, protein and/or energy undernourishment is a major issue. Approximately 1800-2000 plus insect species are used for human consumption globally (Jongema, 2011; van Huis et al., 2015). According to Cook (2015), FAO states that globally the most commonly consumed insects are:

- Beetles (*Coleoptera*),
- Caterpillars (*Lepidoptera*),
- Bees,
- Wasps and Ants (*Hymenoptera*),
- Grasshoppers,
- Locusts,
- Crickets (*Orthoptera*),
- Cicadas,

- Leafhoppers,
- Planthoppers,
- Scales insects and true bugs (*Odonata*).

Insects contain more polyunsaturated fatty acids and have higher contents of minerals. However, the chitin in insects can be undesirable in many food products due to its indigestibility which limits nutrient absorption. Thus, methods that extract the nutritional content from insects while leaving behind the chitin are highly desirable (Morales-Ramos et al., 2013). Insects as food and feed can only make a significant difference if they are mass-produced. This is done already in Thailand where 20,000 domestic cricket farms produce an average of 7,500 metric tons of insects a year for home consumption and for the market primarily through drying. Finding methods of preserving them in parts of Africa where the humidity is very high is often a challenge (van Huis et al., 2015; Hanboonsong et al., 2013). Preparation and processing methods such as sun drying, boiling, frying or even freeze drying can also influence nutritional composition. A summary of the processes for preservation and processing of insects (Anses, 2015) includes:-

- Slaughter
  - 24-hour fasting to purge digestive tract
  - Freezing 24 hr at -18°C
  - Boiling (1-5min)
- Processing and preservation techniques
  - Dehydration in a ventilated oven (60-110°C)
  - Deep-frying (>160°C)
  - Toasting
  - Freeze-drying
- Preservation
  - Whole or fractionated insects/flour (after grinding)
  - Optimal conservation methods (cooking, acidification, fermentation…)
  - Packaging finished products (sealed to avoid becoming rancid)

Insect Products

While there are a number of culturally different ways to prepare and cook insects, mostly they are consumed whole. There are three ways insects can be consumed namely:

- As whole insects,
- Processed in some powder or paste form, or
- As an extract of protein, fat or chitin for fortifying food and feed products.

Whole insects are often consumed as a fried snack or as part of a daily meal with rice. Live, ready to eat insects or those boiled can be sold at local markets. Farmed insects can be processed into a dried form such as insect powder, suitable for protein enrichment for a variety of low-nutrient foods or feed. Protein could also be extracted from insects and applied in food and/or feed as alternatives to soy or meat protein (Klunder et al., 2012; FAO, 2013).

Before insects are prepared for meals, precautions such as killing the larvae by freezing them alive for about forty-eight hours can be a method for inactivation. The frozen insects can be kept in the freezer for a few months if they are properly wrapped in airtight bags or containers. Insects can deteriorate quickly, just like meat that is left unrefrigerated, so it is important to keep them in the freezer until they are ready for consumption. When insects are taken out of the freezer, a good practice is that they should be rinsed in running water before cooking. Insects which are of a suspect quality such as emanating a rotten smell, unusual color, and such like; should be discarded. With excess mealworms, the late instar larvae (older larvae, about to pupate) can be placed in plastic containers with small perforations in the lid. Such larvae can be covered with wheat bran and placed in the refrigerator up to one month using this technique, prior to cooking (Food Insects Newsletter, 1996).

Pastes/Powders/Protein Isolates

In societies where consumers are not accustomed to eating whole insects, granular or paste forms may be more suitable for consumer acceptance. Edible insects can be processed into paste or powder and added to otherwise low-protein foods to increase their nutritional value. This can be done through techniques of grinding or milling (FAO, 2013). The application of Sorghum frequently consumed in African countries and enriched with nutritious termites *(Macrotermes spp.)* can be consumed as part of the daily diet. Sorghum can be enriched with boiled or roasted and ground termite powder and the mixture fermented and used for porridge preparation (Klunder et al., 2012). There are also insect powders that are being incorporated into other bakery and food products such as noodles/pastas. Research is on-going on the use of insect fat for ice-creams and salad dressings (Cook, 2015).

Separating extracted protein from insects based on their solubility in solvents produces water-soluble and water-insoluble fractions, which can be used for specific applications in both the food and feed industries however these extraction techniques can be costly. Extracting fats, chitin, minerals and vitamins are also possible. At present, such extraction processes are too costly and more research is required to further develop the process and to render it profitable and applicable for industry use (FAO, 2013).

Cricket Flour and Other Secondary Products

The cricket (*Acheta domesticus*) due to its high protein content and taste is a preferred insect that can be converted to secondary products. Cricket flour and cricket protein products can be used in recipes instead of the practice of serving full insects and crickets in meals. Cricket flour can be obtained from companies that buy live crickets from local cricket farmers, or frozen crickets from cricket farms, or from breeding and raising their own crickets to make cricket flour. Additionally, it has been reported by some breeders, that the taste of the crickets can be determined on the choice of food fed to the crickets such as apples, mint, among others. (Cricket Flours, 2015).

Most companies harvest their crickets around 8-weeks in their development, but they can also be harvested from about 6-weeks, before their exoskeleton has fully formed. Once the crickets have been gathered at the cricket processing facility, they must be dried before the cricket milling process. Crickets can be dried by several methods:

- Including solar,
- Freeze-dried,

- Placed in a food dehydrator, or
- Baked in an oven.

Depending on time requirements and desired taste profile, these parameters can be experimentally varied. After drying, the crickets are then ground using two different grinding or milling machines. The first machine is set to a coarse grind. Once the crickets have been placed in the first machine, the coarse cricket flour is then sifted to remove the lighter content which consists of legs, wings, and such like, and is removed from the final cricket flour product. Next, the remaining coarse cricket flour is placed in the second milling machine which is set to a fine grain size to produce fine cricket flour. Most cricket flour production processes will follow this general method using the cricket feed, the freezing processes, drying processes, along with the final grinding procedures (Cricket Flours, 2015; FAO, 2013).

The Farmed Insect Company (http://www.thefarmedinsectcompany.com/) are producers of cricket protein powder (cricket flour), that has become popular within recent times. Organically reared crickets are sterilized and dehydrated before a grinding process that converts them into an extra-fine light fluffy flour. This flour is then incorporated for use in energy bars, biscuit baking, protein shakes, and other protein supplements. It must be noted however that the Codex Alimentarius standards relating to cereals, dried vegetables, legumes and plant protein materials prohibit the presence of whole live insects in flour or grains, but authorize a maximum of 0.1% of insect fragments by mass of the sample (Anses, 2015).

Two species of fly, the black soldier fly, *Hermetia illucens,* and the housefly, *Musca domestica,* are being studied and their larvae used to recycle organic waste into fertilizer. Other compounds which can be extracted from the biomass of insects, apart from protein intended for animal feed, are chitin for its antimicrobial action and lipids for the production of biodiesel (Anses, 2015).

CONTROL OF DISEASE AND GENERAL FOOD SAFETY

Farmers and Processors should take the following precautions to ensure the health of their insects and that they deliver a safe end product:

1. Ensure that the design of the breeding facility can allow for controlled ventilation and humidity and that it mimics the natural conditions in which the species of insects are found, as much as possible.
    a. Insects are very sensitive and will react in a negative way when the artificial conditions deviate too much from their natural conditions. Microbial contamination by air can be reduced by air filtration. Visitors should not be allowed in breeding areas to prevent contamination by humans. Measures should also be put in place that would minimize rodents and wild birds from entering. If the humidity is too high, this may result in fungal or other disease problems and might even cause drowning of larvae and asphyxiation of adults (Schneider, 2009).
2. Control population size
    a. For most species crowding is not a problem since they live together in high densities in nature as well. However crowding can lead to heat development and disease is not only dependent on a microorganism, but also an interaction with the environment and host. Microorganisms that live in the alimentary canal of insects, and so not harming the insect under natural conditions, can become infectious pathogens under abnormal conditions such as too high density, and this can lead to death in a large proportion of the population.

3. Newly introduced insects should be bought from registered farms that have cGMPs and not harvested from the natural environment.
    a. They should be screened and tested for the presence of pathogens that can affect the rest of the insect population on the farm and inoculated for prevalent diseases (for example, MdSGHV).
4. Records of registration of feed, sources, storage temperatures and so forth, should be retained.
    a. Artificial diets may contain various fungi and bacteria. Antibacterial agents can be used to prevent contamination from artificial diets. The same can apply to nutrients such as vitamins, wheat germ, caseins, tap water and gelling agents. Natural diets, such as leaves and fruits, can also be contaminated with microorganisms, especially on their surfaces but also inside tissues, these can be stored in dry areas to prevent population growth of these microorganisms as too high humidity can cause mass population growth of many microorganisms, especially fungi.
5. Proper slaughtering and processing - when insects are reared for human consumption, hygienic measures must be taken especially after sifting.
    a. Insects should be sterilized in hot water then freeze-dried and refrigerated or preserved using acid and dried. Insects should always be kept in a freezer until they are ready for use and good practice entails rinsing them in running water prior to cooking.
6. Preservation, packaging and cooking at the right temperature is critical.
    a. Because insects are far more distantly related to human beings than pigs, cattle, and sheep, it is far less likely that the pathogens that affect insects would affect humans. However, insects should still be cooked properly because uncooked insects can carry nematodes that can infest human hosts and spore forming bacteria can be a concern even for cooked mealworms and crickets. Since insects are nutritious for us they are also nutritious for bacteria. Even in insects that have already been cooked, there exists possible contamination from bacteria, so proper measures should be put in place during packaging, to prevent recontamination of the product. Packaging should always be food grade and should not be stored in material that has bisphenol A (BPA), lead or any other material identified as containing harmful compounds. Follow proper processing procedures for each species. Some insects are toxic to humans as is the case with the grasshopper species *Zonocerus variegatus* which stores toxins from the plants they consume. They can be made safe as long as they are prepared properly, such as heating the insects in tepid water to extract toxins, and then changing the water before cooking.
7. Proper labeling and allergy warnings on products
    a. Humans with Immunoglobulin E-mediated allergies have been known to suffer food allergies to crustaceans, and may suffer food allergies to other arthropods as well.

ECONOMIC OPPORTUNITIES

In some instances, consumers are willing to pay a premium for the safety of street foods including insect preparations if prepared, stored and sold in a hygienic condition (Akinbode et al., 2011). In 2010 in the USA, an attempt was made to promote the industry by organizing an international seminar on 'The potential of edible insects' at Linvile, Alabama, USA, by the Southern Institute for Appropriate Technology. Similarly, a workshop at Chiang-Mai in Thailand on 'Edible insects' co-organized by the FAO in 2008 was a great success. Entomophagy can be revalidated by worldwide campaigns and launched in those countries that are facing acute food shortage.

The capturing, processing, transporting and marketing of edible forest insects provide interesting income and livelihood opportunities for an undetermined number of people around the world. Traditionally, these activities were all locally based and largely under-recognized. Recently, however, more sophisticated and wide-reaching marketing and commercialization of edible forest insects have been advanced, including attractive packaging and advertising.

Insect gathering and rearing as mini livestock at the household level or industrial scale can offer important livelihood opportunities for people in both developing and developed countries. In developing countries, some of the poorest members of society, such as women and landless dwellers in urban and rural areas, can easily become involved in the gathering, cultivation, processing and sale of insects. These activities can directly improve their own diets and provide cash income through the selling of excess production as street foods. Insects can be directly and easily collected from nature or farmed with minimal technical or capital expenditure (for basic harvesting/rearing equipment). Rearing insects may also require minimal land or market introduction efforts, as insects already form part of some local food cultures. Protein and other nutritional deficiencies are typically more widespread in disadvantaged segments of society and during times of social conflict and natural disaster. Due to their nutritional composition, accessibility, simple rearing techniques and quick growth rates, insects can offer a cheap and efficient opportunity to counter nutritional insecurity by providing emergency food and by improving livelihoods and the quality of traditional diets among vulnerable people.

There is considerable potential in widening the market for edible insects by incorporating insect protein in supplements, processed foods and animal feeds. Worms, flies and larvae are natural foods of poultry and some fish species in the wild. The Food and Environment Research Agency (FERA) is coordinating an international research project – ProteINSECT – investigating how insects can be reared safely and economically for feed production. Insect meal is rich in protein and nutrients, and industrial rearing in factories could theoretically produce far higher yields of protein per hectare of land compared to soy. GREEiNSECT is a consortium of public and private institutions investigating how insects can be utilized as novel and supplementary sources of protein by means of mass production in small to large scale industries in Kenya.

POTENTIAL BARRIERS TO INSECTS AS HUMAN FOOD AND FEED FOR ANIMALS INTENDED FOR HUMAN CONSUMPTION

Critical elements for successful rearing include research on biology, control of rearing conditions and diet formulas for the farmed insect species. The major challenges and opportunities will be discussed.

The general market and potential consumers will need to be convinced to accept edible insects and food products with insect ingredients as palatable, viable and safe for their consumption. Masking the insect shape can be a strategy. An example is the use of insect powder in protein bars. Including insect ingredients in trial dishes at popular restaurants may also promote acceptance by providing opportunities for adventurous chefs. The market pull will drive a higher turnover for insect farms and this will assist insect farmers in overcoming the challenge of scaling up.

Litigation and loss of market share can arise if there are any occurrences of allergic reactions due to improper warning on the packaging or because the public was not educated on potential allergies. There is the possibility of having similar reactions to edible insects if they were allergic or sensitive to consuming other arthropods such as shellfish.

Current production systems can be expensive; a major challenge of such industrial-scale rearing is the development of automation processes to make plants economically competitive with the production of meat (or meat-substitutes like soy) from traditional livestock or farming sources. Another main factor is the high cost of labor in insect farms in temperate countries as compared to insect gathering in the tropics. Development and up-scaling of automation technologies in rearing, harvesting and processing are required to reduce costs and increase the competitiveness of alternative animal protein products. Mealworms are approximately three times more expensive than pork and about five times more expensive than chicken. Fish meal is more expensive than soy meal as feeds. Insect meal is currently substantially more expensive than regular meat or soy meal products. Raising species on manure and organic food waste, enabling nutrient recycling and large-scale production units can reduce costs. However, manure cannot legally be used as feed under current EU regulations.

Developing legislation and standards, which will allow the use of insects as ingredients in food, the use of insects directly as food, and as feed for animals intended for human consumption is much needed. This legislation will open up the market for farmers/producers and, therefore, increase the market and hence allow the farmers to scale up their production and reduce the cost of their products.

Legislation that will allow the use of organic waste as insect feed to be used for human and animal consumption must also be developed. This will streamline wastes and reduce the feed cost needed by insect farms. However, this can bring with it another safety concern of potential carryover of heavy metals from these waste streams to insects during rearing.

More research and development is required for processing the insects as ingredients that can be incorporated into different food products (such as insect flour) instead of whole insects. This will mean increased automation and mechanization processes in order to arrive at processed end products and therefore increase the investment needed for insect farms and producers.

Invasive insect species have the potential to disrupt the natural ecosystems and destroy crops. All precautions have to be taken to contain them during the transport of living animals across borders when supplying insect farms in countries where they do not naturally occur.

CONCLUSION

There is no simple solution to sustainably feeding the world's growing population. Dependence on scientific and technological innovation to improve conventional livestock farming and intensification must be tempered by the challenges of achieving this while also; controlling GHGs, conserving water, preserving or reducing biodiversity losses for easy grain production and all the while meeting the world's food and nutritional demands. Mini livestock ranching has the potential to address these challenges. Edible insects not only contain high quality protein, vitamins and amino acids for human nutrition, they also have a high food conversion rate. For example, crickets need six times less feed than cattle, four times less than sheep, and twice less than pigs and broiler chickens to produce the same amount of protein. Compared to conventional livestock rearing, mini livestock ranching of edible insects has a minimal ecological footprint in that they require less land and water and also emit less greenhouse gasses and ammonia than conventional livestock. Insects can be grown on organic wastes and are easier to rear than livestock. Therefore, insects are a potential source for conventional production (mini-livestock) of protein; either for direct human consumption, or indirectly in recomposed foods (with extracted protein from insects); and as a protein source into feedstock mixtures. Edible insects can be processed into paste or powder and added to otherwise low-protein foods to increase their nutritional value. There is an untapped potential for novelty food items from edible insects, and insect gastronomy will play a key role in changing consumer attitudes and perceptions to consuming insects as a food of choice. Using insects as a source of food and feedstock can only make a significant difference if they are mass-produced. Developing insect farming technologies will assure that future demand requirements are met. But a key factor is understanding biotic and abiotic constraints to mass mini livestock ranching (insect farming. Further research to determine the risk that insects for food and feed will pose with respect to transmitting diseases to humans, must be done so that proper controls could be put in place. Additionally, new efforts and standards will be required to assure increasingly sophisticated and health-conscious consumers, of the nutritional quality and safety of insect foods and prevent restrictions on exporting insects and products made from insects into international markets.

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KEY TERMS AND DEFINITIONS

Entomophagy: The consumption of edible insect species.

Environmental Impacts: Possible adverse effects caused by a development, industrial, or infrastructural project or by the release of a substance in the environment.

Food Security: When all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life.

GREEiNSECT: Is a consortium of public and private institutions investigating how insects can be utilized as novel and supplementary sources of protein by means of mass production in small to large scale industries in Kenya.

Healthy Food: A healthy food is a plant or animal product that provides essential nutrients and energy to sustain growth, health and life while satiating hunger.

Insect Farming: Practice of rearing insects for food and agricultural use.

Novel Foods: A type of food that does not have a significant history of consumption or is produced by a method that has not previously been used for food.

PROteINSECT: A European Commission FP7 funded project coordinated by the Food and Environmental Research Agency (FERA) in the United Kingdom.

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Section 4
Veterinary Education

Chapter 16
Examining the Use of Web-Based Reusable Learning Objects by Animal and Veterinary Nursing Students

Emily Chapman-Waterhouse
Harper Adams University, UK

Ayona Silva-Fletcher
Royal Veterinary College, UK

Kim David Whittlestone
Royal Veterinary College, UK

ABSTRACT

This intervention study examined the interaction of animal- and veterinary nursing students with reusable learning objects (RLO) in the context of preparing for summative assessment. Data was collected from 199 undergraduates using quantitative and qualitative methods. Students accessed RLO via personal devices in order to reinforce taught sessions. Interviewees reported that the RLO helped them meet the requirements of the curriculum. Quantitative data supported two valid points; the lack of engagement of students when given a free-choice and reluctance for self-assessment. The practical significance of the qualitative outcomes lies with how first year undergraduates on animal and veterinary nursing-related courses use RLO designed to address equine management and health topics, where the students have mixed equine experience.

INTRODUCTION

The increased demand from learners in higher education to access study materials at any time, at any location and increasingly on a range of platforms including mobile devices has resulted in considerable development in the usage of Reusable Learning Objects (RLO) across the sector (RLO-CETL, 2005; Jenkinson, 2009; Kurilovas *et al.*, 2011; Windle *et al.,* 2011; Windle *et al.,* 2010). RLO, also known

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as Shared Content Objects (SCO) are self-contained digital resources such as video, audio, web-pages, documents and graphics which are stored and accessed independently and can be used to support web-based learning. Kay and Knaack (2007) expand on this by saying that RLO are interactive tools which enhance and amplify the cognitive processes of learners. Literature tells us that one purpose of RLO is to enable students to learn new skills (Windle *et al.,* 2010), within a controlled environment, at a range of difficulty levels and with arrangements for regular feedback (AAMC, 2007). Although there have been a number of studies undertaken to examine the role of RLO in higher education, they originate from medicine and health sciences education in the main. Therefore, in the first instance, practice in Veterinary Education must draw from findings in other subject areas.

A number of researchers have identified that the underpinning rationale for developing RLO is wide ranging, but those studies have emphasized flexibility (Johnson *et al.,* 2013; AAMC, 2007), achievement of higher grades (Windle *et al.,* 2011; Lymn *et al.,* 2008; Trowler, 2010; Bacsich *et al.,* 2011), meeting the needs of professional practice (Windle *et al.,* 2011; Windle *et al.,* 2010; Keefe & Wharrad, 2012; DoH, 2011; Evans, 2013; Blake, 2010) or those of institutions (Johnson *et al.,* 2013; AAMC, 2007; Concannon *et al.,* 2005; Evans, 2013; Kurilovas *et al.,* 2011) as opposed to attempting to impact student learning as a whole. Firstly, to help students achieve higher marks in summative assessment and/or an improved overall outcome (Trowler, 2010), educators typically supplement face to face teaching (Lymn *et al.,* 2008) with additional learning resources. The need to do this may in part be explained by the challenging nature of a subject for some students (Windle *et al.*, 2011; Lymn *et al.,* 2008). It has also been reported that some students feel they lack time to study content heavy modules, so they take a superficial approach to their studies, over which they feel they have limited control (Windle *et al.*, 2011). To be effective, RLO require students to actively engage with the content (Johnson *et al.,* 2013; AAMC, 2007). We know that student engagement *per se* is the extent to which students take an active role in a range of educational activities and that this process is likely to lead to high quality deeper learning (Trowler, 2010). Furthermore, formative assessment as a function within RLO would be advantageous in terms of preparing students for the high stakes summative assessment. RLO have been found to have a significant effect on examination result (Windle *et al.,* 2011; Keefe and Wharrad, 2012), where RLO users have achieved an improved performance in assessment over non-users (Johnson *et al.,* 2013).

Secondly, like other vocational disciplines, medical and veterinary sciences are subject to change in professional practice or policies (Windle *et al.*, 2011; Blake, 2010) with typically profession-driven curricula (Keefe and Wharrad, 2012). Both these issues could be effectively addressed via RLO. It is important to note that high examination results and professional competencies have been considered as separate variables effected by RLO use, although based on the principle of active engagement, one could argue that the engaged students may achieve both high examination results and the required professional competencies following RLO use. Researchers have found a number of other desirable outcomes have been affected by RLO use including learning experience (Blake, 2010), critical thinking, practical competence, skills transferability, cognitive and psychological development, self-esteem, formation of identity, moral and ethical development and student satisfaction (Trowler, 2010; Sandlin *et al.*, 2014). Lastly, development of RLO has in some cases been driven by the need for institutions to save money (Johnson *et al.,* 2013; Kurilovas *et al.,* 2014), be more competitive and attract a wider cross section of the potential student market. In addition, institutions have in some cases needed to reduce staff contact time within a module (Johnson *et al.,* 2013).

The reasons why students choose to use RLO is reported as being affected by a number of factors, one being the student's prior experiences (Bacsich *et al.,* 2011; Kirkwood, 2008; Littlejohn *et al.,* 2010).

Use occurs where students have a positive attitude towards computers and they prefer to use technological educational resources (Concannon *et al.,* 2005). Commonalities exist between the reasons students choose to use RLO and how educators should approach the development of such resources. In terms of the practical implications for this study, exploring why and how students use online learning resources is a starting point. Therefore, the present study was designed to answer why and how some students choose to access web-based RLO and others choose not to in relation to preparing for animal and veterinary-science related assessment.

METHOD

Participant Characteristics

Data was collected from a total of 205 students, which equated to 82% of the total eligible student population in their first year of a degree (BSc) or foundation degree (FdSc) in an animal- or veterinary nursing subject at Harper Adams University (HAU). The eligibility criteria for this study was that they were undertaking the core module, A4016 Large Animal Management (LAM). There was no pre-requisite requirement for evidence of equine specific learning, therefore, this led to participants having mixed prior equine experience.

The course areas represented in this study were Animal Behaviour and Welfare, Animal Health and Welfare, Bioveterinary Science, Veterinary Nursing, Veterinary Nursing with Practice Management, Veterinary Physiotherapy and lastly Animal Management and Welfare. All the students who took part in the study volunteered to do so and attended a face to face briefing and signed a participant consent form. The study consisted of two cohorts of students who undertook and were assessed in LAM in either 2011/12 (n = 98) or 2013/14 (n = 107). Students were grouped as follows:

Group i: 2011/12 - who did not have access to the RLO.

Then of 107 students undertaking LAM in 2013/14, all of which were given access to the pre-test and RLO, the following groups were identified based on what students themselves chose to access (student access data were collected from user logs):

Group ii: 2013/14 - but accessed neither the pre-test, nor the RLO.
Group iii: 2013/14 - who accessed the pre-test, but did not utilize the RLO.
Group iv: 2013/14 - who accessed both the pre-test and the RLO.
Group v: 2013/14 - who did not access the pre-test, but did utilize the RLO.

Groups i and ii were the control groups because they did not access either the pre-test or the RLO. Group size was pre-determined by the enrolment figures for 2011/12 and 2013/14 respectively as LAM was a core component of those courses. Data was collected via paper-based questionnaires, online quiz hosted in the HAU virtual learning environment, Moodle (pre-test), paper-based written examination (post-test), interviews, and online survey. Module delivery was not modified for the purpose of this research. Data was not collected during the academic year 2012/13, as this was a developmental year in terms of the RLO. Participants did not receive any payments, but interviewees were offered refreshments at the time of the interviews. The study was approved by the HAU Research Ethics Committee. As one of the research questions within this study related to how students used the RLO, instructions to this effect this were not prescribed to participants beforehand. At the point that RLO were launched, as well as during the marking of the post-test, self-assignment of students to groups were not known by the researchers or the students. This was facilitated by implementing a delay on the researchers assessing Moodle user logs until after the post-test.

MOODLE USER LOGS

Within this study, Moodle access logs was collected, comprising which students had selected which RLO, on how many occasions and at what time and date. The known limitations of this data meant that it was not robust evidence of student engagement and hence could not be used as to infer impact on assessment performance.

REUSABLE LEARNING OBJECTS

This was an intervention study using RLO as the intervention, which in this case were five web-based narrated videos (defined as RLO as per the definitions of Valderrama *et al.* (2005) and Windle *et al.* (2010)), organized into chapters, each covering a key equine health management topic; farriery, dentistry, weight assessment, body condition scoring and worming. RLO duration was between 10-25 minutes and delivered in English. RLO were produced by two members of academic staff with equine backgrounds and an e-learning technologist during 2011/12 - 2012/13. All staff had prior experience in creating learning resources of this type. All five of the RLO were made available concurrently and continuously to all students ten days prior to the post-test via Moodle. This was the sole route to accessing the RLO. Notification of RLO availability was initially presented to students via e-mail including a hyperlink to the relevant course page in Moodle, immediately after the resources were made accessible to view. Instructions on how to use Moodle would have been issued at the start of the academic year and given the time of the year that the RLO were launched, the authors expected participants to have accumulated ample Moodle user experience by that stage. A hyperlink to each RLO was placed in a pre-determined topic in the LAM Moodle course page with set up such that a new window opened on a RLO being selected. The incentive for students to use the RLO was as a revision aid for the post-test, and therefore frequency of access to the RLO was unlimited. In order to encourage engagement with the RLO, a reminder e-mail was circulated two days prior to the post-test. Access data for participants in groups iv-v was exported from Moodle and saved in MS Excel format.

PRE- AND POST-TEST DATA

The pre- and post-tests each comprised twenty multiple-choice questions (MCQ) and were moderated prior to use by two separate academics at HAU, in line with the university assessment regulations. The pre-test was administered via Moodle, being available to all students in groups ii-v. The post-test was administered to groups ii-v as a paper-based written examination, under examination conditions. Equivalent post-test performance data for group i was collected from the HAU student records system and recorded anonymously; the pre-test (which from a student perspective was a revision quiz) was made available to groups ii-v via Moodle immediately following LAM taught sessions in 2013/14 but preceding access to the RLO, with results being exported from Moodle and saved in MS Excel format.

SEMI-STRUCTURED INTERVIEWS

On the basis of the pre- / post-test score difference in combination with RLO access data, students in groups iii and iv were organized into four categories, namely:

- Low score difference and did not use the RLO;
- Low score difference and did use the RLO;
- High score difference and did not use the RLO;
- High score difference and did use the RLO.

For this purpose, low score difference equated to a negative or nil difference between pre- and post-test scores, whereas a high score difference equated to a positive difference within the range 6 - 68%. In addition, students were categorized as 'did use the RLO' where Moodle usage data indicated they had accessed one or more of the RLO. Students in group iii were categorized as 'did not use the RLO' where they had not accessed any of the resources. One student from each of the four categories referred to above was randomly selected and invited by telephone (with a follow-up e-mail) to a semi-structured face to face interview. The interview questions were piloted 3 months earlier with 3 female second year students, who were out with the study group but studying across the same course areas. The interview questions related to themes informed by the RLO-CETL evaluation toolkit (RLO-CETL, 2005) with the purpose of addressing both the 'why' and 'how' aspects of accessing RLO. Interviews were conducted by a qualified journalist, who was not the primary researcher. Interviews were recorded digitally, with the permission of the participants and transcribed by an external organisation. Interview transcripts were then analysed using a process of open coding and theory-related material themes.

RLO EVALUATION

Concurrent to the semi-structured interviews, a modified RLO-CETL evaluation was administered to groups iii-v, via a Bristol Online Surveys (BOS) online survey, responses to which were collated and exported to MS Excel format for later analysis. Use of a web-based platform enabled prompt exporting and filtering of data.

STUDY DESIGN

The planned timings for data collection are shown in Table 1.

Table 1. Timings of data collection for each stage of the study

Data	Week during the 2013/14 Academic Year
Pre-test	24
Accessed RLO	24-26
Post-test	26*
Semi-structured interviews	27
RLO-CETL evaluation	26-28

*With the exception of that equivalent data for group i, which was collected prior to week 1.

STATISTICAL ANALYSIS

Microsoft Office Excel was used to tabulate quantitative data and the statistical software program SPSS (version 21) was used to analyse that data. Descriptive statistics were produced for the pre- and post-test data including mean, standard deviation and range. A one-tailed paired t-test was administered to assess the relationship between pre- and post-test results for groups iii and iv. Post-test data were checked for normality and as they were normally distributed a t-test for two independent sample means were conducted to compare the groups.

RESULTS

The demographic characteristics of students on LAM are shown in Table 2.

The mean age of students in the 2011/12 and 2013/14 cohorts was broadly the same. The key difference was disability, which increased in 2013/14. Furthermore, the first language of students in 2013/14 was not exclusively English. The participation characteristics of students on LAM and results of self-selection to groups are shown in Table 3.

The flow of participants through each stage of the study is shown chronologically in Table 4. Timings shown are in line with those originally intended.

Six students did not complete the study; 4 students withdrew from their course, 1 student postponed studies and 1 further student did not undertake the post-test for unknown reasons.

Table 2. Demographic characteristics of students undertaking LAM in 2011/12 and 2013/14

Characteristic	Students	
	2011/12 Cohort	2013/14 Cohort
Age range (years)	17-35	18-33
Mean age (years)	19.0	19.5
Disability status	84% no disability; 12% specific learning disability; 4% comprising blindness, deafness, longstanding illness and two or more impairments	80% no disability; 14.5% specific learning disability; 2% with two or more impairments; 3.5% comprising longstanding illness and mental health conditions
First language	English	English, Spanish, Welsh

Table 3. Participation characteristics of students on LAM

Group	Academic Year	Accessed Pre-Test	Accessed RLO	*n*
i	2011 -12	No	No	98
ii	2013 -14	No	No	62
iii	2013-14	Yes	No	13
iv	2013-14	Yes	Yes	7
v	2013 -14	No	Yes	19

Table 4. Flow of participants at each stage of the study (independent of group)

Stage of Data Collection	*N*	
	2011/12 Cohort	2013/14 Cohort
Pre-test	n/a	20
Accessed RLO	n/a	26
Post-test	98	101
Interview	n/a	4
CETL-RLO evaluation	n/a	7

PRE- AND POST-TEST DATA

Post-test performance was significantly higher in students who had accessed the RLO despite the small number of RLO users ($p < 0.001$). When data was analysed after excluding the 2011-12 group (as they did a different post-test; although the test was of same format, number of questions, same question style, both tests written by the same teacher and both moderated by another academic), the students who accessed the RLO still performed better ($p < 0.05$). However, it was noted that the post-test results between RLO non-users including 2011-12 and RLO non-users of 2012-13 were also significantly different. This was mainly due to the fact that the 2011-12 cohort had overall lower post–test results compared to the 2013-14 group. One student in group iii was considered to be an outlier, therefore excluded from further pre-/post-test data analysis. Changes in performance for group iv ranged from -16% to +23%, with mean pre-/post-test score difference of 12% for 57% of the group. Post-test performance declined in 3 of 7 students who used the RLO. Post-test performance was highest in the RLO users, however, the authors also saw an improvement in performance of 5% (range = 17% to +33%) in 55% of RLO non-users. Pearson product moment correlation coefficient showed a positive correlation between pre- and post-test performance ($r = 0.42$), although a paired t-test indicated that the results should be considered non-significant ($P = 0.26$).

SEMI-STRUCTURED INTERVIEWS

Five themes arose from the interviews - the RLO in relation to the taught module; approach to using the RLO; functionality; challenges and lastly approach to study. Within each theme, frequently arising topics were coded to produce a total of forty-four codes. In terms of the students' approach to using the RLO, all interviewees reported that they viewed a RLO once [CODE SV], in their own room within halls of residence [CODE BE]. Under the functionality theme, all students reported using a laptop [CODE LA] to access the RLO. Indicative Moodle usage data showed that only 1 student accessed a RLO more than once. Three of the 4 interviewees referred to reinforcement as a rationale for using 1 or more RLO [CODE RM] with the same interviewees reporting that they used the RLO due to the extent of academic challenge posed by LAM [CODE EAC]. Only interviewee #2 ('low score difference and did use the RLO') and #4 ('high score difference and did use the RLO') reported previous equine experience

[CODE EE]. Interviewee #4 ('high score difference and did use the RLO') reported that they used the RLO for purposes other than the LAM summative assessment [CODE LOA] and that they would reuse the RLO in the future [CODE RP]. In their approach to study, three of the 4 interviewees reported that they remained focused on a RLO once they had opened it [CODE FR]. Interviewee #1 ('low score difference and did not use the RLO') reported being disappointed that they had not realized the RLO were available [CODE DP].

RLO EVALUATION

All seven respondents to the modified RLO-CETL evaluation were female and from across BSc and FdSc level courses. They reported either "high" or "very high" confidence in using computers and web tools, although 28.5% of respondents reported "low" confidence in using web multi-media. Fifty-seven percent of the RLO evaluation respondents used "all" of the RLO, with the remainder using only "some".

Use occurred on weekdays only. The reasons given for not using RLO included:

'I already know about these topics', 'I don't use these sorts of resources from which to revise', 'the RLO weren't clear about their objectives', 'the RLO are not linked to other modules in my study diet' and 'the RLO weren't pitched at the right level'.

Responses were not consistent as 100% respondents also reported that the RLO helped them meet the requirements of the module. Technical difficulties in using RLO was reported by 28.5% of respondents, specifically regarding the web-links. More than 85% reported that they didn't intend using the RLO again.

DISCUSSION

The aim of this mixed methodology study was to examine student interaction with RLO in the context of how students on animal- and veterinary nursing-related undergraduate courses performed in a summative assessment. In this study, interviews were used to provide more detail beyond the findings of a RLO evaluation. The interviews provided valuable information as to the practical approach students took to using the RLOs and why they did so. There were quantitative and qualitative approaches within the study, with some overlap between the data collected in the interview and RLO evaluation stages.

WHY AND HOW DO SOME STUDENTS CHOOSE TO ACCESS THE WEB-BASED RLOS AND OTHERS CHOOSE NOT TO?

In terms of how and why students interacted with the RLO, key findings showed that students accessed RLO via personal devices, independently, in order to reinforce what they had covered in taught sessions. However, because of the independent setting in which students were expected to use the RLO, the authors cannot be sure, beyond those students who were interviewed and/or those who completed the RLO evaluation, how the RLO were used (e.g. running the video and not paying attention to repeated viewings in one sitting or discussing in a group). Findings reported here concur with those of Windle *et* *al.* (2011) and Lymn *et al.* (2008) in terms of students using RLO to support them on challenging subjects. Three of the 4 interviewees in this study reported that they accessed the RLO due to the academic challenge posed by LAM.

In terms of how findings reported here reflect learning theory more widely, interview responses coded under the themes 'approach to using RLO' and 'approach to study' provide examples of Piaget's theory of assimilation and accommodation in action. Furthermore, the interview categories as a whole represent parts of the experiential learning theory proposed by Kolb (Kolb and Kolb, 2005). Where Honey & Mumford expanded this cycle to reflect a typology of learners (Caple and Martin, 1994), those students that engaged with the RLO could be identified as activists or pragmatists within that framework.

By using Moodle as the platform for delivery of the RLO, resources were successfully implemented and freely available to students on LAM for the entirety of the pre-defined period. As reported by interview and RLO evaluation respondents, the key barriers to implementing the RLO were technical difficulties with internet connections and the voluntary response bias of students not to use the RLO in their preparations for assessment.

Quantitative data supports two valid points; the lack of engagement of students when given a free-choice and reluctance for self-assessment, which was unexpected. Only 24% of the students used the RLO; as engagement with the pre-test and RLO was not prescribed (teacher-led), this goes some way to explaining the voluntary response bias of students in this study. Therefore, the pre-test was not a truly representative sample since not all students in the 2013/14 cohort were included in the data analyses. Instead, data was representative of the motivated students. Those students who made the choice to use the RLO could be categorized as 'engaged' and literature suggests that as such, they would perform better in assessment in comparison to non-users (Trowler, 2010; Boyle *et al.,* 2003; Vermunt and Vermetten, 2004; Concannon *et al.,* 2005) because engaging with technology in itself results in a shift in learning strategies; educational technology provides a platform for continuous revision, not feasibly replicated by a lecturer in the case of a large group (Concannon *et al.,* 2005). This deeper approach to learning may in part have been evidenced in our study by interviewee #4, who demonstrated a high pre-/post-test score difference (interpreted as the impact of them revising, hence learning after engaging with resources in between the pre- and post-test) and responded in the interview that they used the RLO for purposes beyond just the LAM summative assessment as well as the intention to reuse the RLO in the future. Interview evidence supported the notion that students that are already engaged with the subject area will use RLO addressing those topics; 2 interviewees in our study who did use the RLO both reported previous equine experience. This is in line with the findings of Bacsich *et al.* (2011) and Kirkwood (2008) who reported that students chose to use RLO to enhance personal knowledge.

However, other than for the interviewees or those who responded to the RLO evaluation, we don't know how the RLO were used by students. The behavior of the majority (76%) of students that chose not to use the RLO may be explained by three influencing factors – signposting, students' perceptions and prior experiences. Published research has reported that for RLO to be utilised optimally a system of signposting needs to be in place both for students and staff (Johnson *et al.,* 2013; Evans, 2013). Furthermore, signposting has been rated a higher priority than the provision of IT training itself (Concannon *et al.,* 2005). The authors have to consider that those who did not engage, did not realise that there was something there with which to engage, which is supported by the responses of one of our interviewees. This leads the authors to question the efficacy of the e-mail mechanism used to notify students of the availability of RLO and at this stage surmise that this method of signposting could have affected RLO usage levels.

Beyond signposting, the low usage levels could be explained by the variation in student's perceptions of the benefits and qualities that RLO offer as described by Kay and Knaack (2007). RLO have been ranked below lecture notes and text books but above journals and other web resources as means of enhancing learning (Lymn *et al.,* 2008). Other researchers have found that students chose not to use RLO where they perceived an additional time commitment in using such resources (Keefe and Wharrad, 2012) or where they experienced computer anxiety and accessibility issues (Lymn *et al.,* 2008; Blake, 2010). Findings reported here from the modified RLO-CETL evaluation identified the reasons given for not using RLO included prior knowledge on the topics, preferences for other types of learning resources, lack of alignment of RLO to other modules in their course beyond LAM and technical difficulties in using RLO. In contrast, students use RLO when they are easy to access (Bacsich *et al.,* 2011) and are encouraged by both peers (Concannon *et al.,* 2005) and tutors (Kirkwood, 2008).

A further alternative explanation for the apparent lack of engagement could be provided by the Moodle access data, where a single student log on may have represented, at the time, a group of peers accessing the RLO together. Although interviews #1 and #3 were conducted with students who according to the Moodle access log, had not accessed the RLO, their interview responses suggested otherwise. So, this data is useful only in so far as indicating the minimum number of students that accessed the RLO, while students who collaborated with peers but did not log in would have effectively self-excluded from later stages of the study.

IS STUDENT PERFORMANCE IN SUMMATIVE ASSESSMENT AFFECTED WITH THE INTRODUCTION OF WEB-BASED RLOS?

Within this study, the RLO usage data from Moodle was not a robust evidence base of engagement with learning. Usage data reflected access to RLO but not 'study'. The time (GMT) of access was recorded, but not duration. There was no fixed time interval between bouts of access required for them to be recorded as repeat bouts. A repeat bout of access was logged as soon as a student selected the link to the RLO again. Activity of students beyond selecting the link to the RLO was not logged. Therefore Moodle usage data cannot be used to infer any impact on assessment performance.

Our findings were not statistically supportive of the original expectations that post-test outcome would improve for RLO users, or that they would achieve higher post-test scores over non-RLO users. Furthermore, improvement in performance for these students was not as great as the +19.2% mean score difference reported by Keefe and Wharrad (2012). Findings reported here showed a positive correlation between pre- and post-test performance, which can be explained using the findings of Roshier *et al.* (2011) and Trowler (2010), who concurred that active engagement with learning resources brings about improvement in assessment performance. That is further supported by Boyle *et al.* (2003) who found a positive association between a deep approach to learning and academic outcome. Another limitation within the quantitative results reported here concerns the two-week time period between the launch of the RLO and the post-test. Because the interventions were implemented for use in an independent setting (e.g. out with taught or tutor led sessions), the authors do not know what other learning resources the students were also using during this period and/or whether those had an impact on assessment performance.

A further unintentional and unexpected outcome was the decline in post-test performance by nearly one half of RLO users in group iv. As the number of students who used the RLO were very small this needs to be repeated with more students to draw a conclusion as to why this happened. One reason could be that as the post-test was administered as part of the University's summer examination period, students may have focused on revising for other module assessments, rather than LAM, or taken an ineffective approach to their revision. Students who 'cram' are demonstrating a superficial approach to learning and in the study by Concannon *et al.* (2005), those that took this approach to their revision did not access RLO; this issue is relevant given the proximity of the launch of our RLO and the University's summer examinations. The final limitation to note is the fact that this study was based in a single institution and as such the authors are only able to assess the value of this educational intervention in this single setting. It remains to be seen whether the interventions retain their value in other institutional settings where equine health and management teaching and learning may be provided by staff from different professional backgrounds.

The qualitative findings can be generalized in terms of how first year undergraduates on animal and veterinary nursing-related courses use RLO addressing equine management and health topics where they have mixed equine experience. However, the quantitative findings cannot be generalized. In future, attributing some marks for engagement with RLO within the module assessment mark scheme may increase usage levels. In addition, to avoid voluntary response bias in future, a randomized controlled trial comparing post-intervention performance of RLO users and non-users, using a facilitated workshop setting for the RLO user group would verify Moodle access logs and provide larger populations of students from which to come to statistically sound conclusions. In conclusion, the qualitative data collection methods gave an insight into how and why students approach RLO and the underlying reasons why using RLO can affect summative assessment performance. The practical significance of the outcomes lies primarily in their unique nature in terms of providing data for animal and veterinary nursing students, although based on a small sample. Further research may provide insight into the behaviours of students from these same courses in later stages of their studies or once in employment, in terms of how and why they approach RLO. Taken as a whole, this study suggests that students on vocationally driven degree courses with a deep approach to their learning choose to utilise RLO.

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Chapter 17
The Use of Reusable Learning Objects to Enhance the Delivery of Veterinary Education:
A Literature Review

Emily Chapman-Waterhouse
Harper Adams University, UK

Ayona Silva-Fletcher
Royal Veterinary College, UK

Kim Whittlestone
Royal Veterinary College, UK

ABSTRACT

The increased demand from learners in higher education to access resources flexibly has resulted in considerable development in the use of Reusable Learning Objects (RLO) via a blended learning format across the sector. This critical review sets out to identify what is currently known about RLO and how those concepts can be applied to veterinary-related degree courses. The review provides an insight into an aspect of blended learning which is currently limited in terms of published research. The effect of computer confidence, students' choice to use and the impact on student performance are some of the variables which have been measured to date. The approach to RLO by students from different courses may vary, but prior experience of technology, alignment of content and availability of technical support are some of the key drivers for usage and reuse. A positive effect is likely to occur following RLO use because those students have adopted a process of active engagement, which the authors know can bring about a deeper approach to learning.

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AN INTRODUCTION TO REUSABLE LEARNING OBJECTS IN VETERINARY EDUCATION

Reusable Learning Objects (RLO), also known as Shared Content Objects (SCO) are self-contained digital resources such as video, audio, web-pages, documents and graphics which are stored and accessed independently in support of a blended learning approach. This feature of technology enhancing learning is also shared by Open Educational Resources (OER) as defined by Clements and Pawlowski (2012). Kay and Knaack (2007) expand on this definition by saying that RLO are interactive tools which go beyond simply supporting learning, but enhance and amplify the cognitive processes of learners. As yet there is no evidence to suggest that this applies to learners within veterinary education blended learning and therefore to promote effective practice in this subject area, the authors set out to better understand why and how some students in veterinary education would choose to access web-based RLO and others choose not to and secondly, if the performance in summative assessment by students in veterinary education is affected by the introduction of web-based RLO.

REVIEW METHODOLOGY

Literature was selected firstly on the basis of its relevance to RLO, secondly in terms of the course areas from which participating students were drawn and lastly, in terms of its relevance to the enhancement of higher education. The authors searched for literature using Google Scholar and their home institution's own search engine (FindIt@Harper) which searched EBSOHost, ScienceDirect and Wiley Online databases to obtain 21 research publications and nine sector reports. The search terms included: reusable learning object, veterinary blended leaning, veterinary online learning, science reusable learning objects and sources filtered for full text copies.

In searching for papers to include, only one was found relating to Veterinary Education (Short, 2002) and another concerning Animal and Agricultural Sciences (Hoover & Marshall, 1998). Other subject areas in which studies have been undertaken in relation to RLO and reported in this review include Biology (Kay and Knaack, 2007), Chemistry (Windle et al., 2011; Kay and Knaack, 2007), Physics (Kay and Knaack, 2007; Kurilovas et al., 2011), Human Nursing (Windle et al., 2010; Keefe and Wharrad, 2012; Blake, 2010; Lymm et al., 2008), Human Anatomy (Johnson et al., 2013), Human Medicine (AAMC, 2007; Blake, 2010), Health and Social Sciences (DoH, 2011; Kirkwood, 2008; Evans, 2013; Boyle et al., 2003), Science (Littlejohn et al., 2010; Kirkwood, 2008), Business (Littlejohn et al., 2010), Maths (Kurilovas et al., 2011), Accounting (Concannon et al., 2005), Engineering (Littlejohn et al., 2010), Computer Science (Kay and Knaack, 2007) and lastly International Culture (Sandlin et al., 2014). In the main, these are STEM subjects with the majority offering insights into the medical education sphere. The sample sizes utilised in these studies, where specified, contained a minimum of 80 students, with one exception being the investigation by Kirkwood (2008) where data was collected from just ten individuals. The largest sample was associated with the study by Littlejohn et al. (2010), in which over 2,000 students participated and, while we know that the greater the sample size, the greater the chance of detecting a true treatment effect (Petrie & Watson, 2006), such a large scale study may not allow us to see the nuances of RLO use which are of interest to practitioners.

The consequence of selecting this particular area of focus, with limited availability of subject-related literature, is that the aim of this thematic review was refined to assess what is currently known about RLO and how those concepts can be applied to enhance the delivery of veterinary-related degree courses.

DOES STUDY MODE OR POINT-ON-COURSE MATTER?

The student demographic examined in these studies, where stated, concerned largely mainstream (full-time) undergraduate degree students, with the exception of the studies by Keefe and Wharrad (2012) and Evans (2013) respectively who investigated postgraduate students and Kay and Knaack (2007) who explored behaviours of secondary school pupils. In terms of the year groups (e.g. first, second, third and so on) that were examined, this was unspecified in a number of papers (Windle et al., 2010; Lymm et al., 2008; Sandlin et al., 2014; Bacsich et al., 2011; Short, 2002; Marcus, 2013; Kurilovas et al., 2011; Kurilovas et al., 2014; Hoover and Marshall, 1998). Students from a range of year groups were examined in studies by Keefe and Wharrad (2012), Blake (2010) and Boyle et al. (2003). Interestingly, Johnson et al. (2013) specifically dealt with third year Bachelor of Medicine students and Concannon et al. (2005) and Littlejohn et al. (2010) captured data from first year students only. Data collection for the latter study took place on course induction day which makes this methodology unique in terms of those studies reviewed herein. To go beyond the mainstream student demographic, the review by DoH (2011) and study by Kirkwood (2008) provide an insight into mature learners undertaking further study. Thus the literature base is wide ranging in terms of the point-on-course at which data was captured.

DOES LEARNER GENDER MATTER?

Between 87-95% of students who participated in the studies by Blake (2010) and Lymm et al. (2008) were female, which goes some way to illustrating the typical demographic seen on degree nursing courses. However, this does highlight the need to explore the impact of RLO across a range of settings to fully understand the behaviour of both male and female students.

So, although there have been a number of studies undertaken to examine the role of RLO in blended learning higher education, they originate from medicine and health sciences in the main. Therefore, in the first instance, practice in veterinary education must draw from findings from this allied subject area.

STUDENT'S CONFIDENCE IN USING COMPUTERS

Given that the definition of RLO (explained above) referred to them as being digital in nature, it is no surprise that five studies included in this review mentioned the extent to which the students were confident in using computers or other devices during their studies. Over two thirds of each cohort examined by Windle et al. (2011) self-reported a high level of computer competence with the highest incidence of low confidence found within the most recent cohort. Furthermore, this study found that there was no correlation between computer confidence, study mode (using RLO in a self- or workshop-facilitated setting) and age in terms of how students rated RLO. This finding may challenge our immediate 'in-practice' assumptions. Where the use of such technology may have been positively approached by students in a number of studies (Windle et al., 2011; Concannon et al., 2005; Kay and Knaack, 2007), Littlejohn et al. (2010) explained that those students whose previous approach to learning did not involve using technology preferred to continue this strategy. This may go some way to explaining the reported confidence levels within the above mentioned study by Windle et al. (2011). Student opinion about technology enhanced learning (TEL) remained unchanged even with the introduction of RLO to support learning (Johnson et al., 2013). The findings of Concannon et al. (2005) and Littlejohn et al. (2010) agree in that some students did not want the flexibility that RLO offered in terms of learning independently and instead requested tutor-facilitated workshops in which to complete tasks. In practice, the authors would consider that such a workshop could be adapted to take a peer-led format, where students who are further through their chosen degree courses facilitate that session. Subsequently, that could lead to a deeper approach to learning for those facilitators as they would need to demonstrate an elevated level of understanding of the topic in order for either student group to benefit. Using peer assisted learning may also develop confidence in the lower year group in the use of computers, or other devices, as well as independence in blended learning format.

Blake (2010) identified a difference in computer confidence across courses, with nursing students reportedly being three times less confident than medicine students. A difference in attitude to using technology may also be seen by remote and/or adult learners as evidenced in the paper by Kirkwood (2008), where mature students reported that the computer skills they developed at work could then be utilised in their studies. This would be advantageous to learning in light of the findings reported by Littlejohn et al. (2010) who found that students who perceived themselves to have advanced computer skills were most likely to use technology-related study methods. We would anticipate the opposite being the case for typical undergraduates; spending time developing computer-based competencies during their studies which could then be applied in the graduate workplace. Keen use of technology was also noted in students with restricted mobility or who were geographically remote to the institution.

The key message that we can arrive at so far is that there is agreement across the literature that students arrive at university with pre-conceived perceptions of their self-confidence in using computers and technology, and this has been shown to affect how they want to approach studying in HE. Confirmation is needed, however, that this applies to a range of subject areas and settings, including the small specialist universities.

PEDAGOGIC PRINCIPLES UNDERPINNING RLO DEVELOPMENT

The literature identifies that the underpinning rationales for developing RLO vary, but primarily focus around three themes, the first attracting most comment:

Helping Students Achieve Higher Grades

As educators we acknowledge the need to provide more resource (in the same or less time) to teaching basic sciences in a clinical context (Windle et al., 2010), to help students achieve higher marks in summative assessment and/or an improved overall outcome (Trowler, 2010), so we typically supplement face to face teaching (Lymm et al., 2008) to create a blended learning format. The need to do this may in part be explained by the challenging nature of a subject for some students (Windle et al., 2011; Lymm et al., 2008). Lymm et al. (2008) went on to report that 37% of students felt insufficient time was spent on challenging topics during their studies. However, in practice, from across a group of students, individual opinions as to the difficulty of a topic may vary in each annual intake. What was a difficult concept for some members of last year's cohort may not be the case this year, and so on. The literature goes on to tell us that some students feel they lack time and control to study content heavy modules, so they take a superficial approach to their studies (Windle et al., 2011). This therefore supports the notion that students need to have autonomy (AAMC, 2007) and flexibility in terms of when (Johnson et al., 2013) where, and the pace at which they learn (DoH, 2011) as well as access to well-designed modules, in order to develop a deeper approach to learning. This ethos has been described in the literature as 'ownership of learning' (Windle et al., 2010; Johnson et al., 2013) and the nature of RLO in terms of them being web-based facilitates this need.

In line with the principles underpinning andragogy, a more flexible approach to module delivery using technology could well be favoured by students who as young adults are becoming increasingly self-regulated, and on this basis, although literature indicates we should design flexible teaching and learning, we do need to ensure that all students are able to access an equitable learning experience (AAMC, 2007). The review by DoH (2011) stated that, in using RLO, we were of necessity offering a blended learning curriculum, although this was not reflected in the self-study arrangements as set out in the study by Windle et al. (2011).

Students should achieve higher grades where they demonstrate they meet real-world learning needs, which may include the attributes of a successful professional in practice. In the context of veterinary education, the alignment of RLO to defined real-world learning needs (Windle et al., 2010) identifies those resources as being 'patient centred', 'service driven' and 'evidence-based' (DoH, 2011). Adult learners meet real-world learning needs by undertaking Continuous Professional Development (CPD), one route being to engage with RLO, to progress within their employment and develop their professional practice. RLO are well suited to CPD initiatives given their scope to reflect bite-sized chunks of learning, since we know that smaller learning packages are more effective than large resources (Windle et al., 2011) as they avoid cognitive overload (AAMC, 2007). While much of the development of RLO requires a focus on technological functionality, as illustrated by the formative assessment of RLO in the study by Evans (2013), it is the learning qualities which should be prioritised over the technical. However, for RLO to be utilised optimally, a key technical requirement is the system of signposting to the resources which needs to be in place, both for students and staff (Johnson et al., 2013; Evans, 2013). Signposting has been rated a higher priority than the provision of IT training (Concannon et al., 2005).

We know that student engagement *per se* is the extent to which students take an active role in a range of educational activities and research tells us that this process is likely to lead to high quality deeper learning (Trowler, 2010). To be effective, therefore, RLO need to be integrated into the blended learning course content (Windle et al., 2010; AAMC, 2007) and require students to actively engage with that content (Johnson et al., 2013; AAMC, 2007). This needs to be well thought out; the way that online resources are integrated into learning may be more important than the fact that such items are available (Johnson et al., 2013). For example, we know that collaborative learning is beneficial (Plendl et al., 2009), so we could encourage students to use RLO in pairs or groups where appropriate. Beyond helping students to achieve higher grades, literature indicates that RLO development needs to involve others so that students have the opportunity to experience relationships with peers and operate within a learning community (Windle et al., 2010). This could be facilitated at the RLO design stage as illustrated in the study by Evans (2013), where students were invited to contribute to the brainstorming process, providing a platform for peer assisted learning.

RLO provide an opportunity to implement a constructivist approach to learning and teaching, whereby tutors facilitate the building of knowledge. From the perspective of clinical skill development, Miller's Model of Clinical Competence illustrates how this may come about (Short, 2002). Sandlin et al. (2014) stated that social learning theory should underpin our development of resources, taking into account that personal, behavioural and environmental factors all affect learning. However, depending on the context and aims of learning, some RLO may be behaviourist by design if the task necessitates. Literature tells us that one purpose of RLO is to provide opportunities for students to learn new skills (Windle et al., 2010) within a controlled environment, at a range of difficulty levels and with arrangements for regular feedback (AAMC, 2007). The feedback functionality is all-important, especially given that a lack of feedback early on in a student's course has been associated with student dissatisfaction, failure and departure from studies (HEA, 2012). A lack of feedback opportunities within a learning resource could then lead us to categorise it as ineffective. We also have the opportunity to expose students to 'assessment for learning' (Bacsich et al., 2011) which, given our aspiration for our students to achieve higher grades, formative assessment and feedback as a function within RLO would enable better preparation for the high stakes summative assessment.

This leads us to draw some interim conclusions in that we can help our students to achieve better outcomes from their blended learning experience by providing flexibility, autonomy, correctly proportioned and well signposted resources, which together have been shown to lead to a deeper approach to learning.

Professional Practice

Like other vocational disciplines, veterinary professions are subject to change in terms of professional practice or policies (Windle et al., 2011; Blake, 2010) and have typically profession-driven curricula (Keefe and Wharrad, 2012). Both these issues could be effectively addressed via the provision of RLO within a blended learning format, which have been reported as effective in developing professional practice for international graduates who are commencing postgraduate courses in the UK but who lack exposure to that country's professional contexts (Evans, 2013). The DoH (2011) reported that professional bodies recognise that new graduates need ongoing clinical and practical skills training most effectively delivered online, as well as needing to utilise technology in the workplace (Blake, 2010).

Institutional Needs

Since the 1980s, the development of learning technologies has been predicated on three ideas; new infrastructure, creation of learning content and the implementation of teaching practices to accommodate the new technology (Short, 2002). Development of RLO has in some cases been driven by the need for institutions to save money (Johnson et al., 2013; Kurilovas et al., 2014), be more competitive and attract a wider cross section of the potential student market; including part-time, those from underrepresented economic backgrounds and/or lifelong learners who, when they graduate, are competent in vocation relevant IT packages (Concannon et al., 2005). Where globalisation is high on the agenda for many institutions, there is motivation to improve the global awareness of students (Sandlin et al., 2014).

In addition, institutions have in some cases needed to reduce staff contact time within a module (Johnson et al., 2013), although teaching and learning content delivered to students can remain unchanged due to the constant availability of online resources in blended learning, which inherently require less manual intervention from an academic member of staff (AMMC, 2007; Kurilovas et al., 2014). The literature identifies with elements of the 'effectiveness versus efficiency' argument (Kurilovas et al., 2014). From an administrative perspective, internal systems within an institution utilise technology, so we should consider why the student facing platform for learning cannot also be technological and offer similar advantages in content management (Short, 2002).

To create effective RLO and hence students with a deep approach to learning, the pedagogic style of RLO should be educationally coherent, innovative (DoH, 2011) and consistent within and between resources originating from the same suite (Windle et al., 2010). However, in order to develop such a resource, we first need to understand the learning gaps of our students (Blake, 2010). The stages to RLO development have been documented by Windle et al. (2010), as well as by the RLO-CETL which promotes a 7-step production process (Evans, 2013). Production is typically tutor centred, although there is agreement in the literature that the end goal is to produce a resource which is student centred (Windle et al., 2011; Keefe and Wharrad, 2012; Sandlin et al., 2014) and used in a self-directed manner (Windle et al., 2010). A slightly different approach was taken by Kay and Knaack (2007) where they developed RLO for use solely in tutor facilitated sessions. In practice, this strategy would limit the extent of RLO reuse and hence the scope for deeper learning in students. In practice, where a number of academic staff work to develop RLO to support their own teaching, it is possible that production style will differ to some extent, an issue which was documented by Sandlin et al. (2014).

Where RLO complement a range of different teaching and learning strategies, reuse (or the extent to which RLO 'travel-well') increases (Windle et al., 2010). In veterinary education, those different teaching and learning strategies represent clinical variation (AAMC, 2007). In addition to complementing a variety of teaching styles, Kurilovas et al. (2011) stated that RLO need to be developed for use within different platforms and modifiable to suit differing staff and student needs.

Institutions may well need to change the extent of academic staff input to teaching, learning and assessment for a number of business or financial reasons. RLO, developed in line with good practice guidance can provide an efficient and effective alternate means of delivering content.

WHY DO STUDENTS CHOOSE TO USE, OR NOT TO USE RLO?

The question of whether students choose to use RLO as part of a blended learning format is reported in the literature as being affected by a number of factors, one being the student's prior experiences (Bacsich et al., 2011; Kirkwood, 2008). Use occurs where students have a positive attitude towards computers and they prefer to use technology-based resources (Concannon et al., 2005). Analytical (field-independent) learners prefer to learn in quiet settings, with the sole aim of completing the task set (e.g. formative assessment as evidenced by Bacsich et al., 2011 and Kirkwood, 2008), compared to field-dependant learners who prefer a more informal setting, with background noise, frequent breaks and multi-tasking (Hoover and Marshall, 1998). Blended learning and RLO could meet the needs of both types of learner as they provide students with control (Windle et al., 2011), often where there is a large choice of content which is constantly available (Bacsich et al., 2011). Therefore, a student can maintain their study pattern (Concannon et al., 2005), which is particularly important if students have limited time or need to be strategic in their studies (Kirkwood, 2008; Blake, 2010). The opportunity that mobile devices offer in terms of learning anywhere and anytime were recognised by Short (2002).

Students choose to use when the RLO is aligned to their learning needs (Windle et al., 2010; DoH, 2011; Concannon et al., 2005) which is notably important for those with specific learning difficulties

(Blake, 2010). From the perspective of international students, RLO have provided support for the development of language and vocabulary skills (Evans, 2013), an issue also arising in subjects with an extensive technical vocabulary such as veterinary education. Pausing a video in order to look up unknown vocabulary would enable such a student to develop a deeper understanding of the topic addressed by the RLO. The reasons why students chose to use RLO can be closely linked to the pedagogic principles underpinning the production of such resources described above. Commonalities exist between the reasons for students choosing to use RLO and how we should approach the development of such resources. This evidence should inform our practice. Literature indicates that students choose to use RLO when the resources have been produced using consistent pedagogic approaches and complement different learning and teaching styles (Windle et al., 2010; DoH, 2011). Although a consistent pedagogic approach has been found to influence use, Windle et al. (2011) found that design differences across a suite of RLO did not negatively impact on student learning. Students opted to use RLO in cases where they realised the usefulness of the resources as well as the scope for subsequent reuse (Lymm et al., 2008). Students chose to use RLO in cases where they perceived the resources may give them an advantage (Kirkwood, 2008) by being interactive. This, and the opportunity to use a range of multi-media (Bacsich et al., 2011) which they perceive is well supported by tutors (Concannon et al., 2005) are influencing factors in student's choosing to access RLO. Kay and Knaack (2007) stated that there was considerable variation in student perceptions of the benefits and qualities blended learning and RLO offer. Clements and Pawlowski (2012) argued that uptake of RLO as open educational resources was still low due to a perception of teachers that these resources lack quality.

RLO have been ranked below lecture notes and text books but above journals and other web resources as means of enhancing blended learning (Lymm et al., 2008). Other reasons as to why students have chosen to use RLO include the enhancement of personal knowledge (Bacsich et al., 2011; Kirkwood, 2008) in intrinsically motivated students, to explore interests outside of a professional field, to remain current, simply because they are aware of the resources which are easy to access (Bacsich et al., 2011) and the use of which peers (Concannon et al., 2005) and tutors (Kirkwood, 2008) promote.

Kirkwood (2008) went on to report that students chose to use RLO to answer their questions on a topic, or fill the gaps in order to fully grasp a concept. They then avoided drawing attention to themselves by asking questions in class and the resultant feeling of embarrassment (Blake, 2010). Although this may be considered by students as a positive functionality of RLO, there ought to be sufficient provision in place for students to ask questions and gain prompt feedback without the feeling of peer-pressure. However, in cases of cognitive overload, where material is overwhelming (Bacsich et al., 2011; AAMC, 2007) students have reported a preference to ask questions in person of their tutor rather than via an online forum (Littlejohn et al., 2010).

Ninety-four percent of students have reported that they would recommend RLO to others (Windle et al., 2011) and a separate study found that 94% of students reported they would reuse the RLO themselves (Blake, 2010). However, this has been found to vary across courses, for example Blake (2010) found that nursing students used RLO more than medical students. Reuse has been documented as highest in graduates who had the lowest level Biology qualifications on entry to their course (Lymm et al., 2008). However, Bacsich et al. (2011) took the view that learners were predictable and simply reused resources which had worked for them previously. Actual reuse has been documented as being typically low (Windle et al., 2010), so based on Bacsich's concept of predictability, that infers that initial usage levels are also low. An explanation for the low usage levels is provided by Kirkwood (2008), who suggested that lecturers lacked awareness of the motivating factors that would encourage RLO use in their students. Usage levels may be lower than we would hope, but the impact of usage shows the value of engaging with RLO via blended learning.

Of the studies which explored this issue, students reported that they chose **not** to access RLO where they were using self-contained resources that did not require reference to further or external sources (Kirkwood, 2008), where they perceived an additional time commitment in using such resources (Keefe and Wharrad, 2012), where they experienced a lack of support from tutors (Bacsich et al., 2011), computer anxiety or accessibility issues (Lymm et al., 2008; Blake, 2010; Concannon et al., 2005; Kirkwood, 2008). This can be expanded to include a lack of guidance in blended learning (Bacsich et al., 2011; Blake, 2010) or poor instructions for use (Kay and Knaack, 2007). The behaviour of students in terms of whether they chose to access RLO was documented by Concannon et al. (2005) who found that students who 'crammed' did not engage with RLO. We can learn from this on a practical level as educators and design learning and teaching strategies in which resources are signposted early on and with which students are required to study at a more continuous pace.

Furthermore, the lack of external motivation, e.g. certification (Bacsich et al., 2011) or the task being made optional for students (Kirkwood, 2008) has negatively affected reported RLO use. Attributing some marks to the student's engagement with blended learning and RLO within the associated mark scheme may have increased usage levels in the study by Concannon et al. (2005). If the RLO addressed a topic that was not of interest (Bacsich et al., 2011) or had been launched after the topic has been learned (Kay and Knaack, 2007), students were reported to opt out. Concannon et al. (2005) reported that 81% students found lectures more effective than online learning alone. We know that in terms of a student's confidence levels in using computers, past experience with technology may lead them to decide against engaging with blended learning and hence RLO (Littlejohn et al., 2010). This is corroborated by Windle et al. (2011) who found that students who were provided with a workshop setting in which to use RLO expressed a preference for this setting. However, the concept of 'digital migrant, digital native', where for example students with prior non-exposure to web-based resources (Marcus, 2013) is thought to be inaccurate by Johnson et al. (2013) due to its crude assumption.

The majority of the studies which explored why students chose to use RLO, also captured the reasons why students chose not to use these resources, with the exception of the publications by Windle et al. (2010) and DoH (2011). Kirkwood (2008) found that the incentives did not always outweigh the disincentives and vice versa. The reasons why students chose to use or not use RLO are multi-factorial, but our interpretation of the literature is that well planned out delivery of critically aligned RLO, with sufficient support in place for blended learning, provide a positive opportunity for students to take control of their education.

USING INTERVENTION STUDIES TO ASSESS IMPACT OF RLO ON STUDENT LEARNING

According to Mayes et al. (2009), research into the impact of technology on students was on the increase at that time. Their meta-analysis identified shifts in research themes towards a more holistic study design and outcomes of such research were increasingly being used to inform institutional decisions about technology in learner-centred teaching, learning and assessment. Bacsich et al. (2011) stated that at that time, the question of whether RLO had an impact on student attainment was being debated. The use of a pre-test to assess knowledge prior to introducing RLO to a curriculum is evident only to a minimal extent (Johnson et al., 2013; Sandlin, 2014). The impact of RLO has then been assessed by a post-test in various forms; MCQ written paper (Windle et al. 2011), student survey (Keefe and Wharrad, 2012; Lymm et al., 2008; Sandlin et al., 2014; Blake, 2010), mixed methods (Johnson et al., 2013) and semi-structured telephone interviews (Kirkwood, 2008).

In the studies reviewed, RLO were integrated into blended teaching, learning and assessment in a range of approaches, including offering them alongside lectures (Keefe and Wharrad, 2012), replacing lectures with RLO delivered in tutor facilitated workshops (Kay and Knaack, 2007), self-study or launched in conjunction with a workbook (Windle et al., 2011). This latter arrangement mimics the principle of 'scaffolding'. RLO have been implemented for use in both compulsory and optional formats, as well as being unlinked to assessment (Kirkwood, 2008). However, based on the findings mentioned so far, the lack of alignment of RLO to assessment would be considered an ineffective strategy. In order to assess impact of RLO, studies included in this review utilised differing numbers of RLO. Johnson et al. (2013) implemented three categories of RLO; formative assessments via an electronic voting system, annotated photographs and scenario-based online quizzes where question style was aligned to formative and summative module assessments.

In terms of capturing the student opinion on blended learning and RLO, Kay and Knaack (2007) found this to be generally lacking at the time. Seven years on, the literature indicates mixed response rates of students of between 40% (Johnson et al., 2013) and 92% (Lymm et al., 2008). The lowest levels of engagement were reported in studies which implemented a questionnaire, which could have been perceived by students as a non-essential task and as such ignored the request to provide feedback. Windle et al. (2011) reported that although only 66% of their study participants engaged with the evaluation process following RLO use, of that group, responses were equitable between students who had used RLO independently and those who had used them within a workshop setting. RLO evaluation in some of the studies reviewed was undertaken using the RLO-CETL toolkit (Windle et al., 2011; Windle et al., 2010; Blake, 2010, DoH, 2011), although it was found to yield inconsistent student responses in terms of their ratings of functionality and media across open and closed question formats (Windle et al., 2010; DoH, 2011). Kurilovas et al. (2011) reported this as a fairly subjective method of assessment. To support the data on impact on learning, studies have also referred to virtual learning environment resource user logs, however they have not been relied on heavily in terms of explaining findings (Concannon et al., 2005; Kirkwood, 2008). In more recent years, studies have been published which propose evaluative frameworks and tools which could be utilised by blended learning / RLO developers and students alike (Kurilovias et al., 2011; Kurilovas et al., 2014).

WHAT IMPACT DOES USING RLO HAVE ON LEARNING AND ASSESSMENT PERFORMANCE?

RLO have been found to have a significant effect on examination results (Windle et al., 2011; Keefe and Wharrad, 2012). Students from tutor-facilitated workshops answered a larger proportion of questions correctly following the introduction of RLO. At face value, one could argue that performance improved here due to the pedagogy underpinning the teaching format rather than the RLO since Windle et al. (2010) reported that using RLO within taught sessions could increase the interactivity of students, however the same improved outcome was found in students from a self-study setting. This is further supported by Windle et al. (2010) who reported that assessment performance improved in students who used online blended learning compared to traditional lectures, the decision for which was unaffected by the student's level of computer experience. AAMC (2007) argued that impact will only result if RLO are used effectively and appropriately, a notion which is supported by the findings of Kay and Knaack (2007) who reported that students benefitted if a RLO had well organised layout, was interactive and used visual aids to explain abstract concepts. Interactivity is evident in tools such as the virtual patient or patient simulator (AAMC, 2007).

The strategic benefits of using RLO in blended learning could include students being able to progress through materials at a quicker pace, whilst performing equitably in assessments to those who attend tutor led sessions scheduled over a longer period of time (Bacsich et al., 2011). The view of students regarding the extent to which lectures or wet-lab specimens helped them prepare for assessment declined following the introduction of RLO in the study by Johnson et al. (2013). However, this opinion was turned on its head once more online anatomy tools were made available, as students requested more text books and face to face tutorials. Beyond examination results a number of other desirable outcomes have been found to be affected by blended learning and RLO use including learning experience (Blake, 2010), critical thinking, practical competence, skills transferability, cognitive and psychological development, self-esteem, formation of identity, moral and ethical development and student satisfaction (Trowler, 2010; Sandlin et al., 2014). The latter is relevant in terms of the annual National Student Survey. Further qualitative studies of student perceptions have found that the majority of students agreed that RLO use had aided their understanding and they felt they could successfully evidence the module learning outcomes. Furthermore, students have reported feeling confident to use the knowledge learnt with RLO, in practice (Lymm et al., 2008).

The key message arising from literature in terms of why performance is positively affected when RLO are introduced lies with the principle of active engagement. Using a RLO to full effect equates to active engagement with learning content. Research tells us that achievement is positively influenced by the amount of active participation students undertake in their own learning process (Trowler, 2010; Roshier et al., 2011). Those findings are supported by Boyle et al. (2003), who found a positive association between a deep approach to learning and academic outcome. Furthermore, students with a deeper approach to learning have been found to exceed those who take a surface approach. Vermunt and Vermetten (2004) stated that "…engaged students share the values and approaches to learning of their lecturers… spend time and energy on educationally meaningful tasks… learn with others inside and outside the classroom… actively explore ideas confidently with others and learn to value perspectives other than their own." Littlejohn et al. (2010) found that undergraduates acknowledged that their learning at university would be different to previous learning experiences as well as expecting to have increased personal responsibility for their academic successes in order to enter their preferred vocation.

Blake (2010) reported that students were aware that repeated use (reuse) of resources consolidated learning, which could explain why the proactive students in our classes choose to use them. Concannon et al. (2005) reported that students who were required to undertake one compulsory assessment and a further four optional assessments following the introduction of RLO approached learning as they would have done prior to RLO launch, simply using the RLO as supplements, which developed the learning and teaching strategy into one of blended learning. However, engaging with technology in itself resulted in a shift in learning strategies as it provides a platform for continuous revision, not feasibly replicated by a lecturer in the case of a large group. In the same way that RLO can be reused, Johnson et al. (2013) repeated a semester of anatomy teaching as well as introducing RLO and the outcome was that RLO users achieved an improved performance in assessment over non-users. However, the improved performance from those students, who evidenced their proactive approach to learning by being identified as RLO users, could simply be attributed to the fact that they were given classroom time to revisit topics they had already learned, prior to the assessment. The RLO in this case added a third 'layer' to learning the same content.

The opinion of Kay and Knaack (2007) was that assessment of impact required multiple RLO to be available to students and that findings across the sector (secondary school STEM subjects) up until that point had been largely descriptive. A number of studies mentioned in this review did not explore to this detail, however, where findings have been documented, the quantitative extent of impact following RLO use has ranged from a 10% improvement for RLO users over non-users (Johnson et al., 2013) to as much as 19.2% (Keefe and Wharrad, 2012). Although Lymm et al. (2008) captured data around the proportion of RLO users who subsequently felt confident in the subject area, or the proportion who then reported that their own practice had changed as a result of using RLO, comparative data for cohorts of non-users was not provided, so it is unclear whether it was solely RLO use that improved the situation in this case.

The effect of not having access to RLO in students in the same cohort does not seem to be an issue according to Keefe and Wharrad (2012), who found that students in their control group who did not have access to RLO performed comparably to other groups who had undertaken the same assessment without those enhanced blended learning resources. However, this could be due to the voluntary-response bias reported in this paper, which led to low levels of engagement by students, therefore wider generalisation of the findings cannot be made.

The development of pedagogic research around the impact of RLO does not come without challenges. To date, these have included staff time to design and develop RLO, time to develop a quantitative post-test as well as the low engagement levels of students with focus groups (Johnson et al., 2013). We do have to consider that some veterinary education cannot be delivered virtually (Short, 2002). There is a sense from the literature that academic staff may be replaced by e-learning technologists in the future, which could then subsequently have an impact on the research generating activities of a university (Short, 2002), where there is a significant shift in the proportion of online learning in a blended learning format. However, without a cross-institutional team of technical staff to support the provision of e-learning, the only academic staff to develop and use RLO in their teaching would be those with prior experience of doing so (Kirkwood, 2008). These challenges are not insurmountable and the barriers to implementing RLO should be addressed, in light of the range of potential benefits to students from actively engaging with RLO (Blake, 2010).

CONCLUSION

The literature reviewed herein provides an insight into an aspect of blended learning which is currently limited in terms of published research. Increasing this documentation of impact is critical in order to advance the development and promotion of RLO in blended learning. The effect of computer confidence on RLO use, students' choice to use RLO, the impact on student learning, assessment and professional performance are some of the variables which have been measured to date. To improve the student approach to learning, universities should continue to invest in blended learning and RLO, along with sufficient staff and student development in order for those resources to have optimal impact. Learners' needs for development of digital literacies is also a reflection of the technological expectations of graduates and their role in society. The approach to RLO by students from different courses may vary, but prior experience of technology, alignment of content and learning needs and availability of technical support are some of the key drivers of usage and reuse. A positive effect on student attributes beyond just assessment performance is likely to occur following RLO use because those students have adopted a process of active engagement, which we know can bring about a deeper approach to learning. In turn, these learners perform better than superficial learners. As educators, ways of motivating students to actively engage with materials are illustrated in cases where they have been dynamic in the development of resources.

Overall, whether a student in veterinary education will choose to use blended learning and RLO and whether that usage brings about a positive impact on performance as a whole appears to be multifactorial, as evidenced by the range of subject areas in which empirical studies have been undertaken. Therefore, practitioners within the veterinary education sector must draw from findings from other subject areas, albeit with care, in order to develop the application of RLO within their teaching.

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Chapter 18
EVAINU Research:
New Virtual Learning Environments for Educational Innovation at University

Alejandra Bosco
Autonomous University of Barcelona, Spain

ABSTRACT

New virtual learning environments for educational innovation at the university of the present-future--EVAINU--is a research project financed by the Autonomous University of Barcelona as part of its support for emerging research groups. The project came about as a result of the growing presence of the ICTs in the higher education system and has focused on identifying typical cases, which use these media at the Autonomous University of Barcelona (UAB) involving some form of curricular innovation or improvement in accordance with the European convergence processes, which the Spanish university system is currently undergoing. As a result, three case studies of different qualifications were carried out in order to investigate their potential for improving university education. One of these cases--Virtual Veterinary Science--is described in this study. Among the preliminary results of this research so far, of particular interest is the fact that while the ICTs are clearly an important opportunity to make a qualitative leap and to go beyond teaching outlooks based on exposition, passive reception, and memorising, more institutional support is necessary in terms of working strategies, which promote new ways of organising teaching, the development of ICT skills among teaching staff and students, and the creation of incentives for teacher training, among other initiatives.

ABOUT EVAINU

New virtual learning environments for educational innovation at the university of the present-future--EVAINU--is a research project financed by the Autonomous University of Barcelona as part of its support for *emerging research groups*[1]. The problem considered in the project arises from the increasing and sustained presence of information and communication technologies (ICTs[2]) in the higher education system where they play an increasingly major role in teaching. The problem also arises as a result of the opportunities, which these technologies give to the European convergence processes that are now

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being implemented, as they may favour teaching methodologies that are less centred on the teacher and content, and more centred on students and on carrying out activities or projects. At university, the ICTs may involve the entire teaching process as they do at the Open University of Catalonia, or just a part of it, covering specific aspects of education. This is the case at various universities in Spain, which complement traditional face-to-face teaching with the use of various electronic environments such as the Autónoma Interactiva (at the Autonomous University of Barcelona) or the UB-Virtual (at the University of Barcelona). These two schemes enable both subjects and training courses of various types to be taught either partially or completely by means of distance learning, using an electronic medium based mainly on WWW (World Wide Web) applications.

The purpose of this research project is therefore to identify new methods of training at a university involving the use of ICTs in order to investigate their potential for improving university education (i.e., for becoming educational innovations beyond the limits of the technological innovation that these tools already represent).

The initial hypothesis is based on the conception that integration of the ICTs and possibly the change involved in non-attendance of regular classes or the means of gaining access to information does not necessarily entail innovation and an improvement in teaching and learning processes. Any educational innovation starts with the inclusion of a new item in the curriculum, but it is still difficult to change the way teaching staff and students see teaching and learning processes, and the organisational and symbolic structure of the institution (Bosco, 2002; Hargreaves, Earl, & Ryan, 1998; Sancho et al., 1998; Stoll & Fink, 1999, 2000). In general, approaches to learning remain more centred on teachers than on students. Knowledge continues to be seen as something that is given and which is external to the students, and not as a construction, which takes place and, which the student must understand. Assessment is still synonymous with examinations and testing and relationships with the community as a factor encouraging learning that is more significant are still scarce (Hargreaves et al., 1998; Sancho & Hernández, 2001).

The specific objectives of the research in its exploratory phase are:

- To identify, describe, and interpret some of the typical educational approaches that have been completely or partially implemented using the various services made possible by the ICTs at the Autonomous University of Barcelona.
- To identify, describe, and interpret the potential of these approaches for educational improvement and change, emphasising the role of teachers and students in the process, ways of representing knowledge, the type of assessment they lead to, and the relationship they establish with the wider community of which they form a part.

Methodology

The study is carried out from the qualitative perspective of educational research, as it aims to find a significance and an interpretation, taking into account the context of the various activities, which teachers and students carry out using these new learning environments. These studies have a curricular or theoretical-contextual focus in terms of research into methods (Area, 1991). The object is thus investigated in an interactive, continuous, and flexible manner in its "natural" context, accepting the complex scenario in which it is located. The inductive route, based on evidence, is used to construct its conceptions and theories.

As a result, *case studies* have been selected as the methodological strategy as they enable in-depth study of one or more units, which represent the subject being researched (Stake, 1999). In fact, this is a design with many cases in which each case is an example in action, and it therefore allows us to "illustrate" the problem for which it is the focus of examination and study (MacDonald & Walker, 1977). For this reason, three typical cases have been selected based on previously established criteria (Goetz & LeCompte, 1988). The main methods for gathering information were exploratory interviews, observation, and analysis of documents and devices, and in some cases, the survey and questionnaire (see Table 1).

THE THREE TYPICAL CASES

The first step in the research was to identify the teaching approaches, which used ICTs and which also considered themselves to be innovative (i.e., they thought of themselves as an improvement compared to the methods without ICTs). To do so, we identified teaching approaches that had presented "teaching innovation projects" to the selection processes for teaching support grants (with financial endowments) of the *UAB Higher Education Teaching Innovation Unit*, or which had been accepted as communications at the *Innovation Day Sessions* organised by the unit. Another requirement for selection was that they had to include more or less all the ways of using ICTs in teaching, which are used at the university.

We thereby identified three cases: (a) The repository of virtual materials in the faculty of veterinary science, "*Virtual Veterinary Science,"* (b) the geography degree through the "*Geography on the Net"* programme, and (c) a *group of three subjects* in different degree courses, which complement face-to-face teaching with the *use of digital materials* and the *virtual campus* of the university (the *Autónoma Interactiva*). Due to limitations of space, we will only look at one of these in this study, *Virtual Veterinary Science (VVS)*, and give a description and analysis of the method of teaching in these studies, based on carrying out "study cases"[3] (Wassermann, 1999), which by means of ICTs contributes extensively to these processes of change promoted by European convergence.

It should be made clear that our study of *Virtual Veterinary Science* consists of three subjects from the Veterinary Science Degree Course, which are analysed in depth. These are representative of the process that takes place in terms of the structure and use of the repository and other possibilities with ICTs--the first year of *Anatomy I*, the second year of *Parasitology,* and the fourth year of *Pathological Anatomy*. Using subjects from different courses enabled us to check the data more extensively.

Table 1. Data gathering tools by participant

		Sources				
		Heads	**Teaching staff**	**Students**	**Technical staff**	**Environment/ Classes**
Tools	Questionnaires			x		
	Observation					x
	Interviews	x	x	x	x	
	Analysis of documents					x

The three subjects organise their teaching in theoretical and practical credits. While the theoretical part is generally covered by classes organised in the traditional way as exposition of content, the practical classes have particular characteristics that are specific to each subject. In Anatomy I, the practical classes consist of anatomical dissections coordinated by the subject's teaching staff, while in Parasitology, specialist equipment is used to observe microscopic organic material (parasites). Finally, in Special Pathological Anatomy, students participate in an autopsy in the practical classes. Based on this, they have to ascertain the cause of death of an animal.

Virtual Veterinary Science

Virtual Veterinary Science is a study case because it is a significant example of the contribution that can be made by ICTs to educational processes in higher education institutions. Another reason is that it is one of the few initiatives including ICTs in the teaching and learning processes, which involve an entire qualification--the *Veterinary Science Degree Course.*

These studies, like many other qualifications at the university, are undergoing a transformation in their teaching and learning process, which is related to the European convergence process[4] in university education in which they consider that the ICTs may have a beneficial role. This is especially true in terms of the implementation of curricular innovation processes in which the organisation of teaching would be more closely related to carrying out a series of activities than to mere class attendance, where knowledge should be built up based on these activities, and where assessment would be nothing more than a means of recording these activities in a clear way, and something which would not necessarily mean in practice that an examination would be sat.

Virtual Veterinary Science (hereinafter *VVS*) is a *repository for learning materials*, which is also called a *learning objects library* by some authors (Pedreño, 2004). This is a collection of digital materials stored, collected, and controlled by a university or higher education institution, regardless of their purpose or origin. Some authors (Crow, 2002) feel that this type of resource should have two complementary objectives: (1) to promote the restructuring of the means of publishing in academia, and (2) to make up a tangible body demonstrating institutional scientific productivity. A repository is thus a digital archive, which brings together a faculty's intellectual output, its academic staff and students, and is accessible to both members of that institution and other institutions in an open manner. Some of the main characteristics attributed to the contents of an institutional repository are:

1. It is *institutionally defined* (i.e., it is not oriented toward the collection of materials in a specific discipline or subject), but it is instead a collection of original material produced or selected by one or several institutions with similar aims (for example, several universities).
2. **Academic:** Depending on the objectives established by each institution, an institutional repository may contain any product generated by the students, teaching staff, researchers, and/or other staff. It could therefore include electronic assessment portfolios from the students, instructional materials, institutional video recordings, software, databases, photographs, virtual works of art, and any digital material, which the institution wishes to preserve. Flexibility and control of what is published must also be strictly regulated. There must be established mechanisms, which evaluate the material published, which should be part of the policy of each participating institution or institutions.

3. **Cumulative and perpetual:** The contents must be of a long-lasting nature, and although they need not be included on a permanent basis, the system must be powerful enough to accumulate several million objects with the passing of time, and many terabytes of data as a result.

In *VVS*, the repository is exclusively composed of teaching resources, and in this respect, it does not meet all the requirements or all the characteristics for this type of resource mentioned above, although it does meet some of them. It is in fact a learning objects library, which is collected by a faculty in order to support teaching, and is therefore institutionally defined. Although it is linked to specific knowledge areas, it is academic, cumulative, and perpetual.

The Repository Materials

The three subjects analysed in these studies have produced materials specifically for teaching (all in *Virtual Veterinary Science)*, and in all of them, these materials present the development of their basic contents in a more or less schematic manner, depending on the subject. This is especially true of the inclusion of images, some of which are even microscopic, which provide a meaningful illustration of the subject in question. The word meaningful is used here because some of the subjects dealt with require an image to at least begin to understand them. For example, if the aim is for students to identify an inflammatory process caused by a disease, bacteria, etc., in a specific organ, it is highly likely that they will need to see what this inflamed organ looks like, including at microscopic level. The same is true if they need to recognise a type of parasite or the muscles or nerves in a specific part of the body. It is highly advisable to look at their appearance, shape, etc. This is at least one of the steps to be followed in order to be able to recognise it later, and attach the appropriate significance to it. In fact, it would be ideal to see this material in reality. Examples where this is possible are in *Anatomy I* and in *Parasitology* in practical classes, although there are some difficulties due to the number of students, as well as in *Special Pathological Anatomy*, but in a different way. The material observed depends on what is available in the *autopsies room* on a given day, and only a small group of students can have access to it at the same time.

In *Special Pathological Anatomy* and in *Parasitology*, there is also a type of more application-based material for acquiring knowledge, which is therefore more interactive in the sense that an understanding of it requires more work in intellectual terms. Examples of these types of materials are the *autopsy of the week* (which is left in *Virtual Veterinary Science* each week) and/or the *self-directed learning cases,* which the students have to resolve (which are created based on the most common diseases of organs and animals) and *Parasitology* tests. This means that it is no longer a question of "presenting" content but instead the content requires a different type of interaction from students. It requires solutions to a problem, and they have to use knowledge that is related to the problem but not developed as part of it. In short, they have to use knowledge, which is assumed to be acquired or which this material can help to produce.

Why Do We Say That Virtual Veterinary Science Could Facilitate Less Traditional and More Innovative Teaching?

At first sight, it could be said that the materials that facilitate less traditional student-centred learning to the greatest extent are connected with those that stress the selection and management of information for solving a problem rather than the presentation of information. They also lead to types of actions that are complex from an intellectual point of view, such as producing and checking hypotheses. However, having access to material where most of the content is dealt with can also facilitate teaching based less on exposition or "information transfer." If the students can consult the material by means of *Virtual Veterinary Science*, some students suggest that it is then not necessary for the same material to be presented in class, unless it is decided that it is highly complex, which could be possible in some cases. On this subject, a first year student said:

The virtual material is very helpful because it enables you to see anatomical aspects, which we do not have time to study, or are very difficult to identify in a dissection (referring to the practical classes in Anatomy I). The negative aspect is perhaps that the teacher often only shows the image and does not explain it in detail.

As can be seen in *Anatomy I*, for example, the material complements the practical dissection classes in which it is difficult to identify some anatomical aspects for various reasons. However, in some cases, the material makes theoretical classes into a mere "presentation of material," which is not especially useful. This is firstly because when the material is easy to understand, it does not need a theoretical class for presentation. The practical class complemented by the material is sufficient. Secondly, when the anatomical structures are sufficiently complex, a new class (the theoretical one), in which they are studied in some depth, becomes necessary, as well as the practical class and the material.

In any event, the material facilitates processes of understanding while it complements practical classes. However, it would seem that the class (theoretical) should become something other than what it is. In fact, the various types of materials in the repository could help to innovate in the sense of making the class less "expositional." This could be because occasional activities are carried out in order to help with dealing with the material in an independent manner, or because they are not necessary, as they have been replaced by the material. This means that as a whole, *Virtual Veterinary Science* could help to promote a type of less traditional/expositional teaching, at least as a first step, which should be complemented with other types of activities, which are more like those promoted by learning based on problems or projects or carrying out activities such as case studies. Learning is based on the formulation of one or more problems in these methodological approaches, and the learning processes are directed by the participants (i.e., it is the students who formulate their own problems based on their experiences and previous baggage). The activity or activities are a central part of these approaches, and are carried out using searching, decision-making, and writing processes, and work is generally done in groups with advice from the teacher.

Some students give various ideas on the type of activities, which could help them toward a better understanding of the concepts and could even bring them closer to working in their future profession. They talk about not completely eliminating classes, but instead making them different and more geared toward understanding, more focused on learning than on teaching (i.e., where what the student does goes beyond understanding a text or memorising names and requires the establishment of more complex relationships), and less toward exposition and lectures. In fact, the degree course could be divided between independent study and autonomous learning, as well as the important practical work that is impossible to replace in these studies. We consider autonomous learning to be learning, which encourages students to work with some degree of independence, setting their objectives and study plan in accordance with their needs and interests. The teacher's task is to facilitate this learning by providing the best conditions and the resources and the materials necessary to achieve the objectives set. As can be seen, this involves an active type of learning, which is committed, not managed or directed from outside, and is meaningful and student-centred. *Virtual Veterinary Science* may be deemed a resource, which facilitates this type of learning.

Study Cases in Special Pathological Anatomy

One of the subjects making up the case, *Special Pathological Anatomy,* already carries out part of its teaching by a methodological approach, which encourages autonomous learning--*study cases*.

As its name suggests, an obvious feature of this way of teaching is that it takes place using an educational tool called a case. A case is a narrative, which includes information and data on a specific subject. However, although the focus is on specific subjects such as history, paediatrics, government, law, business, education, psychology, child development, nursing, etc., they are by their nature interdisciplinary. In fact, good cases are based around problems or broad-based ideas--important points in a subject or knowledge area--although the narratives are based on real-life problems, which present real people:

A good case is a vehicle by which a piece of reality is taken into the classroom in order for the students and teacher to examine it in minute detail. A good case keeps the discussion focused on some of the stubborn facts which one has to face in some situations in real life ... it is the anchor for academic speculation; it is the record of complex situations which must literally be dismantled and reassembled for the expression of attitudes and ways of thinking that are set out in the classroom (Lawrence[5], 1953, p. 215).

These cases are also solved in group work, which is guided by the teacher thanks to a series of procedures such as critical questions, examination of the case, and follow-up activities. Critical questions are usually asked at the end of the process forcing the students to review important ideas related to the case. They are not questions with a single closed answer such as a name, date, or description of a phenomenon or event. Their objective is instead to promote understanding in such a way that they require students to apply what they know (they even require them first to ascertain what they do not know) when they analyse data or suggest solutions. This means that they have to prepare hypotheses for solving or understanding the case, and therefore bring superior cognitive skills to bear. This examination of the case is crucial in helping students to carry out a more acute analysis of various problems, and encourages them to make an effort to obtain a deeper understanding.

After these critical questions, basic ideas play the central role in the discussion. Trivial issues disappear and problems are not necessarily solved, which is tangible proof that complex questions do not have faultless solutions. It is often necessary to suspend one's judgement and tolerate ambiguity and uncertainty.

Finally, the follow-up activities are put forward in order to give improved responses to the case. They may be very varied and whatever they are, their value increases when further discussions take place leading to a wide-ranging examination of the problems with the introduction of new perspectives.

In the subject dealt with here, the objective of this work is twofold. Firstly, cases help in developing content for the programme of the subject (i.e., various pathologies in different species of animals. Secondly, the aim is to create an activity similar to the professional work that the students will have to do when they have completed their studies.

The "case" is made up of the autopsies carried out in the subject's practical classes--"a piece of reality, which is brought to the classroom" to which a solution is be found using a degree of "academic speculation" achieved by consulting bibliographies, the teaching staff, and by means of group work with partners. This is a tool bringing together important points in the syllabus to be dealt with, which warrants in-depth examination. The objective is to find out which pathology caused the death of a real animal, and whether the diagnosis and treatment received were correct. To that end, all the necessary background is available wherever possible, and is the basis for the beginning of a cooperative research process. One of the teachers in charge says:

(…) the student who attends an autopsy… looks at a case under the supervision of the teacher, and the teacher tells him or her why it is unusual: why it is a species that is seen rarely, because of certain reasons, and that there are between 2 and 4 students who are assigned this case, and then they work on it (...) The students can search for information wherever they want, on the Internet, in libraries, coming to see me here, with class notes, using whatever they want...

The case exactly as it (...) happened. (…) you receive it, you do autopsies in the autopsy room, you take the macroscopic and microscopic photographs, they discuss them, they give differential diagnoses, they look for reasons, what we call the 'pathogeny', i.e. 'this organ has this because this has happened to it…', 'the cause-effect relationship is this, and this is also related to the symptom that the animal had of convulsions, etc...

The information about the case is organised with guidance from the teacher and mostly follows the same structure: presentation of the animal, clinical history, macroscopic findings, microscopic findings, diagnosis, pathogeny, differential diagnosis, and synopsis. This same structure is followed for its presentation in public after it has been "resolved" or at least once the most plausible hypotheses have been presented (see Table 2).

Table 2. Case study presentation diagram

CASE PRESENTATION STRUCTURE **Presentation of the animal:** Species, breed, age...(i.e., everything concerned with the details of the animal). **Clinical history:** The evolution of the disease which caused the animal's death: Its general state when it arrived at the hospital, symptoms, laboratory data, radiology, and all the practices and everything done to diagnose the disease in question. **Macroscopic findings:** All the pathologies the animal suffered from and which were readily apparent during medical examination (e.g., lesions on the skin, state of the fur…). **Microscopic findings:** The data that are found concerning the disease when the material is analysed with a microscope, and the findings that can thus be made about what was affecting the animal, which can corroborate the diagnosis of the vet who treated it or show new results, which explain the disease. **Diagnosis:** a) **Lesional:** Concerning the anatomopathological lesions observed. b) **Etiological:** Concerning the origin and the specific cause of the disease. c) **Disease:** This is the optimum diagnostic level, including lesional diagnosis, etiology, and symptomology. **Pathogeny:** Establishment of the cause-effect relationships between all the lesions observed during the autopsy, and between these lesions and the signs and symptoms of the disease recorded in the clinical history. **Differential diagnosis:** Carried out in accordance with the initial clinical diagnosis recorded in the clinical history. This involves the production of a diagnostic algorithm allowing the probabilities that the final diagnosis will be the most correct one possible to be increased. **Synopsis:** A synthetic integration of all the above.

It can be seen that resolution of the case leads to a series of activities involving a search for and analysis of information, consultation of experts, interviews with those involved, etc., which is indeed a practice that is very similar to what they will do as future professionals, in which the teacher is a *tutor* and when assessing the resolution of the case, an *expert*.

As mentioned previously, this working approach is a small part of a subject. We are therefore a long way from removing the exposition-based class, which continues to have an important role. However, for the purposes of this study, we are interested in the contribution of the ICTs to this type of development, to the extent that permanently and in itself, and the methodology used is an approach for autonomous learning, which is more in line with the processes of change taking place in higher education institutions in Spain.

What Do the ICTs Contribute to This Way of Working?

In order to be able to answer the question posed in the title of this section, it is necessary to reconstruct the production process of *Special Pathological Anatomy* cases. Firstly, the ICTs enable the relevant information related to the case to be gathered quickly. Both the macroscopic and microscopic photographs are mainly taken on the day the autopsy is carried out. These are an important basis for the research process, which has begun. The condition of the various organs involved in the disease and presumed death of the animal can be seen in them. They are digital photographs, which can be shared and managed from the outset with major savings in effort and can also be touched up, enlarged, etc. for all conjectures that can be made during the process of producing hypotheses and resolving the case. They therefore become an important intellectual tool in the sense that they "expand" the ability to transform reality for the purposes of thinking about it.

These photographs are also available to each member of the group and even to the rest of the "group class" as they are placed in a shared disk unit. They therefore facilitate independent work at the same time as reinforcing group work as each person can make progress to the extent that their time allows, and quickly share their findings and their progress within the process, by e-mail, for example.

As far as the case resolution process is concerned, the ICTs are present in both the process of searching for information and in the location of and communication with experts, contacts with associations of interest, and even with the owners of the animal. They also improve it by making communication and consultation with the teaching staff permanent.

Another feature of this experience is also the availability of hypermedia materials from *Virtual Veterinary Science* produced by the subject's teaching staff where all the possible pathologies of the various organs in the different species are available (as if it was an encyclopaedia). These materials are undoubtedly the initial reference point in the search for information and subsequent resolution of the case.

During the case development process, the ICTs expand communication opportunities extending them beyond the spaces of the classroom, office, and the campus itself. The discussion can be extended as much as is necessary. A "real" meeting is not always necessary, even between members of the group.

Having reached the case presentation phase, making multimedia presentations (diagrams, audiovisual material, etc.) will help with conceptualisation and reasoning of the main hypotheses to be shared in the defence. Their multimedia and interactive nature facilitates representation of information in a type of reasoning in which images have a key role. The digital nature of the presentation also enables flexible management of information allowing partial products to always be recovered. These show various points in the process without having to start again. Finally, they allow access to the material by the rest of the class (in a shared disk unit) so that everyone can find out the main hypotheses for debate before exposition of the case.

We therefore have tools for gathering information in a flexible and simple way, which are crucial for the development of the case, tools which enable us to represent information in a very significant interactive multimedia way to support the type of arguments being used, and all types of tools for online communication and cooperation. These all support and expand the scope of an approach which in itself already encourages autonomous learning, but which the ICTs undoubtedly improve by multiplying its benefits.

By Way of a Conclusion and Perspectives

As a conclusion to the arguments set out in this article and the data presented with regard to the research in progress, it can be emphasised that the ICTs offer significant opportunities for improvement and for a qualitative leap from traditional teaching to other types.

In the case presented here, it can be seen that the *Virtual Veterinary Science* repository could help the configuration of a "class" that is much more focused on the needs of the student than the "exposition of information" every time the student has had a practical class plus a consultation of multimedia material online. The class could therefore focus on supplementary questions or support for the understanding of more complex ideas. This improvement is made possible by the ICTs, although it cannot be truly updated without the desire to organise teaching in another way.

Tools such as e-mail, tools for collaborative work, all those enabling multimedia materials to be created, etc. expand the scope of autonomous learning within the approach of work by study cases even further, increasing the possibilities at every point in the process.

It can therefore be said that the ICTs provide a range of opportunities for the implementation of improvements--in accordance with European convergence--such as the following:

- They facilitate the gathering, access (faster), and management of information (hypermedia material).
- They improve the organisation of information (better logical structuring).
- They promote understanding of contents based on multimedia materials (they reinforce retention--recognition and synthesis processes).
- They stimulate independent study and decrease the dependence of the "class" on the "exposition of content."
- They widen the scope of approaches based on autonomous learning, such as work by study cases or other approaches such as continuous tutoring, collaborative work, etc.
- They improve communication between teaching staff and students and other members of the community, and increase participation by the wider social community.
- They promote the development of ICT skills among the teaching staff and the students.
- They make attention for various learning styles and rhythms possible.

The main limitation is to believe that in themselves they are able to transform teaching, and that they can only do it in a single specific way. Some of the measures that could counteract these beliefs are:

- Regular institutional support for all improvement initiatives, which by including the ICTs are able to organisers teaching in alternative ways, moving the “class” from the centre of the approach.
- The supply of resources for the development of digital materials adapted to the possibilities of the interactive multimedia, which in some cases can contribute to the processes of understanding.
- The establishment of incentives for teacher training in order to cooperate with the production of interactive multimedia materials and the development of new methodological strategies which make use of the ICTs and are able to create new ways of organising teaching.

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ENDNOTES

[1] The purpose of the grants is to finance the costs of performing research of an exploratory nature, which will be carried out in full after it has taken part in an official public competition process for grants. The members of the research group that carried out this study are Pere Marquès, Carlos Dorado, Noemí Santiveri, David Rodríguez Gómez, Gemma Carreras, and Laura Chaito, who are all part of the Applied Pedagogy Department of the UAB. We are especially grateful to David Rodríguez Gómez for his co-operation with this article.

[2] By ICTs, in this study we refer to the various digital devices that enable us to present, manage, store and disseminate information.

[3] By "study cases," we mean a teaching strategy, which should not be confused with a case study, which in this paper means a methodological research strategy.

[4] The term "European convergence" includes various policies aimed at making the characteristics of higher education in the European context more uniform. These policies affect both the structure of the qualifications (comparable grading systems, graduate and postgraduate cycles, etc.) and the way teaching is organised.

[5] Quoted by Wassermann (1999).

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Chapter 19
Veterinary Medicine:
All Collections Great and Small

Esther Carrigan
Texas A&M University, USA

Ana Ugaz
Texas A&M University, USA

Heather K. Moberly
Oklahoma State University, USA

Jessica Page
The Ohio State University, USA

Kristine M. Alpi
North Carolina State University, USA

Carol E. Vreeland
North Carolina State University, USA

ABSTRACT

The purpose of this chapter is to present the specifics of veterinary collection development within the context of general health sciences collection development. A basic understanding of the principles of collection development and its processes is assumed. The chapter provides historical background and current information on external forces that impact veterinary collections. It presents important aspects of the veterinary literature and the community of veterinary libraries and explains their impact on veterinary collection development. The chapter provides practical advice and strategies for developing and maintaining veterinary collections. It discusses important trends and future issues in veterinary collection development, including the need for an active advocacy role for veterinary collection librarians.

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INTRODUCTION

With only twenty-eight veterinary schools in the United States, veterinary libraries represent an interesting case study in collection development. Veterinary libraries face many of the same challenges as any other academic or special library, such as space and budget challenges, materials inflation, and the consolidation of publishers, but they also face a special set of challenges in dealing with the nature of the veterinary literature and their small number of geographically dispersed colleague libraries. The strong tradition of cooperation and information sharing among veterinary librarians, both nationally and internationally, serves to mitigate these challenges.

In addition to the typical academic veterinary library collection development context, there are numerous other types of libraries that collect in veterinary medicine. These include academic libraries serving pre-veterinary or biomedical sciences, animal science and equestrian programs, libraries serving veterinary technology training programs in community colleges and universities, zoo and aquarium libraries, and special libraries within drug companies and pet food companies. Professional practice specialty training continues beyond the veterinary school into internship and residency training programs at over 150 veterinary hospitals, most of which are not associated with universities and must also collect in veterinary medicine.

The scope of materials in an academic veterinary medicine collection is strongly influenced by the availability of resources in human medicine, agriculture, and life sciences. The collection must support the professional veterinary curriculum both in the classroom and in the clinical teaching arena. The academic veterinary library collection also often supports veterinary teaching hospitals, state diagnostic laboratories, pathology and parasitology departments, and veterinary and comparative medicine research programs.

This chapter provides an overview of collection development in veterinary medicine in the United States. It builds on standard concepts and operations in collection development to emphasize what is different or special in the context of the veterinary medical literature and the veterinary medical library. It builds on the principles and practices of collection development in health sciences libraries to provide practical advice and strategies relative to collection development for veterinary medicine.

BACKGROUND

Evolution of US Veterinary Medical Education

Formal veterinary medical education in the United States began with privately operated, for-profit institutions located in major cities. Inadequate curricula and entry requirements that could not meet the developing national accreditation standards, lack of support from the U.S. government, and a drop in enrollment due to the decline in horse-drawn transportation and World War I, led to the closing of proprietary colleges before 1927 (Miller, 1981; Smith, 2010). There is no record of libraries associated with these private institutions, and sadly, much of their history has been lost (Boyd, 2011).

Many current U.S. veterinary schools are based at large universities, aided by land grant funding which began with the Morrill Act of 1862. Located in rural communities, new veterinary colleges founded at land grant institutions placed priority on agricultural animal medical management and associated public health issues (Smith, 2010). These public veterinary colleges began to emerge with Iowa State in 1879 and developed slowly. Only 10 schools were established before World War II so the majority of U.S. veterinary schools and their libraries are relatively young. This has major implications for the preservation of the historical record for United Sates veterinary education and practice.

Traditionally, the four-year veterinary medical curriculum has consisted of three years of pre-clinical courses, taught using primarily didactic, lecture-based forms of instruction, followed by a fourth year of hands-on, clinical rotations. Two learning methods introduced in the human medicine curriculum, problem-based learning, and evidence-based practice are being transplanted into veterinary curricula.

Problem-Based Learning (PBL) emphasizes self-directed, group learning and integrates the basic sciences into patient cases (Dodd, 2007) to solve a defined problem. During the 1980s and 1990s, PBL became accepted in medical schools across America and in Europe (Savery, 2006). The inclusion of PBL is increasing in veterinary schools; a small number of schools use it as the predominant method of instruction for their pre-clinical curriculum.

Evidence-Based Medicine (EBM) involves the integration of the best research evidence with clinical expertise and a patient's unique values and circumstances in making a clinical decision (Straus, Richardson, Glasziou, & Haynes, 2005). In the 1990s, the approach spread rapidly through the medical school curricula, aided by the increase in published results of patient-centered clinical research. The term *evidence-based medicine* in a veterinary context does not appear in the veterinary literature or its indexes until 1998 (Hardin & Robertson, 2006). Although the concept is being explored, many veterinary colleges do not yet have a course in evidence-based veterinary medicine (Fajt, 2010). Implementing an evidence-based approach in veterinary medical education has also been hampered by the limited number of evidence-based reviews and clinical trials in the veterinary journal literature, resulting in little primary scientific evidence on a particular topic (Cockcroft & Holmes, 2003).

The shift in the veterinary curriculum toward a more problem-based or evidence-based approach, which is much more library and collection resource intensive, influences veterinary collection development.

US Academic Veterinary Libraries

The development of veterinary education at large, land-grant universities has had a direct impact on the nature of U.S. academic veterinary libraries. Academic veterinary libraries serving the 28 American Veterinary Medical Association (AVMA) accredited veterinary colleges in the United States are often administrative units within a university library system, reporting to the main university library. A minority report directly to the veterinary college. More than half of these 28 libraries exist as a separate library that primarily serves the faculty, staff, and students of a school or college of veterinary medicine. The remaining libraries exist either as a separate library unit that serves veterinary medicine and additional curriculum areas such as medicine or agriculture, or as a veterinary collection that is housed in separate locations, like a campus library and a clinical library (Ugaz, Carrigan, & Moberly, 2011). Organizational reporting lines directly impact the scope of veterinary collections, their funding levels and the degree of autonomy with which they are developed.

SOURCES OF INFLUENCE ON COLLECTIONS

American Veterinary Medical Association Accreditation

The AVMA accreditation standards that address expectations for libraries are important to any library that serves a professional school. Advanced certification and specialty training programs also establish expectations for the availability of resources. These both have a significant, positive impact on veterinary collections. In veterinary medicine, the AVMA, through its Council on Education and its Recognized Veterinary Specialty Organizations, wields significant influence on veterinary collections. In 1921, when the AVMA approved the first outline for essentials of an approved veterinary college (American Veterinary Medical Association, 1922), it recognized that colleges needed a working library with veterinary texts and journals, but this description covered only the library space and materials. Beginning with the "Essentials of an Acceptable Veterinary School" published in the 1947 AVMA Directory, the list of library requirements expanded to include more than facilities and materials, stating "a trained librarian should be employed to supervise the operation and development of the library" (American Veterinary Medical Association, 1947, p. 22).

The AVMA Council on Education (COE) is the only recognized accrediting agency for colleges of veterinary medicine in the United States and Canada. Accreditation of programs leading to a doctor of veterinary medicine or equivalent ensures that colleges meet quality standards and prepare graduates for entry-level positions in the profession (American Veterinary Medical Association, 2011a). The COE's policies and procedures include an official set of standards which cover everything from admission policies to curriculum and physical facilities.

Libraries and information retrieval are essential to veterinary medical education, research, public service, and continuing education. Timely access to information resources, whether through print, electronic media, or other means, must be available to students and faculty. The library shall be administered by a qualified librarian. The college shall have access to the human and physical resources necessary for development of instructional materials (American Veterinary Medical Association, 2011b, Standard 5 section, para. 1).

Advanced Specialty Training Programs

The AVMA COE's standards state that colleges "should establish post-DVM/VMD programs such as internships, residencies, and advanced degrees (e.g., MS, PhD), that complement and strengthen the professional program," (American Veterinary Medical Association, 2011b, Standard 6 section, para. 2). Internships and residency programs provide in-depth training in a specific clinical discipline. A residency usually leads to specialty certification in an AVMA-recognized veterinary specialty organization. Veterinarians can become certified as specialists in particular systems (e.g., theriogenology), disciplines (e.g., internal medicine), and types of practice (e.g., zoo medicine) or species. Most of the 21 AVMA-recognized veterinary specialty organizations that administer specialty examinations provide candidates with reading lists to help them prepare for the tests. It is imperative that veterinary librarians maintain an awareness of the AVMA accreditation standards and shape veterinary collections and services to meet them. Recognized veterinary specialty organization reading lists are also important tools in building or benchmarking veterinary collections.

Veterinary Medical Libraries Section of the Medical Library Association

The Veterinary Medical Libraries Section (VMLS) of the Medical Library Association has been a positive force in the development of veterinary collections for nearly forty years. In an effort to improve interlibrary cooperation, veterinary librarians sought to create their own group within the Medical Library Association. Officially recognized in 1974, the Veterinary Medical Libraries Group, later renamed Veterinary Medical Libraries Section, encourages "development of and cooperation among veterinary medical libraries, and fostering a forum for the exchange of ideas and the discussion of mutual problems and concerns" (Henley, MacNeil, & Stephens, 1999). One of the section's earliest projects was the preparation of the first list of veterinary journals essential to the operation of a veterinary medical library, which was published in 1978. The section has produced union lists to facilitate resource sharing across veterinary libraries, three editions of a basic list of serials to guide veterinary journal collections, and compilations of recognized veterinary specialty organization lists (Henley, et al., 1978; Boyd, Hull, MacNeill, Malamud, & Anderson, 1986; Medical Library Association, 1980; Medical Library Association, 1988).

Recognizing the need to provide guidance, the VMLS undertook the development of a set of standards for academic veterinary medical libraries, written from a librarian perspective. In 2000, it appointed a Standards Committee to define standards for an ideal academic veterinary medical library. Six standards were released in 2005 (Murphy, Bedard, Crawley-Low, Fagen, & Jette, 2005), which describe collections, services, personnel, hierarchical reporting within institutions, resource allocation, space, and participation in cooperative programs. "The library's collection supports the educational, clinical, and research programs of the veterinary medical institution. The collection may be the library's principal collection or may be integrated with other complementary collections such as agriculture or human health," according to Standard 1 (Murphy, et al., 2005, p. 130). The explanation specifies collecting all types and formats of veterinary materials at the research level and related materials, including biomedical research, clinical sciences, and animal science, based on local availability from other libraries. The standard further directs that professional library staff responsible for collection development have a written collection development policy. VMLS continues to provide and update a corpus of materials to guide the development of veterinary collections.

National Libraries

Veterinary libraries have, in effect, three national libraries, the National Library of Medicine, National Agricultural Library, and the Library of Congress. No single national library covers all resources in veterinary medicine. These three libraries have developed a joint collection policy on veterinary medicine materials (National Library of Medicine, National Agricultural Library, & Library of Congress, 2009). This policy statement can serve as a collaborative collections model and provide guidance for veterinary libraries within a university library context and for those veterinary libraries that also cover other subject disciplines. All veterinary librarians should stay informed of developments at these libraries relative to veterinary collection coverage and consider their implications for local collections.

Library Users

While professional influences on the collection create a foundation for quality and adequate coverage in veterinary collections, input from users provides an important parallel guiding force for collections. Ultimately, users are the judge of whether the collection meets their needs, so a clear understanding of those needs and the development of readily available feedback loops for user input are essential elements in any effective collection development operation. Richards and Eakin (1997) provide a thorough discussion of needs assessment and feedback loops in health sciences collection development.

Mechanisms should be in place to encourage and allow easy submission of individual user recommendations for additions to the collection. The collection policy should document how individual user recommendations are handled, including a review process that can be readily shared with users. In a more formal arrangement, college or departmental library committees, curriculum committees, or other advisory groups can provide purchasing decision input. Regular review of departmental syllabi or lists of required and recommended reading for courses can help ensure that the collection supports the curriculum and provide users with another channel for input into the collection.

PRACTICAL ADVICE

Skill Sets for Veterinary Collection Development

The basic skill set for most collection development work, which is also valid for veterinary medicine collections, includes subject knowledge, analytical skills, knowledge of the publishing industry and technology, critical judgment, negotiation skills and communication skills (Carrigan, Higa, &Tobia, 2008).

Developing and maintaining a veterinary collection requires a broad knowledge of the veterinary literature. A multifaceted approach is recommended to keep current with veterinary materials. Book reviews, found in veterinary journals and through the CAB Abstracts database, are an essential tool in awareness of the literature and informed purchase decisions in veterinary medicine. Regular searching of online bibliographic monographic databases, such as OCLC, using a consistent set of keywords, or developing alerts based on a subject profile on aggregate online sites can be very effective current awareness tools. Subscriptions to e-mail, print, or online catalogs from publishers, or RSS feeds are also useful. Periodic scanning of species and specialty organization websites often yields information on new resources. There are also free online services available, such as ChangeDetection.com, which will supply a notification of any content updates. Veterinary librarians are sometimes able to register on veterinary information service websites that are actually intended for veterinary students and practitioners. These can be an excellent source for information on current topics of interest or recommended publications.

Another requirement for veterinary collection development is an understanding of the local academic and veterinary community environment. This includes an awareness of the institution's academic programs, clinical services, and research strengths. Academic programs to be supported beyond the college of veterinary medicine might include areas such as physiology, animal science, poultry science, zoology, genetics, biostatistics, public health, fisheries, or wildlife management. Good sources for this information include relevant institutional websites, course catalogs and annual report publications. An awareness of faculty-authors can also help to build the collection and garner support for it. Tools such as Web of Science can identify which journals are publication outlets for faculty research. Outreach efforts to maintain contact with alumni and local clinicians through state and local associations or the alumni association provide an opportunity to discover topics discussed and materials used in practices. Attendance at veterinary conferences and publisher exhibits can also provide insights.

Staffing and Workflows for Collection Development

The span of activities involved in collection development as well as staffing and workflows are not primarily subject-dependent. They are more directly influenced by the administrative reporting relationships of the veterinary library, the degree of autonomy of the library and its budget, and the degree to which library services have been centralized. Since most U.S. veterinary libraries undertake collection development within the framework of the main university library, an understanding of the collection development staffing and workflows of the main university library is essential.

There are a few key issues specific to veterinary collection development that are worthy of note. Because of the importance of grey literature and the international nature of the veterinary literature, an approval plan alone does not provide adequate coverage of the veterinary literature. Since they are seldom included in approval plans, publication listings of small veterinary publishers and important veterinary associations should also be checked regularly. Because veterinary medicine also relies on the literature of biomedical research, human medicine and other areas such as nutrition, animal science, wildlife management, and zoology, establishing regular communications and patterns of collaboration with other institutional collection development colleagues is critical.

Collection Policies

As noted above, a collection development policy is expected by the VMLS Standards for Veterinary Libraries. Since the policy serves as a guide in making choices about items chosen for the collection, it is also a practical tool for the librarian. A collection policy can also serve to inform users, colleague libraries, and the parent library/institution about the scope of the veterinary collection. The fact that veterinary medicine relies on other resources in the areas of biomedical research and other life sciences makes a collection policy for the veterinary collection especially helpful in clarifying and building collection collaborations within a university library context. Collection policies vary in the level of detail contained, their specificity and format, but all should contain a statement of the purpose and scope of the collection, an institutional context for collection practices, specific information about types of materials added to the collection and details about how comprehensively the library attempts to cover specific areas within and peripheral to veterinary medicine (Bryant, 2006; Mississippi State University Libraries Faculty, 2006; University of Pennsylvania Libraries, 2007; Wiese, 2006). The collection development policy should guide the selection of both core veterinary and peripheral collections. It should consider institutional programs to ensure a collection that meets the needs of veterinary students, faculty, and researchers. The policy should also specify which of the types of collections described below are included in the library's collection.

Current Clinical Resources

The development of clinical practice skills is a critical component of veterinary medical education. Clinicians and students in veterinary medicine programs need access to a comprehensive collection of resources that present information on current clinical research and treatment of animal diseases. Unlike other fields, textbooks in veterinary medicine often serve as reference books and form an integral part of any clinical collection. Beyond the standard textbooks and journals, this literature is largely grey and includes important clinical studies, drug studies, trial and case reports, and conference proceedings. Growing interest in evidence-based veterinary medicine will increase emphasis on this type of literature, which seldom appears in the conventional book and journal literature (Jaros, et al., 2008). In some cases, veterinary medicine draws from clinical human medicine literature; but for the most part, a veterinary collection needs to cover a broad range of species and specialties relevant to animal health. Directly associated with clinical veterinary medicine is animal husbandry as it relates to animal health and public health. The library's collection development policy serves as a guide to select items that should receive emphasis, like items for specialty training programs and research areas that are a focus for the local veterinary institution. Clinical collections could also include resources to help establish a veterinary clinic like resources on veterinary economics, practice management, handling, and housing of animals.

Biomedical Research Resources

Because of the interdisciplinary nature of veterinary medicine and its reliance on the literature of human medicine, a standard veterinary medicine collection also requires access to materials that support biomedical research as well as clinical practice. This access to biomedical research materials may be provided through broader university library collections, collaborative resource sharing arrangements with colleague libraries, or through the purchase of selected biomedical research materials by the veterinary library. Smaller veterinary branch libraries usually focus predominantly on resources that support veterinary medicine, depending on the university library to provide the majority of the biomedical resources, while libraries that combine other programs like medicine, agriculture, or animal science will cover a broader range of subjects. Those libraries that support programs in the life sciences or a medical program will collect basic sciences and biomedical research more comprehensively. The collection development policy should clearly define the scope of biomedical collections for the particular library situation.

Consumer or Popular Materials

A veterinary library collection might include collections of resources aimed at the consumer of veterinary services, the animal owner. However, the collection development policy should state goals and the purpose for materials in this area, and set clear expectations for these materials to meet the same standards for reliability and authority that is expected of other materials. This type of collection is also a resource to professionals in clinics who want reference materials aimed at the general public; or if the library is open to the public, professionals could refer clients to the library for further reading. Murphy (2006) developed a specialized core list of books about pet health appropriate for pet owners. If non-English languages are common to audiences for consumer or popular materials, consider online resources in those languages, such as the website of Spanish Animal Health Information Resources (North Carolina State University Libraries, 2011).

Archives

When there is not an established veterinary archives collection elsewhere, the library is often considered the obvious choice to house historic institutional materials. These could include official publications of the college, personal papers of notable faculty or leaders, photographs, newsletters, collateral material from sponsored events, institutional regalia, and copies of locally produced conference proceedings, symposia, or continuing education publications. Veterinary librarians should investigate where the college archives are maintained and gather details about the scope of the archival collection. If an archival collection does not already exist, the veterinary librarian should undertake its development in an effort to preserve the history of the college. The availability of personnel and space resources will determine the scope of the collection that is feasible. As with all collections, the archives should be developed following a policy that clarifies a specific mission or purpose, defines program goals, and specifies items to include and exclude. Archival collections usually have different processing procedures, management plans, or special handling requirements.

Historical Collections

Some veterinary libraries, especially those connected to a large university library with established broader historical collections, may develop a veterinary historical collection. These collections are usually developed to document the history of the veterinary literature and the history of the practice of veterinary medicine. They sometimes exist as part of a plan to collect comprehensively in veterinary medicine because users have communicated the need for historical veterinary collections. It is often the case that gift items build the historical collection. Items in the collection are selected for importance and as the best representative works that serve library users' research and educational needs. These include early editions of monographs or other materials that chronicle changes and developments within the field of veterinary medicine. The collection development policy should address whether to actively acquire materials for the historical collection and should clearly define the scope and any special focus for the historical collection (e.g., equine). There should also be procedures for the proper handling and preservation of rare or fragile items, including digitization. It is most important to find an acceptable means to provide intellectual, as well as physical, access to the historical collection while maintaining security measures for valuable or fragile materials.

Languages

Veterinary medicine is an international discipline with a literature that spans many non-English languages. German and French, as the primary non-English languages of science, are the languages most commonly acquired. Languages for species-specific content vary. The languages spoken or read by local user populations will also influence the selection of materials in other non-English languages. The collection development policy should define the languages that are in scope for the collection.

Gifts

The collection policy should also clarify the library's approach to accepting gift materials and provide gift handling procedures that are available to all library staff. Gifts can be an excellent source for filling in gaps in journal holdings or proceedings, or for adding a copy of a popular text. Retirements or office moves are an opportune time to remind people of the library's gift procedures or policies. The administrative or development office in the veterinary college often receives direct donations of newly produced books, conference proceedings, and subscriptions. These offices are also a good information source on collections that alumni or local veterinarians wish to donate. Developing a relationship with the Dean and administrative assistants will help to remind them to contact the library about these donated materials. Some gifts may contain ephemera that might not be part of the intended scope for the library collection. Explore the veterinary college or university's interest in this material.

Material Types

Types of material the library collects should be defined in the collection policy, which should also clarify the preference for particular formats, such as a preference for electronic versions over print.

As is the case for most health sciences and medical collections, scientific journals form the heart of the veterinary medicine collection. While the proportion of veterinary journals that are available in both print and electronic format continues to increase, there are still important journals like the *Journal of Veterinary Dentistry* that are only in print. A review of the candidate journal titles for inclusion in the "Basic List of Veterinary Medical Serials" (Ugaz, Boyd, Croft, Carrigan, & Anderson, 2010) revealed that 76% were available online. A review of the journal titles chosen for inclusion in the veterinary listings in *The Medical Library Association's Master Guide to Authoritative Information Resources in the Health Sciences* (Boyd & Carrigan, 2011) yielded 97.4% available electronically. Although for some veterinary journals print will still be the only format available, veterinary librarians do need to consult with their users and parent libraries/institutions to clarify a policy for format preference and whether duplicate print versions of journals will be purchased and/or retained.

Monographs are especially useful to students during the first three years of veterinary education and are often part of assigned reading lists. Many veterinary textbooks actually serve as a key reference text in a subject area. Electronic versions of veterinary monographs are much less available than veterinary journals. A review of the monograph titles in the *Master Guide* publication (Boyd & Carrigan, 2011) identifies only 20.5% are available electronically. Often, print textbooks have video content or references that are only available online using the individual purchaser code that comes with the book. Other publishers may include a CD or DVD in the book that contains supplementary content that is not available in print. Librarians need to plan how to handle digital content that comes with print materials.

Grey literature is critical to the study and practice of veterinary medicine and poses challenges for collection development. Professional societies, academic and government institutions generate publications such as conference proceedings, research studies, and other works that are not controlled by commercial publishers. There are three types of particularly endangered grey veterinary literature: publications from and about defunct veterinary schools, veterinary supply catalogs, and publications from veterinary-related companies or house organs (Boyd, 2011; Jaros, et al., 2008). In a 2002 citation analysis of 12 core veterinary journals, grey literature was estimated to comprise 6 percent of the veterinary medical literature (Pelzer & Wiese, 2003); many practicing veterinary librarians now consider that a very low estimate. In 2007, veterinary librarians met and formed the Veterinary Archives Grey Literature Steering Group (V-Ags) to explore identification, collection, and preservation of grey literature, hidden collections, and archival materials (Jaros, et al., 2008).

Conference proceedings, usually also grey literature, are a key source of information on veterinary research studies and case reports, often emanating from specialty meetings. Databases such as CAB Abstracts index only some of these papers, but also include online full text for a number of veterinary conference proceedings. In some cases, the society responsible for the conference captures multiple years of proceedings into a searchable digital library. Some conferences send complimentary copies of proceedings to each veterinary college, but individual veterinary faculty can also be excellent sources of these proceedings. It is important for the veterinary librarian to identify key veterinary associations and actively pursue the regular purchase of their proceedings. International Veterinary Information Service (IVIS, http://www.ivis.org/), an online resource that is free to veterinary students, veterinarians and librarians provides access to numerous proceedings of international veterinary associations.

Government documents, a subset of grey literature, provide veterinary collections with critical animal disease statistics and industry standards information. Major producers are the World Organization for Animal Health (OIE), Food and Agriculture Organization of the United Nations (FAO), the U.S. Department of Agriculture, the Environmental Protection Agency, the Centers for Disease Control and Prevention, and state public health, veterinary, agriculture, or consumer affairs divisions.

As in any library collection, bibliographic databases are central to the process of locating relevant literature. Online bibliographic databases such as PubMed and CAB Abstracts are essential components for any veterinary collection. Databases that serve the fields of zoology and biology can also provide additional information resources pertinent to the wide range of species and particular environments that are encountered in the study and practice of veterinary medicine, particularly in zoo and wildlife medicine. Alpi, Stringer, DeVoe, and Stoskopf (2009) described species coverage of wild animals in various literature databases.

Electronic decision support tools are also important resources for the veterinary collection, although there is limited availability of products. These resources integrate clinical veterinary information from a point-of-care perspective. The Consultant database is an example of a free decision support tool created by the College of Veterinary Medicine at Cornell University (2011). VetMed Resource is another database designed for practicing veterinarians that is available free of charge to veterinary students (http://www.cabi.org/VetMedResource/). It is the most comprehensive single source of information on all aspects of veterinary medicine available online, being based on the indexing and abstracting citations and full text documents from CAB Abstracts. IVIS is another freely available online full text resource and decision assist tool.

Images greatly enhance the study and practice of veterinary medicine. While the recent trend has been to issue these in online versions, there are still physical veterinary audiovisual media available. Image collections also accompany and supplement print veterinary texts. These image resources often require collaboration with information technology experts. Exercise caution when purchasing physical media produced in other countries since the format may be incompatible with United States standards. Some media may require installation of special software in order to function properly.

Veterinary collections with a focus on wildlife health, infectious diseases or public health benefit from geographic information systems, maps, and other data sources. Market data from commercial sources is typically quite expensive, but the American Veterinary Medical Association also produces veterinary data sets that are much more reasonably priced.

As more veterinary electronic resources become available, it is critical that librarians develop clear policies and guidelines for selecting them. The purchase decision for electronic resources contains layers of complexity beyond the print resource since there are numerous additional factors for consideration such as user interface, search functionality, and license parameters. The usability and discoverability of electronic resources are important considerations. For some users, if the journal website is not searchable to the article level using Google, the content is practically invisible. Evaluate the suitability and value of electronic resources during a trial period when both library users and staff can assess the product and provide feedback before purchasing. Usage data (preferably COUNTER-compliant), institutional authorship, and citation data can be used to evaluate current electronic resources. Carrigan, Higa, and Tobia (2008) provide practical suggestions and extensive checklists for the selection and evaluation of electronic resources. Issues surrounding the technical suitability and currency of the format should also be explored. Give careful consideration to terms of licensing agreements for electronic materials. Licenses will define details such as who is considered an authorized user, how access is accomplished (IP Registration or login and password), limitations on the number of simultaneous users, and whether archival access to purchased electronic content is guaranteed. Many institutions provide a centralized legal review service for contracts that should play a key role in any license review.

SELECTION TOOLS

Approval Plans

Although no approval plan alone can adequately cover the veterinary literature, they can be useful tools in acquiring material. Many veterinary medicine libraries use approval plans with book vendors such as YBP Library Services, Matthews Book Company, Rittenhouse Book Distributors, or EBSCO Book Services. These plans are either blanket approvals, where books meeting selection criteria are shipped to the libraries; or paper or electronic slip plans, where collection managers receive notifications when materials meeting their selection criteria are available. The first step in implementing or refining an approval plan is the review of the collection development policy. Approval plans can be customized to include call number ranges, subject headings, faculty authors by affiliation, and interdisciplinary topic groupings, as well as specifying preferred formats, and other standards established in the collection policy. Many of the small publishers of veterinary books may not be covered by the approval plan; those materials will need to be acquired through other means. Approval plans also can offer the opportunity to engage in peer collection analysis with other veterinary libraries using the same approval vendor.

Core Lists

Since the time of its publication, the “Basic List of Veterinary Medical Serials” (Henley, et al., 1978) has served as a collection development tool at veterinary medicine libraries and non-veterinary libraries that support programs in animal health and related subjects. A recently updated edition of this list (Ugaz, et al., 2010) provides a current tool for selecting and evaluating serials in veterinary medicine. In recognition of the interdisciplinary nature of veterinary medical research, the first list included not only core veterinary medicine titles, but adjunct titles in human medicine, agriculture, and general science. Research into the interdisciplinary nature of veterinary medicine has led to the development of core lists of journals in other subject areas considered valuable to a veterinary collection (Crawley-Low, 2006; Youngen, 2011). Youngen’s (2011) research suggests a methodology for each library to develop its own complementary list of core resources.

Core lists also exist for veterinary medical monographs. Olson's (1993) core list of monographs in animal science and health, while not current, looks deep into the literature and places an emphasis on materials that continued in print through multiple revisions. Crawley-Low's (2004) bibliography is a thorough list of recommended books across subject areas in veterinary medicine, with an updated, searchable online version currently hosted by the University of Saskatchewan Veterinary Medicine Library. Core lists in human medicine, such as *Doody's Core Titles in the Health Sciences*, (http://www.doody.com/dct/) are also useful to select top publications for a basic medicine collection within the veterinary library.

Recognized Veterinary Specialty Organizations

As mentioned previously, the lists created by specialty organizations for suggested reading materials to help candidates prepare for veterinary specialty exams are important tools for building or benchmarking veterinary collections. Experts in various practice specialties have identified the books, journals, and other materials listed as crucial to their fields. The VMLS has a project currently underway to consolidate and maintain these recommended reading lists, which can be a challenge to locate on the Web or through direct communication with the organizations.

Book Reviews

As with other subject disciplines, book reviews are useful tools in identifying materials to be added to the veterinary collection. Book review publications like *Library Journal* (Media Source Inc.), *Choice* (Association of College and Research Libraries), *Booklist* (American Library Association), and publications like the *Journal of Agricultural & Food Information* (Taylor & Francis) and the *Journal of the Medical Library Association* (Medical Library Association), include reviews of books and electronic resources in veterinary medicine and related subjects. Book reviews in veterinary medicine are featured in journals, newsletters, and websites. Government organizations like the USDA's Animal Welfare Information Center, veterinary specialty organizations, and other veterinary and animal science organizations also review books. Doody's Review Service, a commercial product, covers veterinary medicine as a separate category. The Veterinary Support Personnel Network and the Veterinary Information Network (VIN) also have book reviews from clinicians.

Budgeting

Because most collection development decisions are made within a budgetary context, budgeting is an integral part of collection development. Specific budget situations and autonomy within veterinary medical libraries span a wide range, which usually follows the financial requirements of the library's parent institution (Richards & Eakin, 1997) and its management structure. According to an informal 2011 email survey of U.S. academic veterinary libraries, most report to a main university library that is also their primary funding source (Ugaz, et al., 2011).

This predominant organizational structure results in a mixed bag of funds that the parent library, the veterinary college, and the veterinary library control. Funds are often allocated on the basis of subjects, academic departments, or material types. The structure and ability to allocate and track the veterinary library budget depends on the university library budget structure and expenditure tracking mechanisms.

Collaborative licensing of electronic resources, both journal and e-book packages, further complicates veterinary library budgeting and expenditure reporting.

Regardless of the source and extent of collection budgets, there is a consistency across veterinary libraries: journals are the heart of the collection and consume the largest portion of the collection budget; there is a preference for online journals; and, veterinary libraries exercise the most autonomy with monograph purchases. The greater autonomy experienced by veterinary libraries in monograph purchases is not unique. Most academic libraries have collection budget structures that still support monograph purchase decisions by the individual subject selector. Those monograph purchase decisions offer a level of autonomy, which is becoming more uncommon in the world of electronic big package deals. Veterinary libraries also face similar collection budgetary challenges as other academic libraries: continuing collection costs inflation and increasing user expectations for information resources.

Collection Analysis and Benchmarking

A good collection analysis plan can reveal the collection's usefulness, identify strengths or weaknesses in subject areas, identify peripheral subject areas in need of development, support decisions regarding electronic or print formats, and support renewal decisions; it is particularly essential for cancellation decisions. Standard analysis methods used for other subject areas of a collection are indeed applicable to a veterinary collection. Collection-centered analysis tools such as veterinary-specific standard lists, bibliographies, and peer comparisons are several approaches to benchmarking or assessing the collection quantitatively (Richards & Eakin, 1997). Use-centered methods which involve analyzing usage data, interlibrary loan requests, and patron purchase requests are additional means of identifying local use patterns and validating collection expenditures.

Core lists, such as the ones created by veterinary librarians are especially useful in determining if the essential titles in the major subjects are held by the library (Henley, et al., 1978; Boyd, et al., 1986; Ugaz, et al., 2010). Librarians have used various methodologies to produce not only lists of serials and monographs necessary for a basic veterinary collection, but lists have also been created to address the breadth of serial literature that complements and supports veterinary medicine (Crawley-Low, 2006; Youngen, 2011). The subject groupings used in most core lists presents the opportunity to select titles in any combination of subject areas, based on the needs of the institution. Similar to specialty boards in human medicine, recommended reading lists compiled by veterinary specialty boards would likewise serve as a tool for assessing the collection's coverage of the many veterinary specialties. The expertise behind the recommended reading lists not only helps guide those preparing for the specialty board exams but the reading selections highlight relevant and practical resources from the point of view of practicing veterinary professionals. Assessment of the collection based on any of these lists will need to take into account title availability from any parent institution, especially for coverage in the basic sciences or other areas of shared collection development. Gaps identified in this type of analysis may also be logically explained by programs that are not a focus of the institution and which have been intentionally excluded.

A major issue for the small community of veterinary libraries is identifying appropriate benchmarking partners with whom to compare collections. Assessment services, such as those though regional library groups or OCLC (WorldCat Collection Analysis Tool), provide programs for comparing collections against peers. While the libraries may be quite different in their sizes and scopes to be considered true peers, collection comparisons can still reveal unique holdings and subject strengths. Comparisons of core veterinary collections using this tool are straightforward, since almost all veterinary libraries catalog their core materials using the Library of Congress S classification for veterinary medicine. There is a challenge in comparing peripheral collection areas within veterinary libraries since those areas may be cataloged either with Library of Congress or National Library of Medicine classifications, depending on the particular situation of individual libraries. Veterinary librarians in the Medical Library Association's VMLS have also been active in conducting surveys of their members to establish benchmarks and best practices in library services, collections, expenditures and staffing (Medical Library Association, 2002).

Collection use data provides the foundation for assessing the collection from the local user perspective and completes the collection analysis process begun through the collection-centered methods mentioned above. It offers the unique perspective of how well the collection is meeting the needs of the user. It is important to have clear goals for collection analysis since processes need to already be in place, or will need to be established based on assessment goals. This could include a process for recording use of the print collection or exploring the ability to gather data from vendors of electronic resources. Examining for potential cancellations will necessarily involve cost per use calculations and typically focus on titles that are not considered core to the collection and which offer the option to cancel, as opposed to being part of a non-cancellable package. Before cancelling, it is important to explore whether low use resulted from users having difficulty finding the resources or from lack of awareness. These two issues may necessitate design changes to the library website to enhance discoverability or a new marketing plan to increase awareness. If an assessment of use in particular subject areas results in a low cost per use figure, then justification can be made for seeking additional materials and increasing funding in that subject area. Analyses of interlibrary loan activity and user purchase requests are also good indicators of subject areas, especially those outside of veterinary medicine, which need to be explored for purchase or licensing. In all of this collection analysis work, particularly cancellation decisions, it is essential to have a good working knowledge of veterinary programs and research activities or to develop relationships with all types of users to solicit feedback and support for collection decisions.

Retention, Deselection, and Cancellation

Retention, deselection, and cancellation decisions may occur as part of the standard acquisitions process or result from a specially planned evaluation or weeding project. Activities like withdrawing items in poor condition, eliminating duplicates that are no longer needed and withdrawing editions that have been updated are routine to most libraries; but within a veterinary collection certain retention, deselection, and cancellation decisions can have a host of issues and implications associated with them. These activities are especially significant when considering the limited number of veterinary programs and the resulting loss of information if no other library has a particular monograph that is being withdrawn or no library owns a complete run of a veterinary serial that has long ceased. Since a single national library does not exist in the area of veterinary medicine, there is a greater likelihood of incomplete coverage and inconsistencies in the retention of older veterinary materials. Growing concerns for the potential loss of veterinary history due to space and budgetary constraints have led to coordinated preservation efforts by veterinary libraries.

Many veterinary collections are held in branch libraries where space restrictions are a problem. These space constraints may result in a policy that limits the retention of older volumes. If the library maintains a historical collection, then materials of historical interest are retained, including earlier editions of veterinary textbooks. For libraries that do not have the space, materials could be moved to a main campus library or special collection that can accommodate them, or if the library has access to a storage facility they could move important pieces out of the active collection and into long-term preservation. Collection decisions related to previous editions or historic collections should be documented for future library staff to implement the policy consistently.

Titles that fall out of scope or prove uneconomical because of cost per use data are often candidates for cancellation in the course of standard collections management operations. More common is the cancellation of print serials in favor of an online subscription. The cancellation decision is a particular type of deselection and should follow a policy and process, as did the original selection decision, including user input.

Preservation and Digitization

Preservation of veterinary library collections includes efforts to retain print materials and ensure continued access to the collection's content, whether print or digital. Examples of efforts to preserve print materials range from binding journal issues to collaborative plans for retaining historical print materials on a regional or national scale. Efforts to ensure continued access include digitizing resources and establishing licensing requirements for archival access guarantees from publishers.

The collection development policy should guide preservation decisions (Richards & Eakin, 1997). The National Library of Medicine (NLM) has outlined a preservation program and print retention plan that provides a framework and context for local decisions about biomedical literature. Preservation and the development of print retention plans in veterinary medical libraries should include gathering and sharing information with other veterinary libraries and the NLM (National Library of Medicine, 1988; Byrnes, 1989; National Network of Libraries of Medicine, 2011). Because of the relatively small number of veterinary libraries, a print retention plan is especially critical. Geographical distribution could be an important factor in building a print retention plan and determining the location of print archives.

Digitization, making an electronic or digital copy of the intellectual content, is another technique to preserve content. Within the veterinary literature, grey literature is the most likely first candidate for digitization because much of the locally created or published content does not have copyright restrictions. As with preservation planning, veterinary libraries should gather and share information with other veterinary libraries to create their digitization preservation plan. The feasibility of large-scale cooperative digitization projects and copyright law limitations are still being tested. There are also audiovisual media created in earlier formats still available in veterinary collections. Librarians should be aware of all formats included in the media collection and be certain all can be accessed with current technology. Conversion of older formats that are still used, such as slide sets, reel tapes, and VHS tapes, to DVD or online versions is necessary to preserve valuable content.

COLLABORATION IN COLLECTION DEVELOPMENT

Given the relatively small number of veterinary libraries, both in the U.S. and internationally, it has been possible to build a close international network of active veterinary librarians, which is supported by several formal associations and an online veterinary discussion list.

North American veterinary librarians have a history of nearly a half century of collaborative work through the VMLS. Members active on the VMLS International Cooperation Committee have expanded their activities and connections beyond the United States and several international veterinary conferences and groups have resulted. The International Conference of Animal Health Information Specialists began in 1992 and continues today with meetings every two to three years. Animal Health Information Specialists in the United Kingdom and Ireland (AHIS-UK and Ireland) was formed in 1993 and the European Veterinary Group was begun in 2004 within the European Association for Health Information and Libraries as a kind of parallel to the VMLS/MLA relationship. These international connections and relationships form the basis for a "just in time" document delivery sharing that is facilitated through the veterinary discussion list.

Long-term collection planning in veterinary medical libraries needs to follow the lead of the National Library of Medicine program discussed earlier in the chapter, with its expectations for regional print retention and preservation of the biomedical literature. Veterinary medical libraries also need to interface with the preservation and print retention plans of their parent institutions and their academic colleague library organizations such as the Association of Research Libraries and the United States Agricultural Information Network, which has begun a national preservation and digitization program for agricultural literature.

TRENDS AND FUTURE ISSUES

Several collection trends in veterinary libraries offer important advocacy roles for librarians. As with all biomedical libraries, the primary collection trend is the move to online content such as videos, books, and journals. Another trend in the veterinary literature is consolidation. The majority of veterinary content comes from just a few commercial publishers. Of the top 30 titles on the *Basic List of Veterinary Medical Serials*, 3rd ed., two publishers are most heavily represented, Elsevier with 37% and Wiley-Blackwell with 23% (Ugaz, et al., 2010). The two highest ranked titles are the exception, coming instead from the American Veterinary Medical Association. The top 30 also includes titles from the Canadian Veterinary Medical Association and the American Animal Hospital Association. A review of the monograph and journal titles chosen for inclusion in the veterinary listings in *The Medical Library Association's Master Guide to Authoritative Information Resources in the Health Sciences* (Boyd & Carrigan, 2011) clearly underscores the consolidation of veterinary content with a few publishers. Elsevier publishes 49% of the monographs listed and 28% of the journals. Wiley-Blackwell publishes 30% of the monographs and 35% of the journals. Combined, these two publishers control 79% of the monographic veterinary content and 63% of the veterinary journal content. The remaining journal content in this listing is primarily controlled by veterinary associations. One area of the veterinary literature with representation from a diverse group of publishers is international veterinary association journals. Several have an arrangement with a publisher in their country or region; however, in the past three years this area has changed significantly. A few of these society titles are moving toward forms of open access, while others have eliminated print and moved to a new subscription model for online access. The commercial consolidation of veterinary content and the importance of association journal content present veterinary librarians with the opportunity to encourage veterinary associations to move into the open access online environment rather than to commercial publishers, and to collaborate with veterinary librarian colleagues to speak with a unified voice to publishers concerning the need for increased availability of online veterinary monographic content.

Another collection trend is the move by veterinary publishers to designing and marketing their products for the individual practitioner. Some important veterinary continuing education journals, such as

Compendium on Continuing Veterinary Education, and *Veterinary Therapeutics*, have converted to online only access with individual registration. Veterinary learning communities, such as the subscription-based Veterinary Information Network (VIN), may be limited to veterinarians. Others, such as the free International Veterinary Information Service, permit registration and access more broadly to animal health professionals who may not be veterinarians. For these types of resources, IP access to an institutional subscription is not an option. Distinction between institutional and individual content availability is also seen with electronic books, where the individual buyer can access added online content (such as educational videos) and manipulation and markup tools that are unavailable to institutional subscribers. While individual registration works for free resources and for veterinarians with means to purchase a complete online library of resources, the nature of the license agreements and the limitations in content for institutional subscriptions often negatively impact librarians' ability to access and disseminate online-only content to remote veterinary practitioners. Often there is no affordable licensing model aimed at providing online access based on affinity group, state, or alumni status. This is an open opportunity for creative partnering of veterinary librarians and content providers to open up access to the practicing veterinarian. A small group of academic veterinary libraries have entered into a pilot program with the CABI organization to make their VetMed Resource product available to recently qualified veterinarians.

A potential growth area in veterinary science electronic books is their availability through aggregators. Few veterinary publishers make significant portions of e-book content available in this way, even though some libraries rely on aggregators to purchase online books. Ebrary, for example, offers a veterinary starter pack of 34 books from a mix of mostly small presses. Primarily consisting of special species, lab animal, food animal, and practical anesthesia texts, these are not books that are typically in high demand and would not be a core starter pack suitable for a basic collection. As of June 2011, Wiley had only about 35 of their online veterinary books available through ebrary, while more than 100 e-book titles are available directly from Wiley. Librarians need to make publishers aware of preferences and needs for book purchasing and licensing. The North Carolina State University Libraries (2011) has prepared a value statement they share with their publisher contacts.

Librarians also have an opportunity to work with veterinary publishers to improve content in clinical point of care resources. The VMLS Task Force on Connecting the Veterinary Health Record to Information Resources reported that six resources useful at point of care were available for institutional purchase only in print, despite four being available in an online format for the individual purchaser. Librarians are in a position to lobby publishers to have these materials distributed online with an infrastructure that permits both individuals and libraries to purchase, search, and link from electronic systems in use when the knowledge need arises. The VMLS task force is communicating closely with the American Animal Hospital Association's Electronic Health Records Task Force, which works closely with veterinary health record and practice management systems developers and vendors to meet the needs of multi-veterinarian animal hospitals. Meeting veterinary information needs in the future will depend on librarians engaging in meaningful collaborations with authors, publishers, systems developers, and veterinary educators.

CONCLUSION

Collection development in veterinary medicine shares a common foundation with general health sciences collection development, but involves unique situations and challenges due to the nature of the veterinary literature and the relative scarcity of veterinary libraries worldwide. Key collection-related challenges for veterinary librarians include providing access and preservation of veterinary grey literature, establishing a plan for print retention, and embracing an advocacy role for the veterinary literature. There is much work to be done to ensure institutional commitments to archives that document and preserve the history of veterinary education, to encourage veterinary faculty and associations to explore open access publishing as an alternative to commercial publishers, and to advocate to publishers for increased veterinary e-book content and for complete e-textbook content available to libraries. Cooperation, collaboration, and information sharing with veterinary library colleagues are essential in meeting these challenges and for effective veterinary collection development.

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KEY TERMS AND DEFINITIONS

COUNTER-Compliant: A term used to indicate that a vendor provides usage statistics for online resources that are compliant with the COUNTER (Counting Online Usage of Networked Electronic Resources) Code of Practice (www.projectCounter.org). The Code of Practice specifies for vendors the content, format, data processing rules, and other details to ensure credible and consistent usage reports for libraries.

Decision Support Tools: These information resources are designed to assist the health care professional in reaching decisions concerning the diagnosis and treatment of a particular disorder, or to make a differential diagnosis among conditions. They are typically evidence-based resources that assist in diagnosis and provide treatment guidelines. The quality of the evidence provided, the updating cycle and the degree of interactivity vary among products.

Evidence-Based Medicine: This approach to the practice of medicine is centered on the use of the highest quality published evidence available to determine treatment options. Techniques, including systematic reviews and meta-analysis of clinical studies and trials, are used to identify and assess risks and benefits and to identify treatment options. This differs from basing treatment options on quality of life judgments, anecdotal evidence, and conventional wisdom.

Grey Literature: Works of grey literature are information resources that are not controlled by commercial publishers. They are produced at all levels of government, in the academic enterprise, and in business and industry, in print and electronic formats. Grey literature is often difficult to locate through traditional bibliographic discovery tools.

House Organs: This type of grey literature is usually serial in nature. It is issued by a business or other establishment for its employees, customers, and other interested readers, to present news about the firm, its products, and its personnel.

Land-Grant Institutions: This designation refers to institutions that resulted from the Morrill Act of 1862 and 1890, which provided states with grants of federal land and funds to establish colleges specializing in agriculture and the mechanical arts. Their original mission was to educate citizens in agriculture, home economics, mechanical arts, and other practical professions. The Hatch Act of 1887 added outreach to their mission, accomplished primarily through extension networks established within the institution's home state.

Problem-Based Learning: This educational pedagogy uses small, student-centered groups to actively investigate real world cases or problems. It differs radically from traditional learning where an instructor presents reading assignments, lectures, and problems with solutions. Synonyms are discovery learning or experiential learning.

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