A COMPARISON OF BEEF TRACEABILITY MODELS DURING SERIAL AND PARALLEL PROCESSING METHODS

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ABSTRACT

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Traceability of beef attributes through supply chains is a market barrier. Automatic identification and data capture technologies offer the feasibility of maintaining animal and product data through carcass fabrication. Individual animal identity of fifty-four (54) beef carcasses were maintained through the supply chain. Carcasses were fabricated into wholesale cuts using a serial processing method (SPM) or a parallel processing method (PPM).

The goal of this study was to identify labeling techniques for two different processing methods, SPM and PPM, in tracking wholesale meat cuts back to the original animal in mid-sized processing facilities. The objectives of the study were 1) to determine the cost of additional labor required for traceability; 2) determine both consumable and fixed costs of traceability; 3) test traceability accuracy utilizing DNA matching.

The mean number of in-process labels generated per carcass for SPM was 3.7 and for PPM was 30.9 ($P < 0.01$). The amount of time required for generating in-process labels for SPM (2 min 16 sec) was less than PPM (8 min 45 sec) ($P = 0.01$). The amount of time required to label each carcass was less ($P < 0.01$) for SPM (18 sec) than for PPM (3 min 10 sec) which required in-process labels. Total cost of traceability, including fixed and consumable cost per carcass, was nearly twice as much for PPM ($17.98) than SPM ($9.02). Traceability, for both processing methods, was found to have 100% fidelity, as verified using DNA marker genotyping.

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KEY TO ABBREVIATIONS

1D	1-dimensional
2D	2-dimensional
AIN	Animal identification number
AM	Activity motivation
BSE	Bovine Spongiform Encephalopathy
CSA	Community supported agriculture
DNA	Deoxyribonucleic acid
EMI	Electromagnetic interference
FDX	Full duplex
FRR	First read rate
GMF	Genetically modified food
GTIN	Global trade item number
HACCP	Hazard analysis critical control point
HCW	Hot carcass weight
HDX	Half duplex
ID	Identification
ISO	International Organization for Standardization
kHz	Kilohertz
MHz	Megahertz
MMS	Multimedia message service
MSU	Michigan State University
NAHMS	National Animal Health Monitoring System
NAMP	North American Meat Processors Association
NBQA	National Beef Quality Audit
PIN	Premise Identification Number
PPM	Parallel processing method
QR	Quick response
RAM	Random access memory
RFID	Radio frequency identification
ROM	Read only memory
SPM	Serial processing method
SNP	Single nucleotide polymorphism
SSI-EID	ScoringSystem Identification – Entity Identification
UPC	Universal product code
USD	United States dollar
USDA	United States Department of Agriculture
WM	Water motivation
WORM	Write once/read many

Chapter 1

INTRODUCTION

During the last two decades, small-to mid-size farms have experienced a decrease in competitive advantage in the beef industry. The U.S. has lost more than one in six farms with annual sales between $2,500 and $500,000 during this time period (USDA NASS, 2007). Since 2007, total number of farms with the same annual sales has decreased by 1.9% in 2012. Total number of farms with annual sales over $500,000 annually grew by 33.4% from 2007 to 2012 (USDA NASS, 2012). Midsize farms are often too small to be incorporated in vertically integrated supply chains, as many retailers often choose to work with few, very large suppliers (King et al., 2010). These smaller farms and supply chains are being put in a position to examine new ways to add value to their products to gain a competitive advantage.

Economically developed countries of western Europe, U.S., Canada, Japan and Australia now have more health-conscious consumers with greater demands for value-added products than in past history. The beef industry has seen forms of value-added products through label claims such as organic, grass-fed, no added hormones, all natural, no antibiotics, and humanely treated cattle.

Another growing segment in the food industry is the ability to track food through traceability systems. Setting aside the farmers market model, the beef industry has yet to encounter a fully traceable supply chain from farm-to-fork while tracking every wholesale beef cut in a commercial, large-scale production system. Traditionally, tracking systems are used within a farm, auction barn, processing plant, distribution center, or retailer for both quality control and inventory purposes. Commonly, this internal tracking is not passed on to the next participant in the supply chain. For example, a harvesting plant may track lot numbers to keep records on which animals came from a particular location. After the carcass passes United States Department of Agriculture (USDA) inspection, the information on the identity or characteristics of each animal is typically no longer maintained (Golan et al., 2004).

The beef industry has seen meat quality pricing expand beyond the characteristics that can be judged by examining the meat itself, such as yield and quality grade. Prices are now reflecting credence attributes related to farm level, live animal characteristics (Golan et al., 2004). Credence attributes are defined as those that cannot be assessed even after the product is purchased and consumed (Caswell and Mojduszka, 1996). Examples of credence attributes in the beef supply chain are process and production attributes such as organic, natural, animal welfare, genetically modified, and origin (Caswell, 1998). Along with product verifications previously mentioned, the growth of "local" food products has increased in the U.S. in recent years.

Direct-to-consumer marketing amounted to $1.2 billion in 2007, up from $551 million in 1997 (USDA NASS, 2007). From 2007 to 2012, direct-to-consumer marketing rose again $1.2 billion to $1.3 billion (USDA NASS, 2012). The number of farmers' markets grew from 1,755 in 1994, to 5,274 in 2009 (USDA NASS, 2013) and the number of community-supported agriculture (CSA) organizations in operation grew from 2 in 1986, to 1,144 in 2000, and by 2005 were estimated to be over 1,400 (Martinez, 2010). The growing local food niche is seen as an opportunity for small and midsize farms to bridge the gap between producers and consumers, enabling them to add value through the use of beef traceability.

Traceability related to food is the capacity to follow the movement of a food through specific stages of production, processing, and distribution (ISO 22005:2007(E), 2007). Through the use of automatic identification and data capture technology, information can be captured and stored in an electronic database. This information can then be passed through the supply chain and shared with other participants in the supply chain. Radio frequency identification (RFID) and two-dimensional (2D) barcodes provide the basic means for this information sharing (Food Standards Agency, 2002).

With the increasing world population, and growing concerns of food safety, there is a need for a fully traceable supply chain within the beef industry. As technologies become available in the beef industry, such as RFID ear tags, and other food tracking systems, along with growing local food markets, these technologies can help provide the tools necessary to implement a fully traceable supply chain. This sort of supply chain may offer small and midsize farms an opportunity to gain comparative advantage over larger producers. Therefore, the objective of this study was to demonstrate and examine two different methods of beef processing while maintaining full supply-chain traceability to discover which method has the greatest tracking efficacy and is the most economical.

REVIEW OF LITERATURE

Definition of traceability

The definition of traceability varies among industries and specific applications. Traceability systems can vary with the number of data points tracked, breadth and depth of tracking throughout the supply chain, and the particular technologies used to track product or characteristics. For example, the supply chain literature reports traceability as "(an) information system necessary to provide history of products and services from origin to the point of sale" (Wilson and Clarke, 1998). Golan et al. (2004) suggested that traceability be defined as; "record keeping systems that are designed to track the flow of product or product attributes through the production or supply chain." The International Organization for Standardization (ISO) has defined traceability as "the ability to trace the history, application, or location of an entity by means of recorded identifications" (ISO, ISO, 2008). The full traceability definition is currently not regularly practiced through the whole beef supply chain. Often the information is not carried through to the point of sale, but rather the information is stored and used within each segment of the supply chain. Over the past 15 years, consumer concerns about food safety have led to an increased demand for information and transparency in food chains, and have acted as the major driver for development of traceability systems (Verbeke, 2001).

Traceability has developed largely as a two-part system in the beef industry; live animal and meat traceability (Bulut and Lawrence, 2007). Live animal traceability is currently being used for disease eradication programs and herd health record keeping. This information is often not shared beyond the live animal segment of production. Bulut and Lawrence (2007) provided definitions of external traceability, internal traceability, chain traceability, backward traceability, and forward traceability. External traceability refers to traceability of product or product attributes through the successive stages of production (*i.e.* cow-calf producer, auction barn, feedlot, slaughter, and processing). Whereas, internal traceability refers to traceability within the plant or production unit, which may be a part of Hazard Analysis Critical Control Point (HACCP) plans. External traceability may require some degree of internal traceability (Lupin, 2006). Chain traceability refers to traceability throughout the entire food chain. Backward traceability, traceback, or tracing is defined as "the ability to identify the origin of a particular unit and/or batch of product located within the supply chain by reference to records held upstream" (Lupin, 2006).

Animal health and foodborne illness scares globally have helped create a demand for source verification, food safety, and supply chain identification of food products (Smith et al., 2005). In conjunction with the rise of source verified programs, traceability in the meat industry has been defined as “the ability to retrieve the history, treatment, and location of the animal that a cut of meat comes from, through a recordkeeping and an audit system or registered identification program” (Mennecke et al., 2007).

Although full traceability systems, such as ‘farm to fork’, ‘gate to plate’ or ‘pasture to plate’ have been attempted numerous times in the beef industry, only a few have been successful. To date, small, local supply chains, due to their lack of complexity, have been the most successful in implementing full traceability systems, where live animal information is actually tracked to the end consumer. The majority of beef cattle raised in the U.S. today are processed through large harvest and processing facilities, that operate on economies of scale. In these supply chain systems, it has not yet been feasible to capture and transfer individual animal information and characteristics to the next stage of production.

As described by Jensen and Hayes (2006), there are two major types of traceability in the beef supply chain; "farm to retail traceability" and "batch traceability". Farm to retail traceability is described as the ability to maintain identity of an individual animal from the farm, through harvest and distribution, to the consumer. To be traceable from farm to retail, each cut from a carcass is kept together in containers, labeled with the animal's identification, and then packaged. This package can then be linked back to the last farm where the animal resided prior to harvest. Batch traceability, which is currently more common, is a method where the animal is tracked from the farm to the carcass, but individual identification is lost at some point along the carcass processing line. Because individual identification is lost, a batch or lot number is used at harvest. When batch identification is utilized, the batch identification number is often directly correlated to processing dates (Jensen and Hayes, 2006).

Traceability standards

To exercise best practices for maintaining a traceability process, five basic business process have been outlined by the meat and poultry data standards (mpXML) which include: 1) plan and organize how to assign, collect, share, and maintain traceability information 2) determine how to align master data required for all products and trading partners and other physical locations 3) record traceability information as products are created and shipped and modified in form 4) request a trace using one of the four information sources from the Trace Guide 5 use the information provided to take the appropriate action as required (Meat and Poultry B2B Data Standards Organization [mpXML], 2010).

For a live animal provider to maintain traceability, it is suggested by Meat and Poultry B2B Data Standards Organization [mpXML] (2010), that the provider have a unique provider identity, accurate herd/house/pen information depending on species of the animals received. The provider must also have a purchase order number or live receiving ticket or received animals, date of receipt, carrier name and trailer number, and count of animals.

Best practices for maintaining traceability for suppliers, retailers, wholesalers, and distributors is to capture all traceable information to be stored. By enabling the information to be scanned, the supply chain does not rely on human visual assessment to capture all traceable information and manually enter it into a database. Starting in 2010, adoption of the GS1 Databar was first implemented with perishables, pharmaceuticals, and coupons. As GS1 standards are finalized, the adoption of the Databar into the meat and poultry industry will begin. The GS1 Databar will enable the meat and poultry industry to move away from the UPC-Type 2 bar code which does not support the Global Trade Item Number (GTIN) or other data elements that are crucial for traceability. The new Databar has the ability to hold up to 74 numeric characters and 41 alpha/numeric characters (Meat and Poultry B2B Data Standards Organization [mpXML], 2010).

Barcode labeling

Maintaining unique individual identification (ID) of products through a supply chain is essential for successful tracking systems. Without maintaining unique ID, traceback on individual meat products are very difficult to achieve when such events as a recall due to a foodborne pathogen outbreak occurs. Most meat products have a batch ID, rather than an individual ID, limiting the ability to trace back to farm of origin. Several different labels and tags can be used to track food products through processing, manufacturing, distributing, and retail facilities. The most established technology for tracking food products is the linear or 1-

dimensional (1D) barcode label. The 1D barcode label is a simple form of systematically representing data. This is done by varying the width and spacing of parallel lines to form an image for an interrogator to read (Wang, 1999). Although the 1D can represent data well, it is limited by its data capacity and mobility (Kato and Tan, 2005).

More recently, 2-dimensional (2D) barcodes have been used in a variety of applications. The 2D barcode was developed to overcome the information limitation in linear barcodes (Al-Khalifa, 2008). The data represented within a 2D barcode can be displayed as rectangles, dots, hexagons, as well as other geometric patterns (Burian et al., 2008). A 2D barcode symbol consists of two broad areas – a data area and a guide area. The primary component of a guide area is a finder pattern, which is a specific pattern in a barcode that a scanner uses to locate the barcode symbol (Kato et al., 2008). According to Tan and Chai (2010), the size of the finder pattern, and its data cells is proportionally related to the 2D barcode user experience. Along with a finder pattern, the other major components of 2D barcodes, like a DataMatrix, is the quiet zone and clocking pattern (Figure 2.1). Readers have been shown to produce reduced error rates when scanning 2D barcodes when the data cell size was magnified or had a distinct pattern, compared to a less magnified, denser pattern (Kato and Tan, 2007).

The quantity of data that is able to be represented in a given barcode varies between 1D and 2D. For example, Code 39, a 1D barcode, takes up much larger area than that of the 2D Quick Response (QR) code when holding the same information. Additionally, the type of character codes that can be stored, such as alphanumeric or numeric, differ (Figure 1.1).

First read rate (FRR), may be indicative of the user experience when using different styles of 2D barcodes. Kato et al. (2009) defined FRR as:

$$FRR = \frac{Number\ of\ successful\ first\ reads}{Number\ of\ attempted\ first\ reads}$$

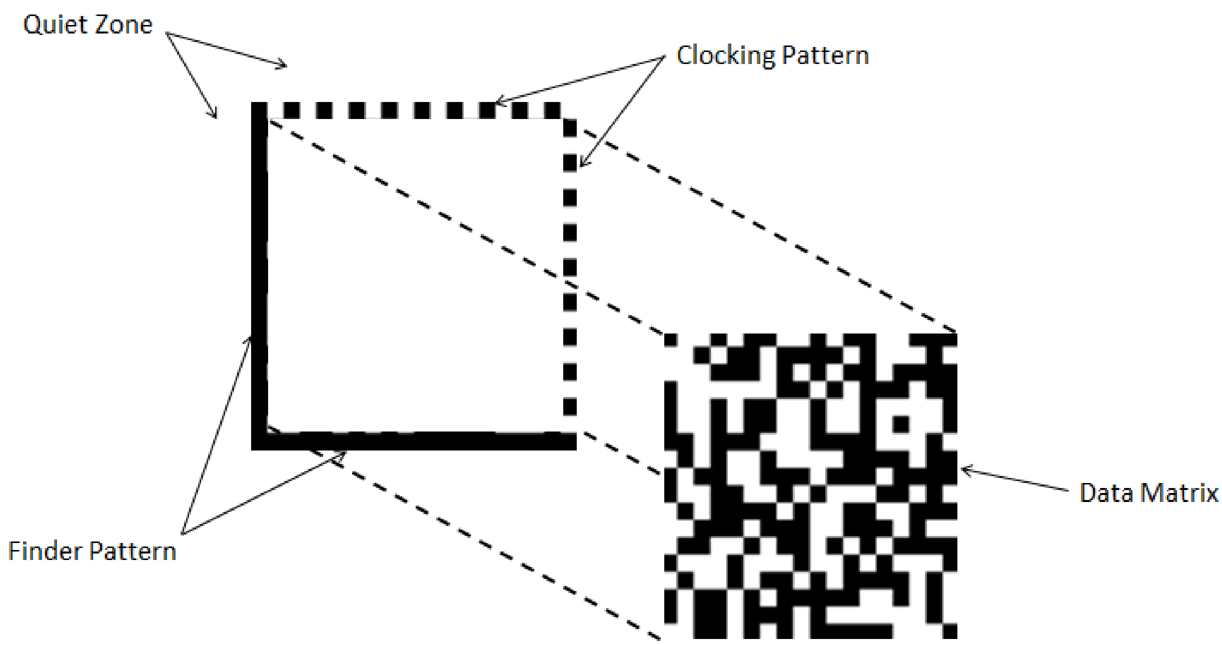
It has been suggested that index-based 2D barcodes (Visual Code, Shot Code, and Color Code) had better FRR (97.9%) than data-based 2D barcodes (QR Code, VSCode, and Data Matrix; 88.1%) (Kato and Tan, 2007).

Figure 1.1 Barcode examples[a]

QR Code	PDF417	DataMatrix	Maxi Code
Dotcode	**Aztec Code**	**Codablock-F**	**Han Xin**

[a]Table adapted from Gao et al. (2007).

Figure 1.2 Major components of 2D DataMatrix barcode



Quick response (QR) codes have been gaining high levels of acceptance largely due to the growing popularity of the smartphone. From 2010 to 2011 QR code scans increased 300% (ScanLife, 2011). From January 2011 to December 2011, QR code usage rose 617% in the top 100 magazines. In a similar report, scans from first quarters in 2013 to 2014 rose another 20%, from 18.2 million scans to 21.8 million scans (ScanLife, 2011, 2014).

In a 2011 study, it was shown that 14 million smartphone users, which represented about 6.2% of mobile users in the U.S, had scanned a QR or barcode label on a smart phone device. Users were more likely to scan various styles of barcodes that were located on newspapers and magazines (49.4%), and on product packages (35.3%), while at home (58%), in a retail store (39.4%), or in a grocery store (24.5%). Of the participants in the study, the motivation behind scanning a barcode was for responding to advertisements, discount coupons or looking for more information regarding a product (Comscore, 2011).

Although QR codes have many benefits, one of the largest downfalls is the reality of limited interaction. When QR codes can only be accessed by smart devices, one eliminates 63% of mobile device users (Shin et al., 2012).

In a survey conducted in 2015 by the Center for Food Integrity, consumers were asked what information they would like to know about their beef and how they would like to access the information. The 6 highest ranking topics that consumers would like to know were 1) impact of food on health 2) food safety 3) environmental impact 4) labor and human rights 5) animal well-being and 6) business ethics. The four places that consumers wanted to go to access this information was on the package, third-party website, company website, and QR code on the package. It was found that consumers wanted to know the impact of food on health, food safety, and environmental impact the most and wanted to access it directly on the package. Only approximately 8.5% of consumers wanted to access the six topics through a QR code on the package (The Center for Food Integrity, 2015)

Radio Frequency Identification (RFID)

Radio-frequency identification (RFID) technology is a wireless sensor technology which is based on the detection of electromagnetic signals (McCarthy et al., 2002; Domdouzis et al., 2007). A typical RFID system includes three components: an antenna or coil, a transceiver (with decoder) and a transponder (RF tag) electronically programmed with unique information (Domdouzis et al., 2007). The principal advantages of RFID systems compared to barcodes are the non-line-of-sight characteristics of the RFID technology. Unlike a linear or 2D barcode, RFID tags can be read through a variety of visually and environmentally challenging conditions such as snow, ice, fog, paint, grime, inside containers and vehicles, and while in storage (Roberts, 2006).

A RFID device that actively transmits to a reader is known as a transponder (Roberts, 2006). In most cases, the transponder is referred to as an RFID tag. Tags can incorporate read only memory (ROM), volatile read/write random access memory (RAM) or write once/read many memory (WORM) (Roberts, 2006). A “read only” tag is programmed at the manufacturer and can only be read from a RFID interrogator (reader). A “read/write” RFID tag has information that can be read from, or written to, a RFID transponder. Read/write RFID tags can have information written to one tag at a time, or have the same information written to a batch of tags (Jackman, 2004). Active RFID tags typically contain a battery, transmit a stronger signal, provide a longer read range, and operate on higher frequencies than passive tags (Table 1.1). Because active tags are battery powered, they need maintenance or expire when the battery power is depleted. Passive tags do not have a battery, are smaller in size, and generally cost less. Passive tags often have a shorter read distance and typically operate on lower frequencies (Hoang and Caudill, 2012). Passive tags are used most frequently for animal ID, with the exception of a few cattle herds which are using active RFID tags (Halverson, 2008).

Table 1.1 Comparison of passive and active radio frequency identification tags[a]

	Passive RFID tags	Active RFID tags
Tag power source	Energy transferred from the reader	Internal to tag
Availability of tag power	Only when found in the field of the reader	Continuous
Required signal strength from reader to tag	High	Low
Available signal strength from tag to reader	Low	High
Communication range	Short	Long
Multi-tag collection	Scanning of hundreds of tags within 3 meters from a single reader; Scanning of 20 tags moving at 1.3 m/sec or slower	Scanning of thousands of tags from a single reader; Scanning of up to 20 tags moving at more than 44 m/sec
Sensor capability	Monitor sensor input when tag is powered from the reader	Ability to continuously monitor sensor input
Data storage	Small	Large

[a]Table adapted from Domdouzis et al. (2007).

Radio frequency bands can very among transponder types and are classified as low, high, and ultra-high frequency (Table 1.2). Each frequency band has different advantages and is used for different applications. Low frequency is typically used for animal identification, access control, inventory control, and car immobilizers. High frequency is often used for access control, smart cards, and library control. Ultra-high frequency is used in railway monitoring, toll collection systems, pallet and container tracking and vehicle tracking (Roberts, 2006).

Table 1.2 Comparison of different operating frequencies of radio frequency identification tags[a]

	Frequency		
	Low	High	Ultra High
Radio frequency	100-500 kHz	10-15 MHz	850-950 MHz
Read range	Short to medium	Short to medium	Long
Relative tag cost	Inexpensive	Potentially inexpensive	Expensive
Reading speed	Low	Medium	High; line of sight required
Typical tag cost	~$2.50	~$5.00	~$10.00
Applications	Access control; animal identification; inventory control; car immobilizer	Access control; smart cards; library control	Railway vehicle monitoring; toll collection systems; pallet and container tracking; vehicle tracking

[a]Table adapted from Roberts (2006).

RFID and barcodes in the beef industry

Barcoded ear tags have been used in other countries for animal ID, but have not been as prevalent in the U.S. Barcoded ear tags on livestock tend to fade, become dirty, or become damaged, which ultimately makes them unreadable (Blasi, 2003). Because a RFID ear tag does not rely on visual reading, the electronic readability on livestock and in harvest plants greatly improves compared to barcode ear tags (Blasi, 2003). Traditional Universal Product Code (UPC) labels can represent only 10 numeric digits (five digits for the manufacturer code and five digits for the product code), whereas a 13.56 MHz RFID tag has the potential of storing up to 256 characters and therefore, is capable of holding a unique number for each individual product or animal. The RFID transponders used for livestock identification are available in several different forms and are used for different applications. The RFID ear tags may operate within low, high, or ultra-high frequency bands. As outlined by Singh et al. (2014), the various types of transponders are:

i. Ear transponders are one inch in diameter and can be embodied in plastic (Sherwin, 1990; Stärk et al., 1998). In addition to the button tag, a visual tag containing the unique information of a button tag can be placed on the animal. However, read write technology is also available. Information stored is strictly in accordance with the ISO standards.

ii. Bolus transponders can be introduced orally into the forestomach of ruminants (Fallon and Rogers, 1996; Hasker and Bassingthwaite, 1996; Caja et al., 1999) by use of a balling gun. Boluses are irretrievable until the time of slaughter.

iii. Collar transponders are similar to that of a neck chain, except they have an attached tag with an electronic number that can be read by a scanner. Electronic collars are easy to use, but they can become a nuisance and can cause choking if they are not adjusted properly to the growth of the animal or if they become hooked on protrusions.

iv. Microchips transponders are covered by a capsule of biomedical glass and injected under the skin (Gruys et al., 1993; Lambooij et al., 1995). Microchips are a form of identification that involves the implanting of an electronic chip, with a miniature radio transponder and antenna, under the skin of an animal near the neck between the shoulder blades, or near the base of the ear (Diez et al., 1994). This application is often used with domestic pets.

Passive RFID transponders can be either “half duplex” (HDX) or “full duplex” (FDX) (Dairy Records Management Systems, 2009). Generally, FDX systems have a tag that generates an identification signal simultaneously to it being energized by a reader’s electro-magnetic field (Lu et al., 2001). Alternatively, HDX identification systems utilize a tag capable of receiving a transmitted “charging” signal, which is used by the tag to charge a capacitor or power storage element. The stored energy of the capacitor or power storage element can then be used to power the tag, and allow the broadcast of a signal from the tag to the reader, which is in a “silent” or non-broadcasting mode.

Radio frequency ID microchips, such as a FDX that operates on 134.2 kHz, can be placed in ear tags, microchips, or boluses. Passive microchip transponders have been implanted in a number of body sites in beef cattle, including the ear scutulum, armpit, upper lip, penile sheath and dew claw (Lambooij, 1991). Studies have demonstrated that an injectable transponder at the base of the ear was a reliable method for identification (Fallon, 2001). However, implanted microchips can "migrate" resulting in the possibility of the microchip not being found when the animal is harvested (Blasi, 2003). If a microchip is not recovered during the harvest process, the transponder may enter the food system (Fallon and Rogers, 1999). Thus, due to food safety concerns, RFID ear tags and rumen boluses, rather than microchips, are most likely to be used in the beef industry for animal ID.

Although it has been determined that RFID ear tags and rumen boluses may be suitable way to track beef animals, and are the most widely used, performance between these technologies can be variable when used in the livestock environment. In a study conducted using 24 transceivers and 60 transponders, it was found that all products met ISO 11784 and 11785 standards. The ISO 11784 standard specifies the structure of the identification code, while ISO

11785 serves as a guideline of how a transponder is activated and how the stored information is transferred to a transceiver. The ISO 11784 and 11785 standards have a defined bit content of 64 bits, which results in a 15 digit numeric ID code, and operates using a FDX-B technology at a frequency of 134.2 kHz. The first 3 digits represent either the manufacturer code or the country code. These two standardizations allow tags to be universally unified and allows all users to integrate and read data (Artmann, 1999). However, actual read distance varied among products and manufacturers, from a mean read distance of 45.1 to 129.4 cm (Ryan et al., 2010). Ryan (2008) found that electromagnetic interference (EMI) can affect the read distance of low frequency RFID ear tags. Of the various areas where low frequency tags would be read, it was discovered that the processing area in feedlots may have the most EMI.

A RFID ear tag can aid in identifying and sorting cattle in feedlots and livestock facilities. Animals can be moved through an alley equipped with a stationary reader, and as the animals pass, the reader may read each tag, even if there is not a direct line of sight. Gates can be set up to automatically sort animals by reading their RFID ear tag. This may reduce stress on the animals and increases efficiency of feedlots and other livestock facilities (Halverson, 2008).

Rumen bolus passive RFID transponders have been used in beef cattle to monitor rumen temperature, activity motivation (AM), and water motivation (WM). By monitoring body temperature, pen activity, and water motivation, a producer can determine effects of fever, photoperiod, and pen design for cattle (Small et al., 2008). By using AM and WM, it provided a non-invasive monitoring and identification throughout the day. This can aid in the detection of such events as fever or estrus. When a magnetic rumen bolus is present in the reticulo-rumen, along with a RFID rumen bolus tag, the strength of the RFID signal can dramatically decrease (Eardprab et al., 2008).

The beef industry has not yet widely adopted the use of RFID active tags. Tag retention is an important aspect to consider when choosing identification tags for livestock. As outlined by Stanford et al. (2001), the key factors affecting tag retention are; position of the tag, size of the tag, proper application of the tag, infection rates, tag design or retention technology, environmental conditions, length of time the tag remained in the ear, and on-farm management (feeder design, fence design, etc.). Active tags for cattle are generally much larger and heavier than passive tags, thus tag retention may be decreased for active tags. Active tags also have a battery life, limiting the amount of useful life the tag has, which potentially is shorter than the life of a breeding beef animal. In 2008, a small passive button tag costed approximately $2, whereas an active tag costed approximately $10 each (Halverson, 2008). The current costs of small passive button tag, when compared to 2008, have risen to approximately $2.50. Active tags currently have not found a niche in the cattle industry.

Use of RFID and barcode technology in the livestock industry

Animal identification programs have existed in in the U.S. since the 1940's, starting with the use of vaccination tags and tattoos as part of the eradication of bovine brucellosis from the national cowherd (Murphy et al., 2008). Unique animal identification is necessary for a variety of reasons, including verification of ownership, biosecurity control, record keeping, efficient farm management, registration, insurance, and theft prevention (Singh et al., 2014).

The National Animal Health Monitoring System (NAHMS) conducted a survey in 1997 using 2,713 beef cow-calf producers. The 23-state target population represented 85.7% of U.S. beef cows and 77.6% of beef cow producers. In the survey, 48.1% of producers used some form of ID on calves, with plastic ear tag identification use accounting for 40.7% of all producers. Hot iron brand, ear notch, and ear tattoos were other forms of identification reported, but each of those forms of ID accounted for less than 6% of producers. A higher percentage (53.2%) of cow-calf operations reported that they individually identified their cows compared to calves. The plastic ear tag was again the most common form of identification (76.9% of cows on operations with 300 or more cows). It was reported that less than 0.05% of calves and cows were identified with a microchip transponder/electronic ID (USDA, 1997).

In 2007, NAHMS again conducted a producer survey regarding beef cow-calf identification systems. It was reported that 0.8% of producers participating in the survey used microchip transponder/electronic ID, accounting for 1.2% of cows represented by the survey. In 2007, the number of cows identified by a plastic ear tag rose to 57.5%, up from 44.7% in 1997. It was documented that the largest portion of calves born alive in 1996 were individually identified with a plastic ear tag (52%), which was similar to that reported in the 2007 (50.2%). Similar to the 1997 survey, the majority (50.4%) of producers used plastic ear tags as individual ID in 2007 (USDA, 2007).

During the 2011 National Beef Quality Audit (NBQA), 18,000 cattle/carcasses in eight large beef processing plants were assessed (McKeith et al., 2011). Individual identification tags were accounted for on 50.6% of cattle surveyed. It was found that 20.1% of cattle assessed were identified using electronic tags. Previously, during the 2005 NBQA, 38.7% cattle were identified with an individual visual tag and just 3.5% of the cattle in feedlots were identified with an electronic tag (Savell et al., 2011). Drawing from the 2011 NBQA, and from the previous surveys done in 2007 and 1997 by NAHMS, suggest that the use of individual tracking and RFID technology in the beef industry is gaining in popularity. Tracking and RFID technology is used more extensively in the feedlot segment compared to the cow-calf segment. Additionally, during the 2011 NBQA, "how and where cattle were raised" surfaced for the first time and ranked in the top 3 categories for quality challenges. The feedlot segment was the highest ranking segment for wanting to know how and here the cattle were raised with the packers, foodservice/distributors and retailers falling directly behind (Beef Quality Audit, 2011).

States in the U.S. are not the only producers to track every animal from farm of origin. It is mandatory in Australia, Brazil, Canada, the European Union, Japan, South Korea, and Uruguay to uniquely ID cattle. Of those countries, only Australia, Canada, and Uruguay require the form of ID to be electronic (Table 1.3).

Table 1.3 Comparison of identification and traceability systems in different countries[a]

	Launch date	Premises ID	Individual cattle ID	Electronic cattle ID	Motivation
Australia	1999, mandate in 2005	M[b]	M	M	Market access, food safety, animal disease
Brazil	2002	M	M	V[b]	Control FMD and market access to EU
Canada	2002	M	M	M	Market access accelerated with BSE
European Union	1997, current law in 2000	M	M	V	Animal health and BSE response
Japan	2003	M	M	V	Response to BSE discovery to restore consumer confidence
Mexico	2003	V	V	V	Animal health, census, traceability
New Zealand	2006	V	V	V	Market access and animal health (TB)
South Korea	2004, updated in 2009	M	M	V	Consumer food safety assurance and animal health
Uruguay	2006	M	M	M	Control FMD and market access
United States	2013	V[d]	V[c]	V	Control diseases for animals crossing states

[a]Table adapted from Bowling et al. (2008) and Schroeder and Tonsor (2011).
[b]M=mandatory and V=voluntary
[c]Michigan requires mandatory individual cattle identification since 2007.
[d]Mandatory premise identification for Wisconsin and Indiana

Current use of traceability in meat supply chain

Going beyond the live animal, Atlantic Beef Products (Albany, Prince Edward Island, Canada), a meat processor, is using RFID tags to track meat product. Radio frequency identification ear tags were placed on the live animal by the producer. Once the animal reached the processor, the RFID ear tag was scanned and recorded in a database. The database then linked the next two meat hooks on the rail to that animal's ID. The meat hooks were then tracked throughout production, which enabled the processor to have real-time monitoring and automated the delivery of data for invoicing, food labeling and shipping (Songini, 2007). This particular meat processor had the capacity to process 500 animals per week, from about 225 farmers (Halverson, 2008). In addition to providing data for food labeling, other important information can be recorded, such as weight and carcass grade, which then can be referenced for billing and sales (Xerafy, 2012).

Chicken beaks and legs were tracked in Ireland using barcode technology with hopes of creating a tamper proof ID for source verification of poultry. Source verifying chickens in the supply chain would enable an efficiency control and trace back program for food-borne illnesses such as Avian Influenza. The goal of a project by Fröschle et al. (2009) was to see if linear or 2D Data Matrix (DM) barcodes could be successfully printed on either the beak or leg and subsequently be scanned to implement a traceability system. Two different DM barcodes (10 x 10 mm and 12 x 12 mm) were also printed on the beaks of chickens. A DM barcode (10 x 10 mm) and a linear barcode were printed on a leg of each chicken. The scanning time for each successful read was only a few seconds per read. Overall, the 10 x 10 mm DM barcode was reported to have promising readability results on the beaks of the mature chickens (Fröschle et al., 2009).

A study by Grose and Dolezal (2004) developed two different RFID devices for tracking pork carcasses through processing facilities. The first device consisted of a RFID tag affixed to a band that was sized to fit around the limb of a carcass. The second device was an RFID embedded block that was adapted to couple to the trolley carrying the carcass. This enabled processors to store identified carcass information in a database (Grose and Dolezal, 2004).

In a study by Shiang-Yen et al. (2010), a traceable supply chain was outlined using 2D QR codes for Genetically Modified Food (GMF) products on the market in developing countries. In this traceable supply chain, 2D barcodes were adopted as the identification method where consumers could capture the image of the QR code. This image was then sent to a server for decoding, which in return sent back details of the GMF product in the form of Multimedia Message Service (MMS), enabling the consumer to retrieve product information (Shiang-Yen et al., 2010).

Following the Bovine Spongiform Encephalopathy (BSE) epidemic which occurred in 2001, Japan was prompted to enforce a traceability program, which took effect on December 1, 2003, as part of the Beef Traceability Law. Currently, all cattle (4 million) raised in Japan are assigned a 10-digit individual cattle ID by the National Livestock Improvement Center, which is a government organization that manages the national cattle database. As a bovine animal moves through the supply chain, an individual ID is carried with the cuts of beef to the retail level. It is optional for the retailer to include the ID number on the final meat package, however, if the retailer chooses to include it, consumers are able to enter the 10-digit number in a web accessible database and view specific information regarding that animal or product. Retailers have also included a QR code on the meat packages, prepared for reading by mobile phone users, that contains a hyperlink to the national database website (GS1 Japan, 2011).

Traceability using deoxyribonucleic acid

A few participants in the meat and poultry industry have implemented meat tracking through the use of DNA fingerprinting. In the late 1990's, use of DNA fingerprinting as a means for tracing swine to pork products and cattle to beef products was considered in the U.S. and by beef companies in Australia. In the early 2000's however, Topel (2002) suggested there was no compelling reason to adopt the technology in the U.S.

In order for a traceback system to function properly, Robb et al. (2006) described the following components: 1) A sample of muscle is archived (identified by calendar date, time of day, carcass ID number) from each individual carcass as it enters the fabrication room; 2) as each box of fabricated product moves past the box scale, it is time-stamped and recorded in the packer's computer system; 3) at the retailer's site, the box serial number can be used to identify each retail package generated from primals/subprimals in that box; 4) if there is need for traceback, a sample of muscle from the retail cut in question, plus the serial number of the box from which it came, are sent back to the packer, and the packer locates the box serial number in the computer database; 5) knowing the average length of time required for that cut of beef to be produced, boxed, and scaled on the fabrication floor from the time the carcass entered the fabrication room, the packer can identify a range of potential carcasses from which the primal cut originated; 6) the packer then sends the sample of the retail cut, along with the samples from that range of potential carcasses to a DNA testing laboratory, to be analyzed until a DNA fingerprint match is achieved.

IdentiGEN (2004) explained that DNA traceback technology achieves traceability by using an animal's own DNA code to identify it, enabling animals and meat to be traced with 100% precision. The DNA may be readily extracted and analyzed from samples of fresh, frozen, or cooked animal products (Meyer et al., 1993). Traceback through DNA sampling can be useful for; 1) auditing traceback in USDA auditing, review and compliance programs (e.g., Process Verified Programs or Quality System Assessments; (Smith et al., 2005); 2) to help identify specific process control problems; 3) for rapid response to a food safety event; and/or 4) for marketing-claim validation. A system like IdentiGEN's is of no value, however, unless complete birth to slaughter history for the animal whose ear-tissue was sampled is available and correlated in a data-set (Smith et al., 2008).

Commercial production systems in countries outside the U.S., such as Australia and New Zealand, have also been participating in DNA sampling. These production systems take blood or muscle samples from beef or lamb carcasses, respectively, which can later be used for DNA fingerprinting. The sample is then matched with meat that is found later to contain harmful chemical residues or to have been unsatisfactory in palatability (Smith, 2004).

The use of barcode labeling and RFID tagging has been implemented on a limited basis in the meat supply industry. Although some traceability systems have been attempted, no system has been developed to fully trace beef carcasses from live animal to retail. With the increase of consumers adopting mobile technology, it has enabled information to be shared through the meat supply chain more easily than ever before. A fully traceable supply chain in the beef industry may help small-to mid-sized producers gain competitive advantage over larger producers with which traceability may become more complex.

Chapter 2

A COMPARISON OF BEEF TRACEABILITY MODELS DURING SERIAL AND PARALLEL PROCESSING METHODS[1]

ABSTRACT

Traceability of beef attributes from small- and mid-sized farms through supply chains is a market barrier. Automatic identification and data capture technologies, such as radio frequency identification (RFID) and two-dimensional (2D) barcodes, offer the feasibility of maintaining animal and product data through carcass fabrication. The objective was to determine the influence of fabrication method on beef traceability system requirements. Individual animal identities of fifty-four (54) were maintained through harvest, processing, packaging, and distribution. Each animal's unique RFID animal identification number was transferred at harvest to a "harvest" (parent) label on each carcass quarter. Following transportation to a processor, nine carcasses were processed on alternating days by one of two methods. Carcasses were fabricated, using a serial processing method (SPM), into wholesale cuts one at a time, or fabricated using a parallel processing method (PPM), by processing multiple hindquarters or forequarters simultaneously into wholesale cuts. In-process, 5.1 x 2.5 cm (child) labels were generated by scanning the 2D barcode on the harvest label with a handheld mobile computer and printed from a wireless mobile printer. Tracking of SPM and PPM carcass quarters was accomplished by creating in-process labels for lugs and individual wholesale cuts, respectively. The mean number of in-process labels generated per carcass for SPM was 3.7 and for PPM was 30.9 ($P < 0.01$). The amount of time required for generating in-process labels for SPM (2 min 16

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sec) was less than PPM (8 min 45 sec) (P = 0.01). The amount of time required to label each carcass was less (P < 0.01) for SPM (18 sec) than for PPM (3 min 10 sec) with in-process labels. Total cost of traceability, including fixed and consumable cost per carcass, was nearly twice as much for PPM ($17.98) than SPM ($9.02). Traceability, within both processing methods, was found to have 100% fidelity, as verified using DNA marker genotyping. Overall, the number of labels generated for traceability was less for SPM than PPM. The overall time spent on generating, applying, and removing labels was less for SPM than PPM. The total cost of traceability was approximately half for SPM compared to PPM, however both methods were able to track product accurately. Tracking of beef from individual animals, using RFID ear tags and 2D barcodes, appears to be feasible for the processing methods used in this study.

Key words: 2-dimensional barcode, beef processing, radio frequency identification, traceability

INTRODUCTION

Many U.S. consumers have been shown to desire farm of origin information (Mennecke et al., 2007) and place significant value on that information (Varnold et al., 2011). Locally produced products have considerable appeal as consumers perceive that purchasing these products supports local agriculture, the local economy, and the local environment. Local products also carry the connotation that products are fresher, delivered with less transportation, and more likely to be traceable (Painter, 2007).

The beef industry uniquely identifies a portion of beef cattle, but the identification is often lost once the animal is harvested. With the combined use of Radio Frequency Identification (RFID) ear tags, and 2-dimensional (2D) barcode labels, a fully traceable supply chain can be obtained through a small-to mid-sized harvesting and processing facility, ultimately supplying consumers with animal origin information (Buskirk et al., 2013). A RFID ear tag can be scanned at harvest and the unique 15-digit number can be recorded in a database. A 2D barcode can then be generated containing the unique identification, as well as other desired information to be placed on carcasses or meat cuts during processing.

The goal of this study was to identify labeling techniques for two different processing methods in tracking wholesale meat cuts back to the original animal in mid-sized processing facilities. Video data was analyzed to determine time requirements and estimate costs of tracking beef products through the processing facility for the two different carcass fabrication methods. The hypotheses for this study is 1) processing time per carcass for PPM would be less than SPM 2) time spent on labeling wholesale beef cuts for PPM would be greater than SPM 3) total cost of processing while maintaining traceability would be less for PPM than SPM and 4) accuracy for SPM would be greater than PPM. The objectives of the study were to 1) determine the cost of additional labor required for traceability; 2) determine both consumable and fixed costs of traceability; and 3) verify traceability accuracy utilizing DNA genotyping.

MATERIALS AND METHODS

Seventy-two (72) Angus × Simmental crossbred steers were used to compare two beef processing methods in a traceable supply chain. Sixty-one (61) steers were born and raised at the Michigan State University (MSU) Upper Peninsula Research and Extension Center, Chatham, MI, and 11 steers were born and raised at the MSU Beef Cow-Calf Teaching and Research Center, East Lansing, MI. All steer calves received a RFID ear tag (Allflex USA, DFW Airport, TX) in the middle one third of their left ear while at their farm of origin. Each RFID ear tag was previously coded with a 15-digit animal identification number (AIN) (Schelhaus and Harless, 2008). All steer calves were transported from their farm of origin to the MSU Beef Cattle Teaching and Research Center, East Lansing, MI to be finished. Upon arrival at the feedlot, the steers were approximately 6 mo of age and weighed an average of 240 ± 33 kg. During the finishing stage, data points for each steer were recorded in an online database (ScoringSystem, Bradenton, FL) and included animal breed, birth date, sex, farm of origin, and AIN. The ScoringSystem database allowed viewing of public information on an entity by searching an AIN or database-assigned identification number (ScoringSystem Identification – Entity Identification; SSI-EID). Animal procedures were conducted according to those approved by the MSU Institutional Animal Care and Use Committee (10/11-202-99).

Harvest

Steers were sorted into four harvest groups, with 18 steers per group, based on weight and 12th rib fat thickness. The 12th rib fat thickness was obtained using ultrasound (Aloka SSD-500; Hitachi Aloka Medical, Ltd., Wallingford, CT). Each group was transported to a processing plant (Ebels Meat Processing, Falmouth, MI) during four successive wks. The first harvest group of 18 steers was used as a pilot study, so the processing personnel could be acclimated to the traceability methods, and data were not included in the analyses. Observations of the two treatments were recorded over three wks. Two days of processing occurred during each wk, therefore processing on d 1 and 2 took place in wk 1 and processing on d 3 and 4 took place in wk 2, and so on. During exsanguination, the RFID ear tag was removed from each animal and scanned using a handheld RFID reader (*Lightning*ROD Reader; I.D.ology, Eau Claire, WI). The RFID data were transmitted into label design and barcode printing software (BarTender; Automation; Seagull Scientific, Bellevue, WA) using Bluetooth data exchange to initiate the parent (harvest) label generation. As the RFID was scanned, the barcode software searched a prepopulated Microsoft Excel 2010 (Microsoft Corp., Redmond, WA) file, which cross-referenced the AIN and SSI-EID. Once exsanguinated, the carcasses were hung on an overhead rail. The rail was continuous and non-branching, therefore carcass order was maintained throughout the harvest process. The HCW of each animal was recorded and entered into the barcode software. Eight identical harvest labels were printed using a laptop computer and an industrial thermal transfer printer (model GP MAXX; Godex Americas, Camarillo, CA). The harvest label included an AIN, SSI-EID, address of feedlot, premise identification number (PIN) of feedlot, print date, print time, federal establishment number of processor, HCW of left and right carcass halves, total HCW, and a 2D, four-segmented, GS1 DataMatrix barcode (Figure 2.1, panel A). The 2D barcode contained the AIN, SSI-EID, federal establishment number of processor, feedlot name and location, and date and time of printing. The printed labels were placed onto heavy weight manila shipping tags (12.07 × 6.03 cm) (OfficeMax, Okemos, MI). One labeled tag was placed on the fore and rear quarter of each carcass half using deadlock tag fasteners. One labeled tag was placed in a plastic bag that contained the hanging tender for each carcass. The head, heart, and liver received the remaining three harvest labeled tags for each carcass, but were not tracked further during this study. The carcasses were chilled 24 h, cut between the 12th and 13th rib, and then yield and quality graded by USDA personnel. Following grading, carcasses were quartered and transported by refrigerated truck to the fabricator (Byron Center Meats Inc., Byron Center, MI).

Carcass Processing

Carcasses were placed in groups of nine and allotted to one of two treatments based on their order of arrival at the fabricator. The groups were processed by one of two treatments, either serial (SPM) or parallel (PPM) processing method. Treatment order was alternated each wk. Only wholesale beef cuts were traced during harvest and processing of carcasses. Ground beef was comingled in separate lugs and was not tracked.

Serial Processing Method The SPM was defined as one individual carcass (both hindquarters and forequarters) being processed before starting on the next carcass. As carcasses were processed to their final wholesale cuts, a set of food-grade polypropylene child (in-process) labels (5.08 × 2.54 cm x 3 mm; Spinnaker Coating, Troy, OH) were generated for each carcass using a mobile unit consisting of a handheld computer (model GPS SC; Intermec Technologies Corporation, Everett, WA) equipped with customized software (Advanced Traceability Solutions, Portland, ME) and a mobile printer (model P4T; Zebra Technologies, Lincolnshire, IL). A carcass specific in-process label was placed in each lug that contained cuts from that carcass. Each lug contained wholesale cuts from only one carcass to preserve the integrity of traceability.

Parallel Processing Method The PPM was defined as multiple carcasses being processed simultaneously. To achieve this, 10 hindquarters were processed, followed by the corresponding 10 forequarters, then 8 forequarters followed by the corresponding 8 hindquarters. During PPM, each wholesale cut was labeled individually with an in-process label which was created using the same method as described for SPM. Identified wholesale cuts were then placed into lugs before being moved.

In-process Labeling The 2D barcodes on carcass harvest labels (parent labels) were scanned immediately before carcass breakdown using the handheld computer. The handheld computer's barcode scanner recorded the information from the barcode of the harvest label. The SSI-EID, AIN and date and time were included in the 2D GS1 DataMatrix barcode (1.59 × 1.59 cm) on the in-process label (Figure 2.1, panel B). The mobile software also assigned a unique identity for each carcass using a three character alpha sequence (*i.e.*, first carcass = "AAA," second carcass = "AAB," and so on) followed by a serialized number indicating the number of labels printed for each carcass (*i.e.*, first label for the carcass = "001", second label for the carcass = "002", and so on), which was also displayed as text on the printed in-process label (Figure 2.1, panel B). This visual serialization method was found to be unnecessary and was discontinued after the pilot run. During the study, each carcass was assigned a sequential number, which was written on the back of the in-process label for quick visual identification by the beef cutters. The handheld mobile unit was used to print six (5.08 × 2.54 cm) labels for each carcass during SPM and 34 labels for each carcass for PPM. The in-process labels for PPM were placed on waterproof cure tags (6.99 × 3.49 cm) and then attached to the wholesale beef cuts using plastic carcass brads (Ketchum, Brockville, ON).

Beef Package Labeling After each lug or wholesale beef cut was identified with an in-process label, the cuts were moved to a vacuum packaging station. The in-process label was removed from, the top-most wholesale cut of each lug for SPM, and each individual wholesale beef cut for PPM. Each beef cut was placed in a vacuum package (Cryovac, Sealed Air, Duncan, SC) bag, vacuum sealed, and dipped into a hot water bath. Each package was dried with a towel and the in-process label for the wholesale cut was scanned with a handheld mobile computer and a final, food-grade, polypropylene beef package label (5.08 × 2.54 cm x 3 mm; Spinnaker Coating, Troy, OH) was printed (Figure 2.1, panel C). The label was then applied to the outside of the dried package. When the in-process label was scanned, the mobile computer stored the unique 3-digit alpha character, SSI-EID, and AIN. The final package label also included the phrase "traceback.com", a serialized number, date, time, and a four-segmented 2D GS1 DataMatrix barcode (1.59 × 1.59 cm) that contained the Uniform Resource Locator (URL) for animal origin information. For example, beef from an animal with an SSI-EID of 09AE16F37C would have a unique URL of www.scoringag.com/scoringag/3/Ag.cfm?sfa=main.PSA&entity_id=SSI_09AE16F37C. This URL references the web page with previously entered data for that individual animal. The wholesale cuts then were moved to a boxing station.

Box Labeling At the boxing station, packages were placed into boxes with similar cuts according to North American Meat Processors Association (NAMP) specifications (NAMP, 2011). Food-grade polypropylene box labels (10.16 × 5.08 cm x 3 mm; Spinnaker Coating, Troy, OH) were created using the same laptop computer and industrial thermal transfer printer as the harvest labels. The box label included the phrase "MSU BEEF", date, serialized number and a 2D GS1 DataMatrix barcode (Figure 2.1, panel D). The 2D barcode referenced a mobile website, beeftrace.wirenode.mobi (Wirenode, Dallas, TX) that was created to contain information about the farm of origin for the beef steers utilized. Boxed beef was frozen and transported by refrigerated truck to MSU Food Service, East Lansing, MI, where the beef was kept frozen until transport to MSU food venues.

Video Analysis

Beef processing was recorded using four video cameras (model MX-9746VF; Skyway Security, Mauldin, SC) placed throughout the processing room and 2 digital video recorders (DVR) (model AV-04; Skyway Security) to capture the tracing process during carcass fabrication. The data collected from the video capture included times for: processing each carcass, processing each day, creating in-process labels, labeling lugs, labeling wholesale cuts, removing in-process labels, and labeling of final beef packages. Times were determined by viewing the captured video on a personal computer using a video player application (2010 HD Player Version 1.1.6.0). Daily processing time was defined as the total cutting and labeling man-hours per day. Start time was recorded when the first carcass quarter was pulled from the rail and ended when the last wholesale cut was labeled. Time spent processing each carcass was determined by dividing the total processing time per d by the number of carcasses processed per d. In-process label creation time per d started when the mobile computer scanned the first harvest label tag and ended when the last label was adhered to the waterproof cure tag. The in-process label generation took place over several intervals throughout each d. Start and stop times were recorded in the same manner as described above and then summed for a total time of in-process label generation per d. Total time for labeling lugs for SPM and total time for labeling each beef cut for PPM was recorded. Start time for SPM was defined as when the beef cutter grasped the label and finished when the carcass brad was pushed in the top-most beef cut in the lug. This was done for all lugs labeled for each carcass. Start time for PPM was initiated when the beef cutter grasped the label and stopped when the carcass brad was placed in the wholesale cut. Time removing in-process labels was defined as the total time required for removing and disregarding the label. Final package labeling time was defined as the total time spent drying and placing the label on the final beef package.

DNA Sampling

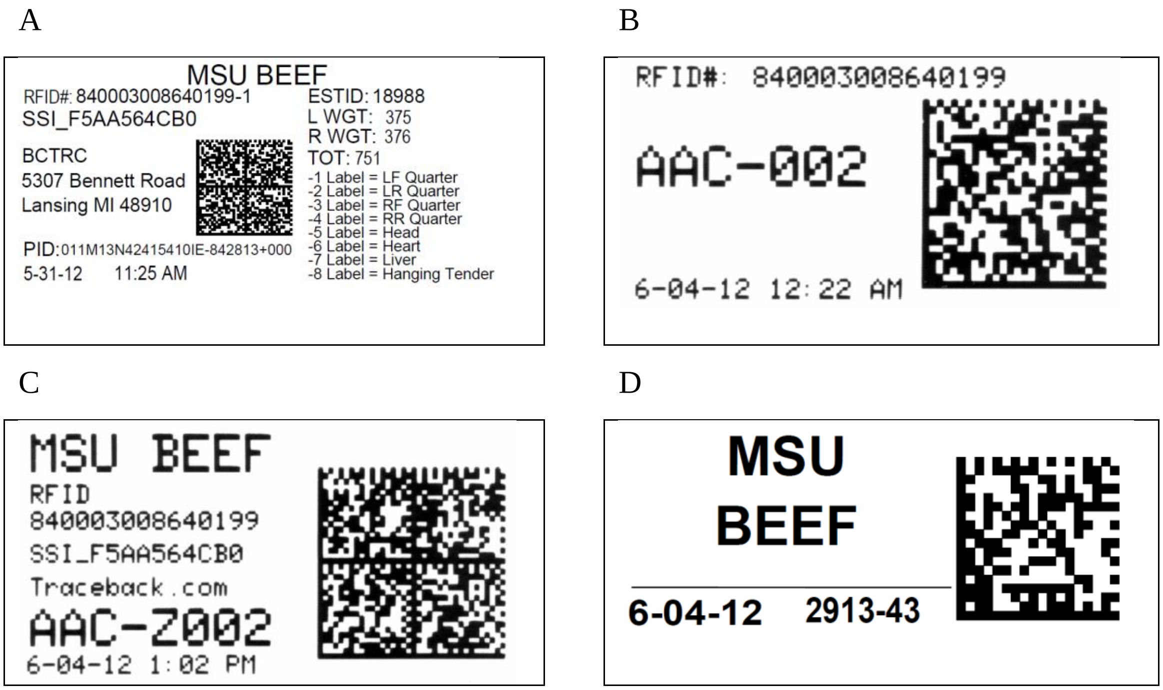
Deoxyribonucleic acid (DNA) marker technology was used to verify the fidelity of traceability between treatments. Use of DNA genotyping of single nucleotide polymorphisms (SNP) has been reported to be a sensitive method to definitively identify beef from individual cattle (Heaton et al., 2002). In the present study, tissue samples of each steer were obtained during feedlot finishing by applying a tissue sampling ear tag (Typifix Yellow Panel Ear Tag, Prionics USA, Omaha, NE). Each ear tag contained a unique 1-dimensional barcode that was electronically cross-referenced with the steer's AIN. The sample collector portion of the ear tag retained a tissue sample which was used for genotyping.

Wholesale cut sampling was conducted during beef thawing and preparation. Ninety-four (94) beef samples were obtained at ten different MSU food venues over the course of nine months. Samples were collected using meat sampling devices (IdentiGEN North America, Inc., Lawrence, KS) as described by Loftus and Meghan (2011). The sampling device contained a unique 1-dimensional barcode that was cross-referenced with the AIN indicated on the package tracking label by use of a handheld computer. Genomic DNA was extracted from the ear tissue and beef samples. Single nucleotide polymorphisms were genotyped using an end-point homogeneous fluorescence assay system (IdentiGEN North America). Individual sample genotypes were compared for identity across all SNP tested using computer algorithms. A match was identified when the probability of two samples having the same genotype was 1 in > 10^6. A non-match was recorded when two or more allelic differences were observed.

Statistical Analysis

The GLM procedures of SAS v. 8.4 (SAS Inst. Inc., Cary, NC) were used to analyze the number of labels used, amount to time to label and track beef cuts, and cost of tracking. Carcass served as the experimental unit when analyzing the cost of in-process labels, number of in-process labels used, and total number of labels used. Day served as the experimental unit when analyzing time to generate in-process labels, apply in-process labels, remove in-process labels, apply final labels, and total amount of time spent on labeling. When number of labels and time were dependent variables in the model and treatment and replicate were independent variables. When cost was the dependent variable, treatment was the independent variable. The level of probability at which main effects were considered significant was $P \leq 0.05$.

Figure 2.1 Example barcode label formats: (A) harvest label (parent) was placed on carcass quarters, (B) in-process (child) label was used to track wholesale beef cuts during carcass fabrication, (C) final package label was placed on vacuum sealed packages, (D) box label was placed on shipping boxes



RESULTS

The time required to label, and the number of labels used, varied between treatments (Table 2.1). Eight times more in-process labels were used on each carcass for PPM compared to SPM ($P < 0.01$). The PPM required each individual wholesale cut to be labeled, whereas SPM required only the lug to be labeled, thus reducing the amount of labels required to track product. More time was tended to be spent on generating in-process labels for PPM than SPM ($P = 0.10$). Nine times the amount of seconds was spent placing in-process labels on wholesale meat cuts for PPM than SPM ($P < 0.01$). Removal of in-process labels at the vacuum packaging station took nine times the amount of seconds per carcass for PPM compared to SPM ($P = 0.01$). Each treatment resulted in the same number of wholesale meat cuts, therefore no variance between treatments for number of labels used and time spent on printing labels was observed during the final package labeling process. The number and time spent on generating the final package labels were constant between the two treatments. Total time spent on generating, applying, and removing in-process labels and time to generate and label final package labels was not significant between the two treatments (P = 0.05). Total number of labels used per carcass for SPM was less than PPM (P < 0.01).

Traceability costs were estimated to be higher for PPM than SPM (Table 2.2). Equipment cost for PPM was estimated to be higher, primarily because there would be a greater use of the in-process mobile printer than for SPM. The estimated useful life of the in-process mobile printer was 1 yr for PPM and 2 yrs for SPM. Consumable costs also varied between PPM and SPM. Shipping tags, deadlocks, stationary printer ribbon, carcass labels, and number of final package labels used were constant between PPM and SPM. The consumable cost for carcass brads, mobile printer ribbon, in-process labels, and waterproof tags were all greater for PPM. Total consumable cost for SPM was $5.54 /carcass lower than PPM.

Labeling labor cost per carcass was 3.5 times lower for SPM than PPM (Table 2.2). The total traceability cost per carcass was more than doubled for PPM compared to SPM. This resulted in a total traceability cost of 0.07 and 0.15 $/kg of wholesale product cut for SPM and PPM, respectively.

A total of 94 meat samples were collected and submitted to a lab; 47 from each SPM and PPM. Samples from 22 different beef animals for SPM were collected and 26 different beef animals for PPM were collected. Nine samples were unable to be cross referenced due to insufficient DNA sampling. All beef samples that could be cross referenced to their animal of origin were accurately labeled and tracked through the harvest and processing facility (Table 2.3).

Table 2.1 Traceability labels and labeling time for serial and parallel beef processing

	Treatment			
	SPM [a]	PPM [b]	SEM	P-value
In-process labels used, number/carcass	3.7	30.9	0.2	<0.01
In-process label generation, sec/carcass	136.0	525.0	52.2	0.10
In-process labeling, sec/carcass	18.0	181.0	3.6	<0.01
In-process label removal, sec/carcass	2.1	18.1	1.26	0.04
Final package labeling, sec/carcass[c,d]	114.1	105.8	16.9	0.92
Total labeling time, sec/carcass	270.0	831.1	52.9	0.05
Total labels used, number/carcass	30.7	57.9	0.2	<0.01

[a]The serial processing method was defined as one individual carcass (both hindquarters and forequarters) being processed before starting on the next carcass.
[b]The parallel processing method was defined as multiple carcasses processed simultaneously.
[c]Time to generate final package labels took 108 seconds for SPM and PPM.
[d]27 labels were printed for each carcass for SPM and PPM.

Table 2.2 Estimated traceability cost for serial and parallel beef processing, $/carcass

	Treatment	
	SPM [a]	PPM [b]
	---------------$/carcass---------------	
Fixed cost		
RFID ear tag[c]	2.10	2.10
RFID handheld reader[d,e]	0.05	0.05
Notebook PC and printer[e,f]	0.36	0.36
Handheld mobile scanner 1 (in-process)[e]	0.39	0.39
Handheld mobile scanner 2 (final package)[e]	0.39	0.39
Mobile printer 1 (in-process)[g]	0.31	0.61
Mobile printer 2 (final package)[h]	0.61	0.61
Total fixed cost	4.21	4.51
Consumable cost		
Shipping tags	0.23	0.23
Deadlocks[i]	0.08	0.08
Carcass brads[j]	0.44	3.67
Stationary printer ribbon	0.32	0.32
Labels (10.16 × 5.08 cm)	0.24	0.24
Mobile printer 1 ribbon	0.15	1.24
In-process labels (5.08 × 2.54 cm)	0.07	0.56
Waterproof tags (6.99 × 3.49 cm)	0.10	0.83
Mobile printer 2 ribbon	1.16	1.16
Final package labels (5.08 × 2.54 cm)	0.52	0.52
Total consumable cost	3.31	8.85
Overall traceability cost		
Traceability equipment cost	4.21	4.51
Traceability consumable cost	3.31	8.85
Labeling labor cost[k]	1.50	4.62
Total traceability cost	9.02	17.98

[a]The serial processing method was defined as one individual carcass (both hindquarters and forequarters) being processed before starting on the next carcass.
[b]The parallel processing method was defined as multiple carcasses processed simultaneously.
[c]Low frequency, half-duplex, radio frequency identification ear tag.
[d]Handheld wand reader.
[e]Useful value of two yrs borrowed money at 5% interest with quarterly payments.
[f]Assumed 250 work d/yr and 20 carcasses processed/d.
[g]Useful value of two yrs for SPM and one yr for PPM with borrowed money at 5% interest with quarterly payments.
[h]Useful value of one yr with borrowed money at 5% interest with quarterly payments.
[i]Metal deadlock tag fastener used to hold carcass labels to carcass.
[j]Plastic carcass brad used to hold in-process label to wholesale meat cut.
[k]Labor cost charged at $20.00/hr which includes employee fringe and benefits.

Table 2.3 Genotyping of SNP from live steers and beef products from live steers and beef

Wholesale beef cut	SPM cuts sampled	PPM cuts sampled	Total cuts sampled	Confirmed DNA match	Confirmed DNA mismatch	Unconfirmed DNA match
Beef back rib	6	6	12	12	0	0
Beef eye of round	6	6	12	11	0	1[b]
Beef ribeye roast	3	6	9	7	0	2[b]
Chuckeye roll	3	3	6	4	0	2[a,b]
Chuck flat iron	3	0	3	3	0	0
Beef flank	3	3	6	6	0	0
New york strip	1	0	1	0	0	1[a]
Skirt steak	6	6	12	12	0	0
Striploin	10	10	20	19	0	1[b]
Top butt sirlion	3	3	6	4	0	2[a]
Top round	3	4	7	7	0	0
Total	47	47	94	85	0	9

[a]Live animal tissue sample did not meet quality standards for DNA genotyping.
[b]Wholesale beef cut sample did not meet quality standards for DNA genotyping.

DISCUSSION

We have demonstrated that an AIN encoded in a RFID ear tag can be transferred to 2D barcode labels, effectively tracking carcasses and wholesale beef cuts through small- to mid-sized processing plants. Data captured in the 2D barcode label, not only provided supply chain participants with information, but ultimately delivered farm of origin information to the beef preparer. Transfer of information from farm of origin to end user can potentially add value to the product.

Differentiation of "local" food is based on attributes other than simply local origin, such as producer values and production methods employed. Caswell and Mojduszka (1996) categorized food product traits as search, experience, or credence attributes. According to their definitions, search attributes can be identified before purchase through inspection or research (*e.g.* marbling, lean color, external fat); experience attributes can be determined after consuming the product (*e.g.* juiciness, tenderness, flavor); and credence attributes cannot be assessed, even after the product is purchased and consumed (*e.g.* locally produced, grass-fed, humanely raised). With growing consumer interest in food origin and processes, comes a growing number of imaginable credence attributes. Labeling or linking beef with verified credence attributes would enable real choice to be exercised among foods produced in different ways.

There is a growing body of research examining the premium values of different beef credence attributes, such as grass or forage fed (Martin and Rogers, 2004; McCluskey et al., 2005; Umberger et al., 2009a; Crandall et al., 2013; Dentoni et al., 2014), no exogenous hormones (Lusk et al., 2003; Ward et al., 2008; Umberger et al., 2009b), no antibiotics used (Ward et al., 2008; Umberger et al., 2009b), all natural (Ward et al., 2008; Markus et al., 2014), source verified (Ward et al., 2008; Allen et al., 2011), and locally produced (Maynard et al., 2003; Alfnes and Sharma, 2010; Goddard et al., 2013; Ridley et al., 2014). To maintain credence attribute claims, a traceability system needs to be implemented to track products through the supply chain. However, traceability has developed largely as two separate systems in the beef industry; live animal traceability and product traceability (Bulut and Lawrence, 2007).

Internal traceability refers to traceability within a production unit or specific stage of production (Bulut and Lawrence, 2007). For a live animal provider to maintain traceability, it is suggested by the Meat and Poultry B2B Data Standards Organization [mpXML] (2010), that the provider have a unique provider identity and accurate herd/house/pen information depending on species. Currently, live animal traceability is primarily being used for disease eradication programs and herd health record keeping that requires individual tagging and tracking of livestock. One example, as described by Murphy et al. (2008), is the use of individual identification in the effort to eradicate bovine brucellosis from the U.S. cowherd. Once an animal is vaccinated against the disease, it is tagged with a uniquely coded metal ear tag. As another example, the state of Michigan has implemented mandatory RFID tagging of all bovine species, before leaving the farm of origin, in an effort to control and eradicate *mycobacterium bovis* (Kirk and Buskirk, 2006). Traceability in these two cases ends at time of animal harvest.

For functional traceability, the live animal must be uniquely identified. The traditional method of identification had been hot-iron branding which was typically used to distinguish one herd from another. Over the last several decades freeze branding and various other external tagging techniques have been practiced in the beef industry (Hanton and Leach, 1981; USDA, 1997, 2007). The use of RFID tags in livestock has been explored in various applications requiring unique animal identification. As Singh et al. (2014) outlined, RFID transponders have been tested as ear tags, rumen boluses, collars, and microchips that are imbedded in the skin.

Chain traceability refers to traceability throughout the entire food chain (Bulut and Lawrence, 2007). Smith et al. (2008) conducted a review of 13 countries or communities that had cattle/beef traceability programs. Of the 13, 11 were mandatory (4 encompassed birth to retail; 7 covered birth to harvest) while 2 were voluntary programs (birth to harvest). Post-harvest individual animal identification traceability can be accomplished using single-carcass processing units, tagging and separation/segregation, and/or DNA fingerprinting technology. In most countries, there has been no compelling reason for the beef industry to adopt such protocols or technology because these processes were time consuming and costly (Smith et al., 2008).

In the present study, chain traceability was attempted by tracking live animal and beef product through the cow-calf, feedlot, harvest, processing, distribution, and wholesale segments of a beef supply chain. There were differences in traceability cost between SPM and PPM due to system components, such as those outlined by Mejia et al. (2010), like capital equipment and software; operating labor; consumable materials; and effects on line speed or operation efficiency. We found that full chain traceability in this study cost less than $20/carcass.

The two carcass traceability models compared in this study proved to have efficacy for tracking beef product. Both methods of tracking may be applicable to various types of beef processors and fabricators based on volume of animals processed and available labor to track product. The two tracking methods used in this study may not be feasible tracking methods in large processing systems (*i.e.*, more than 100 carcasses fabricated daily). Large processing facilities typically comingle large numbers of carcasses on moving fabrication lines, thus making it difficult to track individual animals in a similar manner to what we used. Because large processing facilities may find it difficult to track product to specific carcasses, this may allow small-to mid-sized processers the opportunity to add value to traced beef products and gain a competitive advantage. However, large processing systems may be able to track product to a batch or farm origin level. This can be done by creating a unique identification number for a batch rather than specific animals and establishing a unique identification number on a barcode or RFID tag on carcass trolley or bins for wholesale beef cuts.

Although tracking of individual wholesale cuts was successful in this study, some of the technology used for label creation could be improved. For example, the handheld scanners used Bluetooth technology, which took nearly 30 sec to communicate with the mobile printer before printing in-process and final package labels. This time delay added overall cost to the label generating process. Future studies may also include such topics as optimal label size and placement on wholesale or retail beef packages.

In this study, the 2D barcode label was created at the harvest level and then a new 2D barcode label was created during carcass processing. On a small scale, a simple, unique, alpha or numeric character could be assigned to each carcass upon harvest that corresponds with the RFID ear tag number that is then carried through carcass processing. This number could be referenced when the beef cut is placed in the final package and a final package label could be created and applied. This alternative could save on printer consumable costs during carcass processing.

Genotyping used to check quality of tracking beef products has been shown to be of high accuracy. On the basis of SNP allele frequencies at 20 loci in beef and dairy cattle, the mean probability that 2 randomly selected individuals would possess identical genotypes was 1 in 23 million (Heaton et al., 2005). During the genotyping process for checking the fidelity of tracking in this study, 3 ear tissue samples and 4 beef samples were unable to be cross referenced due to insufficient amount of DNA sampled. Failure rates of tissue and beef samples found in this study are similar to that typically observed in DNA genotyping (S. Eliades, 2016, IdentiGEN, Lawrence, KS, personal communication). To date, there are no published standards set by the industry on acceptable rates of success when tracking beef products.

This study used wholesale beef cuts for food service distribution channels, and did not expose retail consumers to the traceability information. Further studies are needed to determine what specific attributes consumer's desire most regarding beef products, the most important data that should be collected and traced throughout the beef supply chain, and aesthetics of 2D barcode design on retail packaging.

Chapter 3

INTERPRETIVE SUMMARY

The two methods of carcass fabrication proved to have high traceability efficacy in a mid-sized processing facility. To incorporate traceability in the demonstrated system, a minimum amount of labor force was added to label meat cuts as necessary. The majority of the cost associated with implementing a fully traceable supply chain was for the equipment and technology used for label generation.

Taking this study a step further, a marketing program could be set forth by small-and mid-sized processing facilities to help recover the addition cost of beef associated with tracking the wholesale cuts. Different marketing avenues need to be explored (*i.e.* restaurant food service such as fine dining, retail counters, and local farmers markets) rather than only the MSU food venues. Survey panels should be conducted to identify consumer preferences on the marketed beef and to discover potential drivers for consumers to purchase within niche markets. With conducting survey panels, one would hope to uncover potential premiums that consumers would be willing to pay, what attributes regarding specific characteristics of beef that consumers would like to know, and attitudes towards locally grown beef and their perceived benefits of purchasing the beef.

A fully traceable supply chain could potentially work in a larger scale processing plant with the addition of increased labor personnel and the purchase of more labeling equipment. It would be a challenge to track whole cuts of beef through a processing facility but could be done with a slower fabrication line and increase labor personnel to label beef products. To track product in a setting such as this, the price of beef per pound would increase proportionally. Large marketing efforts would need to be set forth to try and recover a premium on the beef.

APPENDICES

APPENDIX A

Barcode Label Design

Step by step instructions for the use of *BartTender Automation* (Version 9.4 SR1) on a personal computer in a Windows 7 Professional 64 bit system for creating a barcode label.

Getting Started

Double-click the *BarTender* icon and *BarTender* will initialize. A welcome screen will appear which will give options to either start a new label format, open existing label format, or open a recently used format. Click “start a new label format”.

Once “start a new label format” is selected, a pop-up screen will appear. Here, one has the option to either start with a blank label format or start with an existing label format. Select “blank label format” and click **Next**.

Another pop-up will appear for printer selection. Select the printing method of choice and click **Finish**.

> *Note:* There is an option on this pop-up to either click **Finish** or **Next.** By selecting Finish, it will enable you to go directly to the label to start designing. If you select **Next**, one has the option to customize paper setting, label shape, margins, rows and columns, label size, printing order, and label background.

The user is now ready to start designing their own label.

Label Design

For this demonstration, the harvest label will be used as an example.

Step 1: To first create a heading, click the "T" icon which will insert a text box. Type "MSU BEEF" and set font to Arial, kept.

Step 2: Creation of RFID #. Insert another text box and type "RFID#:" and set font to Arial Narrow, regular in 11 pt. Double-click the RFID text box and a pop-up screen will appear. This enables modification of the selected text object. Click on the **Position** tab towards the top. Set the X-axes "0.125" inches and the Y-axes to "0.431" inches. Select the object reference point as **Bottom Left** and click the Advanced tab and select **Top Left** in Label drop down menu. Finish by clicking **OK** at that screen and then click **OK** again. This positions the text in the correct location on the label.

Set up a Microsoft Excel spreadsheet with three headings labeled as RFID, SSI, and PIDC and put in the animal information that the label is going to reference. This is used as a database for information to be pulled into on the harvest label. Save the Excel file in a location that is easily referenced.

Now, add another text box to the label and double-click the box to modify the settings. Click the Advanced button and change Source to **Database Field** in the pull down menu. Next, click the **Database Connection Setup** button. A welcome screen will appear and click **Next**. Another pop-up screen will appear that enables the user to select the database of which to pull information from. Select **Microsoft Excel** and click **Next**. Hit the **Browse button** in the next screen and locate the Excel file that the data are in and click **Next**. The next screen gives the option of which tables to use. Select **Sheet1$ TABLE** and click the **Add** button and then click the **Finish** button. On the next screen click **OK**. In the "Field Name" pull down, select **RFID**. Move over to the "Sub-String List" box and **click** in the white space. Go the "Source" pull-down menu and select **Screen Data**. Replace "Sample Text" with "-". Add another Sub String and again select **Screen Data** as the source. Type in a "1" in place of "Sample Data". While still on the same Sub-String, click **More Options** and click the **Serialization** tab towards the top. Check the **Serialization** box. Go to the "Type:" pull down menu and select **Numeric (Base 10)**. Move to the Rollover section and select **Rollover** and Limit it to "8" and set the Reset to "1". Next, go to options sections, and select the box for **Preserve sub-string length** and then click **Close**. Lastly, set the font to Arial, Regular 11pt and position the text with the X-axes to "0.500" inches and the Y-axes to "0.375" inches and select **Top Left** as the reference point, then click **OK**.

<u>Step 3:</u> Creation of SSI#. Insert another text box and double click it so the pop-up appears to modify the selected text. Click the **Data Source** tab towards the top and then click the **Advanced** button. Change "Source" to **Database Field** in the pull down menu. The Excel file should automatically be inserted in the "Sample Data" box. Make sure that in the "Field Name" pull down, that **SSI** is selected. Now select the Position tab towards the top and set the X-axes to "0.114" inches and the Y-axes to "0.429" inches and set "Object Reference Point" to **Top Left** on the pull down menu. Click the **Advanced** button in the "Position" box and select **Top Left** again from the pull down and click **OK**. Go to the **Font** tab and set font to Arial, Regular style, in 11pt and click **OK** at the bottom.

Step 4: Owners name and address. Insert a text box on the label and double-click the text box again. Click the **Data Source** tab and type in “BCTRC” in the Options box. Set the font to Arial, Regular 11pt. Set the position as X-axes “0.113” inches and the Y-axes “0.888” inches and set the reference point to **Center Left** and click **OK**.

Insert another text box on the label and double-click the text box again. Click the **Data Source** tab and type in “5307 Bennett Road” in the Options box. Set the font to Arial, Regular 10 pt. Set the position as X-axes “0.110” inches and the Y-axes “1.087” inches and set the reference point to **Center Left** and click **OK**.

Repeat the last step three more times for City, State and Zip code. Use “Lansing” as the city, “MI”, for the state and as “48910” the zip code. Set the font to Arial, Regular 10 pt for all three text boxes. Below are the position settings for the text:

> Zip Code - X-axes “0.108” inches and the Y-axes “1.303” inches and set the reference point to **Bottom Left** and click the **Advanced** button in the “Position” box and select **Top Left** again from the pull down and click **OK**.
>
> State - X-axes “0.686” inches and the Y-axes “1.303” inches and set the reference point to **Bottom Left** and click the **Advanced** button in the “Position” box and select **Top Left** again from the pull down and click **OK**.
>
> State - X-axes “0.893” inches and the Y-axes “1.303” inches and set the reference point to **Bottom Left** and click the **Advanced** button in the “Position” box and select **Top Left** again from the pull down and click **OK**.

Step 5: Creation of PID#. Insert another text box and type "PID:" and make Arial Narrow, Regular in 11 pt. Double-click the RFID text box and a pop-up screen will appear. This enables modification of the selected text object. Click on the **Position** tab towards the top. Make the X-axes "0.123" inches and the Y-axes "1.570" inches. Select the object reference point as **Center Left** and click the **Advanced** tab and select **Top Left** in "Label" drop down menu. Finish by clicking **OK** at that screen and then click **OK** again. This positions the text in the correct location on the label.

Insert another text box and double click it so the pop-up appears to modify the selected text. Click the **Data Source** tab towards the top and then click the **Advanced** button. Change "Source" to **Database Field** in the pull down menu. The Excel file again should automatically be inserted in the "Sample Data" box. Make sure that in the "Field Name" pull down, that **PIDC** is selected. Now select the **Position** tab towards the top and set the X-axes to "0.427" inches and the Y-axes to "1.595" inches and set "Object Reference Point" to **Center Left** on the pull down menu. Click the **Advanced** button in the "Position" box and select **Top Left** again from the pull down and click **OK**. Go to the **Font** tab and set font to Arial, Regular style, in 11pt and click **OK** at the bottom.

Step 6: Creation of date and time stamp. Insert a text box and double-click it. Go the **Advanced** button a change "Source" to **Date** in the pull down menu. This will put the date stamp in every time a label is printed. Make the text Arial, regular, and in 11 pt. Click on the **Position** tab towards the top. Make the X-axes "0.125" inches and the Y-axes "1.850" inches.

Select the object reference point as **Bottom Left** and click the **Advanced** tab and select **Top Left** in “Label” drop down menu. Finish by clicking **Ok** at that screen and then click **OK** again.

Step 7: Creation of barcode. On the top navigation bar, select the barcode icon and then click in the center of the label to insert the barcode. Click the “Bar Code” tab on the top and select “Data Matrix” under the **symbology** drop-down menu. Set the x dimension to “19.71 mils” and then move to the “Data Source” tab. Double-click the barcode and go to the **Advanced** button. Change the “Source” to **Label Object String** and then add the substrings into the Sub-String list for the data that should be included in the barcode label. Finish by clicking **OK** at that screen and then click **OK** again.

APPENDIX B

SAS Editor Codes

Table 3.1 Number of in-process labels used

```
data tag;
input rep obs label trt$;
cards;
3	72	3	S
3	71	3	S
3	70	4	S
3	69	5	S
3	68	4	S
3	67	5	S
3	66	4	S
3	65	4	S
3	64	3	S
3	63	30	P
3	62	30	P
3	61	28	P
3	60	28	P
3	59	29	P
3	58	31	P
3	57	30	P
3	56	28	P
3	55	30	P
2	54	30	P
2	53	32	P
2	52	31	P
2	51	32	P
2	50	32	P
2	49	32	P
2	48	30	P
2	47	31	P
2	46	30	P
2	45	3	S
2	44	3	S
2	43	2	S
2	42	4	S
2	41	4	S
2	40	4	S
2	39	3	S
2	38	3	S
2	37	2	S
1	36	6	S
1	35	4	S
1	34	4	S
1	33	5	S
1	32	4	S
1	31	3	S
1	30	4	S
1	29	4	S
1	28	3	S
1	27	32	P
1	26	33	P
1	25	32	P
1	24	33	P
1	23	32	P
1	22	32	P
1	21	32	P
1	20	32	P
1	19	32	P

run;
proc glm data=tag;
class rep trt;
model label=trt rep;
lsmeans trt/stderr;
run;
```

Table 3.2 In-process label generation time

```
data inprocesslabelgenerationtime;
input rep trt$ time;
cards;
3	S	179
3	P	555
2	P	413
2	S	145
1	S	84
1	P	607

run;
proc glm
data=inprocesslabelgenerationtime;
class rep trt;
model time=trt rep;
lsmeans trt/stderr;
run;
```

Table 3.3 In-process labeling time

```
data inprocesslabelingtime;
input rep trt$ time;
cards;
3	S	15
3	P	171
2	P	180
2	S	20
1	S	19
1	P	192

run;
proc glm
data=inprocesslabelingtime;
class rep trt;
model time=trt rep;
lsmeans trt/stderr;
run;
```

Table 3.4 In-process label removal time

```
data inprocesslabelremoval;
input rep trt$ time;
cards;
3       S       2.06
3       P       16.78
2       P       15.67
2       S       1.94
1       S       2.37
1       P       21.89

run;
proc glm
data=inprocesslabelremoval;
class rep trt;
model time=trt rep;
lsmeans trt/stderr;
run;
```

Table 3.5 Time of final labeling

```
data finallabelrelabingtime;
input rep trt$ time;
cards;
3       S       99.9
3       P       138.2
2       P       97.9
2       S       120.3
1       S       122.2
1       P       81.3

run;
proc glm
data=finallabelrelabingtime;
class rep trt;
model time=trt rep;
lsmeans trt/stderr;
run;
```

Table 3.6 Total time spent labeling

```
data totaltimespentlabeling;
input rep trt$ time;
cards;
3	S	295.46
3	P	884.28
2	P	706.77
2	S	286.84
1	S	227.57
1	P	902.29

run;
proc glm data=
totaltimespentlabeling;
class rep trt;
model time=trt rep;
lsmeans trt/stderr;
run;
```

Table 3.7 Total number of labels used

```
data totaltag;
input rep obs label trt$;
cards;
3	72	30	S
3	71	30	S
3	70	31	S
3	69	32	S
3	68	31	S
3	67	32	S
3	66	31	S
3	65	31	S
3	64	30	S
3	63	57	P
3	62	57	P
3	61	55	P
3	60	55	P
3	59	56	P
3	58	58	P
3	57	57	P
3	56	55	P
3	55	57	P
2	54	57	P
2	53	59	P
2	52	58	P
2	51	59	P
2	50	59	P
2	49	59	P
2	48	57	P
2	47	58	P
2	46	57	P
2	45	30	S
2	44	30	S
2	43	29	S
2	42	31	S
2	41	31	S
2	40	31	S
2	39	30	S
2	38	30	S
2	37	29	S
1	36	33	S
1	35	31	S
1	34	31	S
1	33	32	S
1	32	31	S
1	31	30	S
1	30	31	S
1	29	31	S
1	28	30	S
1	27	59	P
1	26	60	P
1	25	59	P
1	24	60	P
1	23	59	P
1	22	59	P
1	21	59	P
1	20	59	P
1	19	59	P
run;
proc glm data=totaltag;
class rep trt;
model label=trt rep;
lsmeans trt/stderr;
run;
```

Table 3.8 Cost of in-process labels

```
data tag;
input obs label trt$ cost;
cards;
72	3	S	0.255
71	3	S	0.255
70	4	S	0.34
69	5	S	0.425
68	4	S	0.34
67	5	S	0.425
66	4	S	0.34
65	4	S	0.34
64	3	S	0.255
63	30	P	2.55
62	30	P	2.55
61	28	P	2.38
60	28	P	2.38
59	29	P	2.465
58	31	P	2.635
57	30	P	2.55
56	28	P	2.38
55	30	P	2.55
54	30	P	2.55
53	32	P	2.72
52	31	P	2.635
51	32	P	2.72
50	32	P	2.72
49	32	P	2.72
48	30	P	2.55
47	31	P	2.635
46	30	P	2.55
45	3	S	0.255
44	3	S	0.255
43	2	S	0.17
42	4	S	0.34
41	4	S	0.34
40	4	S	0.34
39	3	S	0.255
38	3	S	0.255
37	2	S	0.17
36	6	S	0.51
35	4	S	0.34
34	4	S	0.34
33	5	S	0.425
32	4	S	0.34
31	3	S	0.255
30	4	S	0.34
29	4	S	0.34
28	3	S	0.255
27	32	P	2.72
26	33	P	2.805
25	32	P	2.72
24	33	P	2.805
23	32	P	2.72
22	32	P	2.72
21	32	P	2.72
20	32	P	2.72
19	32	P	2.72
run;
proc glm data=tag;
class trt;
model cost=trt;
lsmeans trt/stderr;
run;
```

APPENDIX C

Animal Use Form

MICHIGAN STATE
UNIVERSITY

MEMORANDUM

TO: Rust, Steven R
Animal Science
2265B Anthony Hall

FROM: Dr. Susan M. Barman, Chairperson
Institutional Animal Care and Use Committee

DATE: 09/30/2011

SUBJECT: APPROVAL OF APPLICATION TO USE VERTEBRATE ANIMALS IN RESEARCH

This is to notify you that your initial application, or annual renewal, to use vertebrate animals in research or teaching has been approved by the Institutional Animal Care and Use Committee (IACUC). Initial applications are approved for a three-year period, pending submission of an Annual Renewal letter.

Yearly, three months before the anniversary date of the initial approval, you will be sent the Annual Renewal letter in which you will be asked to check the appropriate section, sign and return it to the IACUC office. SHOULD YOUR PROJECT EXTEND BEYOND THE INITIAL THREE YEAR APPROVAL PERIOD, YOU MUST SUBMIT A NEW APPLICATION WHICH CAN BE FOUND ON OUR WEB SITE (www.iacuc.msu.edu). Please note that, according to the Policies, Responsibilities and Procedures for Animal Use and Care at Michigan State University, no significant changes may be made to your research without submitting an amendment to the IACUC for review and approval before any changes can be implemented.

In order to be eligible for research funding from the National Institutes of Health (NIH), Michigan State University has filed with the Office of Laboratory Animal Welfare (OLAW) an assurance document which commits the university to compliance with NIH policy and the Guide for the Care and Use of Laboratory Animals. All principal investigators should be aware of the existence of this formal obligation.

Title: MSu Beef Cattle Teaching and Research Center Standard Operating Procedures

Application #: 10/11-202-99

Funded By: Department of Animal Science

Original Approval Date: 09/19/2011

Expires: 09/19/2014

SMB/cjf

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