Radio Frequency Identification Tagging as a Mechanism of Creating a Viable Producer's Brand in the Cattle Industry

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Abstract

This manuscript reports on a project to examine the feasibility of extensive radio frequency identification (RFID) tagging to determine product provenance in the meat production industry. The investigators examined existing technologies and meat production processes as well as emerging technologies in RFID tagging to assess the potential of RFID technologies for provenance assurance. While RFID technologies hold tremendous promise for traceability, the current state of the technology and production process creates challenges for effectively creating full traceability. However, RFID holds tremendous potential for improving processing throughput, which will help make RFID-based traceability more attractive for adoption by meat processors.

Keywords: brand marketing, provenance assurance, radio frequency identification (RFID), traceability.

RADIO FREQUENCY IDENTIFICATION TAGGING AS A MECHANISM OF CREATING A VIABLE PRODUCER'S BRAND IN THE CATTLE INDUSTRY

Introduction

Agricultural animal products represent the archetypical commodity because there is relatively low potential for the individual producer to differentiate his product. This is because information about producers is lost when the animal is sent through the cutting floor. This lack of differentiation in turn limits the potential of packers and aggregators to create branded products because the source of the product generally cannot be traced to individual producers when animals from multiple producers are included in large production lots.

Where product branding exists, it is important because it allows producers to have greater control over pricing and profits. For non-branded commodity products, the consumer lacks information about the origin of the product, which means that there will be little or no reward to the producer for quality improvements and innovations beyond what is necessary to continue within a commodity category. Because innovation and quality improvements will not be rewarded and product differentiation will be difficult, the consumer will make purchasing choices based primarily on price. Thus, when branding is absent, producers are at the mercy of the market and have limited incentive to add value to their products beyond that of relevance to their direct customer, the packers and processors.

As noted, the primary problem associated with tracking meat products from the farm through the production process and to the retailer lies with the loss of individual animal identification on the cutting floor. This is because in a typical U.S. high-production processing plant, animals are processed on high-speed cutting lines. Parts are typically removed from the carcass as it passes a cutting station while hanging on a gambrel. Typically the cutters are trained to focus on making accurate cuts and on directing products to the appropriate destination (e.g., a packing bin or a conveyer belt sending the product to other cutters). In most high-production cutting floors, the cost of adding tagging, labels, or other forms of identification has outweighed the benefits associated with tracking individual cuts of meat back to individual animals.

However, several recent events and legislative acts are likely to push U.S. producers into capturing a greater amount of information about the origin of meat products. For example, the discovery of one cow infected with bovine spongiform encephalopathy (BSE) in Washington State in the fall of 2003 raised a great degree of consumer awareness of the vulnerability of the meat food chain to foodborne pathogens. Although the infected animal was found to have originated in Canada, the event highlighted the limited capabilities of retailers, producers, and regulators to trace animals in the U.S. food production system. In fact, it was likely the countrywide tracking system that was recently instituted in Canada that allowed investigators to confirm that the cow originated in Canada. While this BSE episode appears to be refocusing attention on Canada, the advent of U.S. legislation requiring the identification of country of origin (COO) by September 2004 also implies that there will be increasing attention focused on issues associated with traceability.

Traceability does exist, to one degree or another, in Canada, Europe, Australia, and a few other countries where there is a greater interest in verifying the origin of agricultural products. In England, France, the Netherlands, and several Nordic countries, a variety of meat products are routinely tracked through some or all of the production process. For example, in the Netherlands, Belgium, and France, the VanDrie Group offers consumers the capability to take an identification code from a veal product, enter it into a query form on a Web site, and receive a report showing the animal's farm of origin, date of birth, slaughter date, and various other pieces of information (VanDrie Group 2005). Of course, traceability means different things to different people, and this definition has different implications for U.S. producers and processors. In some cases, tracing an individual animal may be relevant while in other contexts it may be sufficient to track meat only within a production lot or to a particular point of origin (e.g., the farm of origin). The meat production chain is also fragmented into three segments, with the result that traceability of individual animals, meat products, or components within one segment may be feasible while it may be infeasible outside of that segment. For example, cattle are routinely tagged and tracked on the farm and this information can easily be carried to the processing plant; however, information about the individual animal is generally lost on the cutting floor. Although lot-level traceability is currently the norm in the United States, and individual animal traceability is not currently required by regulation or consumer demand, it is conceivable that there will be a greater need to trace animals in all stages of the production chain in the future. Here we examine the feasibility and implications of using RFID to enable meat traceability in each of the three segments of the meat production process.

Traceability, Branding, and Safety

The purpose of our research was to examine the potential of radio frequency identification (RFID) as a mechanism to enable product branding. We note this here because there is an important difference between traceability for branding and traceability for safety. The literature on traceability, both popular and professional, generally refers to meat traceability as a mechanism of ensuring food safety, and RFID-based systems are often expected to provide individual animal traceability and some assurance that a particular meat product is not diseased. With current systems of factory processing, processors can record individual animal information for each lot, keep the lot sizes relatively controlled through multiple lot per-day runs, and limit the amount of contact with other animals that can occur from a diseased animal's contamination of a lot. The next level of disease control comes with new processing technology, whereby animals are processed in effective hygienic isolation from other animals, with individual animal information passing through the system as the animal is processed.

This extreme form of traceability is not necessary though to establish effective branding; all that is necessary is to establish an animal's provenance or characteristic set that adds the value associated with the brand. Current mechanisms in production of branded products involve creating common characteristic lots (such as all-Angus), so that an entire lot can be brand-identified. Many processors whom we spoke to in the context of this project indicated an active desire to expand vertically backward to the ranch, so that they could grow their own brand-specific animals.

The only downsides to lot-based brand identification are that it is not optimally efficient and it does not allow for types of branding other than animal provenance (i.e., organic, grass fed, Angus, etc.). BSE testing or tenderness grading offer important opportunities for branding that require individual animal tracing through a system. Individual animal tracing also increases efficiency by allowing mixed lots while still providing full brand-identification through the system. An additional benefit of individual animal traceability accrues to the processor in that the processor can also use individual animal identification to develop better information about its animal suppliers. By tracking the individual animal's yield profiles, cost, and so forth, the processor can precisely identify producers that are providing it with the best profit profiles.

Finally, traceability itself may become a brand characteristic over time, with individual animal identification becoming a value-adding characteristic of the product. We saw extensive individual animal information provided in final meat products in Europe, and retailers there assured us that the identification of a particular meat cut's provenance added value to the product on the store shelves.

Radio Frequency Identification Technologies

RFID uses tags affixed to assets (cattle, containers, bins, etc.) to transmit accurate, real-time information to users' information systems. The basic elements of any RFID system consist of three components:

- Antenna
- Interrogator (transmitter and receiver)
- Transponder (the tag itself)

At its most basic level, an RFID tag contains a tiny transponder and antenna that have a unique number or alphanumeric sequence; the tag responds to signals received from an interrogator's antenna and transmits its number back to the interrogator. While the tags themselves are relatively simple, they allow the development of tracking software that can maintain much better inventory information than can bar-code systems or systems that rely on human entry of identification information. These tags have an advantage over bar coding in that the tags can be embedded in a container or item without any adverse effects on the data, and RFID tags also provide a non-contact, non-line-of-sight ability to gather real-time data and can penetrate most non-metallic materials, including bio-matter.

Active versus Passive Tags

While RFID tags can simply hold identification numbers for tracking, they can also be much more sophisticated, carrying more complex information and interacting differently with reader systems. Tags, from simple to complex, take one of two primary forms:

Active Tags

- Catch the attention of the RFID reader by broadcasting a signal.
- Function with battery power (a battery is either connected to or built into the tag).
- Work over a greater distance and are more expensive (because of the cost of the battery).
- Are generally readable only by proprietary technology of the tag's manufacturer.

Passive Tags

- Only react to an interrogator's contact signal.
- Communicate without battery power (giving them essentially unlimited life).
- Derive power from the interrogator antenna's electromagnetic field.
- Are beginning to be able to be read by a variety of equipment.

The main difference between active and passive tags is that passive tags possess an effective reading range that is shorter and much smaller than an active tag. However, in the case of a reusable container (such as are used in bin-processed meat), a passive tag will last the entire lifetime of the container to which it has been assigned without the need to change batteries or interrupt the signal.

Read-Only versus Read/Write Tags

In addition to being passive or active, tags may also be classified as read-only or read/writable. Read-only tags are preset to a specific number and retain that information throughout their life, whereas read/write tags can actually be written to by an appropriate read/write device. Writeable tags are particularly useful when information about an item needs to be easily associated with an item, particularly if there might be a problem with access to the database that would associate a read-only number with an item's information. A RFID-tagged animal, for instance, would benefit from a tag that contained the full information about the animal's health and feed data and its recent transportation history, so that processors would not have to access any outside database to extract the animal's relevant information. Writeable tags are also useful in creating information redundancy within an inventory system, maintaining information about an asset that is physically separate from the main database.

Frequency Ranges and Characteristics

Common RFID Frequencies

- Low (around 125 KHz): low reading speed
- High (around 13.56 MHz): medium reading speed
- Ultra-high frequency (UHF) (around 850-900 MHz): high reading speed
- Microwave (around 2.45 GHz): high reading speed, line of sight is required (not as commonly used as others, which may be because line of sight is required)

If one type of RFID tag cannot meet all the requirements or is not suitable for all the materials that would be tagged, a combination of tags can be used. The marginal cost for adding another chip would be nominal.

Applications Depending on the Frequency

There are important factors related to tag frequency that must be considered when determining the type of tags that will be used in a given installation.

- Low frequency tags are cheaper, use less power, and are better able to penetrate non-metallic substances. They are ideal for scanning objects with high water content at close range. These tags are most appropriate for use with meat products, particularly where the tag might have meat between it and a reader.
- UHF frequencies offer better range and can transfer data faster. They use more power and are less likely to pass through biological materials. They have a greater range, however, and are more useful in many container-scanning applications.

Read Ranges

a. Low frequency tags—a foot or less
b. High frequency tags—about 3 feet
c. UHF—10 to 20 feet
d. Microwave (uncommon)—about 3 feet.

When longer ranges are needed, batteries can be used (requiring active tags) to boost read ranges to 300 feet or more. Even in low frequency tags, larger-sized tags can have greater read ranges (up to 5 feet). Again, suitable antenna arrays may be used to increase read distances. Other vendors quote read distances of 90 feet and greater for types (c) and (d) (http://www.amiglobal.org/technologies/rfid/what_is_rfid.html).

The Cost of Radio Frequency Identification

The costs of RFID are rapidly decreasing as companies such as Wal-Mart, Hy-Vee, and 7-Eleven adopt the technology. Standardization will also bring the costs down drastically. Estimates by Forrester Research show that costs of RFID tags will fall to the 1¢-per-tag level after 2007. The research also shows that the tag costs may reach the 5¢ level by 2004 (http://techrepublic.com.com/5100-6296-5056001-2/html). Basic cost considerations in purchasing RFID systems are given in Table 1.

Table 2 gives a summary of cost estimations based on the cost of chips, which may depend on the process, etc.; cost of inlay, which depends on size and substrate; and cost of assembly, which is fixed. The cost of chips is estimated based on the estimated price of $500 for a wafer that produces 12,500 chips using traditional process and 125,000 chips if production is done using a new process (the Alien FSA or similar processes). The pricing is somewhat hypothetical.

This cost estimation is optimistic based on the chip manufacturers' willingness to offer their wafers at $500. Today, the pricing is at least twice this amount. If the new manufacturing process is proven effective, the price of chips can drop as much as to 10 percent of the current estimated cost for chips. The chip would then be insignificant in the cost analysis.

Potential Problems

There are a number of potential problems that could occur with the tags themselves and/or the reader system. The range of problems include mechanical damage, print quality degradation, damage due to the environment, such as excessive heat, cold, dust, water, etc., and damage due to static electricity (http://www.rfidjournal.com/article/articlereview/659/1/1). Additionally, there is the possibility that the tags and readers could experience identification data "collision" problems. This occurs when two or more tags or readers errantly possess the same physical digital addresses. This will not physically damage the

TABLE 1. RFID systems, basic costs

Readers	A reader costs $1,000 to $12,000 depending upon the reader's scan range and the application.
Tags	Cost of tags range from 30¢ to $50.00 depending upon whether active or passive a. Finished smart labels that can be applied on top of products (50¢ or more) b. Active tags (with a battery) cost more c. With a sophisticated sensor ($100) d. Low frequency tags are cheaper but have less range
Application Software	Application software ranges from a few hundred to tens of thousands of dollars, depending upon its functional capabilities.

Source: http://www.rfidjournal.com/article/articleview/207.

TABLE 2. Estimated cost of smart tags based on different substrate/metallization for different frequencies

Operating Frequency	13.56 MHz	915 MHz	2450 MHz (2.45 GHz)
Cost of Chip	♦ $0.04 (Traditional) ♦ $0.004 ("Alien")	$0.04 (Traditional) ♦ $0.004 ("Alien")	$0.04 (Traditional) ♦ $0.004 "Alien")
Cost of Inlay	♦ $0.01 (Smallest) ♦ $0.16 (Largest)	♦ $0.12	♦ $0.02
Cost of Assembly	♦ $0.02	♦ $0.02	♦ $0.02
Smart Tag Cost ($500/8" traditional wafer)	♦ $0.07 (Smallest) ♦ $0.22 (Largest)	♦ $0.18	♦ $0.08
Smart Tag Cost ($500/8" Alien's wafer)	♦ $0.04 (Smallest) ♦ $0.18 (Largest)	♦ $0.15	♦ $0.05
Smart Tag Cost ($1000/8" traditional wafer)	♦ $0.11 (Smallest) ♦ $0.26 (Largest)	♦ $0.22	♦ $0.12
Smart Tag Cost ($1000/8" Alien's wafer)	♦ $0.07 (Smallest) ♦ $0.22 (Largest)	♦ $0.15	♦ $0.09

devices, although it will adversely affect the integrity of the system (http://www.rfidjournal.com/article/ articlereview/207). Finally, as an electronic device, the system could experience problems due to signal noise and interference from electrical equipment or electronics operating in the vicinity (http://www.acsisinc.com/media/RFID.pdf).

Health Risks

Questions concerning the widespread use of radio wave technology in the workplace and its potential impact on humans are always important. Since RFID tagging systems use low wattage within the same frequency spectrum as wireless telephones, these devices pose no greater threat to human health than do the wireless telephones already in common usage (http://www.rfidjournal.com/article/articlereview/207).

Standardization Problem

Almost all RFID systems use proprietary technology. International standards have been adopted for very specific applications such as tracking animals. There are several standardization initiatives. ISO 18000-6 creates a foundational code for the GTag (for UHF tags) and Auto ID center's Electronic Product Code (EPC). EPC and its surrounding technology is not a formal standard currently, but the Auto ID center hopes that it will be widely adopted and become the de facto standard (http://www.rfidjournal.com/article/articlereview/207). Published standards were completed at the end of 2004, and standardization should serve to reduce further the cost of most commercial RFID systems (http://www.trenstar.com/pdfs/rfid_fact_sheet.pdf). As of this writing, the codified standards have not yet been incorporated into commercially available products.

Radio Frequency Identification in Meat Tracking

A variety of technologies and techniques are used for tracing meat in the United States, Europe, Australia, and other countries (e.g., see EAN International 2002). While RFID is beginning to be used to track individual cattle, the real challenge for traceability is to migrate individual cattle information into the meat processing facility.

Tracking Cattle from the Farm to the Processing Plant with RFID

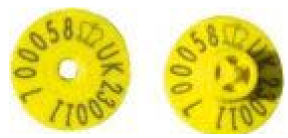
RFID is beginning to be widely used for tracking cattle from birth to the processing plant. In fact, this application for RFID is unarguably the most well developed use of

RFID in any of the segments of the beef supply chain. For example, Canada and Australia have already implemented RFID-based tracking systems, while numerous other countries (e.g., Brazil, Mexico, the European Union, and the United States) are investigating the feasibility of using RFID for tracking cattle from the farm to the plant. This section reviews the technology used for tracking cattle from the farm to the plant and provides a synopsis of the RFID-enabled traceability programs currently in operation in Canada and Australia.

Electronic Identification (EID) Ear Tag Technology. Cattle identification systems use RFID technology that is embedded in ear tags such as those produced by Fearing International, Ltd. (see Figure 1).[1] The electronic components are embedded in tags that are similar to those that have been used for cattle identification and tagging for several decades. Tags are laser-engraved with an identification number that corresponds to the ISO number that is programmed on the RFID tag. In some cases, an engraved barcode is also included on each tag as a backup identification mechanism.

Cattle RFID systems use passive tags that operate at low frequency ranges (134.2 kHz). Low-frequency tags can be effectively read-only for a few feet; however, tags operating at this frequency range are not as susceptible to absorption by biomaterials as are tags operating at higher frequencies. Ear tag interrogators (i.e., readers and antennae) are available in a number of configurations. For example, Destron Technologies (www.destronfearing.com) offers three different types of RFID interrogators: a hand scanner (Figure 2), a chute reader (Figure 3), and a walk-through reader (Figure 4). There are also multi-gate chute readers that allow multiple animals to egress a portal in parallel (Figure 5).

The Canadian Cattle Identification Program. The Canadian Cattle Identification Program (CCIP) was developed and is managed by the Canadian Cattle Identification Agency (CCIA), a non-profit, industry-led corporation designed to establish a national cattle identification program. CCIP was implemented in January 2001, with the requirement that all cattle be tagged with a CCIA approved ear tag. The program went into full-scale implementation with 100 percent required compliance on July 1, 2002. Packing plants began reading all tags as of July 1, 2001.



Source: http://www.fearing.co.uk/

FIGURE 1. Fearing International, Ltd., electronic identification tag

Source: http://destronfearing.com/pipdf/lsrdO1_isoPaddle_033003.pdf

FIGURE 2. Hand scanner, Destron Technologies, Inc.

Source: http://destronfearing.com/pipdf/an4211headgateneckeExtenderantenna050702.pdf

FIGURE 3. Chute reader, Destron Technologies, Inc.

Source: http://destronfearing.com/pipdf/an4500portablecattlewalk_hroughantenna080103.pdf

FIGURE 4. Walk-through reader, Destron Technologies, Inc.

Source: http://www.aleis.com/products/Commercial%20Systems.pdf

FIGURE 5. Multi-read system, Aleis International

Ear tags contain a visible unique identification number, a bar code, and the CCIA logo (a maple leaf). The unique identification numbers are given to tag manufacturers by the CCIA. Producers obtain tags through authorized service centers and other distribution channels. The service centers maintain records about the numbers assigned to each producer and submit this information to the central CCIA database. Once the tags are applied to an animal, the identification number stays with the animal until it is processed at the processing plant. Processing plants are required to maintain information about the carcass (i.e., the identity) to the inspection point.

The CCIP initially made use of bar code technology; however, as of January 2005, the program began replacing bar code tags with RFID enabled ear tags. The RFID tags have the numeric identification number imprinted on the surface of the tag, an imprinted maple leaf emblem, and the embedded RFID chip. As of February 2005, the CCIA approved six brands of RFID tags for use in the CCIP (see Figure 6).

Australia's National Livestock Identification System (NLIS). Australia's National Livestock Identification System (NLIS) is a state mandated trace-back system designed to track cattle from birth to the processing plant (*Beef News* 2004). The program was initiated in 2004 as a replacement for the 30-year-old tail tag identification and trace-back program.

The NLIS program was initiated during the summer of 2004 with the requirement that all cattle born after July 1 must be identified with an NLIS approved device. Approved devices include RFID enabled ear tags as well as a rumen bolus. The rumen bolus is an RFID capsule that is inserted into the animal in the back of the throat (see Figure 7); a non-electronic ear tag is applied to the animal when the rumen bolus is applied. The second phase of the program begins in July 2005 with the requirement that any animal that leaves a property must be tagged with an authorized NLIS tag. In addition, feedlots and processing plants must be able to read tags by the July 1 deadline and report identification numbers to the central NLIS database. The third phase of the program requires that all movement of cattle between properties be tracked with an approved tag and that the identification number and location be reported to the central NLIS database. There are two types of tags approved for use during the last two phases of the program: a white breeder tag that is used on cattle that are still on the property of birth and an orange tag for untagged cattle that are purchased for feedlots (MLA 2004).

The program is designed to track the animal from birth to the plant, but, like the Canadian system, it does not provide a mechanism for tracking animals through the processing system. Information available to producers includes the date of slaughter, the NLIS tag number, the vendor's property identification code, and the hot standard carcass weight, or weight at slaughter. In other words, the system provides a means by which the

Allflex FDX
Allflex USA, Inc.
P. O. Box 612266
2805 East 14th Street
Dallas Ft. Worth Airport, TX 75261-2266
1-800-989-8247
http://www.allflexusa.com/

Allflex HDX
Allflex USA, Inc.
P. O. Box 612266
2805 East 14th Street
Dallas Ft. Worth Airport, TX 75261-2266
1-800-989-8247
http://www.allflexusa.com/

Destron Fearing etag FDX
Digital Angel Corporation
490 Villaume Avenue
South St. Paul, MN 55075-2443
1-800-328-0118
http://www.digitalangelcorp.com/

Nedap FDX
Eidap Inc.
172 - 2257 Premier Way
Broadmoor Place IV
Sherwood Park, Alberta Canada T8H 2M8
1-780-467-2707 http://www.eidap.com/

Reyflex FDX
Ketchum Manufacturing Inc.
396 Berkley Avenue, Ottawa, Canada
1-613-722-3451
http://www.ketchum.ca/

Y-Tex TechStar II FDX
Y-Tex Corporation
PO Box 1450
Cody WY 82414
1-888-600- 9839
http://www.y-tex.com/

Source: http://www.canadaid.ca/tags/tag_options.shtml

FIGURE 6. Canadian Cattle Identification Agency approved radio frequency identification tags

ALEIS International Pty Ltd PO Box 5219 Brendale BC QLD 4500 Australia 07 3205 9842 http://www.aleis.com	
Animalife ID Pty Ltd Unit 1-6 Jones Rd Capalaba QLD 4157 Australia 07 3823 2130 www.livestock-id.com	
Allflex Australia Pty Ltd 33 Neumann Rd Capalaba QLD 4157 Australia 07 3245 9100 http://www.allflex.com.au	 Breader's Tag  Post Breader Tag
Leader Products Pty Ltd Unit 4 13 McGowan St POORAKA SA 5095 Australia 08 8262 6722 www.leaderproducts.com.au	

Source: http://www.agric.nsw.gov.au/reader/nlis/beef-news-april04.pdf

FIGURE 7. National Livestock Identification System approved radio frequency identification devices

producer is able to identify when, where, and in what condition an animal reached a processing plant. Of course, this does not provide information about the way the animal was processed, post-processing quality characteristics, and similar information.

It should be noted that questions have been raised by producers about the benefits offered by this system in relation to its costs. The tags cost approximately $3.50 (AUS) and cannot be recycled or recovered by the producer. As a result, the Australian Beef Association, a major producer association, has lobbied for change in the program because of the cost-benefit issue. For example, during the fall of 2004, an unsuccessful attempt was made to remove the board of directors of Meat and Livestock Australia, a government supported producers group that favors the NLIS system (ABC Online 2004). The implications of this controversy for U.S. producers are (1) that a mandated RFID tracking system will likely be costly to producers, (2) the benefits of a system that only provides tracking to the abattoir will offer limited benefits to producers, and (3) involvement and leadership by producers and other industry stakeholders in such a system will be crucial in leading to buy-in by all industry stakeholders.

Radio Frequency Identification in Processing

While RFID at the producer level is predominantly a replacement for conventional ear tagging, there is little precedent for the use of RFID to enhance traceability through the processor. The general feeling among many processors that we contacted for this study was that, particularly in the U.S. market, introducing anything beyond lot-level traceability would needlessly slow product throughput. Further, with much current production using multiple daily lots (i.e., four lots per shift), there exists great enough sensitivity within the current production process to avoid the extremely large product recalls that have characterized disease problems in the past.

Although lot-based traceability is certainly a viable mechanism for controlling recalls, it is somewhat less useful in providing the provenance assurance necessary for effective meat branding. Depending upon the relative size and characteristic structure of a particular meat brand (i.e., lineage, conformity, tenderness, etc.), the lot-based system may not provide a sufficiently efficient mechanism for capturing brand nuance. Further, once BSE testing is certified by the U.S. Department of Agriculture (USDA), there will be an additional imperative for being able to associate meat products with a particular tested animal to fully capture the consumer value associated with testing.

RFID is not necessarily essential to individual animal tracking and hence to brand support, yet it does offer considerable promise toward making fully traceable production possible in larger-scale operations. Given that the key to individual animal traceability resides in the producer's ability to transfer animal information sequentially and accurately to sub-parts of the animal during production, RFID-based tracking systems (coupled with appropriate processing procedures) provide an accurate and reliable automated method of providing that information exchange.

Radio Frequency Identification versus Optical Methods. Optical methods of information transfer, such as bar coding, are popular both in supply chain applications and in retail applications yet offer only limited utility in meat processing. There are two primary reasons for this:

1. *Optical tags require a clear line of sight and proximity to be accurately read*. This is problematic in an often-messy production line, where carcass positions may not easily be uniformly controlled. Even among the best industrial logistics firms, there is a relatively high read failure rate because tags are smudged or torn during relatively clean and uniform processing operations.
2. *Optical tags cannot take on new information*. While new optical tags can be printed with new information and affixed at any point in the production process, this requires significant additional time and a process change to accomplish. The newest generation of writable RFID tags can be embedded in processing carriers and reused repeatedly, taking on new product information during each pass down the line.

Thus, while optical tags can be potentially engineered into a processing system, they are not an optimum solution to individual animal tracking during meat processing because of the amount of extra work they require and because they cannot easily handle updates in product data.

A General System of Radio Frequency Identification in Processing. While there are a number of ways that beef can be processed using RFID, there are two fundamental RFID processing applications that are repeatedly appearing among meat processors:

1. *Gambrel Identification.* A number of the processors that we spoke with and visited use a gambrel embedded with an RFID chip to move large carcass parts through their systems. While this would seem to be a relatively straightforward use of RFID, it is actually a technically difficult challenge. One processor with whom we spoke indicated that the organization had gone through three different gambrel designs before finally achieving one that would work effectively in its facility. The problem with designing an effective gambrel and chip reading sys-

tem is a function of the severe environment in which the system must operate. When there is a carcass on the hook, there is significant biomass that can absorb antenna power and interfere with a signal, while simultaneously there is a significant amount of metal in the gambrel track that can also absorb a signal. Add to all of this the sterilization requirements for gambrels, whereby they are submerged and sterilized several times daily, and a gambrel designer is faced with a real challenge in creating a long lasting and responsive RFID system. In spite of the difficulty, however, processors are able to create systems that work in their specific environments. The gambrel portion of the system's information assimilation is straightforward: information is read (when available) from an animal's ear tag and then passed to the RFID chip (and the broader information system); additional information about date and lot number is automatically appended at this time, and a post-slaughter weight is also automatically passed to the tag and information technology system. Ideally, this information is then also passed to tags as the animal is halved and quartered, with all hooks containing tags and animal information.

2. *Bin or Board RFID.* While the gambrel enables processors to track an animal up to the point of separating the primals (generally speaking), once more specific cutting begins, the hook is no longer useful in tracing. At this point, some method of tracking individual animal parts off the hook is required. If the primals are placed into an RFID-equipped bin, then the individual animal tracking can continue. Pieces that are cut from these RFID-tracked primals can then either be returned to the bin, or placed into secondary bins that pick up identifying information from the primal bin. Although this seems complicated, RFID can make this information exchange relatively simple once it is built into the processing line. While bin-based systems can provide individual animal traceability throughout the entire system, unless cutting boards are fully sterilized between bins, a disease recall will still affect the entire lot. A second method, currently in use in Australia, allows both individual tracking and individual recall. Developed by QED, Ltd., the system involves a processing line in which moving RFID-embedded cutting boards (sterilized between animals) move down the line with information about their primals. Boards are then moved to

> individual meat cutters who perform their operations on the moving board, leaving both value cuts and scrap on the board for later separation and packaging.

Maintaining individual animal identification through the more complex cuts does not necessarily require RFID; as long as part sequences are carefully maintained and correlated with the original animal, full individual tracking can be maintained. Indeed, sequenced distribution can be an important part of an otherwise fully RFID-based system, particularly as parts are moved into individual packages. (Information from the bins or boards is passed into the information system and is correlated with the product's position on a packaging conveyor; when the product is packaged, it is identified with a barcode label containing the product's information.) The schematic in Figure 8 shows an overview of the system.

Case Studies: Radio Frequency Identification Applications in the Processing Plant

It is only recently that RFID has begun to be used within meat processing facilities, and in most U.S. plants its use is still relatively limited in application and scope. One of the primary objectives of this research project was to understand how RFID is currently being used in meat processing facilities, with the goal of identifying trends and opportunities for its use in a wider variety of U.S. beef processing facilities. To understand how RFID technology is being used in meat processing, the researchers visited two meat processing facilities and also consulted with a vender of an RFID-enabled meat processing system. In this section, we document these site visits and the observations and conclusions drawn based upon these visits.

RFID Applications in Meat Processing: The Case of Dalehead Ashton. Dalehead Foods (http://www.flagshipfoods.co.uk/dalehead/) was established in 1969 and is currently the largest independent hog processor in the United Kingdom. Dalehead specializes in supplying packed pork to retailers in the United Kingdom. In addition, the company also supplies pork cuts such as hams to manufacturers for further processing. The company also produces a select number of value-added pork products, such as sausage, basted pork, kebabs, and meatballs. Dalehead operates five facilities in the United Kingdom in Cheshire, Nottinghamshire, Cambridge, Suffolk, and Bristol. In June 2004, the researchers visited the Dalehead facility in Cheshire, Ashton-under-Lyne, and

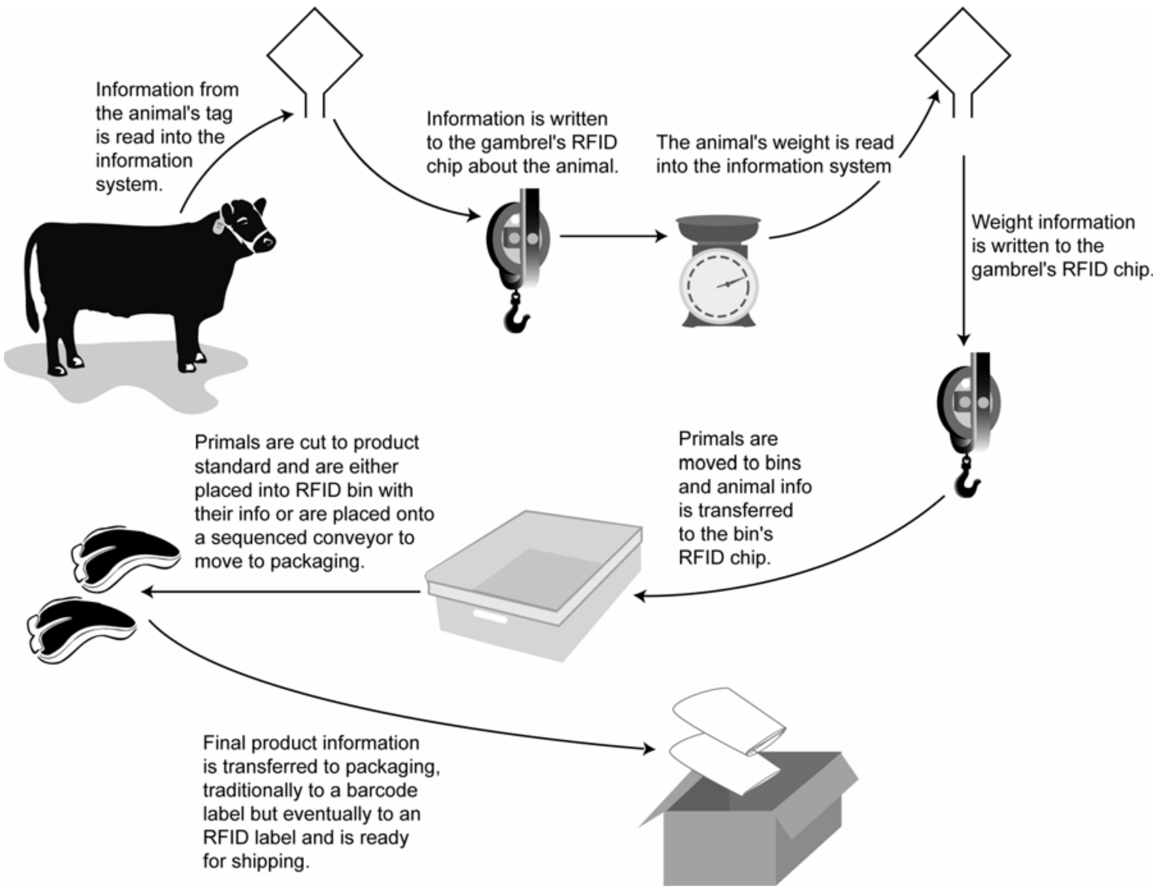


FIGURE 8. Illustration of the fundamental radio frequency identification tracking process

were given a full tour of the facility. The goal of this visit was to observe the use of RFID in this facility, which is limited to tracking whole carcasses and select cuts during the initial stages of processing. The production facility was substantially redesigned about three years prior to our visit. In addition to the construction of a fabrication facility and expansion of capacity for live-hog pens, several enhancements (e.g., introduction of RFID) were made to the abattoir and to several components of the production line.

The United Kingdom requires that hogs be identified with information about the animal's origins and characteristics. These data are maintained with the live hog on ear tags, tattoos, and, increasingly, RFID tags when the animal is brought to the facility (Madec 2001). These data are manually transferred by a technician into Dalehead's information system when the animal is slaughtered. This information is associated with the gambrel by storing an identification number on the RFID tag located in the gambrel

(Figure 9) and recording this identification number in the production information system. The animals are then carried on the gambrel and rail system through the de-hairing and scalding tanks and into the cooler (Figures 10 and 11).

Following the 24-hour (minimum) cooling, the carcass is ready for processing. At this point, identification of individual carcasses is possible since the carcass is still carried by the gambrel containing the RFID chip. After leaving the cooler, the carcass is split and quartered (Figure 12). At this juncture, much of the meat is distributed to cutting stations without further identification or traceability; however, select cuts such as hams are tracked by placing the meat in bins that contain an embedded RFID tag (Figure 13). Information about the product is used to inform meat cutters about how each ham is to be processed during the initial stage of meat processing (Figure 14). The main focus of tracing the carcass to the cutting floor is for quality control, employee accountability, and precision cutting. Once primals are processed, individual pieces of meat are removed from the bins and sorted into aggregate bins by type, grade, and cut. As a result, individual animal traceability stops at the cutting floor and no information about the individual

FIGURE 9. Gambrel radio frequency identification assembly

FIGURE 10. Hog carcasses in scalding tanks

FIGURE 11. Hog carcasses on gambrels in the cooler

FIGURE 12. Carcass splitting and quartering

FIGURE 13. Tracking bins with hams and parts

FIGURE 14. Computer monitors instructing meat cutters about how to process each ham

animal is carried through the system or associated with the final product. Discussions with managers at Dalehead reveal that there is interest in tracing select cuts further through the production process; however, there is currently insufficient demand for information about animal characteristics and history to justify the investment in the technology and substantial plant redesign required to enable full trace-back to the individual animal.

Radio Frequency Identification Applications in Meat Processing: The Case of Creekstone Farms. Creekstone Farms Premium Beef (www.creekstonefarms premiumbeef.com) is a small beef processor located in Arkansas City, Kansas. The Creekstone plant was purchased in 2003, following the bankruptcy of the previous owner of the facility, Future Beef. The $94-million, 450,000 square-foot processing plant was designed by Future Beef to support modern beef processing techniques and by using state-of-the art processing and information technologies. For example, Future Beef won the Food Engineering's Plant of the Year award in 2002 for the design and construction of the facility (see Higgins 2002). The plant was initially designed to process approximately 1,600 head of cattle a day and to integrate several processing functions beyond meat processing and packing. The plant includes facilities for pet product production, hide tanning, and fabrication. Currently, in addition to the primary function of meat processing and packing, Creekstone runs the meat fabrication facility, but the plant has idled the pet products and tanning facilities.

The researchers were impressed by the forward-thinking perspective held by the management team at Creekstone Farms Premium Beef. Several innovative programs have been undertaken by the firm with the focus on offering high-quality products for domestic and foreign consumers. For example, when Creekstone purchased and retrofitted the plant, the focus was on producing a branded line of certified Black Angus beef. Creekstone's beef is certified by the USDA's Agricultural Marketing Service (AMS) by having a USDA grader visually inspect all cattle to certify they meet AMS's quality and certification standards. Recently, Creekstone introduced a "Natural" Black Angus Beef brand, which certifies that the cattle in the program have been produced without supplemental growth-promoting hormones, without antibiotics, and raised on a vegetarian diet since birth. Creekstone managers indicated that special attention is paid to sourcing beef from quality producers and that information about the quality and consistency of the cattle provided by producers is used in future purchasing decisions.

When Creekstone purchased and retrofitted the plant, it also developed an innovative plan for testing all of the cattle processed through the plant for BSE. The focus of this effort was to certify BSE status of its meat products for both domestic and foreign customers such as the Japanese. Creekstone invested approximately $500,000 in developing a BSE testing laboratory that would have the capability of testing and certifying the BSE status of each animal processed at the facility. However, in the spring of 2004, the USDA refused to allow Creekstone to conduct animal testing by refusing to authorize the sale of the BSE testing kits (Steward and Fielding 2004). As a result, Creekstone currently operates the plant at much less than capacity. For example, the plant is run only four days per week and recently the plant has had to lay off 150 employees (Hegeman 2004).

Creekstone currently tracks animals in a similar manner to the way hogs are tracked at Dalehead in the United Kingdom. After the animal is killed, the carcass is attached to a gambrel that contains an embedded RFID tag. Information about the animal's characteristics are written to the tag and carried through processing until the carcass is halved and quartered. The information is used to capture information about each animal's grade and fat characteristics so that this information can be used to inform sourcing decisions related to particular producers. Unlike the Dalehead operation, however, Creekstone does not use RFID-enabled bins to carry information about the animal to the cutting floor. Discussions with the management team at Creekstone indicate that they have an interest in working toward full traceability, particularly if they can identify a market niche for a beef product that can be traced to the farm. As with the Dalehead facility, the plant would need to be retrofitted and the cutting floor redesigned to accommodate the use of RFID in subsequent stages of processing.

Radio Frequency Identification and Branding: Some Conclusions

While RFID does not create a brand per se, it clearly does provide a mechanism to maintain an information set about an animal that can include value-adding information associated with a brand. Clearly, producers and processors have been able to develop branded products without RFID, but RFID holds the promise of providing better and more efficient tracking of brand information throughout the processor's system.

In addition to providing processors with more options for brand throughput in their facilities, familiarity with RFID will help producers who supply Wal-Mart or other RFID-requiring customers (such as the Department of Defense). RFID in packaging and shipping is remarkably complex, and it is much easier for companies with process-RFID to accommodate these evolving standards.

The Retailers' Perspective

Ultimately, the value of any branded product must be apparent to retailers in order to develop consumer brand recognition and preference. We spoke with executives from large grocery retailers in both the United States and the United Kingdom about the value of traceability in their consumer markets, along with the relative importance of branding of meat more generally.

As might be expected, the U.K. experience with traceability is much more tightly linked to concerns about BSE and other diseases, than is that of the United States. Our contacts in the United Kingdom indicated that country of origin information, in particular, was very important both in the United Kingdom and on the continent as well. Interestingly, while the country of origin information in Europe is designed to offer consumers health and safety assurances, there is also a clear subtext of nationalism in the way that the country of origin information is presented. Most of the national origin information is not relevant in the U.S. market, at least not yet, according to our U.S. contacts. A large-scale BSE contamination, particularly if it is from off-shore cattle, will quickly shift both consumer attitudes and the legal reporting requirements imposed upon U.S. processors (National Identification Development Team 2003).

What is of interest to U.S. retailers, as well as to their European counterparts, is the increasing value of de-commoditized meat products. Consumers already familiar with branded cheese and wines appear (at certain income levels) to also favor branded meat products. Both U.S. and U.K. retailers report that branded meat products are doing very well, and there appears to be room for further brand differentiation. No one is precisely sure what the differentiating characteristics will be, but retailers in both countries agree that an assurance of an individual meat product's provenance may be an important addition to an existing brand, or the basis of a branded product in itself. The Creekstone Farms experience provides an excellent example of this expansion of branded product; Creekstone began its brand differentiation with its Angus beef and then later added a second branded product around its organically raised beef.

The Importance of Integrators

The implementation of RFID systems in meat processing is a complex undertaking, and as we talked to processors that either have undertaken RFID-based systems or are considering doing so, it became abundantly apparent that the assistance of a system integrator is essential to the development of a well-functioning process. The RFID portion of the traceability system, while challenging to engineer, is not nearly as complex as the information technologies that undergird the RFID readers. Effective RFID-based systems require a variety of server and database systems, as well as complex data networks to gather and analyze the data generated during the production process.

We worked closely with QED, Ltd., a United Kingdom–based integrator, during the course of our research and were impressed with its full-spectrum integration of processing equipment, information systems, and RFID technologies. By engineering traceability in from the design and planning stages forward, processors using systems like QED's can implement RFID with maximum impact.

Endnote

1. RFID tags can also be injected subcutaneously. Injectable tags are encased in a small glass capsule that can be injected below the skin. While these tags are in widespread use for a number of pet identification products and even for human identification systems, most national regulatory systems discourage the use of these tags because of concerns that tags may accidentally contaminate finished animal products.

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