Tracking Pork from Pen to Plate

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▪ Introduction

The pig industry has been dramatically successful in maintaining its competitive position through the early deployment of technology in the form of genetics, nutrition and husbandry. In a changing world that brings new risks to food production, the pig industry must respond to increasing public awareness of safety. As margins fall and some of Canada's traditional advantages in pig production are eroded, the industry must find new ways to differentiate its products and protect against the risks of disease. This paper reviews the need for traceability in pork production, and describes the initiative on DNA traceability now being adopted by Maple Leaf Foods.

▪ Why do we need traceability?

It is time to recognize that the responsibility of the pig industry goes well beyond the physical form of the product. Foremost, there is public accountability for food safety. As medical knowledge grows, there will be increasing responsibility for human dietary health. There will also be responsibility to defend the various claims that might add value to the finished product, involving for example "high welfare, organic, barley-fed, omega-3, animal protein-free or antibiotic-free". The need for traceability arises from the following:

- Increasing focus on food safety.
- Need for zoning in the event of epidemic animal disease (eg foot and mouth).
- Tracking the source of drug residues.
- Recall in the event of contamination (eg pesticides).
- Feedback to allow quality control.

- Protection against bioterrorism.
- Marketing the 'Canada Brand' worldwide.

Today the demand for traceability provides a golden opportunity for Canada to *differentiate* its products. The industry is relatively small in terms of key players, communicates well, and already has high standards of production and health. In the wake of BSE and foot and mouth, Canada will also need to demonstrate to its export customers that it could maintain supply of product in the event of a major disease outbreak. Reliable tracking systems would be a key requirement for zoning that would allow unaffected geographical regions to continue exports.

Traceability, *as a key point of difference,* can therefore be a major competitive advantage for Canada, as its cost advantages are lost to subsidies and gains in efficiency in other countries. At Maple Leaf Foods traceability forms an integral part of its commitment to food safety, of which the major components are *prevention*, *preparedness*, and *proof,* through investment and innovation.

Table 1 Examples of some tracing methods

Live animal	Visual ear tags RFID ear tags Bar code ear tags Tattoos Antibodies by injection
Slaughter & processing	Paper bar codes RFID tags Batch markers Smart trays and gambrels Molecular bar codes Quantum dots Microwave radar
Retail & distribution	Machine readable codes
Consumer	Numerical codes Public access website

■ Tracing Methods

A variety of options exist for tracing (**Table 1**). In the live animal, ear tags and tattoos are cheap and easy. Radio Frequency Identification (RFID) tags and transponders are very expensive and can be unreliable. Subcutaneous transponders raise questions of welfare and the risk of entering the food chain. Some elegant ideas such as injecting a unique antigen into the pigs from each farm to give readable antibody in the meat may find even less favour with the consumer.

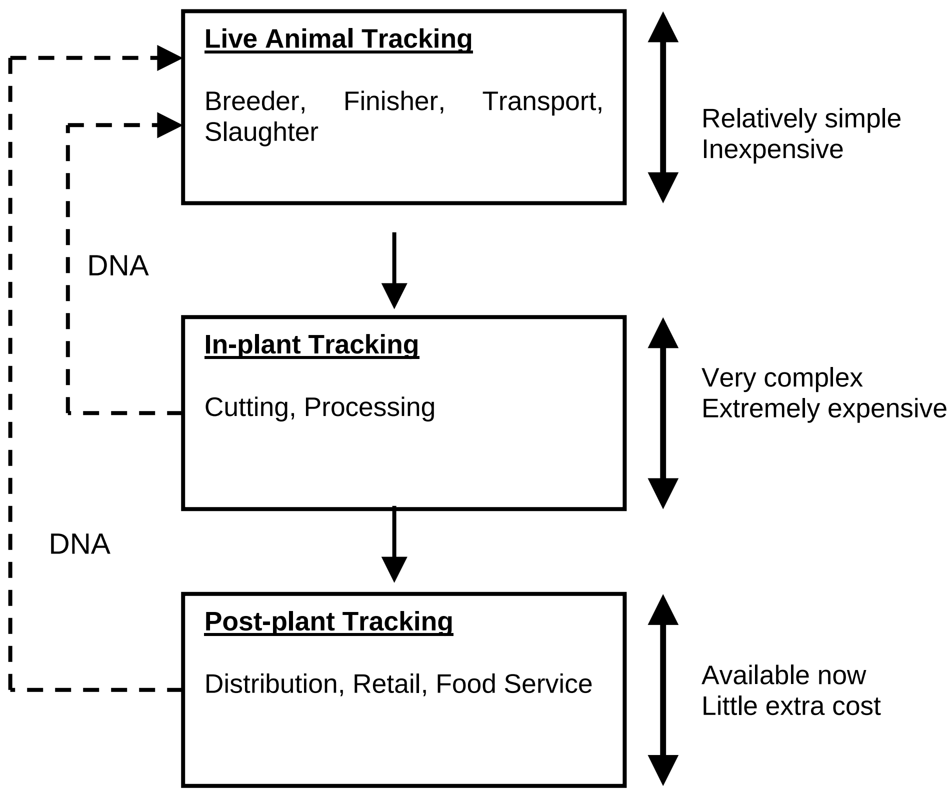
Inside the slaughter and processing plant, the simpler options include paper bar codes that can be read and reprinted at each point where a cut is divided into smaller portions. Batches can be identified by some form of "marker" or interruption that passes through all lines within the plant. More expensive options include RFID or "smart" credit card type systems. In the future, it may be possible to create some form of spray-on bar codes that might identify a particular cutting line or hour of the day. The main requirement is that any code must be readable very quickly. One long-term idea is to read innate DNA sequences using some form of high-energy radiation.

■ What to trace?

The ultimate objective will be to track every piece of meat from plate to farm through each step in the value chain: retail, distribution, processing, slaughter, production, nutrition, breeding and genetics. The value chain can be divided into three components: live animal, processing, and distribution and sales (**Figure 1**). Although it has yet to be implemented in most countries, live animal tracking using tags and tattoos is relatively easy. Many countries are already arranging to track slaughter pigs on a batch basis. Similarly tracking the packed retail product is relatively easy, and in many cases the necessary machine-readable labels already exist.

Tracing pork through slaughter and processing is an order of magnitude more complex, since each carcass may be broken into hundreds of items through several different production lines. Hams, loins and wieners may each be manufactured at different plants. Both the pathway and the technology are complicated in a high-speed and often-dirty environment. For a high-speed slaughter plant, the cost of introducing full traceability could be as high as $15 million dollars with a further $4 million development costs, resulting in an impossible $4.50 extra cost per carcass.

Figure 1. Role of DNA in the three major tracking steps that make up the pork value chain



▪ Role for DNA Tracking

In an evolution of forensic genetic fingerprinting, DNA tracking can link meat back to the farm of origin, bypassing the expensive step of tracking through the plant. The attraction of DNA is that it requires little capital investment, and uses existing laboratory services. DNA typing is very accurate, and relatively free of the human error compared to hand-labelling systems. It can therefore be used to audit and verify other tracking systems that are vulnerable to human error. DNA can be detected in cooked as well as fresh product, and if necessary in stomach contents.

Maple Leaf Foods therefore plans to introduce traceability in three stages:

- DNA tracking to the farm, with live animal tracking to the plant.

- Tracking through the slaughter plant and processing.
- Public access through the Internet (if appropriate).

In the short-term, much of the benefit from traceability is to identify the farm of origin and the slaughter plant. The first stage will therefore be to introduce DNA tracking. By connecting with live animal tracking in batches, this will identify the slaughter plant. While this is introduced, the next stage will be to comprehensively research systems for tracking through the slaughter and processing plants. The objective will be to introduce tracking through the plant as soon as it is cost-effective. The third stage will be to meet market needs for transparency, and if necessary for the competitive success of the pork industry, to provide consumer access through product codes and a website.

▪ DNA Tracking Systems

A number of genomics companies are developing DNA tracking systems for meat. The tracking systems exploit natural variation in the DNA code, which is made up of just four units or *nucleotides* (A=adenine, C=cytosine, G=guanine, T=thymine). The systems fall into two types: the first uses restriction fragment length polymorphisms (RFLPs), and the second uses single nucleotide polymorphisms (SNPs or "snips").

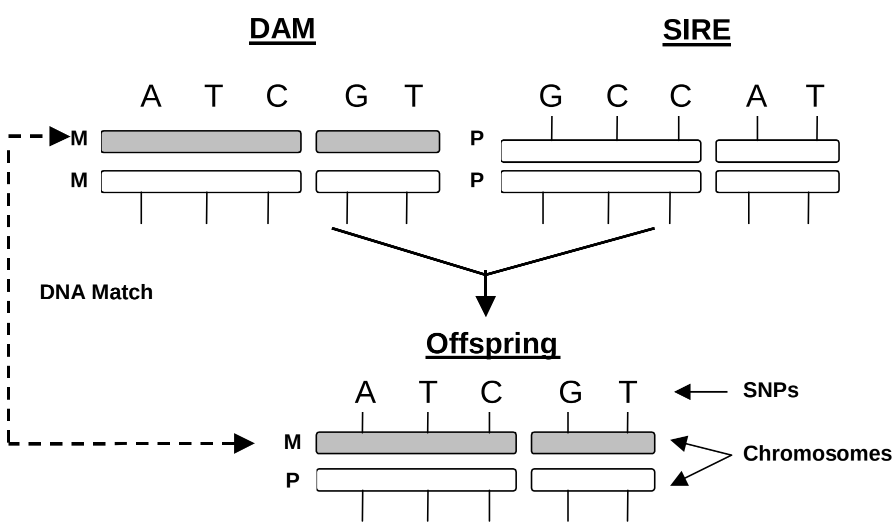
RFLPs are fragments of DNA of varying length that can be separated by electrophoresis. They are created by an enzyme that cuts the DNA at a particular recognition site. They identify repetitive sequences of DNA that are naturally variable, so that for example some individuals may be '-ACACAC-' while others are '-ACAC-'. The advantage is that many are known already. The disadvantage is that there may be many fragments of different lengths in a population, and that the different variants can therefore be difficult to identify without error.

SNPs are single units of the code that vary naturally, so that some animals may be A while others are C. The halothane C to T mutation is actually one such SNP. Unlike RFLPs, there are usually only two variants at a site, and there is no reliance on interpretation. SNPs are therefore like a digital code. The disadvantage is that SNP discovery is expensive, but SNP maps and libraries are being established. With their greater precision, SNPs are therefore the preferred solution for the long term.

▪ Maple Leaf Research on DNA Tracking

In December 2002 Maple Leaf Foods placed a contract with Pyxis Genomics Inc to identify a panel of SNPs that can trace meat back to the mother of the slaughter pig. SNPs on the maternal chromosomes in meat are matched back to the mother (**Figure 2**). Matching to individual slaughter progeny would be too expensive. Terminal sires give no information on the farm of origin due to the use of AI across a large number of locations.

Figure 2. Tracing from meat to farm via the dam, using single nucleotide polymorphism (SNP) DNA markers



Tells the farm and date of birth

The DNA panel is expected to consist of 200-300 SNPs. The number and cost will be minimized in two ways. First, the SNPs will be selected in groups that are close together on the same chromosome. Second, maximum use will be made of mitochondrial DNA that is maternally inherited only in the cytoplasm of the egg. This occurs as a single strand (*haploid* instead of *diploid*) with no recombination and very little mutation.

Tracking then works as follows. As each replacement gilt enters commercial production, a blood sample is DNA-typed for the SNP panel and the identity information entered in a database. Meat is matched to the mother's identity, which indicates the breeding farm and date of birth of the progeny. A batch live animal tracking system will then link to the nursery, finisher, and from there to transport and the slaughter plant.

The live animal tracking system is thus an essential and complementary part of DNA traceability. The trail stops at delivery to the slaughter plant, but at Maple Leaf certain prime products will almost certainly be tracked right through to the customer.

▪ Cost of DNA Tracing

Today the cost of DNA typing a single mother or meat sample is expected to be around $35.00. If a sow produces 70 market pigs in her lifetime, the cost is around 50 cents per carcass. Allowing 50 cents for collection and administrative costs, the total is $1.00 per carcass. If gilts are typed on entry to the herd, their first progeny will be slaughtered more than eight months later. In view of the long lead-time, large batches of blood samples can be accumulated to take advantage of economies of scale for DNA typing.

The largest cost comes at the start of the scheme when the existing sow population is DNA typed. After that, only herd replacements are typed, so annual testing costs fall to around 40% of the start-up cost. For example it would cost around $80 million to type all the 1.2 million sows in Canada, but the annual cost thereafter would be only $35 million. If the opportunity arises, it will be worth typing all the AI boars in Canada. This may reduce the number of SNPs required to discriminate among dams, and therefore lower the total overall cost.

Within three years the cost of high speed SNP typing is expected to come down to around $6.00 per dam, or less than 10 cents per carcass. It will make sense therefore to introduce traceability in the very high value markets first, and phase in lower margin markets as the costs descend.

▪ Rewards for Traceability

How might the cost of DNA traceability be recovered? Either through added value to the end product, or as a cost of increasing or even just retaining market share. Since traceability adds cost to an industry with low and cyclical margins, it is important that the costs and rewards are shared among all steps in the value chain: genetics, production, nutrition, processing, and distribution.

This is the rationale for the *vertical coordination* approach adopted by Maple Leaf. Vertical coordination is not common ownership or even control; it is coordinated action to maximize overall profitability and share the rewards.

Thus the producer can be more than compensated for the additional costs of typing the sow herd. It must be emphasized that the objective is not to apportion blame to the producer for any errors that occur, but to provide more confidence in the Canadian pork value chain, as a point of difference compared to our competitors.

▪ Genetic Improvement

The ability to track to the dam of slaughter pigs has valuable implications for genetic improvement. The parents of meat that is either defective or of excellent quality can be identified. This can track back to families in the nucleus that should be selected as parents of the next generation. Individual SNPs within the traceability panel may also show associations with performance and meat quality traits. In this case the SNPs would most probably be acting as genetic markers for nearby genes affecting production traits (*quantitative trait loci* or QTLs). Using current mapping techniques this can lead to the identification of SNPs actually within the functional gene, so-called *quantitative trait nucleotides* (QTNs). In the purebred nucleus lines, the QTNs then allow direct selection on performance traits.

▪ Timetable and Next Steps

Pyxis has completed production of the Maple Leaf SNP panel. Early in 2004 traceability will be selectively introduced into certain Maple Leaf plants. After a six month trial period it is expected that the Maple Leaf SNP panel will be made available to the whole of the Canadian pig industry. When introduced into a plant, of course all suppliers to that plant, both Maple Leaf's own Elite Swine producers and independent suppliers, will need to have their sows typed. It is a basic requirement that the Maple Leaf traceability database will link into any present or future system of national traceability in Canada.

Provided the right vehicle exists, DNA traceability can play a key role in quality assurance. For example Maple Leaf's vertical coordination strategy has allowed the adoption of Six Sigma at all levels of the value chain. Pioneered by Motorola and GE, and widely used in the aviation industry, Six Sigma is a formal analytical approach to the control of unwanted sources of variation in meeting customer requirements. Together with Six Sigma, traceability takes quality control and product consistency to a new level.

■ Conclusion

Traceability offers a key point of difference for Canadian producers. The ideal goal for the Canadian pig industry will be to track every step of production from genetics through to the plate. Tracking every piece of meat through modern high-speed plants represents a major challenge. In the meantime DNA offers a way of tracing meat back to the farm and circumventing the plant. Due to its high accuracy and use of genetic information, DNA can be used to audit other tracking systems.

Maple Leaf and Pyxis Genomics have developed a panel of DNA single nucleotide polymorphisms. It is planned to introduce traceability using this DNA panel at selected plants during 2004. At the same time, research will continue to develop systems for tracking through the plant. The DNA panel will be used for quality control to track sources of substandard product. It will also be used to identify genetic markers for meat quality traits that can be used for selection in purebred nucleus populations. We hope to make the DNA panel available to the whole of the Canadian pig industry.