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Traceability

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TRACEABILITY FROM FARM TO CONSUMPTION

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Background.

The integrity of the food chain is now a dominant issue for consumers, and therefore also for producers, processors, retailers and the food service industry. At the centre of any response is the requirement for reliable product traceability.

This paper describes the application of DNA identification technology as a method for providing traceability in the beef industry. As DNA is found in all tissues, the product can act as its own label. Using this method it is possible for a meat processor to assure its clients and consequently the consumer, of the integrity of the beef supply chain.

A full scale industrial trial of DNA based traceability was conducted from April-November 1998. The method has since been implemented commercially. It was found that genetic identification could be effectively used as an analytical audit tool. In parallel with effective product batching, the DNA approach establishes a direct link between meat at point of sale and the exact animal of origin.

Introduction.

BSE precipitated a crisis of confidence in the meat industry. While beef consumption in Europe had been declining slowly, the BSE crisis in 1996 caused a sudden drop of some 15-25% in European markets. BSE created an environment that demanded new measures to guarantee the integrity of the product and the production chain.

In response to consumer demands for meat products of known origin, many processors and retailers initiated quality assurance schemes. Specific elements of these schemes have provided the basis for various labelling claims: free-range, grass-fed, hormone-free, BSE-free, Certified Angus etc. Integrity is a critical component of such claims.

Reacting to consumer pressure, the regulatory agencies have taken a strong interest in the integrity of the meat production chain. This is most clearly demonstrated by the implementation of the EU Beef Labelling Regulations (1), where it is now required that a direct link is established between meat at point of sale and the animals of origin.

As it is during carcass transformation that traceability to the animals of origin is often lost, it is the beef processing industry which is faced with the challenge of fulfilling the regulatory requirements. In most cases, the response has been to tighten production systems and to introduce or improve internal batching arrangements.

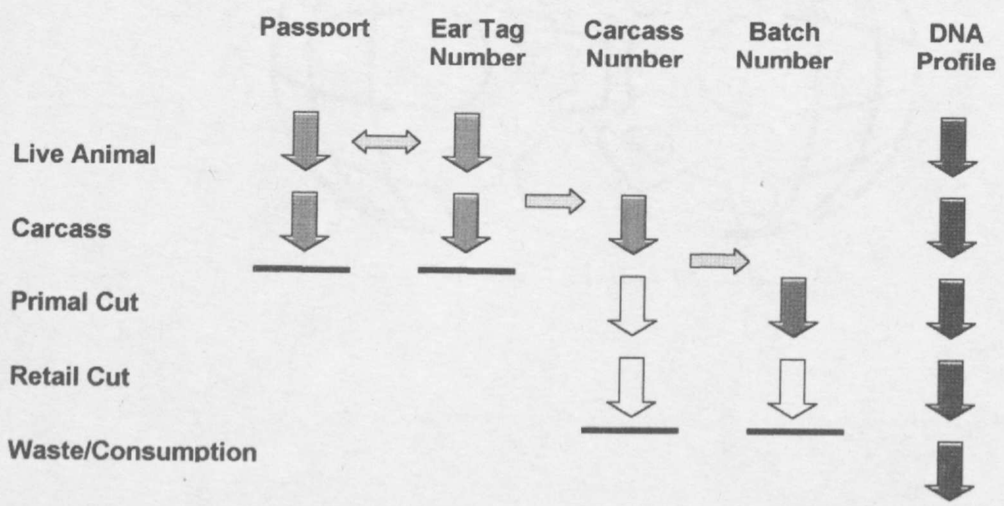
A beef carcass of 350 kgs is at present worth over 1,000 euros. By the time it is sold to the end user, the consumer, its value has risen considerably. If this were a manufactured product of the same value, it would be regarded as entirely reasonable that it should carry a serial number which linked back to full array of information about its origins and assembly. The meat carcass is different in that it is disassembled before sale. What began as an entire carcass, and before that, an intact animal, ends in the form of 500 or more retail pieces. The challenge of providing a secure form of identity through this process is therefore a formidable one.

It is against this background that we have developed the application of genetic identification techniques as a method for improving the reliability of traceability and verifying the integrity of point of sale information.

Options for traceability.

The possibilities for implementing traceability in the meat industry, using the full range of available technologies, are shown in Table 1. In the European beef industry, now processing some 25 million animals per year, virtually every animal arrives at the slaughter point accompanied by an official passport document. This is linked to the ID number registered for the animal. The animal may carry this number in a numeric ear tag, an electronic ear tag, an electronic rumen bolus, a barcode, or a tattoo. At slaughter, the carcass receives a factory carcass number which is normally cross-linked to the animal ID number. Thus, as long as the carcass remains intact, traceability is possible up to that point.

Table 1: Possibilities for implementing traceability



Once the carcass is cut, the problem becomes progressively more difficult. In some customer assurance schemes, carcass numbers are replicated on wholesale cuts. More frequently, the identity of the batch of carcasses may be preserved through the wholesale cutting stage. In very rare cases, and at considerable expense batch identity, and even individual animal identity is replicated on retail cuts. Considerable work is being devoted to improving the technical efficiency and reliability of the various numbering, reading, batching and recording of information through this complex product chain. (2). However, against the reality that a beef carcass ends up as some 500 retail pieces in different places and at different times, no generally satisfactory solution has emerged.

All of these methods have relied on the imposition of some unique identity on the animal and its products. In reality, each animal already has a unique in-built identifier in the form of the genetic code.

Principles of Operation.

Any piece of meat, within the scope of application, can be traced to the individual animal of origin. The system is based on the fact that all biological tissues contain DNA and that the DNA of each animal is unique.

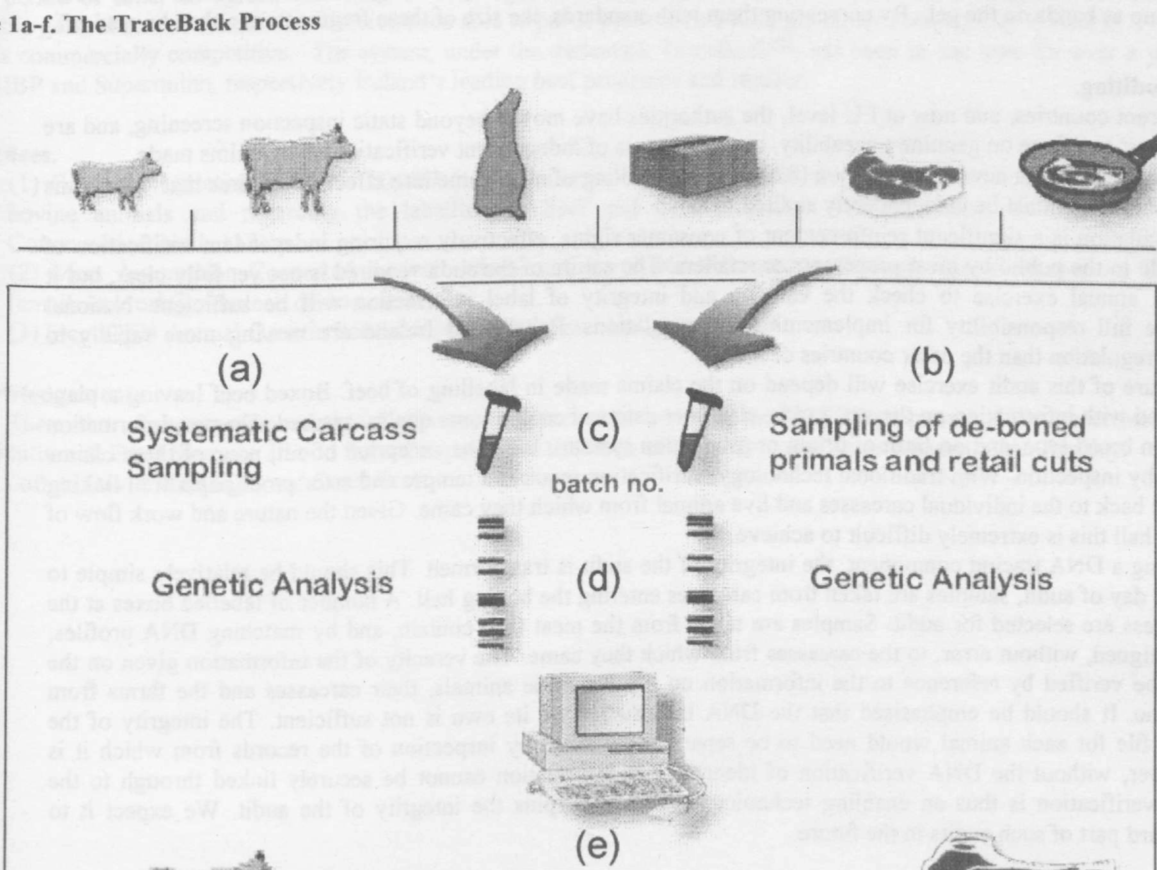
A biological tissue sample, termed the Reference Sample, is taken from each carcass at a point prior to the loss of the individual animal Identity. The Reference Sample is identified with a code that links it to the individual animal identity and the sample is maintained in a sample archive (Figure1a). The storage period can vary but is typically a multiple of the normal recommended usable life of the meat product.

Further samples are routinely taken from a defined proportion of meat derived from the source carcasses, these are termed Verification Samples (Figure 1b). A critical requirement is that the existing traceability system provides a link between the meat from which the Verification Samples have been taken and one or a number of Reference Samples (Figure 1c). The level and structure of Verification Sampling is typically agreed between the meat processor and retailer, where an opinion as to the suitability of the proposed plan should be obtained from the Competent Authority or appropriate EN45011 accredited third party auditor (Beef Labelling Regulation 820/97).

Reference Samples and their associated Verification Samples are processed through the DNA Identification Analysis system (Figure 1d). For each Reference and Verification Sample an animal specific DNA Profile is generated. Comparison between the Reference and Verification Sample DNA Profiles is made (Figure 1e). This comparison enables individual Verification Samples to be matched to an individual Reference Sample. It is inferred that the meat from which the Verification Sample was taken is derived from the same carcass as that from which the Reference Sample was taken (Figure 1f). It is then inferred, within specified limits, that any piece of meat can be traced to the individual animal of origin. The requirement that an existing traceability is in place allows its performance to be monitored in parallel.

The performance of Reference Sampling and DNA Identification Analysis is reported on an agreed basis.

Figure 1a-f. The TraceBack Process



Technical background.

In 1953, James Watson and Francis Crick discovered the double helix. They decided that the genetic material had to be made up of long strands of a molecule called DNA, which had been discovered about ten years earlier. Furthermore, they concluded that these strands of DNA were double strands, running in parallel, and crosslinked at regular intervals. The structure therefore looks like a ladder. The final element in their theory was that this ladder of DNA is twisted into a spiral form - hence the name double helix.

Each unit of DNA is called a base, and there are only four types of base. The DNA code for any individual is replicated in every one of that individual's cells. The full DNA set is incredibly large - in cattle, for example, it is approximately 3,000 million units (i.e. bases) long. To get some idea of the scale involved, consider typing the full genetic code for one animal, one letter at a time. The typed message would be 7,500kms long.

Not all of this DNA is equally important. The most clearly important segments are those that directly control the development and functioning of the organism. These segments are called genes. They generally make up less than 5% of the total DNA.

This model for the structure of the genetic material has stood the test of time, and is now universally accepted as true. The next step was the discovery of other molecules, called enzymes, which do various things to the DNA. Some can break a string of DNA, others stitch it together. Others again cause the two parallel strands to separate from one another while further enzymes help single strands of DNA to synthesise new partner strands. With these enzymes, it is now possible to cut, splice, separate and duplicate DNA.

The chance discovery in 1982 of heat-stable enzymes in bacteria living in very high temperature conditions around volcanic vents on the ocean floor led eventually to the development of a new technique, called PCR, which enabled the whole field to make a leap forward. In essence, PCR is very simple. A particular piece of DNA is first heated to 95 degrees, which causes the two DNA strands to separate. The temperature is then reduced to 54 degrees, and an enzyme causes each strand of DNA to pick up short matched pieces of DNA (called primers) at each end. Finally, the temperature is increased to 72 degrees, and a second enzyme called polymerase becomes active, causing the DNA strand to replicate itself between the two primers. This process can be repeated many times, each time doubling the amount of the original DNA fragment. Hence the name, Polymerase Chain Reaction, or PCR.

Two supporting pieces of technology are also required. The first is the ability to synthesise the short primer sequences. They are used to home in on the particular piece of DNA of interest, and to lift it out from among the billions of DNA units, for amplification using PCR. The second piece of technology is an old one. Just as blotting paper soaks up a liquid, so any solution containing fragments of DNA will migrate through a special porous gel. The bigger pieces of DNA will settle out early on, and the smaller pieces will be carried further along in the gel. These different sized DNA fractions show up as bands on the gel. By comparing them with standards, the size of these fragments can then be read off.

Compliance auditing.

In different countries, and now at EU level, the authorities have moved beyond static inspection screening, and are beginning to insist not alone on genuine traceability, but on systems of independent verification of all claims made.

Since April 1 1998, a new EU regulation (820 / 97) on labelling of meat came into effect. It requires that "all claims made in meat marketing must be independently audited."

This regulation is a significant reinforcement of consumer rights, effectively requiring independent verification of any claims made to the public by meat processors or retailers. The nature of the audit required is not yet fully clear, but it seems as if an annual exercise to check the veracity and integrity of label information will be sufficient. National authorities have full responsibility for implementing the regulations. Britain and Ireland are moving more rapidly to implement this regulation than the other countries of the EU.

The nature of this audit exercise will depend on the claims made in labelling of beef. Boxed beef leaving a plant might be labelled with information on the sex, grade, slaughter date and cut. In some quality assured schemes, information may be given on breed type, and on farm of origin or production system. With the exception of cut, none of these claims can be verified by inspection. With traditional technology, verification requires a tamper and error proof paper trail linking the cuts of meat back to the individual carcasses and live animal from which they came. Given the nature and work flow of modern boning hall this is extremely difficult to achieve.

By adding a DNA tracing component, the integrity of the audit is transformed. This should be relatively simple to achieve. On the day of audit, samples are taken from carcasses entering the boning hall. A number of labelled boxes at the end of the process are selected for audit. Samples are taken from the meat they contain, and by matching DNA profiles, these can be assigned, without error, to the carcasses from which they came. The veracity of the information given on the label can then be verified by reference to the information on file for these animals, their carcasses and the farms from which they come. It should be emphasised that the DNA information on its own is not sufficient. The integrity of the information on file for each animal would need to be separately checked by inspection of the records from which it is derived. However, without the DNA verification of identity, this information cannot be securely linked through to the product. DNA verification is thus an enabling technology which underpins the integrity of the audit. We expect it to become a standard part of such audits in the future.

Commercial traceability.

For any meat company or supermarket group with serious ambitions to compete for market share or to earn a premium for its products, compliance testing alone is insufficient. The retailer may in addition wish to offer his customers a guarantee of product traceability. To enable such a guarantee to be made, the meat company must also be able to offer traceability. In addition, the capacity to verify that product delivered to the supermarket is precisely what was contracted for with the meat company can be a valuable assurance for both parties.

Such commercial traceability clearly forms part of a wider quality assurance guarantee scheme. There is no point in providing a guarantee of traceability of meat to animal of origin unless the supply company is in a position to provide information about that animal. Conversely, if a meat company is investing time and money in a contract procurement system which enhances the value of the product, much of the benefit of that investment may be lost unless there is some independent verification that this is in fact the product being supplied through the distribution chain.

The straightforward solution to this would be to do a DNA profile on every animal involved in a particular contract. A sample could be taken at any point up to the breaking of the carcass. Once generated, these profiles could go in a computer database. Any piece of meat could then be traced to its carcass of origin by doing a second DNA profile and matching this against the computer files.

Such a system, involving the generation of a DNA profile for every carcass, would be rather expensive, since the unit cost of a DNA profile is in the order of 25 euro. However, it could be justified for some very high value products, such as baby food.

In searching for ways to make DNA traceability affordable in the context of regular commercial beef supply, we have developed a system where full guarantees of traceability can be given, but where much of the analysis is avoided. This system, which we have called TraceBack ™, also begins with the taking of a biological sample from every carcass. These samples are identified with the carcass number, which links in to the ear tag number and the full array of information on that animal. The samples are prepared for analysis, and stored in systematic batches. The expensive part of the process, the DNA profiles, is not done at this stage. The product is then distributed in the normal way. In any subsequent stage, up to the point of consumption, any individual piece of meat can be traced to the animal of origin. In the case of such a query, a DNA profile would be done on the meat in question, the stored samples relating to the batch or batches involved would be retrieved, DNA profiles would be done on these, and the queried sample would be matched against this array.

This system offers the best of both worlds. A full unequivocal guarantee of traceability can be given with all product. At the same time, the cost of doing large numbers of DNA profiles is avoided. The overall cost will vary with the structure of the contract, and in particular with the nature of the batching. We also feel that even if there were no queries over a period of time, an agreed low level of interrogation of the system should be done on a routine basis. For a reasonably general sets of conditions, we have been able to put in place such a fully guaranteed traceability system at a cost which is commercially competitive. The system, under the trademark TraceBack™, has been in use now for over a year (3) in AIBP and Superquinn, respectively Ireland's leading beef processor and retailer.

References.

(1) Council Regulation (EC) No 820/97 (1997) Establishing a system for the identification and registration of bovine animals and regarding the labelling of beef and beef products. Official Journal of the European Communities, No L 117/1

(2) Meat Automation Concerted Action: Adoption Control and Information Tracing. EU Commission, 1998. (email: koorosh@culmtech.demon.co.uk)

(3) IdentiGEN Animal Genetic Services. (website: www.identigen.com)

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