Science Media Centre of Canada

Tracing Livestock with Genomics

Where does your meat come from? How do you know? A quick glance at the label on a T-bone steak purchased in your local grocery store might give you the country of origin of the product, perhaps even the province. But can you be sure? And what if you wanted to trace it to a particular farm, or a particular animal?

Customers are increasingly concerned with the origin and quality of the food they buy; for example, they might like to know whether it was raised with or without the use of antibiotics, whether it's certified Angus beef, or whether it comes from within 100 km of where it was purchased. While some retailers endeavour to provide this information, the complicated supply chain can make it difficult to trace exactly where that meat came from. In 2013, Irish and British customers were shocked when new tools used by food inspection agencies showed that burgers labelled as beef contained pork or even horse meat[1].

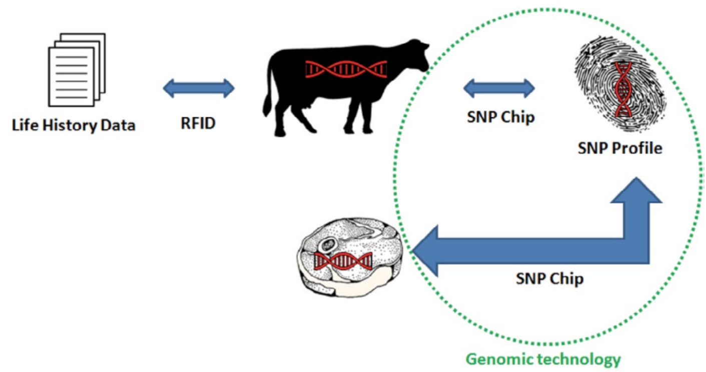
These new tools take advantage of genomics, the branch of science that deals with the genetic blueprint of an animal, as encoded in its DNA. It allows us to quickly and easily obtain DNA sequences from an animal and compare them with a reference or database. Because it provides definitive information on whether a given tissue sample (e.g. a burger) matches another (e.g. a tissue sample taken at a slaughterhouse) the field of genomics can provide customers with clear proof of where their food came from, as well as added assurance that it's safe to consume. As for producers and retailers, the ability to differentiate their products based on location, methods of production, breed and other factors opens up new possibilities for increasing the economic value of their product.

Tracing animals vs. tracing meat

The Canadian Cattle Identification Program began in the late 1990s with the goal of containing and eradicating animal disease. As of July 1, 2010, all cattle in the program must be tagged with an approved radio frequency identification (RFID) tag prior to moving from their current location or leaving their farm of origin[2]. The magnetic tag can be read remotely with an electronic sensing device, and the ID number encoded on the tag is linked to key information about the animal, including when and where it was born, any diseases it has contracted and/or been treated for, vaccinations, ancestry, feeding, etc. In other words, everything you might want to know about an animal is tied to the RFID tag.

The problem is that when the animal goes to slaughter, the resulting meat is separated from the RFID tag. While some meat processors may include barcoding information on the meat they ship, there is no requirement to do so. Furthermore, in some cuts of meat (e.g. ground beef) meat from several animals may be mixed together, further complicating the ability to trace it.

Genomics allows a given sample of meat to be mapped back to the animal it came from, provided a sample of tissue or blood is collected from the animal at slaughter. This in turn allows consumers, producers and retailers to access the rich database of information gathered throughout an animal's lifetime, which can ensure safety but also open up new possibilities for retail models.



Information on an animal's life history is tied to its RFID tag, which is separated from the carcass at slaughter; there's no RFID for a steak. Genomic technology makes it possible to trace a piece of meat to a given animal through its genetic profile and then to detailed information on that animal's life history.

How it works

An animal's genome is the 'blueprint of life,' the complete set of instructions for making the molecules, cells and tissues that come together to form an organism. The instructions are written in the language of DNA, which is a long chain molecule made by combining four possible types of building blocks. Thus, the genome can be thought of as a book written in a code that contains four possible letters: A, C, G and T. Scientists have learned some of the words in this code, for example, sequences that describe how to make a particular protein molecule are called genes. But even DNA that isn't part of a gene can still impact which genes are turned on and when, though scientists are still working to understand the mechanisms by which this happens.

The DNA of a given animal is more than 99 per cent identical to every other member of the same species, but the tiny differences that make each animal unique can tell us a lot. One type of difference is called a single nucleotide polymorphism, or SNP (pronounced 'snip'). A SNP is a location in the genome code where some members of the population have one letter (e.g. an A) and other members have a different letter (e.g. a G). On its own, an individual SNP can't tell you much, but by looking at a number of different SNPs and determining which version of the SNP an animal has, it's possible to map out a 'SNP profile' that is completely unique to that organism; it's a kind of biochemical fingerprint that is printed into every one of the animal's cells. A genome may contain billions of SNPs, but in practice we only need to track a few. For example, 30 SNPs with two possible versions each gives rise to 230 or about 1.1 trillion possible combinations. That's enough to ensure that every animal's SNP profile is unique.

Once they've chosen which SNPs to track, scientists can create a 'SNP chip'. This technology provides a simple, fast and inexpensive way to test a DNA sample from the animal - a few hair follicles would be enough - for dozens of possible SNPs and create the SNP profile. From that point on, any material from that animal - be it meat, bones or nerve cells - can be matched back to it by comparing the SNP profiles. It's even possible to distinguish between different animals in a single burger.

While the test for a single animal can be complete in a few hours for only pennies a pound, a single SNP profile is not all that useful; what's needed is a database containing the SNP profiles of every animal that has been processed into meat. There are a handful of international companies that provide this service, and they typically work directly with the meat processor. By creating a SNP profile for each animal at slaughter and linking that profile to the RFID and all its associated data on the animal's origin and life history, genomics provides a way of extending the value of the identification system beyond the life of the animal.

Benefits of the technology

Food safety and quality

In 2003, a case of bovine spongiform encephalopathy (BSE) was discovered in an Alberta cow, setting off a crisis that rocked Canada's beef industry[3]. BSE is a fatal disease that attacks the nervous system, causing animals to become disoriented, violent and weak. BSE can be passed on when material from an infected animal containing the infectious agent known as a prion is consumed by another. In humans, the prion causes variant Creutzfeldt-Jakob Disease (vCJD.) Of the 227 cases of vCJD that have been reported since 1996, the vast majority have been linked to consuming beef from the UK; this is the case with the 2 Canadian instances of vCJD, one in 2003 and the other in 2011[4].

Since 1997, Canada has banned the feeding of material from ruminants (cows, sheep, goats, etc.) to other ruminants, and in 2003 implemented the removal of specified risk materials - brain, spinal cord and other tissue most likely to contain the prion - from the human food chain[5,6]. Despite these safety protocols, 18 cases of BSE in Canadian herds since 2003 have caused other countries to temporarily close their borders to Canadian beef and live animals. Beef exports to the US went from over 1.6 million animals per year to 0. The Canadian Cattlemen's Association estimates that, all told, the BSE crisis cost the industry between $6 billion and $10 billion[3].

Today, borders have re-opened, and Canada now exports 271 million kg of beef per year to 67 countries, with an annual value of over $1.2 billion[A,B]. Still, the crisis underlines the importance of science-based tools to reassure

Ontario Corn-Fed Beef

In 2001, the Ontario Cattle Feeders' Association (OFCA) launched an initiative designed to provide consumers with a recognizable brand and logo, assuring them of a product consistently produced in accordance with established quality standards. The brand is known as Ontario Corn-Fed Beef and is a valuable marketing tool for producers, helping them get better prices for their product.

In 2013, the OFCA joined with Loblaw Companies Ltd. - Canada's largest food retailer - and the Irish company IdentiGEN to introduce a DNA traceability program into the supply chain. By providing DNA samples to IdentiGEN, the OFCA members create a database of SNP profiles from every slaughtered animal. That ensures that any piece of meat labelled as Ontario Corn-Fed Beef can be traced back to a particular animal via its SNP profile, increasing consumer confidence in the product.

Ontario Corn Fed Beef is using genomic technology to ensure its meat is traceable. (Credit: Ontario Cattle Feeders' Association) governments and the public of the safety of Canadian beef[9].

Using genomics for traceability provides inspectors with just such a tool; the SNP profiles can unambiguously trace meat product to individual animals on a particular farm, rather than relying solely on the information provided on the package. However, as described above, this requires the creation of databases that profile each animal at slaughter.

Know Your Steak

A group of Canadian Angus Rancher Endorsed participants with branded beef programs are testing the ability of genomics can help them improve the traceability and the quality of their product at the same time. In collaboration with Livestock Gentec (a research centre at the University of Alberta) and the Canadian Angus Association, they're using SNP technology to get identify which calves are sired by which of their bulls for genetic improvement purposes, and simultaneously, the same technology can verify the origin of their branded beef product. The SNP technology enables producers to link performance data on the calves obtained from the feedlot and the meat processor, everything from average daily weight gain to carcass weight, marbling grade, and rib eye area back to their bulls for subsequent selection decisions.

Kajal Devani, Director of Breed Development for the Canadian Angus Association, who is running the project has already been able to single out which bulls sired the most calves, a measure of fertility. This information helps breeder pick the best sires for next year's crop. At the same time, the creation of a profile for each calf allows Canadian beef producers with branded beef programs to be traced back to the individual animal it came from, increasing the integrity of the brand.

Angus breeders in Alberta are using genomics both to trace their product and to improve the value of their breeds. (Credit: Canadian Angus Association)

Improved farming techniques

Genomic technology can also be used to improve food quality in more subtle ways. For example, inspectors, producers, or breed associations could take cuts of meat that are of particularly high or low quality and use the SNP profile to access information to all the rich data on the life history of the animal that produced that meat, including its genetics and environmental factors. This would allow them to discover associations between raising techniques and meat quality that were previously hidden, increasing value for both farmers and consumers.

Product differentiation

Would you pay more for a burger made from a cow that was raised without the use of antibiotics? What about one that was certified Angus, or one that was raised within 100 km of where it was purchased? By reliably tracing a given cut of meat to a particular animal with a given life history, producers and retailers can increase consumer confidence in claims made about their product. The increase in consumer choice would allow the development of new markets. SNP profiling provides those organizations with another tool to ensure compliance and increase consumer confidence.

Limitations

As with any new technology, genomics for traceability comes with an economic cost: generating a single SNP profile may cost only a few cents per pound of beef, but generating the large databases required for traceability and linking that information with an RFID system for tracking live animals can run into the hundreds of thousands. The cost is borne jointly by producers, meat processors and retailers, who must decide for themselves if the increased income available through product differentiation or increased quality is worth the investment; this will vary by market. As technology improves and if more industries decide to invest, economies of scale could further lower the price.

A recent study that examined consumers risk perceptions and attitudes around meat consumption showed that 65% of Canadian pork consumers prefer a traceable product and that they are willing to pay a premium for it. However, this same study found that group willing to pay the most for traceability was the group least concerned about the safety of pork consumption. Thus, the existence of traceability alone may not be enough to convince people who already have concerns about the safety of meat processing[10].

Conclusions

The effectiveness of government regulations on food safety depends entirely on the tools available to inspectors to enforce them. At the same time, consumers are increasingly demanding more information about their food including where it comes from, and the rise of specialty markets has shown that at least some are willing to pay more to be confident of this information. Though it comes at an added cost, genomic technology is essentially the only way to unambiguously trace a given product back from fork to farm, and as such its role in our food system is likely to continue to grow in the future.

"Fishy" business

A recent study by the US conservation group Oceana used DNA barcoding to show that snapper (pictured above) is mislabelled 87 per cent of the time. (Credit: Ron Dolette, via Flickr)

While SNP profiles can match a sample to a particular animal, more general techniques that trace DNA to a particular species are often just as useful. For example, a particular set of genes in the DNA of mitochondria - components of the cell that are passed down from mother to offspring - has a unique sequence in every animal species, allowing it to act as a kind of barcode. Researchers at the Canadian Centre for DNA Barcoding at the University of Guelph have compiled a database containing sample sequences of these genes from hundreds of thousands of animal species; different genes are used to barcode plants or fungi.

In 2013, the US conservation group Oceana issued a report in which they partnered with the Centre for DNA Barcoding to test 1,247 seafood samples from 674 retail outlets across the United States. They found that on average, a third of the seafood available for purchase in grocery stores was labelled as something other than what it actually was. Particularly problematic was snapper, which was mislabelled 87 per cent of the time, but tuna, hailbut and others all had high rates of mislabelling[11].

Researchers from Guelph have also developed a certification program called TRU-ID that licenses third party DNA molecular diagnostics testing labs to test commercial products. In June of 2013, western Canadian seafood supplier Organic Ocean announced that they would be using the technology to certify their products.

About

Science Media Centre of Canada

The Science Media Centre of Canada is an independent, not-for-profit organization that exists to raise the level of public discourse on science in Canada by helping journalists access the experts and evidence-based research they need in order to cover science in the news.

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