Literature Review

Traceability Tools for an Inland Fishery

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Project Forward

This paper proved more difficult than anticipated because there is a lot of traceability research being published, particularly in recent years. Some of the science is quite complicated and requires a significant amount of expertise to understand and assimilate. It can be difficult to know when to stop reading papers and settle down to determining what is appropriate. One of the goals of this paper is to translate the heavy science into understandable terms for people that are not associated with scientific research. In addition, this paper needs to clearly state the reasons for the final recommendations. One point that must be made is that, while there is the perception that traceabilty cannot be accomplished without performing some type of sophisticated testing, the fundamental good business and food safety practices must be in place. If resources are limited, they are better spent on putting in a business management system such as ISO rather than on an instrument that may need a significant amount of resources to operate. This knowledge comes from my expertise as a HACCP Plan and Food Safety Management practitioner. My experience working with more than 40 HACCP Programs has driven home the understanding that food safety and their commensurate traceability programs cannot be laid over top of poor business and management practices. This paper logically reviews traceability and gives strong recommendations based on knowledge of how monitoring and verification programs need to work in Food Safety programs and how the Inland Fishery operates.

Definition of Traceability

ISO (International Organization for Standardization) defines traceability as the "ability to trace the history, application, or location of that which is under consideration" (Golan 2004). It refers to "the original of the materials and parts, the processing history, and the distribution and location of the product after delivery" In other words, traceability involves in the whole supply chain. However, this is a quite broad definition. It does not specify a standard measurement for the materials or parts that need to be considered, the size of location, processes that require to be identified, or a specific identification technology).

In the food chain, traceability is "the ability to trace and follow a food, feed, food-producing animal or substance through all stages of production and distribution" (Food standards Agency 2002). As mentioned before, it requires that the product should be able to be traced through the whole supply chain at any time and at any stage.

Why is Traceability Necessary in Food Chains?

Traceability is necessary to a food chain because control of hazards that may be present is not possible unless it can be demonstrated where all inputs into the food chain have been sourced. It is also necessary to be an active participant in this process through the application of interactive communication, system management, and hazard control through the use of Hazard Analysis Critical Control Point (HACCP) tools. This logic is well described by Faergemand (2004) in a description of how ISO 22000 works to enhance Food Supply Chain Management.

The need for traceability is also being driven by other factors including:

Significant contamination due to contamination with a hazard

- The emergence of Bovine Spongiform Encephalitis (BSE) or "Mad Cow Disease" in cattle
- Deliberate adulteration of ingredients in the food chain to artificially elevate the apparent protein levels in food such as melamine in gluten and dairy products
- Contamination of a food with a chemical hazard because of adulteration in one part of the food chain such as dioxin contamination of poultry feed by one processor

Misrepresentation of the food and ingredients:

- Species misrepresentation of fish – the fish may be a species at risk or a lower cost fish
- Partial substitution with less expensive ingredients such as adulteration of olive oil with hazelnut, soybean or other oils.
- Misrepresenting the source of a high value food such as a medicinal mushroom – the mushroom grown in "artificial" circumstances is represented as that grown in a traditional manner

Substantiation of claims for foods with perceived added benefits for consumers

- Organic foods
- Non-Genetically Modified Organisms
- Proof of Origin – some foods such as wine and olive oil market their products on the basis of geographical locations
- Animal Health & Welfare – some products are selling animal health and welfare to consumers
- Conservation of the food – some foods are presented as being produced in circumstances that promote conservation

Recall

This is the traditional view of the need for traceability – it assists with the speed and effectiveness of a recall when traceability is built into a food chain.

What does Traceability do for the Inland Fishery?

Traceability assists with several key issues in the fishery including:

1. Conservation – this fishery must demonstrate that the salmon runs are being conserved and, ideally, enhanced.
2. Poaching – there are long-standing problems with unlicensed fish entering the food chain. This aspect is linked with fish conservation.
3. Proof of proper handling and processing – it is useful to firmly link fish products to when and where they were handled.

This inland fishery is being promoted as a means by which salmon is conserved and all of the fish are from a legal fishery. This means that a significant amount of effort must be put into proving the fish are not from an endangered run. The chance of illegal fish entering the food chain must also be minimized. These are significant challenges. In addition, the chain must establish systems by which lot numbers are tracked and it is proven that the weight and volume of fish is appropriate.

How do Other Food Systems Manage Traceability

This section will briefly describe what different commodities and food sectors are doing with respect to traceability.

Meat

As stated above, the meat industry has had to incorporate significant traceability mechanisms because of “mad cow disease” in cattle. Loftus (2005), Shackell (2008) and Webb (2004) describe the use of

myriad methodologies including ear tags, RFID[1] tags, barcodes, tattoos and DNA technologies. The European Parliament has also adopted a regulation that requires country of birth, country of fattening, country of slaughter, country of cutting, and the approval number of the slaughterhouse and cutting hall (Yordanov, 2006). It has come clear over time that DNA technology is a useful tool and there has been a significant amount of research and commercialization of these technologies. This is because it is very important to trace finished products back to an individual animal if it is determined that the animal was afflicted with BSE. DNA is very appropriate because a DNA code is permanent, unique to the individual (except identical twins) and remains intact through the lifespan of the animal and associated food products (Loftus,). This has proven very useful because the other methods of tracking animals tend to break down when the animal is butchered, the ear tag or tattoo , for example, cannot remain with all of the finished products.

DNA technologies are also appropriate because the power of DNA technologies lies with knowing the DNA profiles of the original animal. A farm system by nature has animals within control ; the DNA profiles are also simpler than that found in wild stock. This has made the development of an economical, rapid test using a DNA marker known as Single Nucleotide Polymorphism or SNP possible. While there are hundreds of potential SNPs in cattle, relatively few are required for identity purposes. Loftus has commercialized some of these rapid DNA tests for use in the meat industry. The evolution of rapid, inexpensive tests methods has facilitated the development of large databases containing DNA information on parentage and their off-spring. As the system gets built, relatively fewer samples must be taken because the parents continue to produce off-spring over many years, only the new animals must be tested.

This technology has also been used to establish breed and adulteration with other species.

The use of DNA technology is limited when it comes to establishing the source of ground beef because there are potentially many animals combined into a batch. This is somewhat ironic because significant biological hazards can be associated with ground beef because these animals are not of the same quality as needed for prime beef cuts. In addition, the equipment used to grind the meat can be a significant source of microorganisms if good sanitation and maintenance programs are not followed.

Shackell (2005) has researched this issue through the use of a DNA microsatellite method. These are larger pieces of DNA than a SNP; they are known as simple tandem repeats (Loftus, 2005). The research, while promising, indicates that there is difficulty tracing animals in batches containing more than 10 animals. There is still a problem using DNA technology for products with many individual contributors. Hamburger traceability is still very dependent on more traditional methods of lot tracking including maintaining records of lot numbers and distribution to customers.

Pig producers are also using DNA technologies (Webb, 2004); in addition to using these methods for product tracking, they are also being used for genetic improvement. Pig health and welfare is also

[1] Radio Frequency Identification (RFID). - an automatic identification technology that uses radio frequency to transmit the identity of an object that contains a transmitter. RFID tags can be read remotely allowing for the identification of data without manual scanning.

important to some customers in Northern Europe. Much of the pig system is still quite reliant on ear tags, tattoos and paper documentation(Madec, 2001).

Seafood

DNA technologies are being used to identify species (Rasmussen, 2008),and to manage some salmon stocks for fishery management (Beacham, 2008). Species identification in particular is an issue because there has been a significant amount of species mis-labelling. This has serious consequences, not the least of which is the undocumented, overharvesting of some seafood. There are further challenges in that the processing and formulation of the finished product will complicate testing methodologies. For example, as outlined in the review paper by Rasmussen & Morrissey, the DNA testing of tuna products will vary. The cetyl-trimethylammonium bromide (CTAB) method is best for tuna in oil or vinegar, Wizard DNA Clean Up procedure is best for tuna in brine, and the Genomic Prep method is possibly best for tuna canned in tomato sauce.

Rapid microsatellite-based stock identification was used by Beacham et al (2008) to provide in-season stock identification for managing a Chinook salmon troll fishery. This provided conservation protection to an endangered stock, while allowing the optimal harvest of a stock that was open to fishing. This is therefore a useful tool for managing mixed-stock Pacific salmon fisheries.

The Aquaculture industry in Norway has investigated the use of DNA technologies for tracing aquaculture fish to their farm of origin (Hayes, 2005). Three different approaches were taken to try and manage the logistics of the high number of individuals that must be tested to be able to trace market fish back to the fish on the farm. The methods examined assignment of market fish to full sib families on the farm, the assignment of market fish to their parents, and the assignment of market fish to their grandparents. Wild fish were made part of the experiment to determine if market fish could be correctly assigned to wild stock. Both microsatellite (more expensive) and SNP methods were examined. It was determined that assignment to grandparents would be the most efficient.

It was determined that the logistics are very complicated for Aquaculture because commercial producers purchase eggs from different sources. For the system to work for tracing to grandparents, the progeny of a set of grandparents must be kept separate throughout the system throughout the chain to the commercial operator. This will be impractical to manage. However, it was determined that these DNA strategies were able to distinguish between fish from captive populations and wild stock. It was also indicated that DNA technology would be appropriate for determining if any of the sampled fish were escapees from fish farms.

This aspect should be further investigated for British Columbia. A provincial fisheries officer expressed concern regarding the “laundering” of some wild stock salmon that may be sold in with aquaculture salmon. It would be worthwhile reviewing the paper further to see if the methods described would assist with positively identifying the source of the salmon in question.

Chinese Medicinal Fungus (*Ganoderma lucidum*)

There has been fraud in some products produced for medicinal purposes in China (Chen, 2008). Some products such as *G. lucidum* is produced in a traditional fashion in a traditional geographic location (orthodox material) as compared to "artificial" production produced by fermentation techniques. The orthodox form sells at a higher price leading to misrepresentation of the artificial version as orthodox. These researchers have used a combination of High Pressure Liquid Chromatography (HPLC) combined with sophisticated data analysis techniques including hierarchical cluster analysis (HCA, principal component analysis (PCA) and partial least squares-discrimination analysis (PLS-DA) amongst others). Results indicated that they are able to differentiate between the orthodox and artificial methods. It could also identify fungus produced in a different province but not between samples grown in different locations of the same province.

This is an example of very sophisticated methodology for use in identification of the origin or provenance of a product.

A different methodology for species identification was employed by Mazzeo et al (2008); this research team examined the use of Matrix-assisted laser desorption ionization-time of flight mass spectrometry (MALDI-TOF-MS). Protein extracts from muscle tissue are examined using this method. This method may have some application because it is less expensive and faster than DNA technologies while still maintaining accuracy and sensitivity.

Olive Oil

Proving the geographical origins or provenance of olive oil has been investigated because olive oil from some geographical locations are viewed as superior (Woodcock, 2008). These researchers investigated the use of near-infrared (NIR) spectroscopy and chemo metric data analysis techniques to confirm provenance of olive oils. Results indicated that these methods may have some use but the establishment of a larger database is required that takes into account other factors such as weather conditions at harvest.

Premium olive oil may also be adulterated with other oils or a low-quality olive varietal. A research team in the University of Parma is investigating the use of peptide nucleic acid (PNA) as a means to bind DNA in food. This method, in combination with HPLC, surface Plasmon resonance, and microarrays, are proving useful for finding adulterants in diverse food matrices.

Agri-food (Produce) Traceability

The agri-food industry has adopted traceability systems relatively recently (Gandino, 2007). Most operators still operate with paper documents while more sophisticated operators use barcodes. RFID offers new opportunities. A typical system is comprised of a reader and passive tags with their own voltage supply. They can be read if they are in the interrogation zone of the reader. Every RFID tag has a unique identification number (ID); they can come with a rewritable memory. This paper examines the use of RFID technology in a fruit warehouse. This warehouse receives fruit from many farmers, is processed, then sold to distributors, then to retailers. In this proposed system, the RFID tags store direct information about the fruit rather than just being used as a barcode.

Each bin is assigned a permanent RFID tag. The data about the fruit and treatments are recorded directly on tag memories and in a central database. Operators use a PDA RFID reader – the operators reach and update the data on tags using the PDA, this information is also stored on the PDA. The data stored on the PDA is updated to the central database several times daily. The proposed system is ideally suited to an industry that, in general, does not have a lot of sophisticated technology.

What Have We Learned from Examining Various Commodities and Food Sectors?

- DNA technologies need a large amount of information about the original individuals. This means that large databases are required to make the system operate for traceability purposes to establish the origin of finished products and progeny.
- DNA technologies have some applicability to managing Pacific salmon mixed fishery stocks; these methods may be useful for establishing the conservation piece in this fishery. A significant amount of science is needed to make this work.
- The Aquaculture industry is trying to devise methods by which the large numbers of original individuals can be managed.
- DNA technology may have some applicability to determining if wild stocks are being sold with aquaculture stocks.
- DNA technologies have not proven useful for products that contain multiple individuals such as ground beef. This means that these methods are not useful for roe.
- Some sophisticated techniques are being used to measure adulteration and provenance – it takes many years to prove the methods and fully make use of the information.
- An interesting, relatively low-tech RFID system has been proposed for the agri-food (produce) industry. This system may have some applicability to the inland salmon fishery. The interesting part of this paper was that the RFID tags were permanently assigned to the tote bins and the RFID tags could be programmed to contain information about the contents of the bin. The tags could also be updated. The PDA's are the means by which information is updated. The information in the PDAs are downloaded to a central database.

Recommendations for the Inland Salmon Fishery

These recommendations are based on several aspects:

- The review of traceability technologies that is summarized in this paper in brief.
- My 15 years of working with various sectors of the food industry to implement food safety through HACCP Plans.
- The state of readiness of this fishery, the recommendations must make sense.

DNA Technologies - Applicability

Continue to interact with the Pacific Biological Station in Nanaimo to ensure the fishery managers understand the latest research into fisheries management. Continue to participate in science-based programs on the river. Determine if some of the latest science can be incorporated into the post-landing traceability system – this should be assessed each year.

Encourage Fishery Participation

The current goal of setting up the fishery such that groups want to participate because they will have greater economic and social gain should be maintained. In addition, it should be made clear that all participants will need to **meet a set of criteria** such as undergoing **accredited training** and **selling through the Virtual Warehouse**. Reducing the amount of poaching is the best way to ensure food safety and traceability in this fishery.

Continue to Develop and Improve the Current Traceability System

- There are simple yet powerful techniques for managing traceability including:
- Sign fish in and out of fishery control – sign the fish from the river into the fishery.
- Ensure all paperwork is transmitted to the Virtual Warehouse – tote numbers, fish pieces and gender
- Determine what is required to weigh fish at the landing site – can this work?
- Record the crew on the Shipping Manifest
- Seal totes
- Link roe to original fish through documentation
- Maintain traditional tracking mechanisms for fish through to final sales
- Sign fish out of the fishery – some fish may be sold to off-shore buyers; this is an appropriate time to sign the fish out of the control of this fishery.

Consider Building in RFID Technology using the Virtual Warehouse as a Backbone

The proposed model for RFID technology in this paper may be workable – using tags that can have their data rewritten as product is moved about is potentially a powerful tool. The Central Database may logically be housed with the Virtual Warehouse

Develop Accredited Education &Training

All fishery participants will be trained in the management of the fishery and the associated food safety programs.

Both management and workers will be trained.

Verify that the Quality Management Plan is Working

Perform unannounced on-site visits

Perform targeted, customized audits that concentrate on where the risks and problems lie

Perform Recall Effectiveness Checks.

Evaluate the Need for Fishery Accreditation

There are several programs that may be appropriate including the Marine Stewardship Council and ISO 22000. There are some costs associated with these programs. There will need to be a cost-benefit analysis performed before proceeding.

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