Chapter 16

Traceability system in FSMS

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Introduction:

The horse meat scandal is known across world. This involved food products across Europe which was labeled as beef where it contained horse meat. Profit driven malpractice was identified by Irish food inspectors who revealed in mid-January 2013 that they had found horse meat in frozen beef burgers. This leads to the path for authentication of food products and open the horizon of thought of people to suspect about crime against food safety and human health. Such food frauds are being carried out in all kind of food stuffs including seafood. Seafood comprises of various species and after their processing it is very hard to know which species it is made of until it is not tested with modern analytical tools.

Food fraud

Food fraudis a significant and growing problem, driven by globalization, economic opportunity, and the low probability and severity of punishment. Analytical verification of food fraud and food authentication is needed to support proper food safety management systems. Food fraud is designed to increase the perceived value of both food and ingredients and is a growing concern in our global food supply**.**

"Consumers expect safe and nutritious foods. They also expect all participants in the supply chain to have effective practices in place that allow for the rapid identification, location, and withdrawal of food lots when problems are suspected or confirmed. The increased focus on food safety and consumer awareness raises the need for the identification and adoption of business practices that will aid the ability of the trading partners in the food industry to track and trace a product throughout the supply chain" (FAO, 2017).

A few of the recent, and possibly well-known, occurrences of food fraud include:

- Melamine or cyanuric acid found in infant formula and pet foods
- Fake food and alcohol seizures in EU borders
- Kiwi wine company accused of complex food fraud
- Exporting falsified hazelnut products to Germany from Georgia
- 75% seafood samples mislabeled with cheaper fish in place of more expensive across Canadian cities.
- Mislabeled giant squid as octopus in North America

DRIVERS for Food fraud

- Deliberate criminal fraud for financial gain (adulteration/substitution – premium products)
- Rising commodity prices
- Shortage of supply
- Raw material quality due to poor yields and variable composition
- Avoidance of tariffs
- Sustainability fishing

***Seafood Authentication*:**

Process that verifies that a food is in compliance with its label description is called as Authentication. This is necessary to preventing Food Fraud and quick Recalls of products distributed in markets.

Traceability is vitally important for food safety as well as operational efficiency. This will help to pinpoint the source of the issue and the scope of any potential incident.

Any deliberate action of businesses or individuals to deceive others in regards to the integrity of food to gain undue advantage. Types of food fraud include but not limited to: adulteration, substitution, dilution, tampering, simulation, counterfeiting, and misrepresentation. There are more than 8,100 (up to 2017) papers dealing with food authenticity have been recorded in the Science Direct database

***Seafood Traceability*:**

Seafood Traceability cab be defined as track and trace a product throughout the supply chain. This requires reliable analytical methods that can give a decisive answer about the authenticity of foodstuffs. This can also be called as measuring features that can discriminate foods of different origins.

There are certain authenticity indicators which includes Rare earth elements and precious metals, Microbial fingerprinting, Metabolomics fingerprinting and Sensory analysis

Food Traceability (terms & definitions)

- **Tracking" or "Tracing forward":** refers to pursuing in the downstream direction
- **"Tracing" or "Tracking back":** refers to pursuing in the upstream direction
- **Traceability system:** A series of mechanisms for traceability, by which "identification", "link", "records of information", "collection and storage of information", and "verification" are performed.
- **Traceable unit:** The unit used for identification. This unit is used when tracing and tracking. In some cases, a lot works as a unit and in others, an individual and/or individual product works as a unit

Timeline (Traceability and Authentication Definition)

1994: ISO 8402 Definition of Traceability-"The ability to trace history, application and location of an entity by means of recorded identification"

1998: Denis (1998) Definition of Food Authentication- "Food authentication is the process by which a food is verified as complying with its label description"

2002: The Food Safety Agency (FSA) basic characteristics for traceability system-

(1) Identification of units/batches of all ingredients and products

(2) Information on when and where they are moved and transformed

(3) A system to link these data

2004: CAC Definition of food Traceability-"The ability to follow the movement of a food through specified stages of production, processing and distribution"

2005: ISO 9000 Definition of Traceability-"The ability to trace the history, application or location of that which is under consideration"

2016: Danezis et al. defined Food Authentication as "Food authentication is the process that verifies that a food is in compliance with its label description. This may include, among others, the origin, production method, or processing technologies

Traceability systems in practice

The key factors to successfully implementing a traceability system within the seafood processing establishments include

• Full details of suppliers of raw materials and ingredients.

• Identification of individual batches by product coding till dispatch from factory

• Maintain batch separation throughout the processing and storage.

• Linking batch codes to production records for each process in the establishment.

Of the various different methods by which traceability can be achieved the following are provided as examples;

• Paper-based traceability

• Bar code/scanner systems

Technology-Enabled Traceability

Data Elements Specific data captured through the traceability system (e.g. origin, water usage, etc.)

Unique Identifiers An assigned unique identifier to the individual food product for tracking along the supply chain; examples include RFID tag or barcodes

Sensor Technology Real-time tracking of identified data elements through supply chain; enables automated data capture

Distributed Ledger Technology Enables easier aggregation, integration, analysis and sharing of data; today, ledgers are often completed using suboptimal paper based systems but can be significantly improved through technology adoptions

There are 7 principal ways a food or food ingredient can be adulterated to increase its perceived value:

1. Substitution
2. Unapproved Enhancements
3. Concealment
4. Mislabeling
5. Dilution
6. Counterfeiting
7. Gray Market

CURRENT FOOD AUTHENTICITY CHALLENGES

CATEGORY	EXAMPLE
Origin of food from sustainable sources	Palm oil, fish, exotic meats
Method of food production	Organic food
Substitution - Quantification of ingredients	Meat species in processed foods
Designation of geographical origin (Food Information legislation)	Meat, fish , composite foods
Specialty foods	Vanilla, saffron, honey, balsamic vinegar, Basmati rice
Adulteration - Alcoholic and nonalcoholic beverages	Fruit juices, wine, spirits
Miscellaneous	High protein foods

ANALYTICAL WAYS:

1. DNA-methods: DNA-based methods for food authentication depend on the highly specific amplification of DNA fragments by the Polymerase Chain Reaction (PCR). The advantage of genomics is that it can amplify minute traces of nucleotide material. The sensitivity of these methods are high since the amount of analyte required is in nanogram (ng).
2. Stable isotope analysis: The isotopic ratios are applicable to food authentication because stable isotope ratios change with the climatic conditions, geographical origin, soil pedology, and geology of the locations of food ingredients origin. The analysis of isotopic ratios uses various methods such as Isotope Ratio Mass Spectrometry (IRMS), Multi Collector – Inductively Coupled Plasma – Mass Spectrometry (MC-ICP-MS), and Thermal Ionization Mass Spectrometry (TIMS).
3. Proteomics: proteins can act as markers for many properties of the food products all along the food chain from farm to fork, and therefore proteomics can be applied for a systematic search of new marker proteins or peptides. Proteomics identifies specific products encoded by DNA. The sensitivity is very high since the amount of required material can be as small as a few cells.
4. Metabolomics: Metabolomics deals with the study of multiple metabolites in a cell, a tissue or an organism. Ultra-high performance liquid chromatography (UHPLC), high-resolution mass spectrometry (HR-MS) and software programs to process the large analytical data sets can be used.
5. Spectroscopy: Spectroscopy, in particular vibrational spectroscopy, is a fast and inexpensive method for both the assessment of food quality and food authenticity. Novel instrumental techniques combined with chemometric methods have enabled the development of rapid methods that apply multivariate (MVA) analysis, to near infrared (NIR) and mid infrared (MIR) data to analyze food matrices.
6. Metagenomics/Next Generation Sequencing: Metagenomic and metatranscriptomic have great potential in becoming valuable options for detecting food authenticity for a specific food product. Traditional DNA barcoding methodologies based on PCR and Sanger sequencing has limitation being low-throughput. Such limitations has been overcome by high-throughput NGS technologies including metagenomic approaches, which provide more information food product.
7. Sensory analysis: Traditionally reliable results in sensory analysis require a well-trained panel of human assessors. Organoleptic test panels comprise a set of techniques for accurate measurements of human responses to foods. Appearance, aroma, flavor and texture properties are important characteristics determining the quality authenticity of food products. These panels require extensive training of judges, adequate replication and detailed statistical analysis of the observations.

Current work – supporting testing and enforcement

Meat speciation

- DNA quantitation breed authentication
- Detection of offal and serum in meat products

- Gelatine speciation (water-retention, chicken plumping agents)

Fish speciation

- Geographic traceability
- EU harmonisation of fish DNA methods
- Nitrogen factors for fish quantitation

Technical Challenges in detecting Food Malpractices

- **3 key difficulties:**

1. Issue is linked to a legal requirement, standard or guidance; conclusion must be beyond reasonable doubt, but data interpretation is made against a background of analytical uncertainty, natural variation etc

2. Finding a marker that characterises the food, one of its ingredients, the adulterant(s), or the processing, production or geographic origin

3. Availability of authentic samples (databases)

Emerging authenticity indicators

Sl. No.	Indicators	Remarks
a.	**Rare earth elements and precious metals:**	o Elemental fingerprinting targets groups of elements including macroelements (such as calcium, sodium, potassium), trace-elements (such as selenium, zinc, copper), rare earth elements (REEs, such as cerium, samarium and lanthanum), or other ultra-trace elements (such as precious metals platinum or gold) o ICP-MS (Inductively coupled plasma mass spectrometry) and ICP-OES (Inductively coupled plasma - optical emission spectrometry) can be used exclusively
b.	**Metabolomic fingerprinting:**	o Quantitative analysis of the complete metabolome or selected subsets is called Metabolomics. o Metabolomics uses mostly nuclear magnetic resonance (NMR) and mass spectrometry (MS) analytical technologies o Gas chromatography mass spectrometry (GC–MS), Liquid chromatography mass spectrometry (LC–MS), ultra performance liquid chromatography (UPLC), QTOF-MS and Orbitrap-based technologies, High-Resolution MS (HRMS), Vibrational spectroscopic techniques (near-infrared or NIR, mid-infrared or MIR, and Raman spectroscopy
c.	**Microbial fingerprinting:**	o Assessment of geographical origin can be achieved through microbial fingerprinting in non-processed foods (fruits, fish, wine, yoghurt).

		○ Microflora was found to be specific of the production system and microbial fingerprints were shown to differ between organically and conventionally grown fruits ○ Polymerase chain reaction-denaturing gradient gel electrophoresis technique, PCR-DGGE is usually used for microbial fingerprinting
d.	**Sensory analysis:**	○ Specialized panelists required with total sensory experience of food combines aroma, taste, texture, temperature, spiciness, appearance. ○ The instrumental sensory techniques electronic tongue (e-tongue), electronic nose (e-nose), electronic eye (eeye) and gas chromatography olfactometry (GCO) are used for objective sensory evaluations.

Opportunities and challenges for Food Authentication

Food authentication is an interdisciplinary area where has input from instrumentation, biology, informatics, mathematics and statistics, agriculture, and food technology are needed.

- Vast volumes of data are generated, but our ability to manage and analyze these date are falling behind the ability to generate these data.
- Mass spectrometry is a frontline technology rapidly replacing other methods in many fields of food science.
- Multi-analyte capabilities are essential for food authentication studies since they provide more descriptors and thus facilitate better classification.
- Programs are being developed and implemented to reduce food fraud, but these programs must continue to evolve in order to keep pace with the ingenuity of food fraud perpetrators.

Opportunities and challenges for Food Traceability

Global supply chain is complex system. Hence ensuring it as effective practices in place is an on-going challenge. One of the biggest traceability challenges goes back to recordkeeping. Without effective procedures to capture multiple dimensions of product information, it becomes difficult to track products and comply with recall requirements. One problem that hinders traceability and increases the scope and cost of recalls is the lag time between when a problem occurs and when a company detects it. Government regulation requires businesses to implement a food traceability system (record system, recall system, etc.)

Development of information technology supports implementation of food traceability system (IoT, Bigdata, machine learning, etc.) is the need of hour for effective implementation of traceability system for any food products.

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