

**FOOD FORENSICS: FROM FARM TO FOLK****Priyanka Verma**[priyankaverma421@gmail.com](mailto:priyankaverma421@gmail.com)

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**Abstract:** Forensic science is the science combining the pure sciences, scientific knowledge, methodologies and their applications in the court of law for the regulation of administration of law and justice. It has emerged as the principle and substantial field for the governance of the criminal and civil cases. Thus, the science involved in the forensic investigation of various kinds of exhibits can be applied in the food safety procedures, food poisoning, adulteration etc giving a new and distinct domain of forensic science, which can be called as 'Food Forensics'. Various platforms call it as food safety science, and food science. Food adulteration has serious adverse effects on living beings' health. There are laws and penalties levied on production and selling of adulterated food items despite which the malpractice is common. There is substantial number of reported cases of food industries involving various chemical and synthetic substances deployed for contaminating food. The chronic consumption of adulterants may prove lethal and therefore the necessity for its timely detection and cure. In this chapter, various adulterants being commonly used in food products are being focused and discussed involving corresponding sophisticated detection techniques.

**Keywords:** Forensic Science, Adulteration, Food Forensics, chain supply

**1. Introduction**

Food is the elementary source of nutrients which provides energy for growth and proper bodily operations hence its administration on regular basis with a reasonable interval of time is a necessary and obvious process. Anything ingested into the body plays a substantial role in forensic toxicological and chemical sciences, equivalently ingestion of food recognises the requirement and gravity of food forensics (Spink, 2013).

Food forensics is a necessary section which must be added as one of the major fields of forensic science. Like pharmaceutical substances, poison, narcotics ingested in the body, food also introduced into the body and is fundamental and essential for being alive. An abridged shelf life makes food

perishable and decomposable, thus consequently dematerialize its fingerprints. Distinct versatile techniques and methods of forensic science and food science aids in identification of the pure substance and adulteration in the food, if any (He et al., 2020).

Food quality control and tracking of 'farm to folk' supply chain plays a substantial role in identifying the corroborative contributing factors of food poisoning cases leading to fatal cases. Mislabelling of the products, deficient pharmaceutical compounding, economic frauds because of greed, further leading to poor quality of food causing health problems (Shepherd, 2006). Therefore, this demands the analytical methods, document analysis, quality check procedures, toxicological analysis employed in forensic science field with the simultaneous application of food science to determine the root cause of cases related to food forensics (Spink & Moyer, 2011).

## **2. Food safety forensics**

Forensics incorporating food safety procedures, principles, adulteration-detection techniques, quality control processes, documentation, and verification collectively can be called as food safety forensics. Food safety forensics can be expressed as implementing food science principles and procedures for the safety of food to eliminate the possibilities of food poisoning and also to reduce the crimes involving adulteration (Biesterbos, Sijm, van Dam, & Mol, 2019).

Food safety involves the handling procedures, preparation of food items, and storage of the end product in accordance with the rules and suggestions lay under the standard operating procedures in order to decrease the risks associated with the illness resulting from food-borne diseases. Food safety forensic is emerging as a substantial domain with the increase in recognition of cases regarding food safety which is a global concern (Primrose, Woolfe, & Rollinson, 2010).

Food safety generally imbricates with food defence but there is a fine difference between the two. Food defence involves the process of safeguarding and protecting the food products and items from contamination by external agents involving biological, radiological, chemical or physical, proposed intentionally to cause deliberate harm. Considering this, food safety involves unintentional contamination corresponding environmental contamination resulting as harmful inference. Food fraud is the term often comes when discussing food safety and defence as it also overlay with both of the processes. It includes intentional mendacity and deception to gain economic acquisition (Johnson, 2014).

All these processes correspond food safety only in the periphery of industry to market. Taking food safety into account with respect to processes involving food safety chain considering market to consumers; it involves labelling of food items, introducing food additives, hygiene conditions, etc. Following food safety procedures also engage the processes mentioned in the guidelines for the proper functioning and management of governmental import and export inspection for the food items followed by certification systems for foods .

### **2.1.Safety principles**

Food safety relies on some fundamental principles which address to prevent food from

decomposition and contamination. These principles engage

- a) Appropriate sanitization and cleaning of all the utensils, equipments, surfaces, containers, and cloth pieces.
- b) Prominent maintenance and preservation of personal hygiene which includes hair tying and wrapping, hand-washing, etc
- c) Following all the operating and storing standard procedures for respective food items corresponding storage temperature, heating temperature, and environmental conditions.
- d) Proper and effective implementation and enforcement of pest control and sanitization of all the floors and spaces.
- e) Understanding and comprehending food poisoning and food allergies to minimize the potential food hazards which in turn results in serious consequences.

### **3. Processes to solve crimes**

Apart from food poisoning cases come to forensic toxicological laboratories, industries and companies also employ forensic techniques and methods to deal and combat with food adulteration, quality and safety issues. Advance and sophisticated techniques and methods are required to identify the cause of botheration which is responsible for the poor quality and ineffective food safety of the products. Food forensics methods and procedures aids in identifying the issue to give convincing and honest response to consumers' complaints, issues raised during quality check and control process to maintain and safeguard the company's credibility and reputation. Forensic investigation identifies the presence of any foreign substance corresponding contamination and adulteration via bioanalytical and chemical laboratory procedures which aids the trial to identify if there is any deliberate adulteration attempt to cause harm or for frauds referring economic profits (Agres, 2013).

The organisation named as Food and Drug Administration has circulated regulations to forbid intentional adulteration which cause potential harm to health. They have suggested to establish mitigation strategies to safeguard the food and food products from contamination and adulteration. It also aimed at preventing the food chain from acts of terrorism aiming at food supply. Forensic Chemistry Center aids in assisting health emergencies by providing support and help to regulatory testing laboratories and law enforcement organisations for the analytical examination of the food products with regards to intentional adulteration, contamination, biological-food terrorism.

### **4. Adulteration**

The process of introducing admixture or alternative of the inferior substance with an intention to reduce the quantity of valuable and expensive ingredient aiming to gain economic profit thus degrading the food quality offered for sale. It is an emerging and evolving concept because of the development in the advancement of the detection methods and techniques. In spite of several legal penalties and punishments, act of mixing adulterants in the food products has become a common and regular practice in developed as well as developing countries. Adding poor quality adulterants degrade the nutrient's content, consequently results in food contamination makes it unsuitable for consumption. Adulterants can be of any form and present in any type of food product (Bansal, Singh,

Mangal, Mangal, & Kumar, 2017).

There are several reasons for greedy companies to adulterate food products which involves; business strategy to escalate profit via small investments; poor quality imitation of rich and wealthy food products; increasing the quantity by degrading the quality of food product; and escalating demand with simultaneous population increase. Numerous methods of adulteration are being adopted for satisfying illegitimate economic profits; introducing chemicals like ethephon, acetylene gas, and calcium carbide into the fruits for rapid ripening; mixing unfit or decomposed food products into fresh and quality food products; addition of chemicals and fragrances to invite and attract customers; introducing stones, marbles, pebbles to the stock of pulses, grains and other similar categories to increase the quantity (Singh & Gandhi, 2015).

It is approximated that around 57% of the population globally is adversely affected and has developed major health issues because of introduction of adulterants and contaminated food in the body. Humans and even domestic animals exposed to packed food are sensitive and vulnerable to food adulteration and evince instantaneous side effects incorporating dysentery, nausea, diarrhoea, loose motions, and vomiting. Beside immediate side effects, adulterated food can cause serious acute and chronic diseases involving major organ dysfunction and impairment viz, ulcer, autism, skin disorders, hepatic and renal failures, leprosy, cancer, tumour, brain damage, vision loss etc.

Here some examples are listed explaining the process of adulteration in common food products:

- a. Milk is adulterated with detergent, urea, unfiltered water, and starch leading to stomach disorders like indigestion.
- b. Crude fruits and vegetables are adulterated via oxytocin, sachharin malachite green etc. leading to harmful health problems like dizziness, paralysis, cramps, chills etc
- c. Jaggery, corn syrup, and sugar are used to adulterate honey which can cause obesity, diabetes mellitus eyes and nerve damage.

To avoid adulteration, there are certain precautions, an individual can take viz; refraining deep colored and processed food products; washing fruits, vegetables, pulses and grains before cooking; verifying the seal of food products, and checking FSSAI- label used for food quality validation.

#### 4.1. Farm to fork supply chain

This chain of supply is a process of tracing the movement of edible items from farms to end consumer. It engages the close monitoring of handling and preparation processes and procedures with respect to farming, distribution chain, retailers, food processing industries to packaging (Ong, Samsudin, & Soto-Valdez, 2020). This process is very complex and convoluted as it involves the monitoring and quality assurance at every step to assure the safety of consumers' health. It not only focuses on monitoring quality but also involves the prevention from contamination during the growth procedure, food preservation, transport and distribution networking.

Once the final food product reaches the fork of the consumer, it is then their accountability to assure the proper storage conditions and handling procedure of the purchased product for their personal health and safety.

### 5. Product Genealogy

Product genealogy is a process where it provides the tracking of every ingredient, substances, raw

materials; a product is formed of. Thus, maintaining the record of information what is there in the product involving list of ingredients, quantity and manufacturing date, batch and serial number of the product after production. This tracing involves the records of chain including interaction, splitting and merging of products' lot. Genealogy provides the data to visualise the information tree of food product to extract the required information like a particular batch of raw material, the product is made up of.

It also aids in verification of the required ingredients required to be assembled at the initiation of assembly operation of the product. It helps in placing raw materials or ingredients on hold to maintain the quality of the product. While searching about all the processes and equipments settings, one can diagnose the failure of any component. Consequently, enabling the investing of the defect in the process of manufacturing.

## **6. Food Poisoning**

Contamination and adulteration in food results in illness known as food poisoning. It is an extensive term which envelops distinct infections. There can be various causes of food poisoning involving organisms that covers bacterial food poisoning, natural food poison through plants, food poisoning via animals. Food poisoning can occur due to addition of chemicals as well. This includes intentional and accidental addition of chemicals like flavouring agents, preservatives, coloring agents, pesticides and insecticides. Contamination of food can be result of wrong packaging or poor-quality packaging material, or packaging employing metallic containers.

When living bacteria or bacterial toxins are involved in food contamination, it leads to acute gastroenteritis after the ingestion of bacterial contaminated food. It gets worsen when these microorganisms proliferate in the gastrointestinal tract resulting in infection, for example, salmonella or Escherichia coli. Poisoning occur due to toxins can be identified in the contaminated food sample or stool sample. Detection of toxin in the food depends on the incubation period. Formation of enterotoxin is called as pathogenesis which characterize stomach upset, and vomiting (Koziolek et al., 2019).

Post-mortem appearances in the fatal cases of food poisoning involves gastrointestinal congestion, ulcers in intestinal mucosa, and sometimes signs of asphyxia. Food poisoning cases have substantial medico-legal importance as it aids in identifying homicidal food poisoning. Apart from intentional and accidental contamination of food products, hygiene plays an essential role in the cases of food poisoning.

Here are some examples of intentional food contamination resulting in food poisoning. Common addition of unhygienic and unfiltered water in the milk culminating in various diseases incorporating viruses, protozoa, and bacteria (Hoffman, n.d.).

## **7. Detection methods**

Food is a basic and elemental source of nutrition obtained from plants and animals. The nutritious elements and health benefits of rich food material motivates fraudulent approach of adulteration to satisfy the greed of gaining illegitimate economic profits. Thus, strict and validated quality control and quality assurance methods must be employed to ensure the authentic quality of the food products

to prevent contamination and harmful effects on the human body. When it comes to quality check, detection comes at priority which demands sophisticated and sensitive techniques and methods. These techniques lately attract the compelling interest of the researchers and industries for the detection of added adulterants (McEntire et al., 2010) (Yang, Ghosh, & Beaudry, 2018).

The detection techniques involve physical methods, chemical methods and bio-chemical methods. Techniques like microscopy, chromatography, and spectroscopy are majorly used and employed for the analysis. Microscopic techniques are employed for the topographic analysis to study the texture of the food items, e.g., pulses are analysed under microscope to study the morphology to check the traces of polish on the outer layer as pulses are usually polished to attract the consumers. Chemical tests involving colorimetry are also used for the detection of adulteration in several food items, e.g., modified Seliwanoff's method is used for the detection of sucrose (cane sugar) present in milk. Generally, milk is adulterated with sucrose. To detect the same in milk, resorcinol in hydrochloric acid is added to the test sample, formation of red color indicates the adulteration of milk with sucrose as fructose present in the sucrose milk react with resorcinol to give red color.

Each substance used as an adulterant has a unique spectral fingerprint which is the basis of chromatographic and spectral analysis. Techniques like Gas Chromatography-Mass Spectrometry, ELISA immune-assays, Liquid Chromatography, UV-Visible Spectroscopy are some confirmatory techniques employed for the sensitive identification of adulterant present in the food product even if in trace amounts e.g., a food poisoning case of baby food was investigated where multiple techniques were employed for the identification of contaminants and adulterants (Aleixandre-Tudó, Castelló-Cogollos, Aleixandre, & Aleixandre-Benavent, 2020). Investigation test sample with multiple technique validate the results. Another example of intentional addition of brodifacoum ( rat poison) in the chilli was investigated where Ion-chromatography-Mass Spectroscopy was used for the detection of question compound (Valand, Tanna, Lawson, & Bengtström, 2020) (Se, Wahab, Syed Yaacob, & Ghoshal, 2019).

## **8. Conclusion**

Adulteration in food materials or manufacturing of sub-standard quality food items has become prevalent in today's times where resources are limited while demand is progressively increasing. Adulteration, as we know, is an illegal practice of adding raw and other cheaper ingredients to excellent quality products with an intention to mostly increase its weight or quantity. Food adulteration has serious effects on our health. There are laws and penalties levied on production and selling of adulterated food items despite which the malpractice is common. There have been reported cases of food industries also using various chemical and synthetic substances deployed for contaminating food. The prolonged consumption of adulterants may prove fatal and therefore the necessity for its timely detection and cure. In this chapter, we tried to focus on various such adulterants being commonly used in food products and also their detection techniques such as microscopy, chromatography and spectroscopy. The detection methods mostly deal with preliminary chemical tests. When found positive, subsequently followed by instrumental techniques like spectrophotometer. Food chain transparency and full raw material traceability is primordial for an effective food fraud prevention system.

## References

- Agres, T. (2013). Food Defense and Protection. *Food Quality and Safety*. Retrieved from <http://www.foodqualityandsafety.com/article/food-defense-and-protection/>
- Aleixandre-Tudó, J. L., Castelló-Cogollos, L., Aleixandre, J. L., & Aleixandre-Benavent, R. (2020, October 20). Bibliometric insights into the spectroscopy research field: A food science and technology case study. *Applied Spectroscopy Reviews*. Bellwether Publishing, Ltd. <https://doi.org/10.1080/05704928.2019.1694936>
- Bansal, S., Singh, A., Mangal, M., Mangal, A. K., & Kumar, S. (2017). Food adulteration: Sources, health risks, and detection methods. *Critical Reviews in Food Science and Nutrition*, 57(6), 1174–1189. <https://doi.org/10.1080/10408398.2014.967834>
- Bhat, P. P., & Balamuralidhara, V. (2020). Regulatory requirements for import of food articles to indian market. *Journal of advances in food science & technology*, 21-25.
- Biesterbos, J. W. H., Sijm, D. T. H. M., van Dam, R., & Mol, H. G. J. (2019). A health risk for consumers: the presence of adulterated food supplements in the Netherlands. *Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment*, 36(9), 1273–1288. <https://doi.org/10.1080/19440049.2019.1633020>
- Christophe Cavin, Geoffrey Cottenet, Christophe Fuerer, Lien-Anh Tran, Pascal Zbinden, Food Fraud Vulnerabilities in the Supply Chain: An Industry Perspective, Editor(s): Laurence Melton, Fereidoon Shahidi, Peter Varelis, Encyclopedia of Food Chemistry, Academic Press, 2019, Pages 670-678, ISBN 9780128140451
- He, Y., Bai, X., Xiao, Q., Liu, F., Zhou, L., & Zhang, C. (2020). Detection of adulteration in food based on nondestructive analysis techniques: a review. *Critical Reviews in Food Science and Nutrition*. Taylor and Francis Inc. <https://doi.org/10.1080/10408398.2020.1777526>
- Hoffman, J. (n.d.). Romaine Riddle: Why the E. Coli Outbreak Eludes Food Investigators. Retrieved from <https://www.nytimes.com/2018/05/07/health/romaine-ecoli-outbreak-fda-cdc.html>
- Johnson, R. (2014). Food Fraud and “Economically Motivated Adulteration” of Food and Food Ingredients. *U.S. Congressional Research Service*. Retrieved from <https://fas.org/sgp/crs/misc/R43358.pdf>
- Koziolek, M., Alcaro, S., Augustijns, P., Basit, A. W., Grimm, M., Hens, B., ... Corsetti, M. (2019). The mechanisms of pharmacokinetic food-drug interactions – A perspective from the UNGAP group. *European Journal of Pharmaceutical Sciences*, 134, 31–59. <https://doi.org/10.1016/j.ejps.2019.04.003>
- McEntire, J. C., Arens, S., Bernstein, M., Bugusu, B., Busta, F. F., Cole, M., ... Ohlhorst, S. (2010, January). Traceability (Product Tracing) in Food Systems: An IFT Report Submitted to the FDA, Volume 1: Technical Aspects and Recommendations. *Comprehensive Reviews in Food Science and Food Safety*. <https://doi.org/10.1111/j.1541-4337.2009.00097.x>
- Ong, H.-T., Samsudin, H., & Soto-Valdez, H. (2020). Migration of endocrine-disrupting chemicals into food from plastic packaging materials: an overview of chemical risk assessment, techniques to monitor migration, and international regulations. *Critical Reviews in Food Science and Nutrition*, 1–23. <https://doi.org/10.1080/10408398.2020.1830747>
- Primrose, S., Woolfe, M., & Rollinson, S. (2010). Food forensics: Methods for determining the

authenticity of foodstuffs. *Trends in Food Science and Technology*, 21(12), 582–590. <https://doi.org/10.1016/j.tifs.2010.09.006>

Se, K. W., Wahab, R. A., Syed Yaacob, S. N., & Ghoshal, S. K. (2019, July 1). Detection techniques for adulterants in honey: Challenges and recent trends. *Journal of Food Composition and Analysis*. Academic Press Inc. <https://doi.org/10.1016/j.jfca.2019.04.001>

Shepherd, A. W. (2006). *Quality and safety in the traditional horticultural marketing chains of Asia*. Rome: Food and Agriculture Organisation of the United Nations. Retrieved from <http://www.fao.org/3/a-a0709e.pdf>

Singh, P., & Gandhi, N. (2015). Milk Preservatives and Adulterants: Processing, Regulatory and Safety Issues. *Food Reviews International*, 31(3), 236–261. <https://doi.org/10.1080/87559129.2014.994818>

Spink, J. (2013). Economically Motivated Adulteration: Another Dimension of the “Expanding Umbrella of Food Defense.” *Food Safety Magazine*. Retrieved from <http://www.foodsafetymagazine.com/magazine-archive1/octobernovember-2013/economically-motivated-adulteration-another-dimension-of-the-e2809cexpanding-umbrella-of-food-defense2809d/>

Spink, J., & Moyer, D. C. (2011). Defining the Public Health Threat of Food Fraud. *Journal of Food Science*, 76(9), R157–R163. <https://doi.org/10.1111/j.1750-3841.2011.02417.x>

Valand, R., Tanna, S., Lawson, G., & Bengtström, L. (2020, January 2). A review of Fourier Transform Infrared (FTIR) spectroscopy used in food adulteration and authenticity investigations. *Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment*. Taylor and Francis Ltd. <https://doi.org/10.1080/19440049.2019.1675909>

Yang, C. T., Ghosh, D., & Beaudry, F. (2018). Detection of gelatin adulteration using bio-informatics, proteomics and high-resolution mass spectrometry. *Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment*, 35(4), 599–608. <https://doi.org/10.1080/19440049.2017.1416680>