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Food fraud prevention: Authentication and traceability

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Abstract

Food fraud refers to the act of making deliberate changes to food and its labels with intent to deceive, and this is a major concern to most food safety standards, consumer confidence, and global economy. Recognizing the fact that counterfeiting activities are on the rise as the food supply chain becomes elongated around the globe, sound prevention measures are called for. This review therefore seeks to establish the importance of food authentication and traceability systems in avoiding the risks associated with food fraud. Identification and confirmation of the origin and content of food products is best done through spectroscopy, DNA profiling and isotopic analysis. Systems of traceability opened by the technologies of a blockchain, Internet of Things (IoT) and bar code help effectively track the flow of food products through the chain, holding producers, transporters and sellers, accountable from the farm to the consumer. All these systems combined help in determining the areas of weaknesses, improving the regulatory standards and protecting the consumers. Therefore, this paper recommends that there is a need for increased multi-stakeholder cooperation, enhanced regulation, and ongoing firm technological development in the fight against food fraud internationally.

Keywords: Food fraud, prevention, authentication, traceability, organic products, voluntary food labels, imported food

Introductions

Food fraud is the deliberate substitution, addition, tampering or misrepresentation of food, food ingredients or food packaging for economic gain. It takes on different forms such as adulteration, counterfeit products, mislabelling, and use of substandard ingredients. Food supply chains have become globalized and with it the complexity of fraud detection and prevention. Nowadays recent food mislabelling has proven the importance of effective methods to assure food authentication and traceability. This paper review existing food fraud prevention strategies, with a primary focus on authentication and traceability systems.

Food fraud, and its more specific category of economically motivated adulteration, is an increasingly recognized risk to the safety of our food supply [Spink, J., & Moyer, D. C. (2011)]^[1]. Food fraud is an age-old ailment in the food sector, and it manifests itself through various criminal practices involving substitution, addition, adulteration and alteration. In recent years, incidents of adulteration to foods, food ingredients and commodities have become a risk issue that is growing sharply perhaps driven by the globalisation of supply chains and the introduction of very complicated distribution systems [Andreas, Schieber. (2018)]^[2]. These problems allow unscrupulous operators to manufacture counterfeit products of greater and greater quality which are increasingly difficult to detect. Furthermore, this practise can also be harmful and endanger consumers by causing irreversible health risks to moderate adverse effects upon human health or acute toxicity possibly resulting in death.

Foodstuffs are heterogeneous materials comprised of various compounds, in varying proportions; depending on their source and geographical origin amongst other factors, derived from animal or plant origins. Preserving the authenticity of food ensures that the foodstuffs available in the market is of the nature, substance and quality expected by the consumer. Food analysis through implementation of traceability systems and analytical techniques allows isolation, identification, and quantification of these compounds, thus providing essential information on foodstuff composition, physiochemical properties, and structure of the food product.

This also enables detection of contamination, adulteration, and verification of foodstuff's authenticity [Romdhane, Karoui. (2012)]^[3].

Types of Food Fraud

Food fraud can occur in numerous ways. There are 7 types of food fraud can occur, those are discussed below-

- **Adulteration:** Adding cheaper, toxic undeclared elements to save money; or foreign high grade [Everstine, K., Spink, J., & Kennedy, S. (2013)]^[4]. Misleading consumers about what is actually in the product and how much it costs and creating a risk to public health. This unfair practice obviously breaches trust with consumers, disrupts markets and creates a bias in competition between fake or cheated players vs legal producers.
- **Dilution:** Adding a liquid ingredient of high value to the water; Dilution that occurs can reduce the safety, nutrition security and genuinity of product, ultimately leading to health hazards, loss in economy or trust for consumer.
- **Substitution:** It is an extensive and deceptive practice where one food product or ingredient is intentionally swapped with another, often of lower quality or lower cost, without the consumer's knowledge. The target of this form of fraud can be basically any food group; beef, fish and shellfish foods are most common, followed by dairy foodstuffs and fresh grains, which constitutes a substantial danger for the consumers as well as reliability in the food market [Marco, Fiorino., Caterina, Barone., Michele, Barone., Marco, Mason., Arpan, Bhagat. (2019)]^[5].
- **Mislabelling:** False or misleading labelling, especially with regard to origin, ingredients, production methods etc. This has a considerable impact on individual consumers, manufacturers and regulators, many times carrying implications for health/safety risks, economic losses and breach of consumer confidence [J., Premanandh., Aman, Sabbagh., M., Maruthamuthu. (2013)]^[6].
- **Counterfeiting:** Copying the brand name, packaging concept, recipe, processing method, etc. of food products for economic gain. In recent years, food counterfeiting has become an increasingly notable concern in the global food industry, partly due to the complexity of modern food supply chains and the challenges associated with monitoring the entire production process [Michael, Blakeney. (2023)]^[7].
- **Grey market production/theft:** Unauthorized manufacturing or distribution of food products that doesn't meet regulatory standards or labeling requirements. Grey market production and food theft are critical forms of food fraud that pose significant risk to consumer safety, brand integrity, and economic stability [Adam, Basilio. (2023)]^[8].
- **Concealment:** Hiding the low quality of food ingredients or product. Concealment in food fraud is a multifaceted concern that poses noteworthy risks to public health, economic security, and consumer trust. Addressing concealment is not only crucial for protecting consumers but also essential for maintaining a fair and sustainable food system [Robert, R., Kerton., Richard, W., Bodell. (1995)]^[9]. Each type of food fraud not only impacts consumer trust but also presents potential health risks, as the substituted or added

substances may be injurious.

Authentication Methods in Food Fraud Prevention

Food authentication is a scientific method to support the origin, composition, and quality of food products [A.M., Pustjens., Yannick, Weesepeel., S.M., van, Ruth. (2016)]^[10].

- **DNA Testing:** One of the most precise strategies is DNA testing which includes DNA fingerprinting and sequencing, for verifying food products [Edoardo, Capuano., S.M., van, Ruth. (2012)]^[11]. This tool can recognize the species or origin of food products through examine of genetic materials. It can identify the species of an animal or plant in a product and determine any swapping or adulterations [Sara, Barrias., Javier, Ibáñez., José, R., Fernandes., Paula, Martins-Lopes. (2024)]^[12]. DNA testing can detect if a food product has been adulterated with unauthorized manufacturing or lower-quality ingredients. DNA testing, for instance, is commonly carried out to authenticate fish species and prevent seafood fraud [Ananya, Mazumder., Sankar, Kumar, Ghosh. (2024)]^[13].
- **Isotopic Analysis:** Isotopic analysis helps detect the geographic origin of food products by inspecting the ratio of isotopes in a sample [J., L., Wilson., Rona, A., R., McGill., Pétur, Steingrund., Clive, N., Trueman. (2024)]^[14]. This procedure is exceptionally functional for verifying the claims of products labeled as "organic" or "geographically protected," such as certain cheeses or wines. It can divulge the existence of adulterants in food products. For example, in honey fraud, corn syrup or other cheaper sweeteners might be added to dilute pure honey. The ratios of isotopes of the adulterants differ from those of natural honey, authorizing detection of such adulteration [Ramazan, Gün., M., Murat, Karaoğlu. (2024)]^[15].
- **Spectroscopy:** Spectroscopy technique such as infrared (IR), near-infrared (NIR), and mass spectrometry, examine the chemical configuration of food products. These methods can detect subtle differences between authentic and fraudulent foods by verifying molecular signatures associated with ingredients or contaminants [Artemis, P., Louppis., Michael, G., Kontominas. (2024)]^[16]. This tool can identify the existence of adulterants that are often added to food products to strengthen volume or weight, such as mixing cheaper oils with premium olive oil or mixing fillers like starch to products. By examine the molecular constitution and chemical composition, spectroscopy can detect these unsanctioned additions even when they are present in small quantities [Diego, G., Much., Mirta, Raquel, Alcaraz., José, Manuel, Camiña., Héctor, C., Goicoechea., Silvana, Mariela, Azcarate. (2024)]^[17].
- **Chromatography:** Chromatography plays an important part in preventing food fraud by isolating, identifying, and quantifying the numerous elements of food products. This technique can determine adulteration, mislabelling, and contamination, assisting to ensure product authenticity and consumer safety. Chromatography can identify substances that have been added to a food product to magnifies its weight or volume but are not proclaimed on the label of the food product [Chiara, Fanali., Laura, Dugo., Luigi, Mondello. (2016)]^[18]. For example, it can detect the

inclusion of lower-cost oils (Such as palm or soybean oil) to olive oil or sugar syrups added to honey. Gas chromatography (GC) and high-performance liquid chromatography (HPLC) are often used for identifying trace amounts of adulterants in the food product [Eric, Deconinck., Surbhi, Ranjan. (2022)]^[20].

Traceability Method in the Prevention of Food Fraud

Traceability refers to the ability to track food products throughout the supply chain, from production to the consumer [Deborah, E., Popper. (2007)]^[21]. It imparts transparency and accountability at each stage, reducing the likelihood of fraud. Several modern traceability systems are utilized to ensure food safety and integrity:

- **Blockchain Technology:** The blockchain is a decentralized digital ledger wherein every transaction or product movement is updated and available in real-time. Blockchain technology is a powerful tool to track food from farm to table as it makes each stage in the supply chain transparent and immutable. It will also confirm the legitimacy of claims about the origin, quality, and safety of a product. Blockchain Technology is a bright star on the sky of many industries and enterprises [Verma, Priti., R.D Srivastava and Senthil Kumar. (2024)]^[2]. A consumer can make sure their favourite brand announces that the coffee beans were sourced from Guatemala (or not), ground in Honduras, taken to France on the ship Esperanto, etc; this would allow consumer to trace and tell if their fair trade/organic/etc claim is true.
- **Barcoding and QR Codes:** Barcoding and QR codes participates a significant role in the prevention of food fraud by magnifying transparency, traceability, and accountability throughout the food supply chain. Barcodes and QR codes permit for real-time tracking of food products as they move from the producer to the consumer. By scanning the barcode or QR code of any food product, retailers, suppliers and consumers can access comprehensive knowledge about its origin, manufacturing process, and distribution. This transparency makes it laborious for fraudulent activities such as mislabelling or substitution to occur unrevealed [Shrawan, Kumar., Vanka, Sai, Avinash., S., Gowri. (2024)]^[23]. For instance, a QR code might provide the farm location, harvesting date, packaging concept, and even transportation data, helping to substantiate that the product has followed a legitimate supply chain.
- **Internet of Things (IoT) Sensors:** IoT involves sensor's utilization and smart devices to monitor and document real-time data about food products, including temperature, humidity, and location during transportation. For example, in the case of perishable products like seafood or dairy, temperature-sensitive IoT sensors secure that products are kept within the needed temperature range. If the temperature diverges, the system can trigger alerts, averting food spoilage, adulteration, or misrepresentation of freshness [Sandip, Pramanik., V., S., Kadam., Shripad, Bhatlawande. (2024)]^[24]. IoT sensors, along with GPS-enabled devices, can trace the exact location of food products at each phase of the supply chain. This permits for traceability from the farm to the plate. Each movement of the food product is documented, and this data is kept securely through tamper-proof digital ledger (e.g.,

blockchain). This transparency makes it hardly unfeasible for fraudsters to tamper with or mislabel products, as each step in the journey of product is observed and recorded [Ana, Margarida, Cachada., Hasmik, Badikyan., Camilo, Anzola-Rojas., Javier, Parra., Fernando, De, la, Prieta., Paulo, M., C., Leitão. (2022)]^[25].

Conclusion

Food fraud continues to be a widespread problem in the global food industry, hurting individual consumers and businesses alike. Food fraud is the act of intentionally deceiving a consumer for financial gain when it comes to food or beverages - be they adulteration, substitution, mislabelling, or counterfeiting. The scam threatens public health and can cost consumers millions by economic losses. The more complex and diverse the food supply chain, the easier it is to cheat. Thus, generating the appetite for deployable methods of preventing and reacting to food fraud, greater than at any time in our history.

Authentication, and Traceability - the two key pillars in fighting food fraud this review has emphasized that management of food fraud is required for both authentication and traceability. When used together, these tools can support the core of an effective food fraud prevention program to protect the authenticity, safety and transparency in every food product.

While authentication and traceability are worthwhile independently, their true strength lies in their integration. A comprehensive food fraud prevention system merge scientific authentication methods with digital traceability techniques to generate an end-to-end solution. This collaboration ensures that food products are both verifiably authentic at the point of production and traceable throughout the entire supply chain.

These technologies not only help detect and prevent fraud but also upgrade the efficiency of product recalls and enhance consumer trust by providing transparency in food referencing and handling. Traceability systems help pinpoint where fraud or contamination might occur, allowing for rapid and targeted responses to any issues that arise.

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