VETERINARY TODAY

Popular Article
ISSN: 2583-8288
Published on: 26.11.2023

Chemistry of Food Fraud: A Critical Evaluation

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Introduction

Food fraud is a serious threat to the integrity of the global food supply chain. During ancient times, food fraud was prevalent because trading was done by barter. Markets offered many raw foods, and processed foods (such as ales, honey, wine, and oils) were more vulnerable to deceptive practices. An untrustworthy practice such as overweighting can alter raw materials. The risks are substantial. Food industry dishonesty is well known, with adulteration, mislabelling, and counterfeiting commonplace. According to the above, these practices negatively affect consumers' trust in the industry and their own safety. The development of analytical chemistry techniques grew out of this difficult work since they were developed to be as effective as possible. In this article, we see how chemistry is a key factor in solving the issue of food fraud and how it is used to verify and authenticate products. This problem will be addressed in a comprehensive way using different methodologies.

Understanding Food Fraud:

Several illegal practices fall under the umbrella of "food fraud," including altering, adding to, or misrepresenting food products to gain an unfair advantage. Several industries are affected, including spices, dairy products, oils, and seafood. Fraudulent behaviour is driven by financial incentives, which results in lower quality products, injuries to consumers, and economic losses to legal manufacturers and their buyers.

The Role of Chemistry in Tackling Food Fraud:

Despite the severe food standards developed and enforced, which are supported by advanced analytical technology, fraudsters keep doing it without fear of getting caught. Multiple food fraud cases have occurred over the last few decades, pointing out the weaknesses in the global detection system. Additionally, many organisms unintentionally threaten food safety because they are harmful to people.

- **Analytical Techniques Overview:**
  - **Chromatographic Methods:** High-performance liquid chromatography (HPLC), gas chromatography (GC), and thin-layer chromatography (TLC) are pivotal in separating and identifying components in complex food matrices. It makes a clear distinction between liquid chromatography (LC) using common detection methods and LC combined with high-resolution mass spectrometry (LC-HRMS).
  - **Spectroscopic Techniques:** Fourier-transform infrared spectroscopy (FTIR), nuclear magnetic resonance (NMR), and mass spectrometry (MS) aid in molecular identification and structural elucidation. The spectroscopy is often thought of as the best way to analyse tiny compounds, especially metabolites. RF radiation is used to create magnetic nuclei while being exposed to a consistent magnetic field.
  - **DNA-Based Methods:** For authentication and traceability, polymerase chain reaction (PCR) and DNA sequencing are commonly used analytical methods due to their high sensitivity, accuracy, and ease of use. The technique has been used for identifying the species of meat in raw and cooked products, as well as for detecting the adulteration of commercial tea products with cashew nut husk.

- **Adulteration Detection:** Fighting food fraud requires the detection of adulteration. The detection and prevention of these fraudulent techniques require a strong understanding of chemistry.
  - **Ingredient Authenticity:** Chemistry helps detect the presence of unauthorized additives, illegal dyes, and undeclared allergens through spectroscopic and chromatographic analyses.
  - **Geographical and Species Origin Verification:** Isotopic and elemental analysis assist in determining the geographic origin and authenticity of food products, especially in cases of wine, honey, and meat.

3. **Contaminant and Residue Analysis:**
   - **Pesticide and Chemical Residue Detection:** Analytical chemistry identifies and quantifies pesticide residues and contaminants, ensuring compliance with safety regulations.
   - **Drug Residue Monitoring:** Techniques like liquid chromatography-mass spectrometry (LC-MS) enable the detection of veterinary drug residues in meat, milk, and eggs.
4. **Emerging Technologies:**
   - **Metabolomics and Proteomics:** Advancements in metabolomics and proteomics facilitate a deeper understanding of food composition, aiding in the detection of unexpected compounds.
   - **Blockchain and Authentication:** Integrating chemistry with blockchain technology enhances traceability, allowing consumers to access detailed product histories.

Analytical methods have challenges and limitations:

- **Complexity of Food Matrices:** Analysing diverse matrices like spices or processed foods poses challenges due to complex compositions.
- **Method Validation and Standardization:** Harmonizing methods across laboratories globally remains a challenge, affecting reliability and comparability of results.
- **Cost and Accessibility:** Sophisticated instrumentation and skilled personnel can be cost prohibitive for smaller producers and developing regions.

Future Directions: Innovative approaches ahead

- **Miniaturization and Portability:** Development of portable devices for on-site testing can democratize food authenticity verification.
- **Artificial Intelligence Integration:** AI-driven algorithms can streamline data analysis, enhancing accuracy and speed.
- **Interdisciplinary Collaboration:** Collaboration among chemists, food scientists, regulators, and industry stakeholders are pivotal for holistic solutions.

Chemists provide a diverse array of analytical methods to fight food fraud. Even though these methods have advanced detection capabilities, continuing research and collaborative efforts are needed to address limitations, enhance accessibility, and ensure our food supply chain is authentic and safe.

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