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DETECTION OF FOOD ADULTERANTS IN FOOD PRODUCTS BY DIFFERENT ANALYTICAL TECHNIQUES

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ABSTRACT

Identifying food adulteration is a significant criterion because it is a recent concern for humankind. The struggle against food adulteration has to concentrate on food authenticity. This article examines contemporary optimization and adulterant identification methods for application in modern analytical techniques. The analysis using these approaches improves our comprehension of a variety of parameters with consistent and precise findings. The number of essential nutrients available and numerous extra dietary components that might interfere with them and produce problems also affect the possible negative impacts of adulteration as well as upcoming challenges and consequences. Food adulterant detection has had great success since the previous decade was a basic investigation. Consequently, the current scenario necessitates the use of analytical instruments. The current review discusses the new techniques that can used for the detection of ppb levels of adulteration.

INTRODUCTION

Concern over food safety and security has grown as a result of the possibility of food adulteration, particularly in relation to powdered food products where the quantity of powder can be increased, or the required aesthetic quality can be achieved by adding inexpensive ground materials or dangerous chemicals. The creation of a quick, label-free, and non-invasive technique for the detection of adulteration over a variety of food goods is required due to the potential health risks to consumers that could occur.

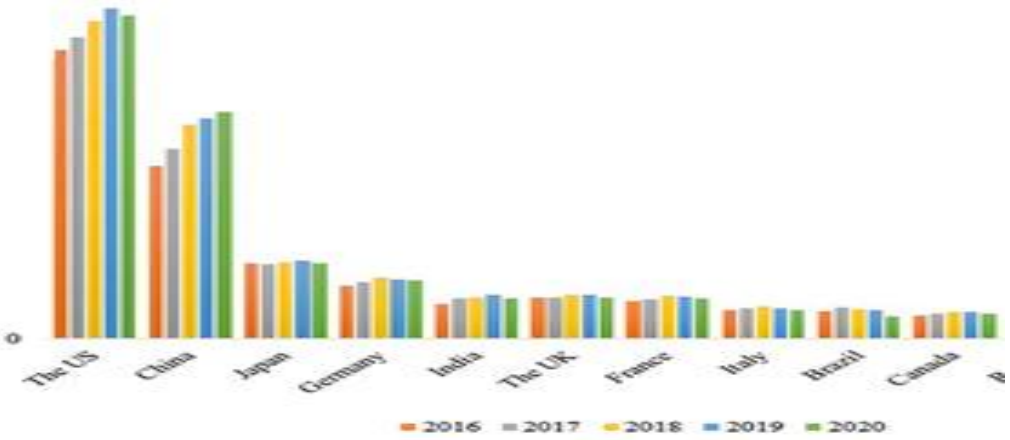

Fig. 1: Number of deaths due to food adulteration over years.

The current systems use wet lab assay for both qualitative detection of chemically and structurally comparable adulterants as well as qualitative detection of physical adulteration such as color, sawdust, seeds, etc. Spectroscopic methods like HPLC, GC, FTIR, and MS reading are used to conduct quantitative analysis.

The right approaches must be chosen for each additional food ingredient or product, which may be present in very small quantities yet still affect the food's nutritional worth.

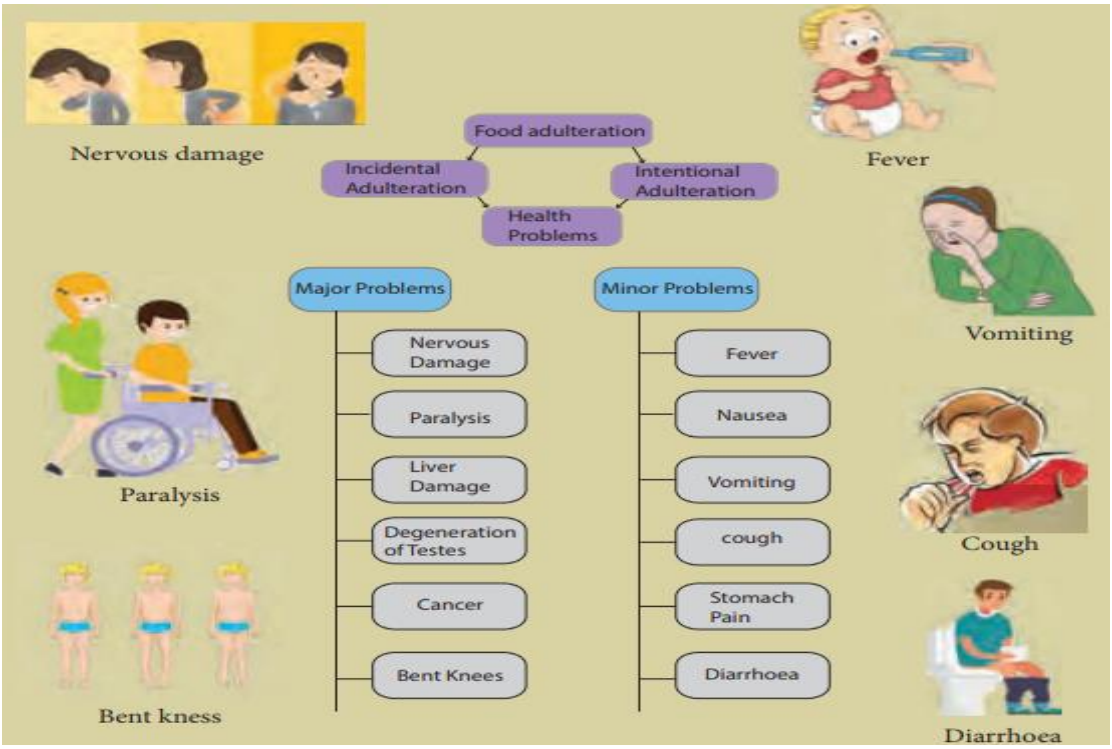

Fig. 2 Multiple causes of food adulterations.

Selecting an Appropriate Technique

Following is a summary of some of the factors to consider while choosing a technique:

1) Precision: A measure of the capacity to duplicate an outcome across tests conducted by the same scientist (or group of scientists) using the same tools and experimental design.
2) Reproducibility: This is a metric for how well an outcome can be replicated by researchers using the same experimental design but in various labs with various tools.
3) Accuracy: A measure of how closely a parameter being measured, such as salt concentration or fat content, can be measured to its actual value.
4) Speed: Operational simplicity measures how simple it is for personnel who are comparatively inexperienced to carry out the analysis. The amount of time required to analyze a single sample or the maximum number of samples that can be analyzed at once.
5) Sensitivity: The lowest concentration of a component that a specific method can detect.
6) Specificity: A measure of the capacity to identify and measure specific food ingredients, even when additional, similar ingredients are present. For example, fructose in the presence of sucrose or glucose.
7) Safety: Many of the substances and techniques employed in food analysis, such as strong acids or bases, poisonous chemicals, or combustible materials, have the potential to be dangerous.
8) Destructive/Nondestructive: Some analytical techniques cause sample destruction while others leave it intact.

Fig 3 Need of additives

Types of ingredients	Need/ Purpose	Labeled as
Preservatives	Prevent spoilage and maintain freshness	Sodium benzoate, Citric acid, Oxalic acid, Tartaric acid, Butylated hydroxy anisole.
Artificial sweeteners	Add sweetness	Sorbitol, Aspartame, Sucralose.
Food coloring	Enhance color	Blue, Green, Red, Orange, and Yellow.
Artificial flavoring and flavor enhancer	Add and enhance flavoring	Monosodium glutamate, Hydrolyzed soy protein, Tartaric acid and Phenylacetaldehyde.
Fat replacers	Provide expected creamy texture	Olestra, Modified food starch etc.
Emulsifiers	For smooth mixture and to prevent separation	Soy lecithin, Sorbitan
Stabilizers	To produce uniform texture	Gelatin, Gum

Consequences of Excessive Use

1. Health Risks: Excessive use of certain additives, such as artificial sweeteners or high levels of sodium (salt), can lead to adverse health effects like obesity, diabetes, hypertension, and other chronic diseases.

2. Allergic Reactions: Some individuals may be hypersensitive or allergic to specific additives, leading to allergic reactions or intolerances.

3. Taste and Texture Alterations: Excessive use of additives can alter the taste, texture, and overall quality of food, making it unappetizing or unpalatable.

4. Nutritional Concerns: Overuse of additives can displace essential nutrients in the diet, potentially leading to nutritional imbalances.

5. Consumer Mistrust: If consumers perceive that a food product contains excessive additives, it can erode trust in the brand or the food industry as a whole.

6. Regulatory Issues: Excessive use of additives may lead to regulatory violations and legal consequences for food manufacturers.

To mitigate the potential negative consequences of excessive additive use, it's essential for food manufacturers and regulatory agencies including International organization of standardization (ISO), Association of Official Agricultural Chemist (AOAC), Food Safety and Standards Authority of India (FSSAI) to:

1) Strictly adhere to established safety guidelines and maximum allowable limits for additives.

2) Continuously monitor and evaluate the safety and efficacy of food additives.

3) Provide clear labeling of additives in food products to empower consumers to make informed choices.

Consumers can also make informed decisions by reading food labels, understanding the ingredients, and being aware of their dietary preferences and restrictions. Ultimately, the judicious use of additives in food processing can provide benefits without compromising safety and quality when managed responsibly.

The selection of a specific method will rely on which of the aforementioned factors is more significant if there are several different methods for assessing a specific attribute of a meal. For instance, in a government lab that verifies the veracity of compositional or nutritional claims on food products, accuracy and the use of an official method may be the most important criteria. However, for routine quality control at the manufacturing site where a large number of samples must be analyzed quickly, speed and the ability to make non-destructive measurements may be further crucial.

Chromatographic, spectroscopic, and chemometric techniques are among the analytical methods used to find adulterants. Chemometrics is a field of study that uses formal reasoning to build or select the best evaluation methods and tests and to provide the bare minimum amount of vital synthetic data by dissecting complex material. In order to determine whether an adulterant has been added to the food product, ratios of the chemical components could be identified and compared. Adulterated food will have a different ratio and can be identified using the appropriate methods, such as chemometrics. He added that a unique commodity marking could establish the product's authenticity or adulteration to his previous study.

To improve quality of life new ideas and techniques are adapted for people. For the same numerous methods are employed today to identify adulterated food. These include spectroscopic techniques including UV/Visible, Infrared (IR), Atomic Absorption or Emission Spectroscopy (AAS/AES), and photo-luminescent spectroscopy. The most suggested approaches for detecting food adulteration are chromatographic techniques like HPLC, GC, and hyphenated techniques like GCMS, LC-MS, and GC-MS-MS.

1) Atomic absorption spectrometry

In an energy-transfer process (in a flame or a graphite furnace), the element being analysed is converted into free ground state atoms in atomic absorption spectrometry (AAS). A light beam with the element's characteristic wavelength is directed through this atomic vapour, and the light's intensity drop is measured. While the relative drop in light intensity defines the relative and absolute quantity of the element, the wavelength of the light being employed determines the quality of the substance being analysed.

2) ICP-MS, or inductively coupled plasma mass spectrometry

Inductively coupled plasma mass spectrometry (ICP-MS) is now one of the most sensitive techniques in the field of elemental analytical measurements. According to its name,

inductively coupled plasma mass spectrometry consists of two main components. The inductively coupled plasma is the first of them, and the mass spectrometer, which performs the separation and detection, is the second. Ions of the measured element (isotope) are generated in ICP-MS, and when they are directed into the mass spectrometer, they are separated according to their mass/charge (m/z) in a magnetic or electrostatic field. While the relative intensity of the created ion beam is proportional to the quality of the element, the mass-charge ratio of the isotope is typical for the grade of the element.

3) Chromatography techniques

Chromatography has a significant impact on analytical chemistry and is a valuable separation technique in the realm of food analysis. In the column chromatography process known as gas chromatography, the stationary phase is either a solid packed inside a closed tube or an immobilised liquid. The thermally stable volatile components of a mixture can be separated using GC (for instance, fatty acid methyl esters). The sample is vaporised and introduced into the column head during the gas-liquid GC process. The mobile phase, which is typically an inert gas, transports the sample across the column by using a regulated temperature gradient. The volatile substances are then divided according to their boiling points, molecular sizes, and polarities.

As of late, GC is used to determine fatty acids, triglycerides, cholesterol and other sterols, gases, solvent analysis, water, alcohols, and simple sugars.

Chromatography using supercritical fluid Chromatography that is carried out above the mobile phase's critical pressure (Pc) and critical temperature (Tc) is known as supercritical fluid chromatography (SFC). Neither a liquid nor a regular gas is a supercritical fluid (or compressed gas). The critical point is the point at which Pc and Tc combine.

By increasing the pressure on a common gas or by raising the temperature on a typical liquid, a supercritical fluid can be created. Because carbon dioxide is a poor solvent for polar and high molecular-weight molecules, it is typically utilized as a mobile phase for SFC. Nitrous oxide, trifluoro methane, sulfur hexafluoride, pentane, and ammonia are further supercritical fluids. In comparison to LC, supercritical fluids have improved resolution and shorter analysis times due to their high diffusivity.

SFC provides a broad range of selectivity adjustments by adjustments to pressure, temperature, mobile phase composition, and stationary phase. Nonvolatile, thermally labile chemicals that are not susceptible to GC can be separated using SFC. SFC has been utilised mostly for nonpolar chemicals and can be carried out using either packed columns or capillaries. SFC is being used more and more on lipids such as fats, oils, and other lipids.

Liquid chromatography with high performance Since early columns produced high operating pressures, high-performance liquid chromatography (HPLC) was originally an acronym for high pressure liquid chromatography. High performance liquid chromatography, emphasising the successful separations attained, had taken over as the popular term by the late 1970s. Any substance that is soluble in a liquid that can be utilised as the mobile phase can be analysed using HPLC. Although it is typically utilised in the analytical mode, HPLC can also be used in the preparative mode.

Compared to conventional low-pressure column liquid chromatography, HPLC has a number of benefits: Speed—many studies can be completed in 30 minutes or less, there are a large number of stationary phases available, different detectors can be used to improve resolution and sensitivity, and sample recovery is simple because there is less eluent volume to remove. A pump, injector, column, detector, and data system make up a fundamental HPLC system. In addition to being widely utilised for the separation and purification of macromolecules like proteins and polysaccharides, HPLC is also employed for the analysis of small molecules and ions, including sugars, vitamins, and amino acids.

(GC-MS) Gas Chromatography-Mass Spectrometry The analytical technique known as gas chromatography-mass spectrometry (GC-MS) combines the separation capabilities of gas-liquid chromatography with the detection capabilities of mass spectrometry to identify various compounds within a test sample. While GC-MS segments the analyte to be identified based on its mass, GC separates the volatile and thermally stable alternatives in a sample. It becomes GC-MS/MS when a mass spectrometer is further added. Single and triple quadrupole modes deliver superior performance. Numerous aromatic chemicals are present in foods and beverages either naturally or as byproducts of processing.

The examination of esters, fatty acids, alcohols, aldehydes, terpenes, etc. is the sole usage of GC-MS. Additionally, GCMS is used to measure and detect pollutants, food spoilage, and adulteration of oil, butter, and ghee that should be examined and managed in accordance with

legislative regulations. Piperine, spearmint oil, lavender oil, essential oils, fragrance reference standards, perfumes, chiral compounds in essential oils, fragrances, menthol, allergens, olive oil, lemon oil, peppermint oil, straw berry syrup, butter triglycerides, and residual pesticides in food and wine are among the things it is used to analyse.

4) Infra-red (IR) spectroscopy: To determine how much IR radiation is absorbed by or reflected from a material, infrared spectroscopy is utilised. The modification of the vibrational or rotational energy states of molecules is related to the absorption of infrared radiation. Applications include the analysis of gaseous, liquid, or solid materials; the identification and quantitative analysis of chemicals; etc. Information about the samples can be gleaned from the IR spectra for functional groups of molecules, molecule makeup, and intermolecular interactions.

Infrared (FTIR) Fourier Transform Spectroscopy Utilizing the naturally occurring electromagnetic spectrum, which is comprised of wavelengths between 2,500 and 25,000 nm, FT-IR is a spectroscopic technique. The technique is known as "mid infrared" since this is the "mid-infrared" zone. However, it is typically the name of a method (Fourier Transform) used to transform measurement data into a useful result.

Fig 4 Overall techniques and methods developed for food adulterants (From FSSAI manual)

Title (products)	GC	HPLC	HPTLC	OTHER METHOD
Thermally Processed Fruits and Vegetables (Canned)	–	–	–	Refractometer, Titration
Thermally Processed Fruits and Vegetable Juices: • fresh & canned fruits, jams,marmalades & preserves • purce,marmalades or jam,fruit, vegetables • liquid products(juices, pulps and syrups)	 – – –	 – – –	 – – –	Refractometer, Titration Titration Titration, distillation(incineration)
Thermally Processed Fruit Drink, Beverages, Pulp, Juice, Puree (Canned, Bottled Poly packed)	–	–	–	Refractometer,Titration,distillation,oil separator trap
Soup Powders	–	–	–	Heating, cooling, weighing
Tamarind Pulp, Puree, Concentrate	–	–	–	Refractometer,Titration,incineration
Fruit Bar / Toffee	–	–	–	Titration
Fruit and Vegetable Cereal Flakes	–	–	–	Incineration …. (heating, cooling, weighing)
Squashes, Crushes, Fruit syrups, Sherbets, Synthetics Syrups, Ginger Cocktail	–	–	–	Refractometer, Titration (electromeric method)

Murabba	_	_	_	Titration
Candied, Crystallised, Glazed Fruit / Vegetable, Fruit Peel	–	–	–	Lane & Eynon volumetric method (titration method)
Mango Chutney	_	_	_	Refractometer, Titration
Tomato Ketchup, Sauce, Culinary Paste	_	_	_	Refractometer, Titration …. (mohrs method.. it is like precipitation method)
Soya bean Sauce	_	_	–	Refractometer, Titration (electromeric method)
Brewed and Synthetic Vinegar	_	_	_	Formal titration
Carbonated Fruit Beverages, Drink	_	_	_	Refractometer, titration
Jam, Jelly and Marmalade	_	_	–	Refractometer, titration, ..(addition manual)
Dehydrated Fruits and Vegetables	_	_	_	Evaporation, dessication, incineration
Pickles	_	_	_	Weighing, Titration
Table Olives	_	_	_	Titration, PH, determination, electromagnetic method, potentiometric method
Dried Fruits and Vegetables	_	_	_	Weighing, evaporation, dessication

CONCLUSION

Traditional analytical techniques including the Soxhlet method (oil content), Gravimetric method (fiber), and Folin-Lowry method (protein) are tried-and-true yet tedious and time-consuming. These techniques are appropriate for examination at the laboratory level using representative samples. However, these approaches cannot be used to screen or monitor the quality criteria of each product at the industrial level since they do not match the plan.

Traditional methods for detecting food adulteration have limitations in terms of accuracy and efficiency. These methods often rely on sensory perceptions or simple chemical tests, making them susceptible to human error and providing only qualitative results. Modern technologies, such as advanced spectroscopy and chromatography, offer more reliable and quantitative analyses, paving the way for improved food safety standards. As we progress, integrating these innovative methods becomes crucial in ensuring the authenticity and quality of our food supply.

We can now quantify trace quantities of dietary adulterants thanks to modern analytical techniques. Modern approaches may precisely determine many factors such as sensitivity, accuracy, precision, selectivity, and detection level; as a result, these techniques are all highly helpful for food authenticity.

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