Evaluating the Regulatory Framework for Food Adulteration in India: An Interdisciplinary Analysis of Agricultural Practices, Hygiene, and Rural-Urban Perspectives

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1. Abstract

Food adulteration remains a major public health, consumer protection, and governance challenge in India, compromising food quality, consumer trust, and the constitutional objective of ensuring access to safe and wholesome food. This study evaluates the effectiveness of India's regulatory framework governing food adulteration by examining the issue through legal, public policy, agricultural, hygiene, and rural-urban perspectives. It situates food safety within the constitutional framework by analysing Article 21, which has been judicially interpreted to include the right to health and safe food, Article 47, which places a duty upon the State to improve public health and nutrition, and Entry 18 of the Concurrent List, which empowers both the Union and State Governments to legislate on the adulteration of foodstuffs. The study also examines the evolution of food safety regulation under the Prevention of Food Adulteration Act, 1954, the Food Safety and Standards Act, 2006, and the role of the Food Safety and Standards Authority of India (FSSAI).

The research adopts a mixed-methods approach, combining an extensive review of academic literature, legislation, government reports, newspaper-based case studies, and judicial and policy documents with primary data collected through a structured online questionnaire administered to 80 respondents, field observations across selected regions in the selected districts of Uttar Pradesh, and informal interactions with farmers. Quantitative data were analysed using descriptive statistics, while qualitative findings were interpreted thematically.

The findings reveal that although respondents demonstrated general awareness of food adulteration, considerable gaps persist regarding food safety regulations, reporting mechanisms, and methods for identifying adulterated food. Field observations highlighted significant variations in hygiene and food-handling practices across rural, semi-urban, and urban areas. Interactions with farmers further indicated that climate variability, pest infestations, and economic pressures have increased dependence on pesticides, raising concerns regarding chemical residues in agricultural produce. The study argues that food adulteration extends beyond the intentional addition of harmful substances to include contamination arising from poor hygiene, unsafe handling, improper storage, and agricultural practices, consistent with the broader legal understanding of adulteration.

The study concludes that India possesses a comprehensive constitutional and statutory framework for ensuring food safety; however, the principal challenges lie in implementation, regulatory enforcement, institutional capacity, consumer awareness, and compliance across the food supply chain. It recommends strengthening enforcement mechanisms, promoting responsible agricultural practices, improving hygiene standards, expanding consumer awareness initiatives, enhancing grievance redressal systems, and adopting advanced food testing technologies. By integrating constitutional principles, legal analysis, empirical

evidence, and field-based insights, the study contributes to a more holistic understanding of food adulteration and offers evidence-based recommendations for strengthening food safety governance and protecting public health in India.

2. Research problem

Food adulteration remains a significant public health and food safety challenge in India, affecting the quality, safety, and nutritional value of food consumed by millions. Despite a comprehensive constitutional, legal, and regulatory framework, adulterated food products continue to circulate in both organized and unorganized markets. The intentional addition of inferior or harmful substances, along with poor food handling, storage, and hygiene practices, compromises food quality and poses serious risks to human health.

The issue extends beyond food safety and directly relates to the constitutional commitment to protect public health. Article 21 of the Constitution of India, as judicially interpreted, includes the right to health and access to safe food, while Article 47 places a duty upon the State to improve public health, nutrition, and the standard of living. However, the continued prevalence of food adulteration raises concerns regarding the effective implementation of these constitutional obligations.

Limited consumer awareness further aggravates the problem. Many consumers are unable to identify adulterated food, lack knowledge of simple detection methods, and are unaware of the legal mechanisms available to report food safety violations. Field observations also revealed considerable variations in hygiene practices among food vendors, including food covering, personal hygiene, storage conditions, waste disposal, and sanitation standards. Combined with irregular inspections, resource constraints, and weak regulatory enforcement, these factors increase the risk of food adulteration and contamination throughout the food supply chain.

Food safety concerns also originate at the agricultural stage. Interactions with farmers revealed that changing climatic conditions, pest infestations, and declining crop quality often increase reliance on pesticides and other agrochemicals. While essential for agricultural productivity, their excessive or improper use may leave chemical residues on food, highlighting that food adulteration is not merely intentional market fraud but also a consequence of environmental pressures, agricultural practices, and supply chain challenges.

Furthermore, food safety challenges vary across rural, semi-urban, and urban areas due to differences in consumer awareness, market infrastructure, regulatory oversight, hygiene standards, agricultural practices, and access to safe food. Existing research has largely examined these issues in isolation, with limited comparative analysis and insufficient attention to farmers' perspectives. Therefore, there is a need for a comprehensive study integrating consumer perceptions, field observations, and stakeholder interactions to evaluate the effectiveness of existing governance mechanisms in advancing the constitutional objectives under Articles 21 and 47 and to develop evidence-based recommendations for strengthening food safety governance in India.

3. Research Objectives

- To assess public awareness regarding food adulteration in rural and urban areas.
- To compare hygiene and food-handling practices among vendors operating in rural, semi-urban, and urban settings.
- To examine the role of contamination and poor hygiene in food adulteration using the legal framework of the Prevention of Food Adulteration Act, 1954.
- To understand farmers' perspectives on climate variability, pest infestation, and the use of pesticides and fertilizers and their implications for food safety.
- To analyze food adulteration as a multidimensional issue involving consumer behaviour, hygiene practices, agricultural production, and regulatory oversight.
- To recommend strategies for strengthening food safety and public awareness across different settings.

4. Research Questions

- What is the level of public awareness regarding food adulteration in rural and urban areas?
- How do hygiene and food-handling practices differ among food vendors in rural, semi-urban, and urban settings?
- How do the hygiene practices contribute to food contamination and potential adulteration?
- What challenges do farmers face in maintaining food quality under changing climatic conditions?
- How do changing weather patterns influence pesticide and fertilizer use, and what are their implications for food safety?
- How does the legal definition of food adulteration under the Prevention of Food Adulteration Act, 1954 support the inclusion of contamination arising from unhygienic conditions?
- What similarities and differences exist in food safety challenges across rural, semi-urban, and urban areas?

5. Literature Review

5.1. Introduction

Food is one of the most fundamental necessities of human life, essential for maintaining health, nutrition, and overall well-being. However, the growing incidence of food adulteration has emerged as a major public health and consumer protection concern worldwide. Food adulteration refers to the deliberate alteration of the quality, composition, or nature of food products for economic gain. This is commonly achieved by substituting high-quality ingredients with cheaper or inferior alternatives, increasing the weight or volume of food through the addition of undeclared substances, or enhancing its appearance using artificial colours, chemicals, or other unauthorized additives. Such practices compromise the safety, nutritional value, and authenticity of food, exposing consumers to serious health risks while undermining trust in the food supply chain.

5.2 Concept and Scope of Food Adulteration

Food adulteration, as defined under the Prevention of Food Adulteration Act, 1954, refers to any act or condition that compromises the nature, substance, quality, purity, or safety of a food product, making it different from what it is claimed, represented, or expected to be by consumers. Under Section 2(i), the Act defines an *adulterant* as any material used or capable of being used to adulterate food. More significantly, Section 2(ia) adopts a broad definition of an *adulterated* food article, recognizing that adulteration extends beyond the intentional mixing of harmful substances. It includes any act or omission that diminishes the quality, purity, safety or authenticity of food, thereby posing a risk to consumers or misleading them regarding the true nature of the product. The concept of adulteration extends beyond deliberate mixing of foreign substances. The scope of food adulteration under the Act is therefore not confined to economic fraud but also encompasses threats to public health arising from poor food handling and unsafe practices. For instance, Section 2(ia)(e) considers food adulterated if it is prepared, processed, packed or stored under unhygienic or insanitary conditions that may contaminate it or render it injurious to health. This provision highlights that maintaining hygienic conditions throughout the food supply chain is as important as preventing the deliberate addition of harmful substances. Likewise, the Act treats food as adulterated when it contains decomposed or filthy matter, is derived from diseased animals, contains toxic or unauthorized substances, or fails to comply with prescribed standards of quality and purity under Section 2(ia). Food may further be classified as adulterated if it contains rotten, decomposed, putrid, insect-infested, or diseased animal or vegetable matter, or if it is derived from diseased animals. The presence of poisonous, harmful, or deleterious substances, whether introduced directly into the food or through its packaging materials, also constitutes adulteration. [1]

Additionally, food is deemed adulterated when it contains unauthorized colouring agents, excessive quantities of permitted colourings or preservatives, prohibited preservatives, or ingredients that exceed legally prescribed limits. A food article may also be considered adulterated when its quality, purity, or composition falls below established regulatory standards, irrespective of whether the deviation causes immediate harm to health. Thus, the Act adopts a broad understanding of food adulteration that encompasses intentional fraud, economic deception, contamination, poor hygiene, regulatory non-compliance, and any reduction in food quality or safety that may adversely affect consumer welfare and public health.[2]

The scale of this challenge in India is reflected in ongoing regulatory surveillance and enforcement efforts. To ensure compliance with food safety standards, the Food Safety and Standards Authority of India (FSSAI), along with State and Union Territory Food Safety Departments, regularly conducts surveillance drives, inspections, and random sampling of food products such as milk, ghee, spices, honey, paneer, and other commonly consumed items. Between 2022–23 and 2024–25, a total of 5,18,559 food samples were analyzed across the country. During the same period, 88,192 cases were decided with penalties, 3,614 cases resulted in convictions, and 1,161 food business licenses were cancelled. Additionally, under

[1] https://www.indiacode.nic.in/bitstream/123456789/15399/1/the_prevention_of_food_adulteration_act%2C_1954.pdf

[2] *Ibid.*

FSSAI's Risk Based Inspection System (RBIS), 56,259 inspections were conducted over the last three years, with annual inspections mandated for food businesses categorized as high risk.[3]

The rapid expansion of fast-food outlets and online food delivery platforms has significantly transformed food consumption patterns in recent years. Increasing consumer preference for convenience and quick service has placed greater pressure on food businesses to deliver meals rapidly. While these services have improved accessibility and convenience, several studies suggest that maintaining food quality, hygiene, proper storage, and safe handling practices throughout preparation and delivery remains a critical challenge. These changing consumption patterns highlight the growing need for effective food safety regulation, regular inspections, and increased consumer awareness regarding the quality and safety of prepared foods.[4]

These figures indicate that food adulteration and food safety violations remain persistent challenges despite an established regulatory framework. However, public discourse often associates food adulteration primarily with the intentional mixing of harmful chemicals or inferior substances. Such a perspective overlooks other important dimensions of the problem, including contamination resulting from poor hygiene practices, unsafe storage conditions, and broader challenges within agricultural production systems. Therefore, a comprehensive understanding of food adulteration requires examining not only deliberate adulteration but also the environmental, behavioural, and institutional factors that compromise food quality and consumer safety.

5.3. Types of Food Adulteration

Food adulteration can be broadly classified into three categories: intentional adulteration, incidental adulteration, and metallic adulteration. This classification provides a comprehensive understanding of how food quality and safety may be compromised at different stages of the food supply chain.

(i) Intentional Adulteration

Intentional adulteration refers to the deliberate addition, substitution, or removal of substances from food products with the primary objective of obtaining economic benefits. Producers, manufacturers, or traders may replace high-quality ingredients with cheaper alternatives, add unauthorized substances to increase the quantity or improve the appearance of food, or remove valuable constituents while continuing to market the product as genuine. Such practices are motivated by profit and constitute a form of consumer deception, as they compromise the nutritional value, quality, and safety of food. Since many adulterants closely resemble the original food in colour, texture, or taste, they are often difficult for consumers to detect without laboratory testing, making this a significant threat to food safety. [5]

[3] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2241083&reg=3&lang=2

[4] https://timesofindia.indiatimes.com/readersblog/rightpath/food-adulteration-2984 /

[5] https://pmc.ncbi.nlm.nih.gov/articles/PMC10724644/

(ii) Incidental Adulteration

Incidental adulteration, also known as accidental adulteration, occurs unintentionally during the production, processing, storage, transportation, or marketing of food. Unlike intentional adulteration, it results from poor hygiene, improper handling, environmental contamination, negligence, or failure to follow food safety practices. Contamination may arise from pesticide residues, microorganisms, insects, dust, packaging materials, or excessive use of preservatives during different stages of the food supply chain. Observations made during this study also suggest that inadequate hygiene among food vendors and improper storage conditions may increase the risk of incidental contamination, highlighting the importance of hygienic practices and regulatory compliance throughout the food supply chain.[6]

(iii) Metallic Adulteration

Metallic adulteration refers to the contamination of food with harmful metals that may enter food products either intentionally or unintentionally. Such contamination may occur through polluted soil and water, agricultural chemicals, industrial emissions, food processing equipment, storage containers, packaging materials, or improper handling practices. Heavy metals such as arsenic, lead, mercury, and cadmium are among the most common contaminants associated with metallic adulteration. Long-term exposure to these substances can pose significant health risks, including damage to the nervous system, kidneys, liver, and other vital organs. Preventing metallic contamination requires effective environmental regulation, safe agricultural practices, regular monitoring of food products, and strict enforcement of food safety standards. [7]

[6] https://pmc.ncbi.nlm.nih.gov/articles/PMC10724644/

[7] *Ibid.*

FOOD ADULTERATION

Enhancement-Based Adulteration

- Artificial ripening agents
- Growth hormones
- Artificial sweeteners
- Artificial colours
- Preservatives
- Texture/consistency improvers

Substitution-Based Adulteration

- Species/tissue substitution
- Protein substitution
- Fat substitution
- Food dilution

Chemical Adulteration (Organic & Synthetic)

- Soy milk adulteration
- Organic acids
- Synthetic acetic acid
- Artificial wine
- Surrogate alcohol
- Pharmaceutical adulterants

5.4 Methods of Food Adulteration

(i) Artificial Ripening Agents

Artificial ripening is widely used to reduce losses during harvest, processing and transportation process, and increase market availability of climacteric fruits. However, it is also driven by commercial motives, such as early market entry and higher profits. Common ripening agents include ethylene and ethephon, while chemicals such as calcium carbide, ethanol, methanol, propylene, methyl jasmonate, and ethylene glycol have also been used, raising concerns about food safety and regulatory compliance. [8]

(ii) Misuse of Growth Hormones

Growth regulators are sometimes misused to accelerate fruit and vegetable growth, improve size, and enhance visual appeal. Although substances such as gibberellic acid and alpha-naphthyl acetic acid have legitimate agricultural applications, the use of oxytocin-a veterinary hormone on crops such as bottle gourd, bitter gourd, pumpkin, and cucumber has been reported. Such practices raise concerns regarding food safety and highlight the need for stricter regulatory oversight.[9]

(iii) Artificial Sweetening Practices

Artificial sweetening is used to improve the taste, appearance, and marketability of food products while reducing production costs. Traders may inject sweeteners into fruits or add sugars and syrups to fruit juices, honey, beverages, confectionery, and bakery products to imitate natural sweetness and increase commercial value. These practices mislead consumers, compromise product authenticity, and undermine food quality, making robust monitoring and detection mechanisms essential.[10]

(iv) Artificial Coloring Agents

Artificial colouring is widely used to enhance the visual appeal and marketability of food products, as consumers often associate bright colours with freshness and quality. Both natural and synthetic dyes are added to fruits, vegetables, spices, meat products, eggs, and confectionery to improve their appearance. However, the illegal use of synthetic dyes such as Sudan I, Sudan IV, Rhodamine B, Metanil Yellow, Auramine O, and Malachite Green has been reported in products including chilli powder, turmeric, fruits, vegetables, and spices to intensify colour and mimic freshness. These practices mislead consumers, compromise food safety, and underscore the need for stricter regulatory enforcement, regular surveillance, and increased consumer awareness. [11]

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[8] https://pmc.ncbi.nlm.nih.gov/articles/PMC9818512/#B23-foods-12-00199

[9] *Ibid.*

[10] *Ibid.*

[11] *Ibid.*

(v) Adulterants Used to Improve Food Consistency

To enhance the texture, viscosity, and appearance of food products, particularly milk and dairy products, adulterants are often added to mimic higher quality and increase consumer acceptability. Substances such as detergents, starch, glucose, salt, gelatin, stabilizers, and surfactants are commonly used to improve consistency and solid content. While some contamination may result from poor hygiene during processing, their intentional addition constitutes food adulteration and compromises product quality and consumer safety. [12]

(vi) Use of chemical preservatives

Chemical preservatives are frequently misused to extend the shelf life of perishable food products, including fruits, vegetables, fish, dairy products, and beverages. Formalin (formaldehyde) is among the most commonly reported adulterants used to delay microbial spoilage in fruits, vegetables, and fish, despite its associated health risks. Other preservatives such as hydrogen peroxide, boric acid, borax, salicylic acid, benzoic acid, urea, and potassium dichromate have also been reported in dairy products to prolong freshness and prevent spoilage. Although preservation helps reduce food wastage, the unauthorized use of such chemicals poses significant public health concerns and highlights the need for stringent monitoring and regulatory enforcement. [13]

(vii) Substitution adulteration

Substitution adulteration involves replacing a high-value food product with a cheaper or lower-quality alternative to maximize profits while misleading consumers. This practice is particularly common in fish, meat, dairy products, and coffee, where visual identification becomes difficult after processing. Examples include substituting high-value fish species with lower-grade varieties, replacing goat, sheep, or buffalo milk with cheaper cow milk, mixing expensive Arabica coffee with Robusta or other low-quality fillers, and substituting premium meat products with cheaper species such as pork or undeclared animal tissues. Such fraudulent practices compromise product authenticity, violate consumer trust, and may also have health, ethical, cultural, and religious implications, highlighting the importance of advanced traceability systems, accurate labelling, and stringent regulatory oversight. [14]

(viii) Protein adulteration

Protein adulteration involves the addition of nitrogen-rich compounds or inexpensive protein substitutes to artificially increase the apparent protein content of food products while reducing production costs. In dairy products, melamine, urea, whey, and low-cost plant proteins such as soy, pea, and wheat proteins are commonly used to mimic higher protein levels, as conventional protein testing methods may not distinguish these adulterants. Similar practices have also been reported in egg products and staple foods, where melamine is used to inflate protein content and gluten-containing cereals are fraudulently mixed into products labelled as gluten-free. Such adulteration not only deceives consumers but also poses significant health risks, particularly

[12] https://pmc.ncbi.nlm.nih.gov/articles/PMC9818512/#B23-foods-12-00199

[13] *Ibid.*

[14] *Ibid.*

for individuals with allergies or dietary restrictions, emphasizing the need for robust testing methods, accurate food labelling, and stringent regulatory oversight. [15]

(ix) Fat substitution

Fat substitution is a common form of economic adulteration in which expensive fats are replaced with cheaper alternatives to reduce production costs while maintaining a similar appearance and texture. In dairy products, milk fat is frequently substituted with vegetable oils or animal fats to lower manufacturing costs and conceal dilution. Similarly, premium edible oils such as extra virgin olive oil, virgin coconut oil, sesame oil, and cod liver oil are often adulterated with lower-cost oils, including palm oil, soybean oil, corn oil, rapeseed oil, hazelnut oil, and animal fats such as lard and beef tallow. Such substitutions compromise product authenticity, reduce nutritional quality, and may conflict with consumers' dietary, religious, or ethical preferences. These practices underscore the need for effective authenticity testing, accurate labelling, and stronger regulatory enforcement. [16]

(x) Dilution adulteration

Dilution adulteration involves the addition of inexpensive ingredients, such as water or low-cost substitutes, to high-value food products without disclosure, primarily to increase volume and reduce production costs. This practice is commonly observed in milk, honey, fruit juices, fish, meat products, cereals, rice, and spices. For example, milk is diluted with water, honey loses its natural consistency through water addition, fruit juices are mixed with cheaper juices or concentrates, and premium products such as Basmati rice, durum wheat, and organic flour are blended with lower-quality varieties. Similarly, fish and meat products may be treated with excess water or brine to increase weight. Such practices compromise nutritional quality, mislead consumers regarding product authenticity, and result in economic fraud, emphasizing the need for effective quality testing, traceability, and stricter regulatory oversight. [17]

(xi) Fraudulent Labelling and Misrepresentation

Fraudulent labelling involves deliberately providing false or misleading information about a food product's origin, quality, species, or composition to increase its market value and deceive consumers. This practice is commonly reported in fish, meat, honey, olive oil, tea, fruit juices, vinegar, and staple foods, particularly products with Protected Designation of Origin (PDO) or strong geographical identity. Premium products such as extra virgin olive oil, Manuka honey, Acacia honey, and region-specific crops are frequently mislabelled to exploit their higher commercial value. Such practices not only violate consumer rights but also undermine fair trade, reduce the economic benefits to genuine producers, and weaken confidence in food authentication systems. These challenges highlight the importance of traceability, accurate labelling, and robust regulatory enforcement to ensure food authenticity and consumer protection. [18]

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[15] https://pmc.ncbi.nlm.nih.gov/articles/PMC9818512/#B23-foods-12-00199

[16] *Ibid.*

[17] *Ibid.*

[18] *Ibid.*

Common Methods of Food Adulteration

Method of Adulteration	Purpose	Common Adulterants	Frequently Affected Food Products
Artificial Ripening	Accelerate ripening	Calcium carbide, ethephon	Mango, Banana, papaya
Growth Hormone Misuse	Enhance size and appearance	Oxytocin, gibberellic acid	Gourds, cucumbers, pumpkins
Artificial Sweetening	Increase sweetness	Saccharin, glucose syrup	Fruits, juices, honey
Artificial Colouring	Improve visual appeal	Sudan I, Rhodamine B, Metanil Yellow	Spices, Vegetables, sweets
Consistency Enhancement	Improve texture and viscosity	Detergent, starch, gelatin	Milk and dairy products
Chemical Preservation	Extend shelf life	Formalin, hydrogen peroxide, boric acid	Fish, milk, fruits
Protein Adulteration	Increase apparent protein	Melamine, urea, whey	Milk, eggs, cereals
Fat Substitution	Reduce production cost	Palm oil, lard, soybean oil	Dairy products, edible oils
Dilution	Increase volume	Water, brine	Milk, honey, juices
Product Substitution	Replace expensive products	Cheaper species/ingredients	Meat, fish, coffee, rice
Fraudulent Labelling	Increase market value	False origin/species claims	Honey, olive oil, tea, coffee

5.5 Pesticide Residues in Milk: Evidence from India

Several studies conducted in India have documented the presence of pesticide residues in foods of animal origin, including milk, meat, and dairy products. While earlier research primarily focused on persistent Organochlorine Pesticides (OCPs), more recent studies have reported the occurrence of multiple pesticide residues, including Organo Phosphates (OPs) and Synthetic Pyrethroids (SPs). This shift reflects changing agricultural practices and pesticide usage patterns in the country.

Despite these findings, comprehensive nationwide studies examining the prevalence of pesticide residues in milk and the associated health risks remain limited. The available evidence suggests that rapid urbanization, increasing population, and rising demand for milk have transformed dairy production systems. To meet the growing demand of urban consumers, dairy farming has increasingly shifted towards peri-urban areas, where intensive farming practices are more common. These production systems often rely on commercially produced animal feed and greater pesticide use for fodder cultivation and the control of ectoparasites, thereby increasing the likelihood of pesticide exposure in dairy animals.

Research conducted across different regions of India has detected residues of organochlorine pesticides such as hexachlorocyclohexane (HCH), dichlorodiphenyltrichloroethane (DDT), and endosulfan in bovine milk, despite restrictions or bans on several of these chemicals. Approximately 8% of the milk samples analysed in the study contained pesticide residues exceeding the Maximum Residue Limits (MRLs), indicating potential risks to consumer health. The continued detection of these residues suggests that banned or restricted pesticides may still persist in the environment or may continue to be used illegally in certain areas.

Another significant finding is the gradual transition from contamination predominantly by persistent organochlorine pesticides to contamination by organophosphate and synthetic pyrethroid pesticides. Although OPs and SPs generally degrade more rapidly in the environment than OCPs, their presence in milk indicates ongoing pesticide exposure resulting from contemporary agricultural and animal husbandry practices. This shift highlights the need for improved regulation of pesticide use, better livestock management practices, regular residue monitoring, and stronger enforcement of food safety standards.

These findings are particularly relevant to the present study, as they demonstrate that ensuring milk safety requires attention not only to intentional adulteration, such as the addition of water or other substances, but also to contamination arising from agricultural practices, animal feeding systems, and environmental exposure. Therefore, effective food safety governance must address both deliberate adulteration and chemical contamination to protect public health.[19]

[19] https://pmc.ncbi.nlm.nih.gov/articles/PMC7229043/

(i) Lessons from International Best Practices for Strengthening Food Safety and Pesticide Management in India

The growing concern over pesticide residues in food has prompted several countries to adopt more sustainable and science-based approaches to agricultural production and food safety. One of the most significant initiatives is the European Union's Integrated Pest Management (IPM) strategy, introduced through Directive 2009/128/EC, also known as the Sustainable Use of Pesticides Directive (SUD). The objective of IPM is to minimize risks to human health and the environment by reducing dependence on chemical pesticides and encouraging sustainable pest management practices.

Under the IPM framework, chemical pesticides are recommended only as a last resort after alternative methods have been considered. The strategy promotes the use of resistant crop varieties, certified seeds, biological pest control agents, beneficial microorganisms, crop rotation, intercropping, stale seedbed techniques, and other non-chemical farming practices. Although the European Union has faced challenges in fully implementing these measures, the IPM framework remains an important example of balancing agricultural productivity with food safety and environmental sustainability.

Another important lesson from international practice is the continuous development of safer pesticides. Current research increasingly focuses on developing pesticides that degrade rapidly in the environment, leave minimal residues in food, remain effective at very low application rates, and selectively target pests without harming humans, animals, or beneficial organisms. In recent years, pesticide innovation has gradually shifted from conventional chemical pesticides towards biological alternatives, including microbial pesticides, RNA interference (RNAi)-based pesticides, and genetically improved crop varieties that require fewer chemical inputs. These innovations have the potential to reduce pesticide residues in food while promoting sustainable agriculture.

Strengthening food safety also requires advanced monitoring and residue detection systems. Modern analytical techniques such as Liquid Chromatography–Tandem Mass Spectrometry (LC-MS/MS), High-Resolution Mass Spectrometry (LC-HRMS), and the QuEChERS extraction method enable the simultaneous detection of hundreds of pesticide residues, veterinary drug residues, and other contaminants in food products. These technologies provide faster, more accurate, and highly sensitive testing, thereby improving regulatory surveillance and enforcement. [20]

Relevance for India

The international experience offers several important lessons for India. While agencies such as the Food Safety and Standards Authority of India (FSSAI) have strengthened food safety regulation, greater emphasis should be placed on promoting Integrated Pest Management, encouraging biological alternatives to hazardous pesticides, educating farmers on responsible pesticide use, and expanding residue-monitoring programmes across both rural and urban food supply chains. Investments in modern laboratory infrastructure, advanced multi-residue detection technologies, and regular surveillance of agricultural produce, milk, and processed

[20] https://pmc.ncbi.nlm.nih.gov/articles/PMC10379487/#B29-foods-12-02709

food products would further strengthen India's food safety system. Such measures would not only reduce pesticide contamination but also improve consumer confidence, protect public health, and enhance the competitiveness of Indian food products in domestic and international markets.

5.5 Analytical Methods for Detecting Food Adulteration

The increasing complexity of food adulteration has created a need for accurate and reliable analytical techniques to verify food authenticity and ensure quality assurance. Conventional methods such as High-Performance Liquid Chromatography (HPLC), Gas Chromatography-Mass Spectrometry (GC-MS), Liquid Chromatography–Mass Spectrometry (LC-MS/MS), and Fourier Transform Infrared Spectroscopy (FTIR) are widely employed to identify and quantify food adulterants. In recent years, advanced techniques including Raman Spectroscopy, Surface-Enhanced Raman Spectroscopy (SERS), chemometric approaches, Principal Component Analysis (PCA), and Artificial Neural Networks (ANNs) have enhanced the rapid detection and authentication of adulterated food products. These analytical methods improve the accuracy of food testing, strengthen regulatory surveillance, and support evidence-based enforcement against food fraud. [21]

(i) Chromatographic Techniques

Chromatography is one of the most widely used analytical techniques for detecting food adulteration and verifying food authenticity. It separates chemical compounds based on their physical and chemical properties, enabling the identification and quantification of adulterants in complex food matrices. Gas Chromatography (GC) and High-Performance Liquid Chromatography (HPLC) are the most commonly employed techniques, while advanced methods such as Ultra-High-Performance Liquid Chromatography (UHPLC) and Liquid Chromatography-Mass Spectrometry (LC-MS) offer greater sensitivity and accuracy. These techniques have been successfully applied to detect adulteration in milk, gelatin, honey, edible oils, and other food products. Despite their high precision and reliability, chromatographic methods often require expensive instrumentation, skilled personnel, and extensive sample preparation, limiting their routine use in large-scale regulatory surveillance. [22]

(ii) Spectroscopic Techniques

Spectroscopic techniques are widely used for the rapid, non-destructive detection of food adulteration and authentication of food products. Methods such as Fourier Transform Infrared Spectroscopy (FTIR), Near-Infrared Spectroscopy (NIRS), Raman Spectroscopy, Surface-Enhanced Raman Spectroscopy (SERS), and Nuclear Magnetic Resonance (NMR) identify adulterants based on their unique chemical signatures. These techniques have been successfully applied to detect adulteration in milk, honey, edible oils, meat, wheat flour, and coffee, including the identification of melamine in milk, high-fructose corn syrup in honey, margarine in butter, and horse meat in beef. When combined with chemometric techniques, such as multivariate analysis, spectroscopy enables rapid and highly accurate food authentication. Despite their high sensitivity and reliability, these techniques often require specialized

[21] https://pmc.ncbi.nlm.nih.gov/articles/PMC11080768/
[22] *Ibid.*

instrumentation and technical expertise, which may limit their routine application in resource-constrained settings. [23]

(iii) Electronic Sensor Technologies

Electronic sensor technologies, including the electronic nose (E-nose) and electronic tongue (E-tongue), have emerged as rapid and non-destructive tools for food authentication. The E-nose mimics the human sense of smell by detecting volatile compounds and distinguishing complex aroma profiles, whereas the E-tongue imitates human taste to analyse the chemical composition of liquid food samples. These techniques have been increasingly applied in the food industry for quality assessment and the detection of adulteration due to their speed, cost-effectiveness, and ability to analyse complex samples without extensive preparation. However, their performance depends on sensor accuracy and advanced data-processing systems. [24]

(iv) Enzyme-Linked Immunosorbent Assay (ELISA)

Enzyme-Linked Immunosorbent Assay (ELISA) is a sensitive and cost-effective immunological technique widely used for detecting food adulterants and verifying food authenticity. It is particularly effective in identifying species substitution in meat products and detecting contaminants such as melamine. ELISA requires minimal laboratory equipment, supports large-scale screening, and is suitable for routine food safety monitoring. However, its accuracy depends on the quality and specificity of the antibodies used in the assay. [25]

(v) Food Quality Control

Food quality control encompasses physical, chemical, microbiological, nutritional, and sensory evaluations to ensure that food products meet established safety and quality standards. Parameters such as taste, aroma, texture, colour, nutrient composition, and chemical quality indicators are routinely assessed to maintain product integrity. As food supply chains become increasingly complex, effective quality control systems play a vital role in preventing food adulteration, protecting consumer health, and strengthening public confidence in food products. [26]

5.6 Food Adulteration in the Digital Food Delivery Ecosystem

The rapid expansion of online food delivery (OFD) and quick-commerce platforms has transformed India's food retail landscape by increasing convenience and accessibility. However, this digital transformation has also altered the nature of food adulteration and food safety risks. Unlike traditional food markets, where consumers can physically inspect products before purchase, online transactions rely heavily on platform-generated information, digital listings, and the integrity of multiple intermediaries. Consequently, food adulteration is no longer confined to deliberate mixing of inferior substances into food products but increasingly involves issues such as expired or relabelled products, improper storage, contamination during transportation, and misrepresentation of food quality. The emergence of dark stores, cloud kitchens, and quick-commerce warehouses has further complicated regulatory oversight. These

[23] https://pmc.ncbi.nlm.nih.gov/articles/PMC11080768/
[24] *Ibid.*
[25] *Ibid.*
[26] *Ibid.*

facilities primarily function as fulfilment centres for rapid deliveries and often remain outside the visibility of consumers. Since the Food Safety and Standards Act, 2006 primarily regulates food business operators through licensing and registration, enforcement mechanisms have struggled to adapt to these new business models. While Section 31 of the Act mandates licensing of food businesses, it does not explicitly require routine physical verification of every operational unit, creating opportunities for inadequately monitored dark stores and cloud kitchens to operate within the digital food supply chain. [27]

Another significant challenge is the fragmentation of accountability in digital food commerce. Food ordered through platforms such as Zomato, Swiggy, Blinkit, Zepto, and Instamart passes through multiple actors, including manufacturers, distributors, warehouses, restaurants, delivery partners, and digital platforms. When consumers receive adulterated, contaminated, or substandard food, responsibility is often attributed to the restaurant or delivery platform, while deficiencies in packaging, storage, transportation, or warehousing remain difficult to identify. This dispersed liability complicates enforcement and weakens consumer protection. The rapid growth of quick-commerce has further intensified these concerns. The emphasis on delivering products within minutes places pressure on inventory turnover, cold-chain maintenance, and handling practices, potentially encouraging shortcuts in storage, quality checks, and hygiene management. As a result, food safety has become a supply-chain governance issue rather than solely a manufacturing concern. Increasing consumer complaints regarding expired food, spoiled groceries, damaged packaging, and contaminated deliveries demonstrate that food adulteration risks have evolved alongside digital commerce rather than disappeared.[28]

These developments indicate that India's regulatory framework must move beyond conventional inspection-based approaches towards comprehensive digital supply-chain governance. International models such as the European Union's Farm-to-Fork Strategy emphasise end-to-end traceability and accountability at every stage of the food chain. Adopting a similar risk-based approach in India—through digital traceability systems, mandatory audits of dark stores, platform accountability, stronger cold-chain monitoring, and transparent consumer grievance mechanisms—would better address emerging food safety challenges associated with online food delivery and quick-commerce while extending regulatory oversight across the entire digital food ecosystem.

5.7 Health impacts of food adulteration

Food adulteration poses a serious public health threat, as the consumption of contaminated food can cause both immediate and long-term health consequences. Depending on the adulterant and duration of exposure, it may lead to diarrhoea, abdominal pain, nausea, vomiting, headaches, dizziness, gastrointestinal and respiratory disorders, anaemia, liver and kidney damage, nervous system disorders, visual impairment, paralysis, cardiovascular diseases, and an increased risk of chronic illnesses, including certain types of cancer. Many adulterants are

[27] https://alladvancejournal.com/media/post/IJASGE-5-4-41.1.pdf

[28] *Ibid.*

deliberately added to improve the appearance, shelf life, or apparent nutritional value of food. For example, melamine has been illegally added to milk and dairy products to artificially increase protein content, causing kidney stones, urinary tract infections, and renal failure. Artificial ripening agents such as calcium carbide have been linked to toxic effects and potential carcinogenic outcomes, while preservatives like formaldehyde can damage the liver, kidneys, lungs, and nervous system. Several incidents worldwide involving melamine-contaminated infant formula, toxic edible oils, methanol poisoning, and chemically contaminated meat products have caused widespread illness, permanent disabilities, and deaths, demonstrating that food adulteration is not merely economic fraud but a major public health challenge. The health effects are often cumulative, with repeated exposure increasing the risk of chronic diseases and irreversible organ damage. Infants, children, pregnant women, older adults, and immunocompromised individuals are particularly vulnerable, highlighting the need for effective regulatory oversight, strict enforcement of food safety standards, regular monitoring of food products, and greater public awareness of safe food consumption.[29]

The serious health implications associated with food adulteration highlight that food safety extends beyond consumer protection and represents a critical public health and governance issue. Ensuring access to safe and wholesome food is therefore essential for protecting human health, improving quality of life, and promoting the overall well-being of society.

5.8 Constitutional and Legal Framework Governing Food Safety in India

India's regulatory framework for food safety is founded on a combination of constitutional principles, statutory legislation, and institutional mechanisms designed to safeguard public health and protect consumer interests. Over the years, the legal framework has evolved from addressing food adulteration as an isolated offence to adopting a comprehensive food safety approach that regulates the entire food supply chain. Despite this extensive legal architecture, incidents of food adulteration continue to persist, raising concerns about the effectiveness of implementation rather than the absence of legislation.

The constitutional foundation for food safety is derived from multiple provisions of the Constitution of India. Although the Constitution does not expressly recognize the right to safe food as a fundamental right, judicial interpretation of Article 21 has expanded the Right to Life to include the right to live with dignity, which necessarily encompasses access to safe and uncontaminated food. [30]

Furthermore, Article 47 of the Directive Principles of State Policy reflects the Constitution's vision of public health as a fundamental responsibility of the State. By directing the State to improve nutritional standards, raise the standard of living, and protect citizens from substances injurious to health, it provides the constitutional rationale for developing robust food safety laws and regulatory institutions. Therefore, food adulteration should not be viewed merely as

[29] https://pmc.ncbi.nlm.nih.gov/articles/PMC10724644/

[30] https://nfsa.gov.in/portal/nfsa-act

a criminal offence but as a governance challenge that directly affects the State's constitutional obligation to safeguard public health. [31]

In addition, Entry 18 of the Concurrent List (List III) empowers both the Union and State Governments to legislate on the adulteration of foodstuffs and other goods, ensuring a shared responsibility in regulating food safety across the country. [32]

India's first dedicated legislation addressing food adulteration was the Prevention of Food Adulteration Act, 1954, enacted with the objective of protecting consumers from unsafe and substandard food. The Act established legal standards for food quality, defined different forms of adulteration, prescribed the duties and powers of food inspectors, local authorities, and magistrates, regulated the import of food articles, and introduced penal provisions for violations. Although the Act played a significant role in strengthening food regulation for several decades, its fragmented approach and the existence of multiple overlapping food laws eventually limited its effectiveness. [33]

Recognizing these limitations, Parliament enacted the Food Safety and Standards Act, 2006, marking a paradigm shift from a reactive anti-adulteration approach to a preventive and science-based food safety system. The Act consolidated various food-related legislations under a single regulatory framework and established the Food Safety and Standards Authority of India (FSSAI) as the apex body responsible for regulating the manufacture, processing, storage, distribution, sale, and import of food. By integrating food standards with risk-based regulation, licensing, surveillance, and scientific assessment, the Act sought to improve regulatory coordination and strengthen consumer protection. The legislative framework also adopts a graded system of penalties, reflecting the seriousness of offences and the extent of harm caused. The Food Safety and Standards Act prescribe increasing punishments, where adulterated food results in non-grievous injury, grievous injury, or death, demonstrating the legislature's intention to deter offences through proportionate sanctions. [34]

In addition to food safety legislation, criminal liability is reinforced under Section 274 of the Bharatiya Nyaya Sanhita (BNS), which criminalizes the intentional adulteration of food intended for sale.[35] However, concerns regarding the adequacy of criminal penalties have prompted certain states, including Uttar Pradesh and West Bengal, to enact stricter amendments providing for enhanced punishment, including life imprisonment in cases where adulterated food results in death or grievous injury. [36]

Collectively, these constitutional provisions, statutory enactments, regulatory institutions, and penal mechanisms demonstrate that India possesses a comprehensive legal framework for ensuring food safety. Nevertheless, the continued prevalence of food adulteration suggests that

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[31] https://www.indiacode.nic.in/bitstream/123456789/19150/1/constitution_of_india.pdf

[32] https://www.mea.gov.in/images/pdf1/S7.pdf

[33] https://www.indiacode.nic.in/bitstream/123456789/15399/1/the_prevention_of_food_adulteration_act%2C_1954.pdf

[34] https://fssai.gov.in/upload/uploadfiles/files/FOOD-ACT.pdf

[35] https://www.indiacode.nic.in/bitstream/123456789/20062/1/a202345.pdf

[36] https://cdnbbsr.s3waas.gov.in/s3ca0daec69b5adc880fb464895726dbdf/uploads/2022/08/2022081632-1.pdf

the principal challenge lies not in the absence of laws but in issues relating to enforcement, institutional capacity, regulatory coordination, public awareness, and compliance across different stages of the food supply chain. It is these implementation challenges that this study seeks to evaluate through field observations, stakeholder interactions, and policy analysis.

5.9 Role of FSSAI

The Food Safety and Standards Authority of India (FSSAI) was established under the Food Safety and Standards Act, 2006 as the apex statutory body responsible for regulating food safety in India. The Act consolidated several pre-existing food laws and regulatory orders into a unified regulatory system, replacing the earlier fragmented multi-departmental framework. Operating under the Ministry of Health and Family Welfare, FSSAI ensures the availability of safe and wholesome food for human consumption. FSSAI develops science-based food standards and regulates the manufacture, processing, storage, distribution, sale, and import of food products. It also frames regulations and enforcement guidelines, while establishing mechanisms for accrediting food safety certification bodies and laboratories to ensure reliable testing and compliance. In addition, FSSAI provides scientific and technical advice to the Central and State Governments on food safety, nutrition, and policy formulation. It collects and analyses data on food consumption patterns, biological hazards, contaminants, pesticide residues, and emerging food safety risks, while developing rapid alert systems for timely risk communication. Furthermore, FSSAI promotes public awareness regarding food safety and hygiene, creates information networks for consumers and local institutions, and conducts training programmes for food business operators to strengthen compliance with food safety standards. The Authority also contributes to the development of international food standards and sanitary and phytosanitary measures, thereby aligning India's food safety framework with global best practices.[37]

5.10 Initiatives by FSSAI to Curb Food Adulteration

To address the growing challenge of food adulteration, the Food Safety and Standards Authority of India (FSSAI) has adopted a combination of regulatory, surveillance, technological, and public awareness measures aimed at detecting adulteration, preventing unsafe food from reaching consumers, and encouraging greater public participation in food safety.

A key strategy is strengthening surveillance and enforcement through regular inspections, monitoring drives, and random sampling of food products across the supply chain by State Food Safety Authorities. Special surveillance campaigns are conducted during festivals, weddings, and other high-demand periods when the risk of adulteration is greater. Where food samples fail to meet prescribed standards, legal action is initiated under the Food Safety and Standards Act, 2006. FSSAI has also strengthened consumer participation by enabling complaints regarding suspected food adulteration through the FSSAI helpline and the Food Safety Connect mobile application. Additionally, mandatory registration, licensing, or

[37] https://fssai.gov.in/cms/about-fssai.php

certification of all food business operators ensures greater accountability and regulatory oversight. Recognising the importance of public awareness, FSSAI has introduced several educational initiatives. The Detect Adulteration with Rapid Test (DART) handbook enables consumers to identify common adulterants in products such as milk, edible oils, sugar, spices, and cereals through simple household tests without specialised laboratory equipment. To improve access to food testing, FSSAI launched the Food Safety on Wheels (FSW) initiative, comprising mobile laboratories equipped for on-the-spot qualitative testing, thereby strengthening surveillance and extending testing facilities to areas with limited laboratory infrastructure. It has also introduced the Food Safety Magic Box, a portable testing kit for school students containing instructional material and equipment to perform more than one hundred basic tests for detecting contamination and adulteration, promoting scientific awareness and responsible food safety practices from an early age.[38]

Collectively, these initiatives demonstrate that FSSAI's approach extends beyond regulatory enforcement by integrating surveillance, consumer empowerment, technological innovation, and public education to build a safer and more transparent food ecosystem in India.

5.11 Rapid Tests for Food Adulteration under the DART Initiative

The Food Safety and Standards Authority of India (FSSAI) has developed the DART (Detect Adulteration with Rapid Test) manual as a consumer awareness initiative to empower the public with simple, rapid, and inexpensive methods for identifying common food adulterants. The manual provides easy-to-perform screening tests for a wide range of food products, including milk, edible oils, cereals, pulses, spices, beverages, fruits, and vegetables. These tests rely on basic physical and chemical principles and can be conducted using readily available household materials or simple reagents, enabling consumers to detect possible adulteration without specialized laboratory equipment. By promoting public participation in food safety surveillance, the DART manual serves as an important educational resource that encourages vigilance against food adulteration and supports informed consumer choices. However, the manual also emphasizes that these rapid tests are intended solely for preliminary screening and consumer awareness; any suspected adulteration should be confirmed through scientifically validated laboratory analysis conducted by authorized food testing laboratories.[39]

5.12 Eat Right India Initiative

Launched by the Food Safety and Standards Authority of India (FSSAI) in July 2018, the Eat Right India initiative is a comprehensive national programme that promotes safe, healthy, and sustainable dietary practices. In response to the growing burden of foodborne illnesses,

[38] https://www.ijllr.com/post/effectiveness-of-fssai-in-controlling-food-adulteration-a-legal-and-practical-analysis

[39] https://foodsafety.delhi.gov.in/sites/default/files/generic_multiple_files/dart_0.pdf

malnutrition, and diet-related non-communicable diseases, it seeks to transform India's food ecosystem through regulatory measures, capacity building, stakeholder collaboration, and consumer empowerment. Adopting a farm-to-fork approach, the initiative integrates food safety, balanced nutrition, and environmental sustainability across the food supply chain. The initiative is based on three pillars: **Eat Safe**, which promotes food safety and hygiene through improved regulatory compliance and food handling practices; **Eat Healthy**, which encourages balanced diets and informed nutritional choices to address malnutrition and lifestyle-related diseases; and **Eat Sustainable**, which supports environmentally responsible food production and consumption by reducing food waste, promoting sustainable agricultural practices, and minimizing the use of plastics and other harmful materials. Under this framework, FSSAI has introduced programmes such as hygiene rating systems for food establishments, the Food Safety Training and Certification (FoSTaC) programme for food business operators, initiatives for the safe disposal and repurposing of used cooking oil, and awareness campaigns in schools, workplaces, and communities. These measures strengthen food safety standards, improve public awareness, and encourage healthier food choices. The Eat Right India initiative has received international recognition, including appreciation from the World Health Organization (WHO) and the Rockefeller Foundation, for its integrated and preventive approach to food safety and nutrition. By combining regulatory enforcement with behavioural change and public participation, it represents a significant step towards improving public health, strengthening food safety governance, and fostering a culture of safe, nutritious, and sustainable food consumption in India. [40]

5.13 Understanding Food Labels

Reading food labels is an important step in helping consumers make informed and healthy food choices. Food labels provide essential information about the quality, safety, nutritional value, ingredients, and storage of packaged food products. Consumers who understand food labels are better equipped to identify safe food products, compare different brands, and reduce the risk of purchasing unsafe or misleading products.
The following information should be carefully examined before purchasing packaged food:

(i) FSSAI Logo and Licence Number

Consumers should first look for the Food Safety and Standards Authority of India (FSSAI) logo along with the **14-digit licence or registration number**. This indicates that the food business is registered or licensed under the Food Safety and Standards Act, 2006. Although the presence of an FSSAI licence does not guarantee the quality of every individual product, it confirms that the manufacturer or food business is operating under the regulatory framework established by FSSAI. [41]

(ii) Quality Certification Marks

Consumers should also look for recognised quality certification marks wherever applicable.

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[40] https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154849&ModuleId=3&reg=48&lang=2

[41] https://eatrightindia.gov.in/how-to-read-label.jsp

- **AGMARK** certifies the quality of agricultural products such as pulses, cereals, spices, honey, edible oils, fruits, and vegetables.
- **ISI Mark** is applicable to packaged drinking water, mineral water, infant food, milk powder, and certain other products that comply with standards prescribed by the Bureau of Indian Standards (BIS).
- **Fortified Food Logo (+F)** indicates that essential nutrients such as vitamins and minerals have been added to the food to improve its nutritional value.[42]

These certification marks help consumers identify products that meet prescribed quality or nutritional standards.



(iii) Manufacturing Date, Best Before and Expiry Date

Consumers should always check the manufacturing date and the "Best Before" or "Expiry Date" before purchasing food products.

- **Best Before** indicates the period during which the product is expected to retain its best quality, taste, and texture when stored properly.
- **Expiry Date** indicates the date after which the product should not be consumed as it may no longer be safe.[43]

(iv) List of Ingredients

The ingredient list provides information about everything used in preparing the product. Ingredients are arranged in **descending order by weight**, meaning the ingredient present in the largest quantity appears first.

For example, if the ingredient list begins with sugar followed by wheat flour and vegetable oil, sugar is the major ingredient in the product.[44]

Consumers should also check for food additives, preservatives, artificial colours, flavouring agents, and common allergens such as milk, peanuts, eggs, soy, wheat (gluten), fish, and tree nuts.

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[42] https://eatrightindia.gov.in/how-to-read-label.jsp

[43] *Ibid.*

[44] *Ibid.*

(v) Nutrition Information

The nutrition panel provides details regarding:

- Energy (Calories)
- Protein
- Carbohydrates
- Added Sugars
- Total Fat
- Saturated Fat
- Trans Fat
- Sodium (Salt)
- Dietary Fibre
- Vitamins and Minerals

This information helps consumers compare products and select healthier options with lower amounts of sugar, salt, saturated fat, and trans-fat while choosing foods rich in protein, fibre, vitamins, and minerals.

(vi) Serving Size

One of the most frequently misunderstood aspects of food labels is the **serving size**.
Nutrition information is generally provided per serving or per 100 g/100 ml, whereas a single packet may contain more than one serving.

For example, if a packet contains two servings and each serving provides 100 kilocalories (kcal), consuming the entire packet would result in an intake of 200 kcal, not 100 kcal. Therefore, consumers should always check both the serving size and the total number of servings contained in the package before interpreting the nutritional information.[45]

(vii) Net Quantity

The net quantity indicates the actual amount of food contained in the package, expressed in grams (g), kilograms (kg), millilitres (ml), or litres (L). This helps consumers compare products based on quantity as well as price.[46]

(viii) Storage Instructions

Food labels often provide instructions regarding storage conditions, such as "Store in a cool and dry place" or "Refrigerate after opening." Following these instructions helps maintain food quality and prevents spoilage.[47]

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[45] https://eatrightindia.gov.in/how-to-read-label.jsp

[46] *Ibid.*

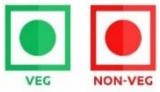
[47] *Ibid.*

(ix) Instructions for Use

Certain packaged foods require specific preparation or cooking methods. Consumers should carefully read and follow the instructions provided on the label to ensure safe consumption.[48]

(x) Vegetarian and Non-Vegetarian Symbols

Packaged foods in India display symbols indicating whether the product is vegetarian or non-vegetarian.



- **Green Dot** – Vegetarian food.
- **Brown Dot** – non-vegetarian food (including products containing egg).[49]

These symbols enable consumers to make informed dietary choices according to their preferences.

(xi) Nutrition Claims and Product Declarations

Consumers should carefully read any claims made on the packaging, such as "Low Fat," "Sugar Free," "High Protein," or "Free from Argemone Oil." Such claims should not be accepted without also examining the nutrition panel and ingredient list, as marketing claims may not always provide the complete nutritional picture.[50]

(xi) Daily Value (%DV) or Guideline Daily Allowance (GDA)

Many food products display the Daily Value (DV%) or Guideline Daily Allowance (GDA) for nutrients. This indicates how much a serving of the product contributes to the recommended daily intake of a particular nutrient.

As a general guide:

- **5% DV or less** indicates that the product contains a low amount of a nutrient.
- **20% DV or more** indicates that the product contains a high amount of that nutrient. [51]

This helps consumers compare products and make healthier dietary choices.

Overall, understanding food labels empowers consumers to make informed purchasing decisions, identify healthier food options, recognise quality certification marks, and reduce the risk of consuming unsafe or misleading food products. Strengthening consumer awareness regarding food labels is therefore an important component of food safety and public health initiatives.

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[48] https://eatrightindia.gov.in/how-to-read-label.jsp

[49] *Ibid.*

[50] *Ibid.*

[51] *Ibid.*

5.14 Selection of Uttar Pradesh as the Study Area

To complement the national analysis, the primary research for this study was conducted in selected districts of Uttar Pradesh. The selection of Uttar Pradesh was informed by enforcement data published by the Food Safety and Standards Authority of India (FSSAI), which indicate that the state has consistently recorded the highest number of enforcement samples analysed as well as the highest number of non-conforming samples among all States and Union Territories. During 2021-22, 21,987 samples were analysed in Uttar Pradesh, of which 13,153 (59.82%) were found to be non-conforming. In 2022-23, the number increased to 30,140 samples analysed, with 18,108 (60.08%) reported as non-conforming. In 2023-24, 27,750 samples were analysed, of which 16,183 (58.32%) were non-conforming, while in 2024-25 (up to September), 13,305 samples had been analysed, with 7,030 (52.8%) found to be non-conforming. These consistently high enforcement figures highlight the scale of food safety monitoring in the state and reinforce the relevance of Uttar Pradesh as an appropriate case study for examining public awareness, hygiene practices, agricultural challenges, and the effectiveness of the regulatory framework governing food adulteration.[52]

The data indicate that Uttar Pradesh has consistently accounted for the largest volume of enforcement sampling in the country. Although the percentage of non-conforming samples has shown a gradual decline over the period, more than half of the analysed samples continued to be reported as non-conforming, underscoring the continued need for effective regulatory enforcement and consumer awareness initiatives in the state.

Year	Samples Analysed	Non-Conforming Samples	Percentage (%)
2021-22	21,987	13,153	59.82
2022-23	30,140	18,108	60.08
2023-24	27,750	16,183	58.32
2024-25 (till Sept.)	13,305	7,030	52.80

5.15 Recent Food Adulteration Cases in India: A Newspaper-Based Analysis

(i) Case Study: Maharashtra Synthetic Milk Adulteration Racket (2026)

Background

In July 2026, the Maharashtra Police and the Food and Drug Administration (FDA) uncovered a large inter-district milk adulteration network operating across several districts, including Pune, Solapur, Jalna, Ahilyanagar, Thane, and Sangli. During the operation, authorities arrested 13 individuals and seized adulteration materials worth over ₹2 crore.

Nature of Adulteration

[52] https://sansad.in/getFile/loksabhaquestions/annex/184/AU5700_0bKomT.pdf?source=pqals

Investigations revealed that the accused allegedly manufactured synthetic milk using skimmed milk powder, detergents, shampoo, palm oil, emulsifiers, and other chemicals. Approximately 500 litres of synthetic milk were mixed with every 1,000 litres of genuine milk before distribution through milk collection centres, chilling plants, and packaging units, making the adulteration difficult for consumers to detect.

Regulatory Response
The investigation was conducted jointly by the Maharashtra Police and the FDA after nearly a month of surveillance. Multiple raids were carried out across different districts, resulting in the seizure of adulteration materials, collection of food samples, destruction of thousands of litres of suspected adulterated milk, and the arrest of those involved. Authorities also traced the supply chain to identify distributors, collection centres, and other participants in the network.[53]

Policy Relevance
This case highlights several systemic issues:

- The organized nature of food adulteration networks extending across multiple districts.
- Weak traceability and monitoring within the dairy supply chain.
- The significant public health risks posed by chemically adulterated milk.
- The importance of coordinated enforcement between food safety authorities and law enforcement agencies.

The need for stronger surveillance, regular inspections, and stricter penalties to deter food adulteration.

(ii) Case Study: Dairy Product Adulteration in India - The Growing Challenge of Fake Paneer and Ghee

Background
An India Today Insight report (2025) highlights the growing prevalence of adulteration in dairy products, particularly paneer and ghee, despite the existence of food safety regulations. According to the report, dairy products remain among the most frequently adulterated food items in India, posing significant public health concerns and exposing weaknesses in food safety enforcement.

Key Findings
The report cites Food Safety and Standards Authority of India (FSSAI) data indicating that 83% of paneer samples failed to meet food safety standards, while approximately 40% of the samples were found to be unsafe for consumption due to adulteration with substances such as

[53] https://theprint.in/india/police-fda-bust-inter-district-milk-adulteration-racket-in-maharashtra-13-held/2979130/

palm oil, urea, and synthetic chemicals. These findings point to widespread quality concerns within the dairy sector.

Factors Contributing to Adulteration

The report attributes the persistence of food adulteration to several structural factors:

- A vast and fragmented food production system with millions of producers.
- Profit-driven substitution of expensive dairy ingredients with cheaper alternatives.
- Inadequate monitoring across the supply chain.
- Limited enforcement capacity despite increasing inspections.
- Rising consumer demand, particularly during festive seasons, which creates incentives for adulteration.

Expert Perspective

Former FSSAI CEO Pawan Agarwal notes that although public awareness and regulatory action have increased, ensuring food safety across India's extensive food supply chain remains a long-term challenge requiring systemic reforms rather than isolated enforcement actions. [54]

Policy Relevance

This case demonstrates that food adulteration is not merely the result of individual violations but reflects broader governance challenges, including inadequate supply chain traceability, regulatory capacity constraints, and the need for stronger surveillance, testing infrastructure, and consumer awareness. It reinforces the importance of adopting a preventive and technology-driven approach to food safety management.

(iii) Case Study: Uttar Pradesh's Statewide Crackdown on Food Adulteration (2026)

Background

In July 2026, the Uttar Pradesh government launched one of its largest statewide enforcement campaigns against food adulteration. The drive targeted the manufacture, storage, and sale of adulterated and substandard food products across multiple districts, reflecting the state's intensified efforts to safeguard public health.

Key Enforcement Actions

- Food products worth ₹11.66 crore were seized during the campaign.
- Unsafe food valued at ₹63.17 lakh was destroyed.
- 2,965 food samples were collected and sent to accredited laboratories for quality testing.

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[54] https://www.indiatoday.in/india-today-insight/story/ghee-to-paneer-how-food-adulteration-thrives-in-india-2819262-2025-11-13

- Six FIRs were registered against individuals allegedly involved in food adulteration and related offences. [55]

Regulatory Significance

The campaign illustrates a shift from reactive enforcement to proactive surveillance, combining large-scale inspections, laboratory testing, and legal action. By collecting thousands of samples and initiating criminal proceedings, the authorities sought to strengthen compliance with the Food Safety and Standards Act, 2006, and deter future violations.

Policy Implications

This case highlights several important policy issues:

- The need for continuous surveillance rather than seasonal inspections.
- The importance of laboratory-based testing for identifying adulterated food.
- Strong coordination between food safety authorities and law enforcement agencies.
- The role of strict legal action, including FIRs and product seizures, in improving compliance.

The need for sustained monitoring and public awareness to prevent the circulation of unsafe food products.

6. Research Methodology

6.1 Research Design and Data Collection

The present study adopts a mixed-method research approach, integrating both quantitative and qualitative methods to examine the issue of food adulteration in India. The study draws upon both secondary and primary sources of data to provide a comprehensive understanding of the subject.

Secondary data were collected from peer-reviewed journal articles, government reports, annual reports and publications of the Food Safety and Standards Authority of India (FSSAI), policy documents, newspaper investigations, and other credible academic sources. These sources were used to examine the legal and institutional framework, trends in food adulteration, methods of adulteration, detection techniques, government initiatives, and challenges associated with food safety governance.

Primary data were collected through a structured Google Forms questionnaire administered to 80 respondents. The study employed a convenience sampling technique, with participants selected based on their accessibility and willingness to participate. The questionnaire was circulated through online platforms, including WhatsApp and LinkedIn. Although the survey

[55] https://timesofindia.indiatimes.com/city/lucknow/firs-against-six-for-adulteration-as-up-seizes-11-66-crore-worth-of-food-products/articleshow/132468829.cms

was not geographically restricted to any particular state, responses were received from participants across different parts of India, with the majority of respondents belonging to Uttar Pradesh. To complement the survey findings, field observations were also conducted in selected districts of Uttar Pradesh, namely Meerut, Ghaziabad, and Baghpat. These observations focused on local markets, street food vendors, dairy outlets, and other food establishments to understand hygiene practices, food handling methods, and consumer perceptions regarding food adulteration.

6.2 Sample Profile

The study received responses from 80 participants representing different demographic backgrounds. Approximately 68.8% of the respondents belonged to the 18–25 years age group, indicating that young adults constituted the largest proportion of the study population. The remaining respondents were distributed across older age groups, providing perspectives from individuals at different stages of life. In terms of gender, 51.2% of the respondents were male and 48.8% were female.

Regarding educational qualifications, approximately 55% of the respondents were pursuing or had completed undergraduate education, while 22.5% had pursued postgraduate education. The remaining respondents represented other educational levels, like higher secondary and doctorate contributing to the diversity of the sample. With respect to occupation, 72% of the respondents were students and 22% were employed in different occupations. A small proportion of respondents belonged to other occupational categories, including homemakers, self-employed individuals, and others.

The survey also included respondents from diverse residential settings, with approximately 51.2% belonging to rural areas, 42.5% residing in urban areas and 6.3% in semi urban areas. This distribution enabled the study to capture perceptions across different geographical contexts.

6.3 Data Analysis

The quantitative data obtained through the questionnaire were analysed using descriptive statistical techniques, primarily frequencies and percentages, to identify patterns in consumer awareness, perceptions, and experiences related to food adulteration. The qualitative insights obtained through field observations were analysed thematically and interpreted alongside the survey findings and secondary evidence. This integration of multiple data sources enabled the study to compare existing literature with on-ground observations and public perceptions, thereby providing a more comprehensive understanding of food adulteration and food safety governance in India.

7. Findings and Discussion

As shown in *Figure 1*, 77.5% of the respondents identified milk and dairy products as the food category most susceptible to adulteration, followed by packaged foods (55%), spices (40%), and, both cooking oil and sweets (46.3%). This perception is supported by recent enforcement actions and media reports, which indicate that dairy products continue to be among the most frequently adulterated food items in India. A recent operation uncovered approximately 2.3 crore litres of synthetic milk allegedly manufactured using harmful substances, including

detergent powder, highlighting the widespread nature of milk adulteration.[56] Similarly, an analysis of 702 food samples reported paneer as the most adulterated food product,[57] while pre-Holi food safety inspections led to the seizure of 1,200 kg of adulterated paneer and 900 kg of contaminated khoya.[58] The convergence of the present survey findings with these recent incidents suggests that public perception regarding the vulnerability of milk and dairy products is consistent with emerging evidence from food safety inspections and enforcement actions, reinforcing the need for stricter monitoring and quality control across the dairy supply chain.

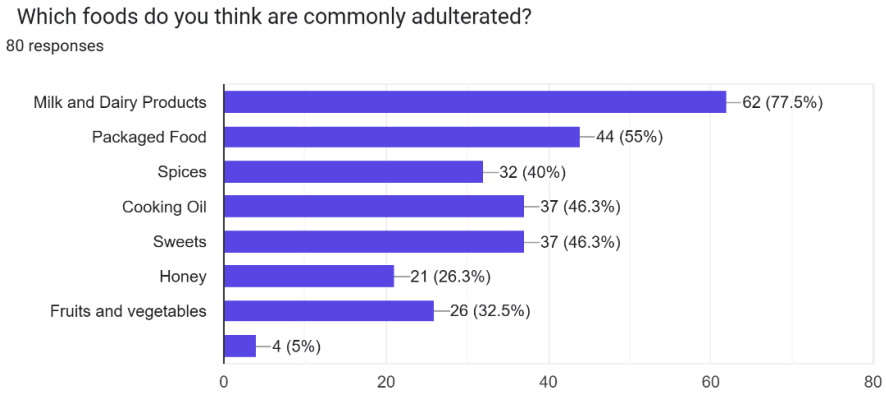


Figure 1

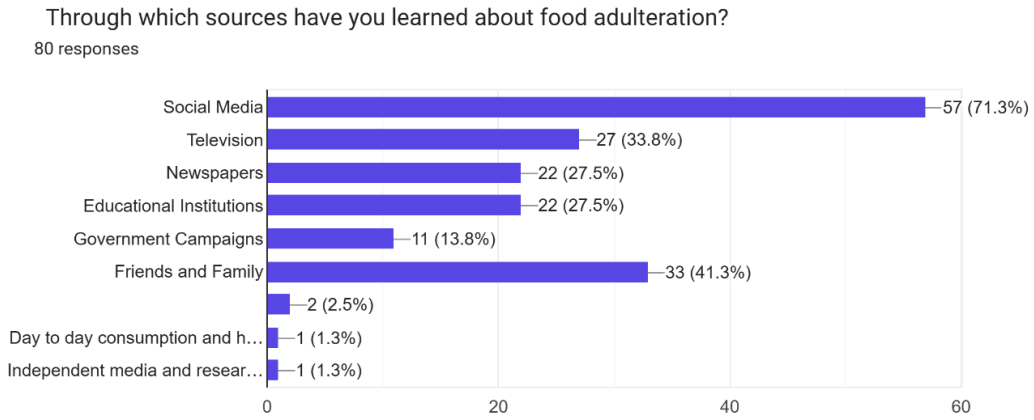


Figure 2

[56] https://timesofindia.indiatimes.com/life-style/food-news/2-3-crore-litres-of-milk-made-with-detergent-powder-seized-why-is-the-shocking-scam-alarming-and-how-to-assure-you-consume-safe-milk/articleshow/132560086.cms

[57] https://timesofindia.indiatimes.com/life-style/food-news/702-food-samples-revealed-paneer-as-the-most-adulterated-product/articleshow/120175050.cms

[58] https://www.ndtv.com/food/1-200-kg-adulterated-paneer-900-kg-contaminated-khoya-busted-in-pre-holi-food-safety-check-11140943

The survey also highlights the growing importance of social media as the primary source of public awareness regarding food adulteration. As shown in *Figure 2*, 71.3% of respondents reported that they acquired knowledge about food adulteration through social media platforms. This finding demonstrates that digital media has become the dominant channel for disseminating information related to food safety. It also suggests that regulatory authorities can effectively utilise social media platforms to conduct awareness campaigns, disseminate verified information, educate consumers about detecting adulterated food, and promote available grievance redressal mechanisms.

When respondents were asked whether they had ever purchased adulterated food products, approximately 43.8% believed that they had, while nearly 35% were uncertain *(Figure 3)*. Among those who suspected purchasing adulterated food, around 37.5% identified milk as the product involved *(Figure 4)*. The high proportion of respondents expressing uncertainty indicates that consumers often find it difficult to identify adulterated food, particularly when adulterants are not visible or easily detectable. This reflects a significant information gap and emphasises the need for greater consumer education regarding food quality indicators, certification marks, and simple methods for identifying common adulterants.

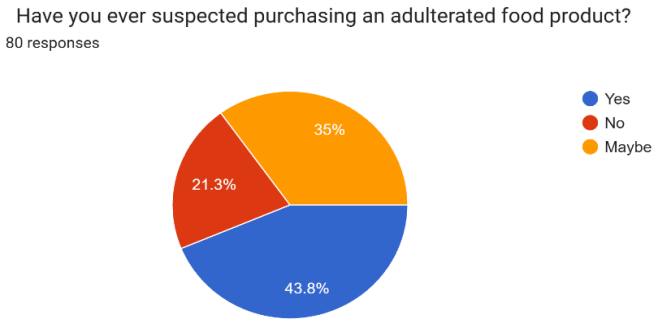


Figure 3

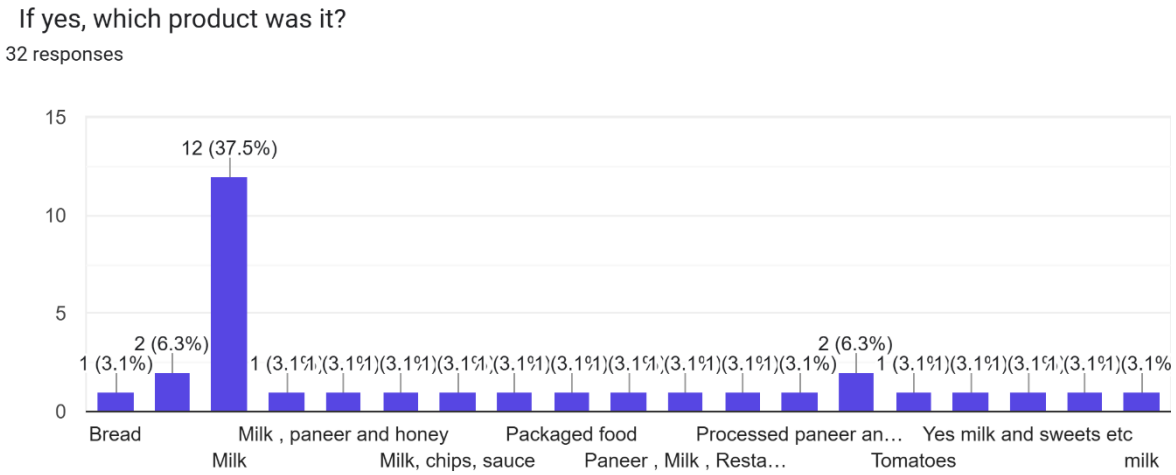


Figure 4

The findings further reveal considerable challenges in reporting suspected cases of food adulteration. Although 26.3% of respondents reported a suspected case, a substantial proportion refrained from doing so due to several barriers *(Figure 5)*. Around 39.4% stated that they did not know where to report complaints, approximately 52% believed that no effective action would be taken by the authorities, and nearly 41% indicated that they lacked sufficient evidence to support their complaints *(Figure 6)*. These findings suggest that under-reporting is not merely a consequence of consumer indifference but reflects limited awareness of complaint mechanisms, inadequate public confidence in regulatory enforcement, and practical difficulties in substantiating complaints. Strengthening accessible grievance redressal systems and improving public trust in enforcement agencies are therefore essential for effective food safety governance.

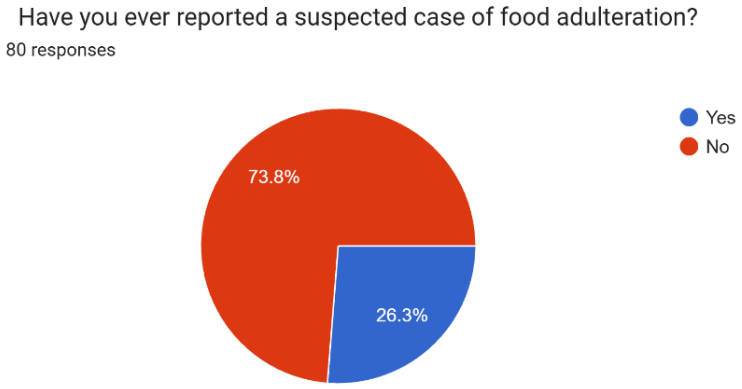


Figure 5

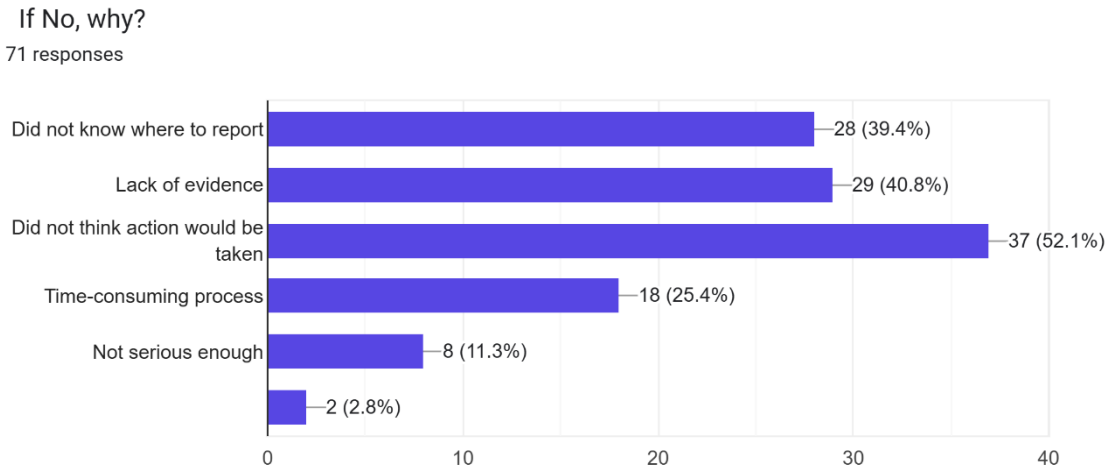


Figure 6

Consumer behaviour regarding food labels also presents important insights. Only 38.8% of respondents reported that they always check food labels before purchasing food products, while approximately 31.3% stated that they do so only sometimes *(Figure 7)*. These findings indicate that a significant proportion of consumers do not consistently utilise product labels as a basis for making informed purchasing decisions. Factors such as limited awareness, misleading packaging, and difficulty in interpreting label information may contribute to this behaviour. Consequently, simplifying food labels and improving consumer awareness regarding their importance should form part of broader food safety strategies.

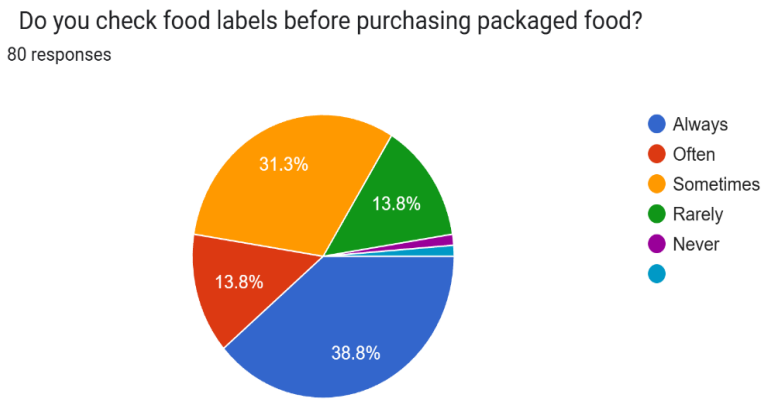


Figure 7

The survey also explored the major challenges consumers face in protecting themselves from food adulteration. Approximately 75% of respondents identified lack of awareness as the primary challenge, followed by misleading labels (53.8%) and insufficient information regarding food safety (47.5%) *(Figure 8)*. These findings demonstrate that consumer vulnerability extends beyond individual behaviour and reflects broader systemic shortcomings in public communication and awareness. Effective food safety governance therefore requires sustained educational initiatives alongside regulatory enforcement.

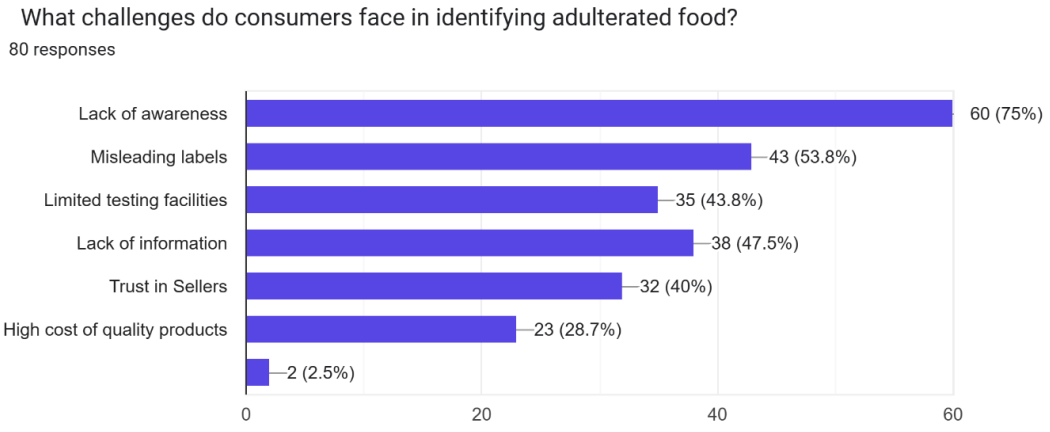


Figure 8

Respondents also expressed clear expectations regarding measures to strengthen food safety regulation. Approximately 52.5% believed that food business establishments should be inspected monthly by the competent authorities, while around 25% preferred quarterly inspections *(Figure 9)*. Similarly, nearly 61.3% recommended more frequent inspections, while 57.5% emphasised the need for stricter penalties for offenders, and about 52.5% emphasised the need for expanded consumer awareness campaigns and 53.8% recommended better food testing facilities *(Figure 10)*. These responses indicate that consumers expect a balanced regulatory approach combining preventive measures, effective enforcement, improved institutional capacity, and continuous public education.

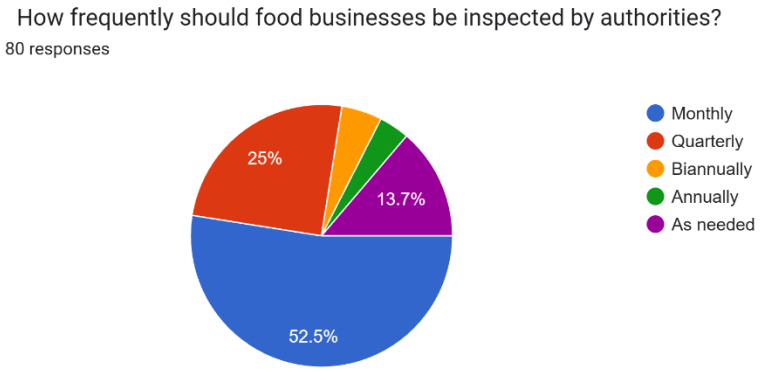


Figure 9

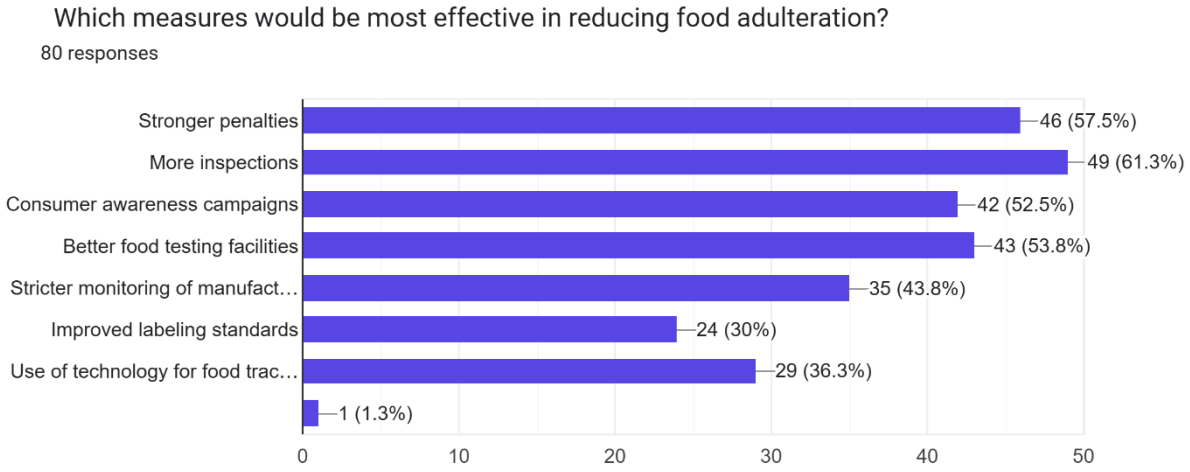


Figure 10

The qualitative responses further reinforce these quantitative findings. A recurring theme across respondents' comments was the demand for regular inspections, stricter penalties against repeat offenders, enhanced food testing facilities, and greater public awareness regarding food adulteration. Several respondents highlighted the importance of maintaining hygienic conditions in food preparation and sale, particularly in sweet shops, street food outlets, and other food establishments. One respondent specifically recommended making food safety data, vendor compliance status, and laboratory inspection reports publicly accessible through online platforms, enabling consumers to verify the quality and safety of the food they purchase. This reflects the growing public demand for greater transparency and accountability in food safety governance. Others suggested that the government should utilise social media, educational institutions, and mass media to disseminate food safety information more effectively. One respondent also recommended adopting best regulatory practices from countries with robust food safety systems, reflecting public expectations for continuous improvement in food safety governance.

Overall, the findings indicate that consumers recognise food adulteration as a serious public health issue and demonstrate a growing awareness of its risks. However, significant gaps remain in consumers' ability to identify adulterated food, access reliable information, and utilise complaint mechanisms. The findings also reveal limited public confidence in regulatory enforcement, suggesting that effective food safety governance requires not only stronger legal enforcement and institutional capacity but also sustained consumer education, transparent grievance redressal mechanisms, improved food testing infrastructure, and greater public engagement. These findings provide valuable empirical support for the policy recommendations proposed in this study.

7.2 Field Observations on Hygiene and Food Safety

In addition to the online survey, field visits were conducted in selected rural, semi-urban, and urban areas of Uttar Pradesh to observe food handling practices, hygiene conditions, and compliance with basic food safety standards. The observations were primarily carried out in and around the districts of Baghpat, Ghaziabad, and Meerut, based on accessibility, to capture diverse food safety and hygiene practices across different settings. During these visits, approximately 40 street food vendors, including chaat vendors and particularly gol gappa (pani puri) vendors, were observed.

The observations revealed that hygiene conditions were comparatively more concerning in several rural and semi-urban areas. Most vendors were found not wearing gloves while preparing or serving food. Although dustbins were present at many vending locations, they were often left uncovered, attracting flies that were frequently observed sitting on prepared food items. In several instances, food was kept uncovered for prolonged periods, exposing it to dust, insects, and other environmental contaminants. Such practices significantly increase the risk of food contamination and food-borne illnesses.

Field observations also indicated that some vendors used stale or previously prepared food items, particularly during periods of low customer demand. While these practices may not always constitute deliberate adulteration, they reflect inadequate awareness of food hygiene and safe food handling practices, thereby compromising food quality and consumer health.





In contrast, many food vendors in urban areas were observed wearing gloves and maintaining comparatively better waste disposal practices, with dustbins available at their stalls. However, consumers and local discussions frequently raised concerns regarding the reuse of cooking oil, the use of degraded or poor-quality cooking oil, and the sale of stale food, particularly by certain fast-food and street food vendors. These practices pose significant health risks despite the presence of better visible hygiene measures. This suggests that while basic hygiene standards may be relatively better maintained in urban areas, concerns relating to food quality and safe food preparation continue to persist.

These field observations are consistent with the Food Safety and Standards Act, 2006, which recognises food as unsafe if it is "prepared, packed or kept under insanitary conditions" under Section 3(1)(zz). [59] They also reflect the objectives of the Prevention of Food Adulteration Act, 1954, which sought to prevent the manufacture and sale of contaminated and unsafe food. The observations indicate that food safety challenges are not confined to intentional adulteration through chemicals or harmful substances. Poor hygiene practices, inadequate sanitation, uncovered food, improper waste management, the presence of flies, the reuse of degraded cooking oil, and the sale of stale food can also render food unsafe for human consumption.

Overall, the field observations demonstrate that food safety concerns differ across rural, semi-urban, and urban areas. While rural and semi-urban areas exhibited more visible deficiencies in hygiene and sanitation, urban areas presented concerns relating to food quality, including the use of stale food and degraded cooking oil. These findings underscore the need for regular inspections, vendor training on hygienic food handling practices, improved sanitation infrastructure, and greater public awareness to ensure safe food practices across all regions.

7.3 Field Insights from Discussions with Farmers

Pesticide use in Uttar Pradesh has increased considerably in recent years due to a combination of environmental, agricultural, and socio-economic factors. Rapid agricultural intensification and the expansion of commercial cultivation have increased the vulnerability of crops to pests and diseases, resulting in greater dependence on chemical pest control measures. At the same time, changing climatic conditions, including irregular rainfall, rising temperatures, and

[59] https://www.indiacode.nic.in/bitstream/123456789/7800/1/200634_food_safety_and_standards_act,_2006.pdf

fluctuations in humidity, have altered pest behaviour and increased the frequency of infestations, often requiring repeated pesticide applications. Limited awareness of sustainable alternatives such as Integrated Pest Management (IPM), coupled with the immediate effectiveness and easy availability of chemical pesticides, has further reinforced this dependence, particularly among small and marginal farmers. The continued use of similar pesticides has also contributed to pest resistance, encouraging farmers to apply higher doses or stronger formulations to achieve the desired results.[60]

These trends were evident during interactions with farmers in the study area. As part of the field study, informal discussions were conducted with farmers in selected rural and semi-urban areas to understand agricultural practices and the challenges affecting food quality and safety. These discussions provided valuable insights into the factors influencing the use of pesticides, crop protection methods, and post-harvest storage practices.

Farmers reported that changing climatic conditions, including irregular rainfall, rising temperatures, and increased humidity, have led to a noticeable rise in pest attacks, insect infestations, and fungal diseases affecting agricultural crops. According to the participants, insects often attack crops from the upper portions of plants and gradually spread throughout the crop, causing considerable damage to fruits and vegetables and reducing both yield and quality.

To minimise crop losses and protect agricultural production, farmers stated that they frequently rely on pesticides and insecticides. They emphasised that the application of these chemicals is intended to safeguard crops rather than to adulterate food. However, the discussions highlighted concerns that the excessive or improper use of pesticides, particularly without adequate knowledge of recommended dosages and pre-harvest intervals, may result in chemical residues remaining on food products. Such residues have the potential to pose risks to consumer health if they exceed the permissible limits prescribed under food safety regulations.

The discussions also revealed seasonal variations in pest infestations. Farmers observed that rabi crops like wheat sown during the winter season generally experiences fewer insect attacks while growing in the field compared to kharif crops like sugarcane. Nevertheless, post-harvest storage presents significant challenges. Traditionally, rural households relied on indigenous practices such as storing grains with neem leaves and matchsticks to protect them from insects and worms. According to the participants, changing climatic conditions and increasing pest resistance have reduced the effectiveness of some of these traditional methods, resulting in greater dependence on chemical fumigants and other preservation measures during storage.

Differences were also observed between rural and semi-urban areas. Farmers in rural areas continued to rely largely on traditional storage techniques, whereas those in semi-urban areas increasingly utilised cold storage facilities and chemical preservation methods to reduce spoilage and extend the shelf life of agricultural produce. Although these practices are primarily intended to minimise post-harvest losses and maintain food availability, they also highlight the need for proper regulation, scientific guidance, and monitoring to ensure that chemical applications remain within prescribed safety standards.

[60] https://pmc.ncbi.nlm.nih.gov/articles/PMC11615616/#bib74

These field discussions demonstrate that food safety begins at the agricultural stage and is influenced by multiple factors, including climatic variability, pest management practices, post-harvest storage, and farmers' access to technical knowledge. The findings underscore the importance of strengthening agricultural extension services, promoting Integrated Pest Management (IPM), encouraging safe pesticide application practices, improving farmer awareness regarding residue management, and enhancing monitoring mechanisms to ensure that agricultural produce reaching consumers complies with food safety standards.

7.4 Rural-Urban Differences in Food Adulteration: Field Observations

Apart from the online survey, several important observations emerged during field visits through direct observation and informal interactions with members of the public. These observations are qualitative in nature and represent patterns noticed during the field study rather than findings from the questionnaire or formal interviews.

One of the key observations was the difference in food consumption patterns between rural and urban areas. Rural households appeared to be relatively less vulnerable to food adulteration because many families consumed food produced within their own households or communities. Milk was commonly obtained from their own cattle, vegetables and fruits were grown in their own fields or kitchen gardens, mustard oil was extracted from home-grown mustard crops, and pickles, butter, and other dairy products were prepared at home. Consequently, rural households depended less on commercial food suppliers and were connected to a much shorter food supply chain.

During informal interactions, it was observed that awareness of regulatory authorities such as the Food Safety and Standards Authority of India (FSSAI) was comparatively lower among participants from rural areas. This contrasts with the findings of the online survey, where respondents demonstrated a relatively higher level of awareness regarding food adulteration and FSSAI. The difference is likely attributable to the composition of the survey sample, which consisted predominantly of students (72.5%) *(Figure 11)* and included a larger proportion of rural respondents (51.2%) alongside urban respondents (42.5%) *(Figure 12)*, many of whom possessed higher educational qualifications and greater access to digital sources of information. In comparison, the informal interactions involved individuals from diverse educational and occupational backgrounds, particularly in rural communities where awareness of food safety regulations and consumer grievance mechanisms appeared more limited. These findings suggest that educational attainment and access to information may have a greater influence on awareness of food safety regulations than place of residence alone, highlighting the need for targeted awareness campaigns among rural populations beyond digitally connected and student communities.

In urban areas, a different pattern was observed. Most households relied on dairy farms, local markets, supermarkets, packaged food products, and commercial food suppliers. Although urban consumers generally appeared to be more aware of food safety issues, they depended on longer and more complex food supply chains involving multiple intermediaries. This greater dependence may increase the possibility of food adulteration, contamination, improper handling, or deterioration in food quality before the products reach consumers.

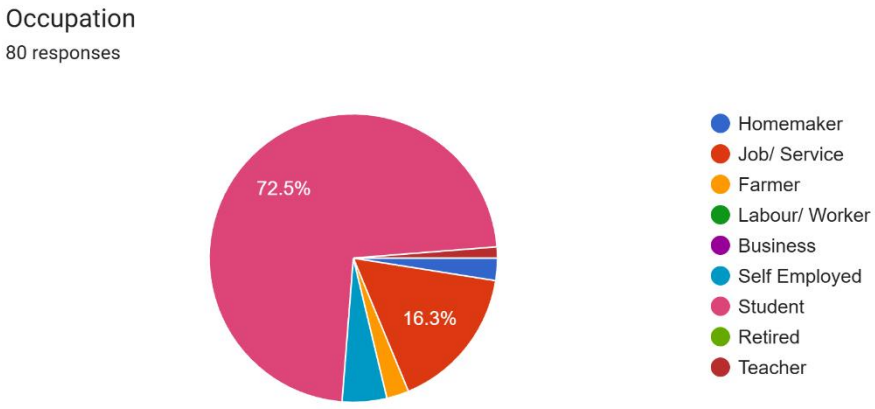


Figure 11

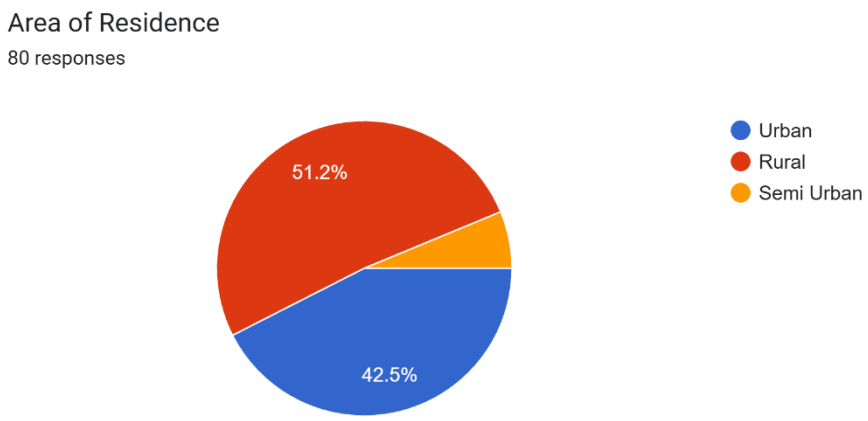


Figure 12

Milk quality was one of the most frequently discussed concerns during field interactions. Many urban consumers complained that the milk purchased from dairy farms sometimes had lower consistency, an unusual taste, or an unpleasant smell. Field observations suggested two possible explanations. First, differences in cattle feeding practices were noticeable. In many villages, cattle were commonly fed nutritious fodder such as bajra (pearl millet), jowar (sorghum), maize, khal (oilseed cake), and chokar (wheat bran). In contrast, during field observations, cattle in some commercial dairy farms were seen being fed stale rotis, stale bread, and comparatively lower-quality or less nutritious fodder. Although feeding practices may influence the nutritional quality and taste of milk, they should not be regarded as food adulteration unless prohibited substances are intentionally added.

Second, economic incentives appeared to play a role in urban dairy markets. Since a large proportion of the urban population depends on commercial milk suppliers, informal

interactions suggested that some producers may add water to increase the quantity of milk and maximize profits. Such practices, if carried out intentionally, constitute food adulteration. Some people also mentioned that milk from different animal sources, such as cow and buffalo milk, may be mixed. However, such mixing is considered adulteration only if it is done fraudulently or without proper disclosure to consumers.

Similar differences were observed in the case of edible oils and pickles. In many rural households, mustard oil was extracted from home-grown mustard crops, while pickles were prepared using traditional household methods. Butter and other dairy products were also commonly produced from milk obtained from the family's own cattle. These practices reduced dependence on commercially processed food products and shortened the food supply chain, thereby reducing opportunities for adulteration.

Overall, the field observations indicate that proximity to the source of food may influence exposure to food adulteration. Households that produce or obtain food directly from local sources appear to face fewer opportunities for adulteration than those relying on long and commercialized food supply chains. These observations are based solely on field observations and informal interactions conducted during the study and should not be interpreted as universally applicable to all rural or urban areas.

7.5 Summary of Key Findings

The findings of this study demonstrate that food safety challenges vary across rural, semi-urban, and urban settings while sharing several common concerns. Rural areas were characterised by comparatively lower consumer awareness of regulatory authorities such as FSSAI and limited knowledge of formal complaint mechanisms. However, field observations indicated that many rural households were comparatively less exposed to certain forms of market-based food adulteration due to shorter and more localized food supply chains. A significant proportion of families relied on milk from their own cattle, prepared dairy products such as curd and ghee at home, and consumed vegetables cultivated in their own fields or sourced directly from nearby farmers. This reduced dependence on commercial intermediaries and packaged food products, thereby limiting exposure to certain forms of adulteration commonly associated with extended supply chains.

In contrast, consumers in semi-urban and urban areas were found to be more dependent on commercial markets, supermarkets, food delivery platforms, and complex food supply chains for their daily food requirements. The involvement of multiple intermediaries in the production, processing, storage, transportation, and retail of food increases the opportunities for intentional adulteration, contamination, improper storage, and quality deterioration before food reaches consumers. Urban consumers also have comparatively fewer alternatives to source fresh milk and vegetables directly from producers, making them more reliant on commercially supplied food products.

Nevertheless, the study also found that rural areas face distinct food safety challenges. Discussions with farmers revealed that changing climatic conditions, pest infestations, and economic pressures have contributed to increased reliance on pesticides and other agrochemicals, creating potential risks of chemical residues in agricultural produce when recommended practices are not followed. Similarly, field observations across rural, semi-urban,

and urban areas identified shortcomings in hygiene practices among certain food vendors, indicating that food contamination is not confined to any one geographical setting.

Overall, the findings suggest that food adulteration should be understood as a multidimensional issue influenced by the interaction of agricultural practices, hygiene standards, consumer behaviour, food supply chains, and the effectiveness of regulatory governance. While the nature of food safety risks differs across rural, semi-urban, and urban areas, strengthening regulatory enforcement, promoting hygienic practices, encouraging responsible agricultural practices, and improving consumer awareness remain essential across all settings.

7.6 Limitations of the Primary Study

While the primary research provided valuable insights into public perceptions and experiences regarding food adulteration, certain limitations should be acknowledged. The study employed a convenience sampling method through an online Google Forms questionnaire, which may limit the representativeness of the findings. Although the survey link was circulated across different regions of India, the majority of respondents were from Uttar Pradesh. Consequently, the results may not fully reflect the perceptions and experiences of the population across the country.

Furthermore, approximately 72.5% of the survey respondents were students, resulting in a relatively educated sample. This may have influenced the overall level of awareness regarding food adulteration, food safety regulations, and regulatory authorities such as the Food Safety and Standards Authority of India (FSSAI). Therefore, the findings may not be representative of individuals from all educational, occupational, or socio-economic backgrounds.

The field observations and informal interactions were conducted only in selected regions in the districts of Uttar Pradesh, including Meerut, Baghpat, and Ghaziabad. As food supply chains, market practices, and enforcement mechanisms differ across states and regions, these observations cannot be generalized to the entire country. In addition, the informal interactions were exploratory in nature and were not conducted using structured interview schedules, thereby limiting the scope for systematic comparison and statistical analysis.

Finally, the study was conducted within limited time and resource constraints, which restricted both the geographical coverage and the sample size of the primary research. Despite these limitations, the integration of survey findings, field observations, and secondary sources enabled the study to provide meaningful insights into the challenges of food adulteration and the effectiveness of the existing regulatory framework in India.

8. Challenges in the Existing Food Safety Regulatory Framework

Despite being the apex regulatory authority responsible for ensuring food safety in India, the Food Safety and Standards Authority of India (FSSAI) continues to face several institutional, operational, technological, and socio-economic challenges in effectively addressing food adulteration. These challenges limit the efficiency of enforcement and hinder the achievement of a safe and transparent food system.

(i) Inadequate Infrastructure and Testing Facilities

One of the major challenges faced by FSSAI is the inadequate availability of modern food testing infrastructure. Although accredited laboratories operate across the country, their number and capacity remain insufficient to meet the increasing volume of food samples requiring analysis. This problem is particularly evident in rural and semi-urban areas, where testing facilities are limited. Overburdened laboratories often lead to delays in sample analysis and reporting, thereby slowing regulatory action against offenders.[61]

(ii) Shortage of Skilled Manpower

The effective implementation of food safety regulations depends on the availability of adequately trained personnel. However, FSSAI and State Food Safety Authorities continue to face shortages of Food Safety Officers, food analysts, and inspectors. In addition to numerical shortages, continuous training and capacity building are necessary to equip officials with the skills required to detect increasingly sophisticated methods of food adulteration and ensure effective enforcement.[62]

(iii) Weak Enforcement and Delays in Legal Proceedings

While the Food Safety and Standards Act, 2006 provides a comprehensive legal framework to regulate food safety, enforcement remains a significant challenge. Investigations, prosecutions, and adjudication of food adulteration cases are often delayed, reducing the effectiveness of regulatory action. Prolonged legal proceedings and inadequate deterrence may encourage repeated violations, thereby undermining consumer confidence in the regulatory system.[63]

(iv) Limited Public Awareness and Consumer Participation

Public awareness plays a vital role in preventing food adulteration. However, many consumers, particularly in rural and economically disadvantaged regions, remain unaware of food safety standards, consumer rights, and available complaint mechanisms. Limited literacy, inadequate access to information, and socio-economic constraints further reduce public participation in reporting food safety violations, allowing adulteration to remain undetected in many cases.[64]

(v) Large Unorganised Food Sector

A significant proportion of India's food production, processing, and retail activities operate within the unorganised sector. Small vendors, street food sellers, and informal food businesses often function outside formal regulatory oversight, making regular inspections and compliance monitoring difficult. This creates substantial challenges for FSSAI in ensuring adherence to prescribed food safety standards across the entire food supply chain.[65]

(vi) Emerging Technologies and Sophisticated Methods of Adulteration

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[61] https://www.ijllr.com/post/effectiveness-of-fssai-in-controlling-food-adulteration-a-legal-and-practical-analysis

[62] *Ibid.*

[63] *Ibid.*

[64] *Ibid.*

[65] *Ibid.*

Advancements in technology have enabled adulterators to adopt increasingly sophisticated techniques that are more difficult to detect using conventional testing methods. The use of synthetic chemicals, artificial colouring agents, and other complex adulterants requires continuous technological upgradation of testing laboratories, investment in advanced analytical techniques, and ongoing research to keep pace with evolving food fraud practices. [66]

(vii) Lack of Consumer Awareness Regarding Complaint Mechanisms

Another significant challenge identified through the survey was the limited awareness regarding complaint and grievance redressal mechanisms. A considerable proportion of respondents were either unaware of the appropriate authority to report suspected food adulteration or expressed little confidence that reporting such cases would lead to effective action. This reflects a gap between consumer awareness and active participation in food safety enforcement.

(viii) Pesticide Use as a Food Safety Challenge

Additionally, interactions with farmers highlighted concerns regarding pesticide use in agricultural practices. Farmers reported increasing dependence on pesticides due to changing climatic conditions and pest infestations, raising concerns about pesticide residues entering the food chain if recommended application practices are not adequately followed.

Overall, these challenges indicate that the effectiveness of FSSAI depends not only on a strong legal framework but also on adequate infrastructure, technological advancement, institutional capacity, efficient enforcement, and active public participation. Addressing these issues is essential for strengthening India's food safety regime and reducing the prevalence of food adulteration.

9. Suggestions and Recommendations

Based on the findings of the present study and existing literature, the following measures are recommended to strengthen the food safety regulatory framework and reduce the incidence of food adulteration in India:

(i) Strengthening Regulatory Enforcement: Although India has a comprehensive legal framework under the Food Safety and Standards Act, 2006, effective implementation remains a challenge. Regulatory authorities should increase the frequency of inspections, strengthen surveillance mechanisms, and ensure timely legal action against violators. Imposition of stricter penalties and greater transparency in enforcement can act as effective deterrents against food adulteration.[67]

(ii) Enhancing Food Safety Management and Quality Control: Food business operators should be encouraged to adopt internationally recognized food safety management systems,

[66] https://www.ijllr.com/post/effectiveness-of-fssai-in-controlling-food-adulteration-a-legal-and-practical-analysis

[67] https://www.researchgate.net/publication/401238147_Current_Strategies_on_the_Prevention_of_Food_Adulteration

such as Good Manufacturing Practices (GMP), Good Hygienic Practices (GHP), and Hazard Analysis and Critical Control Point (HACCP). Regular quality checks throughout the production, processing, storage, and distribution stages can significantly reduce both intentional and accidental adulteration.[68]

(iii) Improving Laboratory Infrastructure and Technological Adoption: Strengthening food testing laboratories with modern analytical equipment and increasing routine sampling of high-risk food products are essential. The adoption of rapid detection technologies, portable testing devices, digital traceability systems, and blockchain-based supply chain monitoring can improve transparency and facilitate early detection of adulterated products.[69]

(iv) Promoting Supply Chain Transparency: A robust traceability system should be implemented to enable tracking of food products from production to consumption. Transparent supply chains improve accountability among stakeholders and facilitate the prompt recall of unsafe food products.[70]

(v) Strengthening Consumer Awareness and Reporting Mechanisms: The findings of the primary survey indicate that a considerable proportion of respondents were either unaware of the appropriate authorities for reporting food adulteration or lacked confidence that effective action would be taken. Public awareness campaigns should therefore focus on educating consumers about food safety regulations, food labels, consumer rights, and the available complaint mechanisms. Increased awareness is particularly important in rural and semi-urban areas, where informal interactions conducted during the study indicated relatively lower awareness of regulatory authorities such as the Food Safety and Standards Authority of India (FSSAI).

(vi) Improving Food Safety in the Informal Sector: As field observations revealed hygiene-related concerns among some street food vendors, local authorities should strengthen licensing systems, conduct regular inspections, and provide periodic training on hygienic food handling practices. Access to clean water, sanitation facilities, and food safety education should also be improved to minimize contamination risks.

(vii) Capacity Building and Stakeholder Collaboration: Continuous training should be provided to food handlers, manufacturers, inspectors, laboratory personnel, and enforcement officials to enhance compliance with food safety standards. Greater collaboration among regulatory agencies, food businesses, consumer organizations, educational institutions, and civil society can further strengthen monitoring, reporting, and public participation in ensuring food safety.

(viii) Strengthening Consumer Grievance Redressal Mechanisms

Regulatory authorities should strengthen consumer grievance redressal systems by promoting accessible reporting mechanisms through helplines, mobile applications, and online complaint portals. Publicising enforcement actions and complaint outcomes may improve consumer confidence and encourage greater public participation in reporting food adulteration.

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[68] https://www.researchgate.net/publication/401238147_Current_Strategies_on_the_Prevention_of_Food_Adulteration

[69] *Ibid.*

[70] *Ibid.*

(ix) Encouraging Sustainable Pesticide Management

Given the concerns expressed by farmers regarding pesticide use, greater emphasis should be placed on promoting responsible pesticide application, integrated pest management practices, and awareness regarding safe pre-harvest intervals. Regular monitoring of pesticide residues in agricultural produce should also be strengthened to minimise potential health risks.

Collectively, these measures can contribute to a more effective, transparent, and accountable food safety system, thereby enhancing consumer confidence and protecting public health.

10. Conclusion

Food adulteration continues to pose a significant challenge to public health, consumer rights, and food security in India despite the existence of a comprehensive legal and institutional framework under the Food Safety and Standards Act, 2006. This study evaluated the effectiveness of the existing regulatory framework by integrating secondary literature with primary research, including an online survey and field observations. The findings indicate that although regulatory mechanisms and enforcement efforts have strengthened over the years, challenges such as inadequate enforcement, shortage of food safety personnel, limited laboratory infrastructure, fragmented supply chains, and low consumer awareness continue to hinder their effectiveness. The primary research further revealed varying levels of consumer awareness, limited knowledge of grievance redressal mechanisms, concerns regarding the adulteration of commonly consumed food products such as milk and dairy products, hygiene-related issues among certain street food vendors, and the impact of pesticide use in agriculture. These findings demonstrate that food adulteration is a multidimensional challenge involving governance, public awareness, food production practices, and consumer participation.

The study highlights that effective food safety governance requires not only strong regulatory enforcement but also preventive measures such as consumer education, technological advancements, improved surveillance, responsible agricultural practices, and collaboration among government agencies, food business operators, farmers, educational institutions, civil society organisations, and consumers. Although the study is limited by its sample composition, geographical coverage, and time constraints, the integration of primary and secondary data provides valuable insights into the challenges and public perceptions surrounding food adulteration in India. Future research may build upon these findings through larger and more geographically diverse studies to examine regional variations and assess the effectiveness of regulatory interventions.

In conclusion, ensuring safe and unadulterated food is a shared responsibility. Strengthening institutional capacity, promoting transparency and accountability, enhancing consumer awareness, and encouraging active public participation are essential for building a safer and more resilient food system, protecting public health, restoring consumer confidence, and advancing sustainable food safety governance in India.

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Annexure

Section A: Demographic Information

1. Age Group

- Below 18
- 18–25
- 26–35
- 36–45
- Above 45

2. Gender

- Male
- Female
- Prefer not to say
- Others

3. Educational Qualification

- Higher Secondary
- Secondary school
- Undergraduate
- Postgraduate
- Doctorate
- Other

4. Area of residence

- Rural
- Urban
- Semi urban

5. Occupation

- Homemaker
- Job/Service
- Farmer
- Labour/ Worker
- Business
- Self Employed
- Student
- Retired
- other

Section B: Awareness of food adulteration

6. Have you heard about food adulteration?

- Yes
- No

7. How would you rate your knowledge of food adulteration?

Scale: 1=Very poor -5 =excellent knowledge

8. Which foods do you think are commonly adulterated?

- Milk and dairy products
- Spices
- Sweets
- Packaged foods
- Cooking oils
- Fruits and vegetables
- Honey
- Other

9. Through which sources have you learned about food adulteration?

- Social Media
- Television
- Newspapers
- Educational Institutions
- Government Campaigns
- Friends and Family
- Day to day consumption and health issues
- Independent media and researchers

Section C: Consumer Experiences and Challenges

10. Have you ever suspected purchasing an adulterated food product?

- Yes
- No
- Maybe

If yes, which product was it?

11. How concerned are you about food adulteration?

Scale: 1=Not concerned- 5= extremely concerned

12. How difficult is it for consumers to identify adulterated food products?

Scale: 1=Very easy- 5= very difficult

13. Do you think food adulteration is a serious problem in India?

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

14. Do you check food labels before purchasing packaged food?

- Always
- Often
- Sometimes
- Rarely
- Never

15. What challenges do consumers face in identifying adulterated food?

- Lack of awareness
- Misleading labels
- Limited testing facilities
- Lack of information
- Trust in Sellers
- High cost of quality products

16. Have you ever reported a suspected case of food adulteration?

- Yes
- No

If No, why?

- Did not know where to report
- Lack of evidence
- Did not think action would be taken
- Time-consuming process
- Not serious enough

Section D: Perception of Regulatory Framework

17. Are you aware of food safety authorities such as the Food Safety and Standards Authority of India?

- Yes
- No
- Maybe

18. How effective do you think food safety regulations are in preventing food adulteration?

Scale: 1= Not Effective- 5= Highly Effective

19. How frequently should food businesses be inspected by authorities?

- Monthly
- Quarterly
- Biannually
- Annually
- As needed

Section E: Recommendations and Opinions

20. Which measures would be most effective in reducing food adulteration?

- Stronger penalties
- More inspections
- Consumer awareness campaigns
- Better food testing facilities
- Stricter monitoring of manufacturers
- Improved labeling standards
- Use of technology for food tracking

21. Do you think consumers receive sufficient information about food safety?

- Yes
- No
- Not Sure

22. What additional steps should the government take to reduce food adulteration?