

Spice Adulteration in India: Review of Detection and Prevention Approaches

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Abstract: Concern over spice adulteration is on the rise in India, where new reports suggest that 15–25% of the spices sold are tainted. This review examines the different kinds of spice adulteration that are common in India, such as flavor, color, substitution, non-edible ingredient, and quality degradation. With an emphasis on the possible dangers of eating tainted spices. In addition to lowering the quality and flavor of spices, adulteration puts consumers at serious risk for long-term health problems, gastrointestinal disorders, and exposure to harmful substances (choudhary, et al.) Enforcement issues still exist in spite of regulatory frameworks such as the food adulteration prevention act and the Food Safety and Standards Authority of India (FSSAI). Stricter enforcement of regulations, consumer education, technology advancements, and assistance for farmers are all necessary to combat this problem. keeping India's rich culinary legacy, keeping economic stability, and protecting public health all depend on combating spice adulteration (sahoo, jyoti, samal, & kailash, 2024).

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I. INTRODUCTION

Different plant components are referred to as spices, which is a vast group of plant materials. Spices are used to define certain portions of plants, while herbs are associated with their green parts. Such as garlic, ginger, turmeric, onion, barks, saffron, pepper, cardamon, and so on (Velázquez et al., 2023). Spices are aromatic vegetable materials that can be whole, crushed, or ground and used to flavour food without contributing extra nutritional value (Castillejosmijangos, 2022) Click or tap here to enter text.. India, known as the world's spice bowl, produces more than 7 million tons of various spices annually. More than 65 kinds are produced in India. 3.15 million hectares of land are used for the cultivation of spices in India (SKV, 2018) Spices are a highly sought-after product on a global scale, with a market estimated to be worth \$12700 million and positive growth prospects in the next years.

Harvesting techniques vary from hand-picking pepper berries to machine-harvesting row crops of spices and pruning wild herbs growing on hillsides. The local regions that are used to grow spices include irrigated desert regions, lush valleys, and mountainous forests. As a result, growth circumstances are quite unpredictable, making it challenging to monitor the quality of spices used as ingredients or in final products (Ford et al., 2022).

A number of processing steps, including production, storage, transportation, and distribution, make spices receptive to fraudulence and adulteration. When foreign substances are added to or removed from spices, the original

composition and quality of the spices are lost, a phenomenon known as spice adulteration. The term adulterants refers to the substances used to lower the quality of spices. They create dirty and filthy spices that harm people's health and can cause a variety of serious conditions like cancer, lead poisoning, and digestive issues (pantola & agarwal, 2021). Urbanization, population development, and the need for more readily available, ready-to-serve food items have all contributed to the temptation to adulterate, especially during periods of food scarcity. Furthermore, there is now a greater chance of economically motivated profit. The ultimate victim of such wrongdoing is typically the consumer, who may have health problems if they unintentionally purchase and eat contaminated foods (Ken Essumanl).

Chemicals known as adulterants are something we shouldn't put in our food, drinks, or fuels. Additionally, adulterants may unintentionally or accidentally find their way into food products. Adulterants are substances that cause food material's quality to decrease or deteriorate. Adulteration makes a lot of money for the traffickers quickly, but it may also ruin a lot of lives. Food products we consume on a regular basis are hazardous and unclear to utilize due to the adulteration problem (Anita et al., n.d.). The deliberate or inadvertent addition of illegal substances to food, known as adulteration, can result in a product that is imitated and loses market value (SKV, 2018)

Saffron, vanilla, turmeric, cardamon, and paprika are common spices that have been tampered with (Castillejosmijangos, 2022). The most often found adulterants are foreign substances such flower wastes, fake

ingredients like artificial colorants, wasted extracts, and plant fragments of foreign spices (SKV, 2018). Furthermore, a great deal of research has been done on the use of herbs and spices in the prevention and treatment of many illnesses. Similar-looking but lower-quality plant compounds (such as peels, leaves, petals, seeds, and grains), previous batches of the same spice, subpar variations, and other goods (such as sawdust, flour, pulverized stones, brick dust, and Rhodamine B) can contaminate spices. Additionally common are artificial colors that can be genotoxic and cause cancer, such as Sudan I–IV, Orange II, Metanil Yellow, Basic Red 46, Rhodamine B, and Malachite Green (Castillejosmijangos, 2022). Spices are in high demand due to their flavor and wonderful taste. Since they are most frequently seen in powdered or ground form, they are a prime candidate for adulteration.

Spices have been utilized in traditional medical systems since ancient times due to their ability to heal a wide range of illnesses. However, one additional noteworthy function of the wide variety of herbs and spices is their capacity to regulate microbial growth, preventing unfavorable food and feed contamination (Velázquez et al., 2023)

For decades, people have utilized herbs and spices for their medicinal benefits. Given their beneficial qualities—antibacterial, anti-inflammatory, antioxidant, anti-hypertensive, anti-thrombotic, and chemo preventive—people have been using herbal spices to improve food flavor and cure a range of metabolic health conditions since ancient times. Garlic, ginger, turmeric, cinnamon, pepper, and cardamom are among the spices that are thought to have special modulatory effects on a variety of illnesses, such as cancer, diabetes, obesity, arthritis, immunological deficits, aging, and mental health. (Khan, 2024)

Examining the development of quality control, its significance for legal handling of spices and regulatory compliance, and its history, with a focus on the Indian setting. As part of quality control, a range of products that have been processed by humans or machines—from simple sorting, grading, or drying to intricate procedures to eradicate contamination even at the trace level—must be inspected and authorized. To guarantee that numerous quality metrics are in line with the legally prescribed limits, which are defined based on scientific study, national regulators in India, most notably the Food Safety and Standards Authority of India (FSSAI), have set the requirements for each spice item.

India is the world's biggest producer and user of spices, supplying the Middle East, Europe, Japan, Australia, and the United States. Therefore, it's critical to market produce in accordance with these nations' criteria. In this context, India began to test for a number of pollutants, including pesticides, heavy metals, natural poisons, and microbiological characteristics. In the early stages of the spice trade, traders were in charge of quality control and inspection, but as importers' complaints about the product's quality increased, the Indian government began to step in to address the problems. The Spices Board was established by the

government through the Spices Board legislation 1986, a parliament legislation, with the primary goal of maintaining the quality of cardamom and, eventually, other spices. The Spices Board has launched a number of campaigns to raise awareness among farmers and manufacturers alike so that the concept of quality control might trickle down to the lowest echelons of primary producers. Enhancing the marketability of spices is essential to increasing exports, which benefit the nation, traders, and farmers. To protect public health and the environment, organic product production is required by both national and international regulations.

➤ *Introduction to Prevalent Adulterants in Spices*

- In Black pepper powder, the adulterants such as papaya seeds, starch, and sawdust are often mixed with black pepper powder. Papaya seeds resemble black peppercorns in appearance, making it difficult to distinguish them. Starch and sawdust are added to increase weight and volume, thereby reducing the quality of the spice.
- In Turmeric powder, lead chromate, metanil yellow, chalk powder, yellow shop stone powder, and starch are some of the ingredients that can be added to turmeric powder to make it a fake. Turmeric's yellow hue is enhanced by the addition of lead chromate and metanil yellow, both of which are unhealthy. Chalk powder and yellow shop stone powder are used to add bulk, while starch is used to increase weight.
- In Chilli powder, common adulterants are brick powder, salt powder, artificial dyes, sand, sawdust and dried tomato skin. Brick powder and sand add to the volume. Artificial dyes will enhance the red color of the chilli powder. Sawdust increases the volume and dried tomato skin acts as a mimic to texture and appearance of chilli flakes.
- Hing consists of addition of soap stone, starch, and foreign resins. Soap stone and starch are added for enhancing volume, whereas foreign resins are mixed to modify flavor and aroma, decreasing the spiciness purity.
- Coriander powder contains animal dung powder along with seed-removed coriander. Animal dung powder is used to increase weight whereas seed-removed coriander is added to enhance quantity that thereby compromises quality.
- Oregano is mixed with similar kinds of leaves or herbs from plants, which can resemble oregano in look and odor but do not possess the same flavor and medicinal qualities. The result is that this process lowers the quality and potency of the herb.
- In Curry powder, the adulterants are mostly starch powder and sawdust. These are added to increase bulk and weight, resulting in a diluted product that lacks the full flavor of pure spices.
- Cinnamon has common form of adulteration which is the substitution of cinnamon with cassia, which is cheaper. While cassia has a similar flavor, it is considered inferior in taste and texture compared to true cinnamon.
- Cumin includes the addition of grass seeds colored with charcoal and immature fennel seeds. Grass seeds are dyed to resemble cumin seeds, and immature fennel seeds are

mixed in to increase volume, thus reducing the quality of the spice (jp & kc)

II. HEALTH IMPACTS OF ADULTERATED SPICES

Artificial coloring, additives, and contaminants are examples of adulterants that can seriously impair your health when added to turmeric. Lead poisoning, for example, can be caused by lead and other contaminants, whereas synthetic colors like metanil yellow cause cancer.

Numerous health issues might arise from long-term usage of tainted turmeric, especially in vulnerable populations like children, expectant mothers, and the elderly. Food adulteration has serious negative effects on our health. Regardless of the type of adulteration, consuming tainted

food over an extended period of time is very harmful to human health. Consuming tainted food causes the body to contain more toxic chemicals. As more and more adulterants are added to food, its nutritional value decreases. Consequently, it is the least healthy. Because of the high concentration of carcinogens they contain, chemical adulterants and food coloring additives might occasionally prove to be fatal due to the health risks or hazards they pose. Additionally, some tainted foods can cause instant harm to our organs, including organ failure and issues with the heart, liver, kidneys, and many other organs (pantola & agarwal, 2021).

Spices adulteration is an issue that brings significant health risks to the consumers; thus, the procurement of spices from reputable and trusted sources is of prime importance in ensuring the quality and purity of the spice.

Table 1 Spices Adulteration

Spice	Adulterants and Disorder Caused
Chilli powder	Yellow and sudan red color are the synthetic colors added to chilli powder and they can cause cancer.
	Brick dust is used as a filler in chilli powder which is harmful as it causes respiratory illness when it is inhaled or consumed.
	Oil soluble tars are the poisonous substances which may be added for color strength that might cause heart disease,liver damage and tumor development.
	Lead soluble salts used in chilli powder lead to metal toxicity and poisoning due to lead.
Turmeric powder	Metanil yellow which is an artificial color included in turmeric powder is carcinogenic.It leads to stomach disorders.
	Lead chromate that is added to strengthn the yellow colour,is extremely toxic and might cause cance,anemia ,neurotoxicity,impotency of males,etc
	Tapioca starch is added for bulk and this adulterant causes stomach disorders.
	Aniline dyes are synthetic dyes that cause severe health problems and are carcinogenic.

➤ Causes of Adulteration

Spice adulteration in India is caused by a number of variables. In order to maximize earnings by increasing volume and lowering expenses, producers and merchants frequently adulterate spices(Sasikumar et.al2016).

In order to meet supply demands, the enormous domestic and international demand for Indian spices also promote unethical behaviours (Essuman, 2022). Adulteration is further made possible by some region's lax regulatory inspection and enforcement, tampering is made more likely by intricate supply chains that involves several middlemen. Spices can include wide range of common adulterants including artificial dyes, filler, etc (Ken Essumanl).

Additionally, some unethical practices are typically adopted to preserve the food's freshness in order to avoid monetary losses brought on by food spoiling during sale and transit. Some food producers and sellers overstate the benefits of their goods. The consumer finds it extremely challenging to choose safe food products due to deceptive or misleading advertising.

In the name of natural spices and branding it as organic, profit makers tend to add adulterants which makes consumers attract and lead to consumption as well. This talks about false branding and marketing of spices.

Sellers and buyers exchange anything through money, due to lack of quality control and safety measures that involves spending money by sellers could corner them to take a shortcut in making gains by adding these cheap bought adulterants which could help them save money. Same goes to the buyers where, when common spices are sold for different prices under different brand names and family with poor financial state chooses to buy low budget spices, which gives sellers a target to approach such people in buying their adulterants added spices and gain money.

Ignorance and negligence of manufacturing spices added with adulterants or sellers having no knowledge of effects of selling these spices containing adulterants to one's health could also constitute to major spice adulteration initiation.

The sellers mainly focus on adding adulterants to spices such as ground spices or green dried spices sold in packs that loses its flavour and colour within 6 months to 2 years to make it long lasting and saves them money, time in re-manufacturing them in less time.

Saving man power is also a main aspect in spice adulteration. Since qualified and verified spices to sell needs lot of man power in processing, here sellers bind to save money on such factor.

➤ *Introduction to Forensic Science and its Impact on Food Quality*

In recent decades, the food business has placed greater emphasis on quality as a result of changing consumer preferences and increased expectations. The significance of quality is emphasized by stricter food laws and private food standards, increased market competitiveness, and the focus on sustainable food production. The food sector must change in order to produce more food in larger quantities with the necessary quality while maintaining sustainability. However, there are a number of challenges facing existing quality control efforts, including expensive prices, lengthy wait periods for sample preparation and results, and human error. A comprehensive examination of crimes against the food industry and the laws put in place to protect it and customers is provided by forensic science. In order to guarantee compliance and preserve consumer confidence, regulatory standards and capable organizations are essential. However, issues including adulteration and inconsistent. There are various definitions and variations in food inspection supervision. A comprehensive strategy that includes expanded employee training, better communication, and uniform procedures is needed to address these issues. Guidelines and laws governing the creation and approval of nontargeted procedures for quality control in the food industry are also required. By tackling these problems, we can improve food safety procedures even further and safeguard people's and communities' health. (barbara). It is feasible to capture and prosecute those accountable for deliberate food fraud by using forensic techniques. It highlights how urgently forensic science must be used to address this problem. Strong regulations and the use of forensic technologies can be used to successfully guarantee consumer safety and preserve the integrity of the food supply chain.

III. METHODS FOR DETECTING ADULTERANTS

➤ *Physical Techniques:*

Although physical techniques for detecting adulterations have been developed, such as microscopic and macroscopic visual structural evaluations and analyses of physical parameters like bulk density, morphological features, structures, and solubility, these techniques do not ensure qualitative adulteration detections (Dhanya & Sasikumar, 2010) (Bansal, 2017).

Mangal 2014 states that visual structure methods using both microscopic and macroscopic approaches is highly useful for identifying harmful bacteria, particularly fungus. Overabundance of starch in powdered spices including cassava, chilli, coriander and cumin can be readily identified under a microscope (fssai,2012). Due to the fact that clean meals are free of contaminants such dust, stones, straw, weed seeds, insects, rodent hair, secretions, etc. By visually inspecting the contaminants and analysing a small quantity on a glass plate, adulteration can be detected.

➤ *Analytical Techniques*

In horticulture, microscopic analysis entails checking the quality and purity of samples. It aids in determining the

concentration, size, and shape of particles. Product safety is guaranteed by the detection of microbiological contamination and adulterants. Microscopy plays a critical role in quality control, helping to uphold standards and guarantee customer satisfaction. Chemical analysis. Spectrophotometry, HPLC, and TLC are among the techniques used for determining purity and assessing quality. Additional tests check the safety of heavy metals, ash, and volatile oils (Ashok Kumar Rath et.al 2024).

In chromatography using Thin-Layer (TLC) the components are separated and identified using thin-layer chromatography (TLC), which is used to assess its purity. On a plate, a thin layer of adsorbent material is coated with a sample. The separated components are visible under UV light or with the use of an appropriate chemical reagent once the plate has dried. The existence and purity of particular chemicals, such curcumin in turmeric, can be ascertained by comparing the resulting pattern with established criteria.

Liquid Chromatography with High Performance (HPLC) is used to assess the purity of spices, HPLC is essential. This procedure involves dissolving a sample in a solvent and injecting it onto a column, where the constituents separate according to their chemical characteristics. As they elute from the column, Ex: curcuminoids which give turmeric its color and health benefits—are identified and measured. The purity and quality of the sample can be evaluated by comparing its amounts to established criteria.

In GC-MS, or gas chromatography-mass spectrometry in order to assess the purity of spice sample, its chemical elements are separated for analysis using Gas Chromatography-Mass Spectrometry (GC-MS). It detects and measures the substances in a sample, guaranteeing that no impurities are present and verifying the existence of important substances. The mixture is divided into distinct components by GC, and these components are identified by MS using their mass and charge.

Methods of Spectroscopy determines the purity of spice sample, spectroscopic techniques like UV-V is spectroscopy are essential. Using this method, a sample is exposed to visible and ultraviolet light, and the absorbance spectrum is measured. UV-Vis spectroscopy can measure the amount of substance, the main bioactive ingredient in sample, in a sample since it shows clear absorbance peaks. This technique offers a quick and non-destructive solution to evaluate sample quality, guaranteeing that items fulfil the purity requirements for safe use or consumption.

When it comes to detecting adulterants in traded commodities of plant origin, DNA-based molecular detection is more successful than other DNA- or molecular-based techniques, particularly when the adulterants are biological molecules., claim Bansal et al. (2017). It will have no trouble differentiating between the adulterant and the sample if they are physically identical. There are three methods for using DNA-based molecular techniques: hybridization, sequencing, and PCR. According to Dhanya and Sasikumar (2010), PCR-based methods are easy to use, reasonably

priced, sensitive, and focused. It has a great potential for adulterant identification and commodity verification, claim Bansal et al. (2017).

➤ *Regulatory Framework and Quality Standard*

With differing degrees of success, India has put in place a regulatory framework to combat the problem of adulterated spices. The main regulatory agency in charge of establishing guidelines and standards pertaining to food safety, including spices, is the Food Safety and Standards Authority of India (FSSAI). By outlawing adulteration, the Prevention of Food Adulteration Act of 1954 provides a legal framework to guarantee the safety and purity of food products, including spices. The Agmark certification mark is also used to reassure customers about the genuineness and quality of agricultural goods, such as spices. Notwithstanding these steps, enforcement is difficult because to things like a lack of funding, corruption, and the intricate supply chain of the spice industry. To effectively prevent spice adulteration in India, regulatory agencies and stakeholders must work together more closely, enforce regulations more strictly, and increase punishments for adulteration. Through the establishment of science-based standards for food items and the regulation of their manufacture, storage, distribution, sale, and import, the FSSAI ensures food safety and wholesomeness for human consumption.

To combat adulteration effectively, several measures can be implemented (Jeeva, 2019). Firstly, stricter enforcement of regulations and the imposition of harsh penalties for adulteration can serve as deterrents against malpractices (Jeeva, 2019). Secondly, raising consumer awareness about the risks associated with adulteration and empowering them to identify pure spices can diminish the demand for adulterated products (c). Thirdly, leveraging technology and innovation, such as spectroscopy and chromatography, can enhance the accuracy of adulterant detection, thereby ensuring the purity of spices. Fourthly, implementing traceability systems to monitor the origin and supply chain of spices can foster accountability and transparency throughout the production process (c) Finally, providing support and incentives to farmers and authentic producers can incentivize the cultivation and production of high-quality, unadulterated spices, promoting integrity within the spice industry (c).

➤ *Challenges and Limitations in Forensic Analysis of Spice Adulteration*

Physical Methods: Benefits include simplicity, affordability, and ease of use. A lack of specificity and potential inefficiency in identifying complex adulterants are drawbacks. **Benefits of Chemical and Biochemical Methods:** High sensitivity and broad detection of adulterants. **Cons:** Frequently difficult and time-consuming, may call for certain tools and reagents. **Spectroscopic-based Methods:** Benefits include speed, non-destructiveness, and the ability to provide comprehensive compositional data. **Cons:** May be pricey, needing expensive and specialized equipment. The ability to recognize specific proteins or antigens and their great specificity are two benefits of immunologic-based techniques. **Cons:** Could be impacted by cross-

reactivity and may not be as dependable for complicated matrices. **Electrophoretic-based Methods - Benefits:** Excellent at separating complicated mixtures; **- Drawbacks:** Frequently labor-intensive and may necessitate extensive sample preparation. **DNA-based Methods - Benefits:** Exceptional accuracy, species-specific identification, and adaptability to intricate feeding matrices. **Drawbacks:** Pricey, time-consuming, and requiring certain knowledge and tools. Every one of these approaches has a unique set of advantages and disadvantages, and how well they work may vary depending on the situation. It might be feasible to detect food adulterants more thoroughly by combining various methods.

IV. DISCUSSION

Many studies on spice adulteration suffer from small sample sizes and a lack of diversity in the types of spices tested. This restricts how broadly the results may be applied. A wider range of spices should be used in future studies in order to give a more thorough grasp of the problem. Research findings would be more reliable and comparable if standardized testing procedures were established. Enforcement issues frequently impede the efficacy of regulatory systems such as the Food Safety and Standards Authority of India (FSSAI). Limited resources and varying regional enforcement standards lead to inconsistencies in the detection and prevention of adulteration. Addressing these regulatory gaps is critical to mitigate the problem. Despite advances in analytical techniques, some methods remain too costly or complex for widespread use, particularly in developing regions.

This restricts the ability to conduct regular and thorough testing of spices. Developing cost-effective, user-friendly detection methods would significantly enhance the ability to monitor and address adulteration. Economic limitations can impede efforts to combat spice adulteration, especially in low-income regions where resources for implementing advanced detection methods and regulatory measures are scarce. There is a significant lack of comprehensive data on how spice adulteration varies regionally. While some localized studies exist, a broader geographic analysis is essential to understand the full scope of the problem and to develop targeted interventions. Current detection methodologies, although advanced, often lack the sensitivity required to identify trace levels of adulterants.

Enhancing the sensitivity of these methods, perhaps through integrating novel technologies or improving existing ones, is crucial to ensure even minimal adulteration can be detected. There is a paucity of data on the long-term health effects of consuming adulterated spices. Many studies identify the presence of adulterants but do not extensively explore their cumulative health impacts on consumers over time. A gap exists in understanding the level of consumer awareness regarding spice adulteration. Further research can assess the effectiveness of current educational efforts and explore additional strategies to inform consumers and protect public health.

V. FUTURE PERSPECTIVES AND CONCLUSION

In the current period, scientists and researchers have significantly advanced techniques for the identification and measurement of spice adulteration. Even though authors from all over the world have published their works on the topic of food adulteration, more research is needed to develop novel onsite testing analytical methods for adulteration in various spices, such as pepper powder, turmeric, and others. This implies that more approaches—especially straightforward and doable ones—need to be created, tested, and authorized. It is important to thoroughly record and examine the many types of spice adulteration and the health effects they may have. Significant changes can be brought about by effective law enforcement and routine food quality inspections. Food and herbs/spices have been adulterated, producing lower-quality and sometimes dangerous goods.

Spice adulteration is a very active fraudulent activity that uses a range of adulterants, including as inorganic, synthetic organic, and plant-derived chemicals. The use of universal adulterants, sometimes known as bulking agents or fillers, which are inexpensive and easily accessible, has been discovered to constitute the basis for adulteration in a number of cases. Starches, flours, bran, sawdust, grasses, straw, and so forth are examples of these. The universal adulterants may be safe to ingest and inactive, or they may seriously endanger consumers health (osman, et al., 2019) Since spices and herbs are valuable components that customers want because of their sensory and functional qualities, the market for these ingredients is highly profitable. Recent studies have attempted to develop tools that distinguish between authentic and counterfeit spices, with DNA-based methods—mainly spectroscopic and image analysis techniques—being the most recommended. In order to guarantee the authenticity of herbs and spices and the development of efficient techniques, future efforts should be made to expedite sensitive and dependable methods, prevent sample destruction, and even guarantee that they can be used in production lines, giving control over all or most of the processed products. It would be ideal to develop effective adulteration prevention strategies and use on-site and/or consumer-friendly detection equipment, given the tendency of informed customers to utilize a device to verify the contents of food labels (R, 2023).

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