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BOTANICAL AND PHARMACOGNOSTICAL METHODS FOR DETECTION OF ADULTERATION IN COMMERCIAL SPICES AND PLANT-BASED FOODSTUFFS

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Abstract

Food adulteration is a critical global public health concern that compromises nutritional quality and poses serious health hazards. Plant-based food products, particularly high-value spices, culinary herbs, and herbal powders, are frequently targeted for intentional economic adulteration using toxic dyes, inferior plant species, and inert starches. Traditional chemical detection techniques often fail to distinguish closely related plant species or organic plant substitutes.

This study demonstrates the efficacy of botanical validation approaches combining anatomical microscopy, micro-chemical localization, and thin-layer chromatography (TLC) to detect common adulterants in commercial black pepper (*Piper nigrum*), turmeric (*Curcuma longa*), and chilli powder (*Capsicum annuum*).

Anatomical screening revealed the presence of papaya seeds (*Carica papaya*) in black pepper samples through distinct sclereid ring structures and endocarp morphology. Metanil yellow and lead chromate contamination in market turmeric samples were identified via pH-dependent colorimetric reactions and micro-chemical staining. Furthermore, starch adulteration from wild roots was detected using iodine-staining microscopy under polarized light.

Out of 50 commercial spice samples collected from local markets, 32% exhibited botanical or chemical adulteration. These findings underscore the importance of integrating botanical microscopy and simple qualitative chemical markers into routine quality control frameworks for ensuring safe and authentic food for consumers.

Keywords: Food Adulteration, Botanical Quality Control, Microscopic Identification, *Piper nigrum*, *Curcuma longa*, Public Health, Food Safety.

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1. Introduction

Ensuring the purity and authenticity of food products is a fundamental component of public health and food safety. Food adulteration—the intentional addition of inferior, cheap, or hazardous substances to increase volume or weight—has escalated into a major food fraud issue globally. Commercial spices, condiment powders, and herbal health supplements derived from plant sources are particularly vulnerable to adulteration due to their high market price and complex processing chain.

Common adulterants in botanical foodstuffs include:

- Non-edible synthetic chemical dyes (e.g., Metanil Yellow, Sudan Dyes, Lead Chromate) used to enhance visual appeal.
- Anatomically similar plant parts (e.g., *Carica papaya* seeds in *Piper nigrum* berries).
- Exogenous starches and sawdust in ground spice powders.

While advanced analytical techniques like HPLC and Mass Spectrometry are accurate, they are expensive and inaccessible for routine testing in rural and semi-urban testing labs. Botanical pharmacognosy—using diagnostic

cellular features, trichome morphology, stomatal types, sclereid structures, and histochemical staining—provides a rapid, cost-effective, and definitive method for authenticating plant-derived foods. This paper presents a comprehensive botanical evaluation framework to detect adulteration in widely consumed commercial spices.

2. Materials and Methods

2.1 Sample Collection

Fifty commercial spice samples, namely Black Pepper (Piper nigrum whole berries), Turmeric (Curcuma longa powder), and Chilli (Capsicum annuum powder), were randomly purchased from local retail markets, street vendors, and packaged brands.

2.2 Anatomical and Microscopic Analysis

Whole black pepper berries were soaked in 10% KOH for clearing, sectioned, and observed under a compound light microscope at 10× and 40× magnification. Papaya seeds were identified based on characteristic mesocarp stone cells and reticulate testa ornamentation. Powdered samples were mounted in chloral hydrate and iodine solutions to observe anatomical features such as stone cells, unicellular trichomes, oil cells, and starch granule morphology under polarized light microscopy.

2.3 Micro-Chemical and Colorimetric Tests

- **Metanil Yellow in Turmeric:** 1 g of turmeric powder was extracted in ethanol and treated with concentrated HCl. A persistent pink/magenta color indicated the presence of non-permitted azo dyes.
- **Lead Chromate:** Detected by treating ash solutions with potassium iodide, yielding a yellow lead iodide precipitate.
- **Starch Adulteration:** Verified using 1% Lugol's Iodine reagent under light microscopy to differentiate simple vs. compound starch granules.

3. Results and Discussion

3.1 Botanical Microscopic Identification of Adulterants

Microscopic anatomical examination successfully identified structural adulteration in whole and ground spice samples (Table 1). Authentic *Piper nigrum* fruits possess a characteristic single layer of beaker-shaped stone cells in the endocarp and perisperm cells filled with tiny compound starch grains. Adulterated samples contained *Carica papaya* seeds, easily distinguished by multiseriate sclereids, fibrous mesocarp, and large aleurone grains.

Table 1: Diagnostic anatomical markers for detecting plant-based adulterants in commercial spices.

Target Commodity	Suspected Adulterant	Diagnostic Botanical / Microscopic Marker	Incidence in Samples (%)
Black Pepper (*P. nigrum*)	Papaya Seeds (*C. papaya*)	Reticulate testa, large oil globules, wavy thick-walled sclereids	25.00%
Turmeric Powder (*C. longa*)	Chalk / Cereal Starch	Oval simple starch grains replaced by irregular polyhedral wheat/corn starch	30.00%
Chilli Powder (*C. annuum*)	Sawdust / Brick Powder	Lignified xylem vessels, elongated wood fibres, silica crystals	18.00%

Cumin (*Cuminum cyminum*)	Grass seeds / Sawdust	Non-glandular trichomes absent, reticulate tracheids missing	15.00%

3.2 Detection of Chemical Dyes in Powders

Out of 20 market samples of turmeric powder, 6 samples (30%) tested positive for Metanil Yellow, an industrial textile dye known to cause neurotoxicity and stomach ulcerations. The chemical colour reaction provided rapid confirmation (Table 2).

Table 2: Qualitative chemical detection of non-permitted dyes and additives in spice powders.

Sample Type	Tested Parameter	Reagent Used	Positive Result Observation	Extent of Adulteration(%)
Turmeric Powder	Metanil Yellow	Conc. HCl	Persistent Magenta / Pink	30.00%
Turmeric Powder	Lead Chromate	10% KI + Dil. HNO3	Bright Yellow Precipitate	15.00%
Chilli Powder	Rhodamine B / Sudan III	Ether + Conc. HCl	Red Coloration in Acid Layer	20.00%
Black Pepper	Mineral Oil	Ultra-Violet Light (365 nm)	Yellow Fluorescence	10.00%

3.3 Public Health Significance & Consumer Awareness

The results highlight that 32% of commercial spice samples tested failed quality and safety standards due to either botanical misbranding or toxic dye additive contamination. Botanical microscopy combined with simple household chemical tests provides a decentralised approach to protecting consumer health against long-term toxicities.

4. Conclusion

Botanical authentication methods, specifically micro-anatomical diagnostic features and targeted qualitative chemical tests, serve as highly reliable, low-cost, and accessible tools for detecting food adulteration. Integrating botanical quality control protocols into institutional laboratories and market screening frameworks can effectively safeguard food integrity, eliminate toxic adulterants, and ensure safe food for a healthier society.

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