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Aspergillus Species Contamination and Aflatoxin Risks in Cold-Stored Chilli Pods: Implications for Food Safety, Public Health, and Post-Harvest Storage Management

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Abstract

Chilli pods are among the most widely consumed spice commodities worldwide and are highly valued for their culinary, nutritional, and economic importance. However, improper harvesting, drying, transportation, and cold-storage conditions favor fungal contamination, particularly by Aspergillus species such as *Aspergillus flavus*, *Aspergillus parasiticus*, and *Aspergillus niger*. These fungi are capable of producing aflatoxins, especially aflatoxin B1 (AFB1), which is recognized as one of the most toxic and carcinogenic secondary metabolites affecting food commodities. Cold-stored chilli pods with elevated moisture content and poor ventilation create favorable conditions for fungal growth and toxin production during prolonged storage periods. Consumption of aflatoxin-contaminated chilli products poses serious health risks, including liver damage, immunosuppression, growth retardation, and hepatocellular carcinoma in humans and animals.

This review highlights the occurrence of Aspergillus contamination in chilli pods during post-harvest storage, factors influencing aflatoxin production, detection methods, and associated public health concerns. The review further discusses the role of environmental conditions such as humidity, temperature fluctuations, storage duration, and handling practices in promoting fungal proliferation. Modern analytical approaches including High-Performance Liquid Chromatography (HPLC), Enzyme-Linked Immunosorbent Assay (ELISA), Thin Layer Chromatography (TLC), and molecular diagnostic techniques used for aflatoxin detection are also summarized. In addition, preventive and management strategies such as proper drying, moisture control, hygienic storage systems, biological control agents, and regular monitoring practices are emphasized to minimize contamination risks. This review provides comprehensive insights into the significance of effective post-harvest storage management for ensuring chilli quality, food safety, and public health protection.

Keywords: Chilli pods, *Aspergillus flavus,* Aflatoxin B1, Cold storage, Food safety, Post-harvest management, Mycotoxins, Public health, Fungal contamination, HPLC and ELISA,

1. Introduction

Chilli (*Capsicum annuum* L. and related species) is one of the most important spice and cash crops cultivated throughout tropical and subtropical regions of the world. It is highly valued for its characteristic pungency, attractive red color, distinct aroma, and flavor, making it an indispensable ingredient in global cuisine and food industries. Chilli belongs to the family Solanaceae and is widely cultivated for both domestic consumption and export purposes. Besides its culinary importance, chilli possesses remarkable nutritional, medicinal, and industrial significance due to the presence of biologically active compounds such as capsaicin, carotenoids, flavonoids, vitamins, and antioxidants.

1.1.1 Culinary and Food Industry Importance

Chilli is universally used as a spice, condiment, vegetable, and coloring agent in numerous traditional and modern food preparations. It enhances the taste, flavor, and appearance of food products and forms an essential ingredient in curries, sauces, pickles, chutneys, soups, snacks, and processed foods. Dried chilli pods are extensively processed into chilli powder, flakes, paprika, oleoresins, and natural food colorants utilized in the food processing industry. Capsicum oleoresin extracted from chilli is commercially employed as a natural coloring and flavoring agent in processed foods, beverages, meat products, and confectioneries (Bosland and Votava, 2012).

1.1.2 Commercial and Economic Importance

Chilli is a major commercial spice crop contributing significantly to the agricultural economy of several countries. India is recognized as the world's largest producer, consumer, and exporter of dry chilli, contributing substantially to foreign exchange earnings. Other major chilli-producing countries include China, Mexico, Turkey, Indonesia, and Thailand. The crop provides livelihood opportunities for millions of farmers, laborers, traders, and workers involved in cultivation, processing, transportation, and export sectors. Due to its extensive applications in food, pharmaceutical, cosmetic, and nutraceutical industries, chilli occupies a prominent place in international spice trade markets (De and Ramanujam, 2004).

1.1.3 Nutritional Importance

Chilli fruits are highly nutritious and rich in essential vitamins, minerals, and antioxidants. Fresh green chillies contain exceptionally high amounts of Vitamin C, often exceeding the concentration found in citrus fruits. They are also excellent sources of provitamin A, Vitamin E, Vitamin K, folic acid, potassium, magnesium, and dietary fiber. The red color of ripe chillies is mainly due to carotenoid pigments such as capsanthin and capsorubin, which possess strong antioxidant properties (Howard et al., 2000).

1.1.4 Medicinal and Health Benefits

The medicinal value of chilli is primarily attributed to capsaicin, the alkaloid responsible for pungency. Capsaicin exhibits analgesic, antioxidant, antimicrobial, anti-inflammatory, anti-obesity, anticancer, and cardioprotective properties. It is widely used in topical creams and ointments for pain relief in arthritis, neuropathy, and muscular disorders. Scientific investigations have demonstrated that capsaicin may help regulate blood glucose levels, improve metabolism, reduce cholesterol accumulation, and enhance cardiovascular health. Chilli also contains phenolic compounds and flavonoids that help neutralize free radicals and reduce oxidative stress (Materska and Perucka, 2005).

1.1.5 Industrial Applications

Apart from food uses, chilli and its extracts are extensively utilized in pharmaceutical preparations, cosmetics, natural pesticides, defense sprays, and traditional medicine systems. Capsaicin extracts are incorporated into pain balms, medicinal patches, and therapeutic formulations. Chilli pigments and oleoresins are increasingly preferred as natural alternatives to synthetic food additives due to growing consumer demand for safer and eco-friendly products.

1.2 Problems associated with fungal contamination

Fungal contamination represents a major global concern affecting human health, agricultural productivity, food quality, and environmental safety. Various fungal species, including *Aspergillus*, *Penicillium*, *Fusarium*, *Candida*, and *Rhizopus*, are capable of colonizing food materials, indoor environments, crops, and living tissues under favorable environmental conditions. These fungi produce spores, allergens, enzymes, volatile compounds, and toxic secondary metabolites known as mycotoxins, which contribute to severe medical, economic, and ecological problems. The increasing prevalence of fungal contamination in agricultural commodities, storage facilities, hospitals, and buildings has intensified concerns regarding food security, public health, and economic sustainability.

1.2.1 Human Health Risks Associated with Fungal Contamination

Respiratory Disorders

Airborne fungal spores are among the most common biological contaminants affecting indoor and outdoor air quality. Inhalation of fungal spores may trigger respiratory diseases such as asthma, allergic rhinitis, chronic sinusitis, and hypersensitivity pneumonitis. Species of *Aspergillus*, particularly *Aspergillus fumigatus*, can colonize the respiratory tract and lead to allergic bronchopulmonary aspergillosis and invasive pulmonary aspergillosis, especially in immunocompromised individuals (Latgé, 1999). Continuous exposure to mold-contaminated environments may also aggravate chronic obstructive pulmonary disease (COPD) and other lung disorders.

1.2.2 Opportunistic and Systemic Fungal Infections

Fungal pathogens have emerged as serious causes of opportunistic infections in hospitalized patients, transplant recipients, diabetic individuals, and cancer patients undergoing chemotherapy. Opportunistic fungi such as *Candida auris*, *Cryptococcus neoformans*, and members of the order Mucorales can cause invasive systemic infections with high mortality rates. Mucormycosis, popularly known as “black fungus,” gained major attention during the COVID-19 pandemic due to its rapid spread among immunosuppressed patients (Skiada et al., 2020).

1.2.3 Mycotoxin-Related Toxicity

Many storage fungi produce mycotoxins that contaminate cereals, spices, nuts, and food products. Among these toxins, aflatoxins produced by *Aspergillus flavus* and *Aspergillus parasiticus* are considered highly carcinogenic and hepatotoxic. Long-term exposure to mycotoxins may lead to liver cancer, kidney damage, immune suppression, teratogenic effects, and growth retardation in children (Bennett and Klich, 2003). Consumption of contaminated food commodities remains a serious food safety concern worldwide.

1.2.4 Skin and Tissue Infections

Direct exposure to fungal contaminants may result in superficial and subcutaneous fungal infections affecting the skin, hair, and nails. Dermatophytic fungi cause common conditions such as athlete’s foot (*tinea pedis*), ringworm, and nail infections. Chronic fungal exposure may also lead to deeper tissue infections such as chromoblastomycosis and candidiasis, particularly in individuals with weakened immunity.

1.2.5 Agricultural and Food Safety Impacts
Crop Destruction and Yield Losses

Phytopathogenic fungi are responsible for substantial agricultural losses globally. Diseases caused by *Fusarium*, *Alternaria*, *Colletotrichum*, and *Aspergillus* species reduce crop yield, seed quality, and market value. It is estimated that fungal diseases contribute to nearly 20–30% loss in global agricultural production annually (Fisher et al., 2012). Chilli pods, cereals, groundnuts, maize, and stored grains are highly vulnerable to fungal infestation during cultivation and storage.

1.2.6 Food Spoilage and Nutritional Deterioration

Fungal growth accelerates the spoilage of perishable foods through enzymatic degradation, discoloration, and decomposition. Spoilage fungi reduce shelf life, alter texture and taste, and decrease nutritional quality. Contaminated food products become unsuitable for human consumption and may pose toxicological hazards due to mycotoxin accumulation.

1.2.7 Indoor Air Quality and Structural Damage

Building and Material Degradation

Fungal contamination is common in damp indoor environments where excessive humidity promotes mold growth on walls, ceilings, insulation materials, carpets, and wooden structures. Species such as *Stachybotrys*, *Aspergillus*, and *Penicillium* can deteriorate construction materials and compromise building integrity. Persistent fungal growth results in expensive repair and remediation processes.

Indoor Air Pollution and Odor Formation

Growing fungi release microbial volatile organic compounds (MVOCs), which produce unpleasant musty odors and contribute to poor indoor air quality. Exposure to contaminated indoor air has been associated with headaches, irritation, fatigue, allergic symptoms, and reduced workplace productivity. Schools, hospitals, offices, and residential buildings are particularly vulnerable to indoor fungal contamination.

1.2.8 Economic and Environmental Consequences

Fungal contamination imposes heavy economic burdens due to crop rejection, reduced export quality, healthcare costs, food wastage, and building remediation expenses. International trade regulations regarding permissible mycotoxin levels often result in rejection of contaminated agricultural exports, causing substantial financial losses to farmers and exporters.

2.0 Introduction to Aspergillus species and aflatoxins

Aspergillus is a common genus of filamentous fungi widely distributed in soil, air, water, and stored agricultural commodities. Several species, particularly *Aspergillus flavus*, *Aspergillus parasiticus*, and *Aspergillus niger*, are important storage fungi associated with food spoilage and post-harvest deterioration of crops such as chilli, maize, groundnut, and cereals. These fungi can grow rapidly under warm and humid storage conditions, leading to contamination of food products.

Certain *Aspergillus* species produce toxic secondary metabolites known as aflatoxins. Among them, aflatoxin B1 (AFB1) is considered the most toxic and carcinogenic mycotoxin affecting humans and animals. Consumption of aflatoxin-contaminated food can cause liver damage, immune suppression, growth retardation, and hepatocellular carcinoma. Due to their severe health impacts and economic losses, *Aspergillus* contamination and aflatoxin production are major concerns in food safety, public health, and post-harvest storage management.

Objectives and Significance of the Review

This review aims to summarize the occurrence of *Aspergillus* species in cold-stored chilli pods, factors promoting fungal growth, aflatoxin contamination risks, and their impacts on food safety and public health. It also emphasizes the importance of proper post-harvest storage management to reduce fungal infestation and toxin production.

Significance

The review is significant because *Aspergillus* contamination reduces chilli quality, shelf life, and market value while producing harmful aflatoxins that pose serious health risks. Understanding these issues is essential for improving food safety, maintaining export quality, and developing effective storage and management practices.

2.1. Overview of *Aspergillus* Species in Chilli Pods

Stored chilli pods are highly susceptible to fungal contamination during harvesting, drying, transportation, and storage. Among storage fungi, *Aspergillus* species are the most dominant and economically important contaminants associated with deterioration of chilli quality and aflatoxin contamination. These fungi can survive under low moisture conditions and rapidly proliferate in warm and humid environments commonly encountered during improper storage practices.

The most common *Aspergillus* species reported in stored chillies include *Aspergillus flavus*, *Aspergillus parasiticus*, and *Aspergillus niger*. These fungi differ in morphology, toxin-producing ability, and pathogenic potential. *A. flavus* and *A. parasiticus* are major producers of aflatoxins, while *A. niger* is commonly associated with black mold spoilage and quality deterioration.(Fig-1).

2.2 Morphological and Biological Characteristics

Aspergillus species are filamentous fungi characterized by septate hyphae and specialized conidiophores bearing chains of spores called conidia. Their colonies vary in color from greenish-yellow to black depending on the species. They reproduce asexually through abundant airborne spores that spread easily through air, dust, insects, contaminated equipment, and storage containers.

2.3 Sources of Contamination

Contamination of chilli pods may occur at different stages including:

- Field cultivation and harvesting
- Improper drying on soil surfaces
- Mechanical injuries during handling
- Contaminated storage bags and containers
- Insect infestation
- Poor sanitation during transportation and storage

Table-1 Important *Aspergillus* Species Associated with Stored Chilli Pods

Species	Colony Appearance	Major Characteristics	Toxin Production	Importance in Chilli Storage
Aspergillus flavus	Yellowish-green colonies	Fast-growing, survives in warm conditions	Produces aflatoxin B1 and B2	Major aflatoxin producer in stored chillies
Aspergillus parasiticus	Dark green colonies	Similar to *A. flavus* but highly toxigenic	Produces aflatoxin B and G types	Serious food safety concern
Aspergillus niger	Black powdery colonies	Common storage fungus, resistant to dry conditions	Produces ochratoxins occasionally	Causes black mold spoilage and quality deterioration

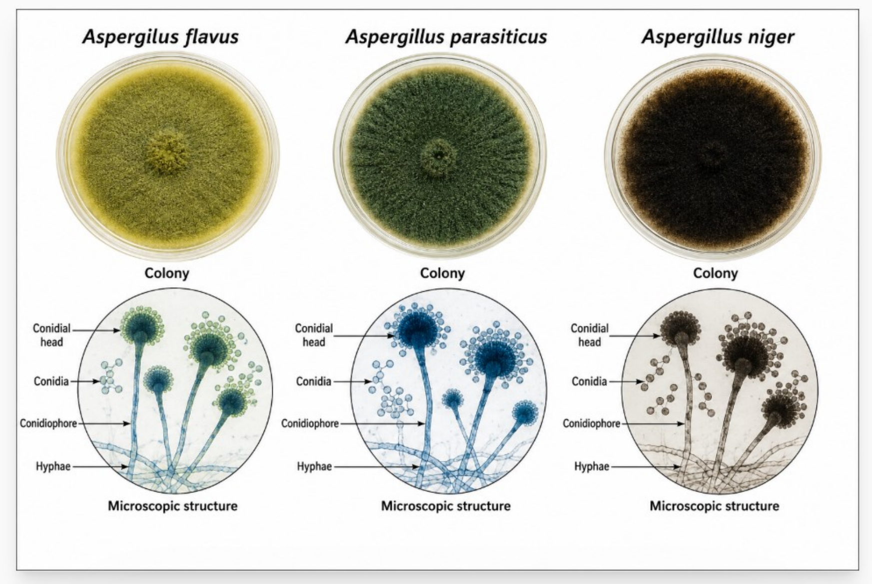

Fig-1: Morphology of Important Aspergillus Species Commonly Found in Stored Chillies

2.4 Environmental Conditions Favoring Fungal Growth

Several environmental factors favor the growth of *Aspergillus* species and aflatoxin production:

- High relative humidity
- Elevated temperature
- Increased moisture content in chilli pods
- Poor ventilation
- Long-term storage conditions
- Mechanical damage to pods

Improper post-harvest handling and inadequate cold-storage management significantly enhance fungal proliferation and mycotoxin contamination.(Table-1)

3. Aflatoxins and Their Toxicity

Aflatoxins are highly toxic secondary metabolites produced mainly by *Aspergillus flavus* and *Aspergillus parasiticus* under favorable environmental conditions such as high temperature and humidity. These toxins commonly contaminate agricultural commodities including chilli, maize, groundnuts, cereals, and stored food products. Aflatoxins are classified as potent carcinogenic, mutagenic, and hepatotoxic compounds that pose serious risks to human and animal health.

3.1 Types of Aflatoxins: The major naturally occurring aflatoxins include:

- **Aflatoxin B1 (AFB1)**
- **Aflatoxin B2 (AFB2)**
- **Aflatoxin G1 (AFG1)**
- **Aflatoxin G2 (AFG2)**

The names “B” and “G” are based on the blue and green fluorescence produced under ultraviolet light during chromatographic analysis (Table-2).

Table-2 Major Types of Aflatoxins and Their Characteristics

Aflatoxin Type	Producing Fungi	Fluorescence Color	Toxicity Level	Major Effects
AFB1	*A. flavus*, *A. parasiticus*	Blue	Very High	Liver cancer, hepatotoxicity
AFB2	*A. flavus*, *A. parasiticus*	Blue	Moderate	Liver damage
AFG1	*A. parasiticus*	Green	High	Toxic and carcinogenic
AFG2	*A. parasiticus*	Green	Lower	Chronic toxicity

Why Aflatoxin B1 (AFB1) is Most Dangerous: Among all aflatoxins, AFB1 is considered the most toxic and carcinogenic. It is classified as a Group I human carcinogen by the World Health Organization and the International Agency for Research on Cancer (IARC). AFB1 primarily affects the liver and may cause hepatocellular carcinoma (liver cancer). It can also suppress immune function, impair growth, and damage DNA by forming toxic metabolites in the liver.

3.2 Mechanism of Toxin Production by Fungi:

Aflatoxins are produced during fungal growth and metabolism when environmental conditions become favorable, particularly: High moisture content, warm temperatures, Poor storage conditions, High humidity and Mechanical injury to crops.

The fungi synthesize aflatoxins through secondary metabolic pathways involving several enzyme-mediated biochemical reactions. Stress conditions during storage further stimulate toxin production.

3.3 Toxic Effects on Humans and Animals

Effects on Humans: Liver damage and liver cancer, Immune suppression, Growth retardation in children, Gastrointestinal disorders, Mutagenic and teratogenic effects, Acute aflatoxicosis in severe exposure

Effects on Animals: Reduced growth and productivity, Liver and kidney damage, Reduced fertility, Weakened immune system and Sudden death in severe toxicity cases.

Long-term consumption of aflatoxin-contaminated food and feed represents a major public health and food safety concern worldwide.

4. Factors Influencing Contamination in Cold Storage

Cold storage is commonly used to preserve the quality, color, pungency, and nutritional value of chilli pods during extended storage periods. However, unsuitable storage conditions promote fungal contamination and aflatoxin production, especially by *Aspergillus flavus* and *Aspergillus parasiticus* (Pitt and Hocking, 2009). Environmental and operational factors such as moisture, humidity, ventilation, temperature variation, and storage duration greatly influence fungal growth and toxin accumulation.

4.1 High Moisture Content: Moisture is one of the most important factors responsible for fungal contamination in stored chillies. Dry chilli pods should be reduced to a safe moisture level below 10–12% before storage. Improper drying or uneven moisture distribution encourages fungal colonization and aflatoxin production (Magan and Aldred, 2007).

4.2 Relative Humidity: High relative humidity (RH) inside storage facilities enhances moisture absorption by chilli pods and increases water activity (awa_waw), creating favorable conditions for fungal growth. Relative humidity above 65–70% strongly supports the proliferation of toxigenic fungi such as *Aspergillus flavus* (Klich, 2007).

4.3 Poor Ventilation: Inadequate ventilation and improper stacking of chilli bags create stagnant air pockets and localized humidity buildup. Poor air circulation increases condensation and facilitates rapid fungal spread among stored chilli batches (Samson et al., 2004).

4.4 Temperature Fluctuations: Although low temperatures are used to maintain chilli quality, sudden fluctuations in storage temperature may result in condensation on pod surfaces. The accumulated moisture supports fungal spore germination and mold development (Pitt and Hocking, 2009).

4.5 Long-Term Storage: Extended storage periods significantly increase the risk of fungal contamination and aflatoxin accumulation. Prolonged exposure to slightly humid conditions gradually deteriorates chilli quality and enhances toxin production (Richard, 2007).

4.6 Mechanical Damage to Pods: Mechanical injuries caused during harvesting, drying, transportation, and handling create entry points for fungal infection. Damaged chilli pods become more vulnerable to microbial invasion and spoilage during storage (Reddy et al., 2009).

4.7 Insect Infestation: Storage insects damage chilli pods and facilitate fungal contamination by spreading spores and increasing pod injuries. Insect activity also generates heat and moisture inside storage containers, indirectly favoring fungal proliferation (Bennett and Klich, 2003).

4.8 Packaging and Cross-Contamination: Improper packaging materials such as porous bags absorb environmental moisture and increase contamination risks. Mixing infected chilli batches with healthy pods or using contaminated storage containers can spread fungal spores rapidly throughout the storage facility (Magan and Aldred, 2007).(Table-3).

Table-3: Factors Influencing Fungal Contamination in Cold-Stored Chillies

Factor	Effect on Storage	Influence on Fungal Growth
High moisture content	Increases water availability	Promotes mold growth and aflatoxin production
High relative humidity	Moisture absorption by pods	Enhances fungal proliferation
Poor ventilation	Creates humid stagnant air	Accelerates contamination spread
Temperature fluctuations	Causes condensation	Supports spore germination
Long-term storage	Gradual deterioration	Increases aflatoxin accumulation
Mechanical damage	Creates infection sites	Facilitates fungal invasion
Insect infestation	Pod injury and heat generation	Enhances fungal colonization
Improper packaging	Moisture retention	Reduces storage safety

5 Public Health and Food Safety Concerns

Contamination of chilli pods and chilli powder by *Aspergillus* species and aflatoxins represents a serious public health and food safety issue worldwide. Aflatoxin-contaminated chilli products not only affect consumer health but also reduce export quality and create major economic losses in international spice trade (Wild and Gong, 2010).

5.1 Risks of Consuming Contaminated Chilli Powder

Consumption of aflatoxin-contaminated chilli powder can cause severe health complications in humans and animals. Aflatoxin B1 (AFB1), the most toxic form, is a potent hepatotoxic and carcinogenic compound associated with liver cancer, immune suppression, growth retardation, and gastrointestinal disorders (Williams et al., 2004). Long-term dietary exposure to low levels of aflatoxins may lead to chronic health effects, while acute exposure can cause aflatoxicosis characterized by liver failure and even death in severe cases. Chilli powder is especially vulnerable because fungal contamination often increases during drying, grinding, packaging, and prolonged storage.

5.2 International Permissible Limits of Aflatoxins

To protect consumer health, several international organizations have established maximum permissible limits for aflatoxins in food products. The European Union (EU) has strict regulations allowing a maximum limit of 2 µg/kg for AFB1 and 4 µg/kg for total aflatoxins in spices intended for direct human consumption. The United States Food and Drug Administration (USFDA) permits up to 20 µg/kg total aflatoxins in food commodities. These limits vary among countries depending on food safety standards and risk assessments (FAO, 2004).(Table-4).

Table-4 International Permissible Limits of Aflatoxins in Food Commodities

Organization/Country	AFB1 Limit	Total Aflatoxin Limit
European Union (EU)	2 µg/kg	4 µg/kg
USFDA (USA)	—	20 µg/kg
Codex Alimentarius	Variable	Regulated for food safety
India (FSSAI)	Regulated	30 µg/kg in certain foods

6. Prevention and Post-Harvest Storage Management

Effective prevention and post-harvest management strategies are essential to minimize *Aspergillus* contamination and aflatoxin production in chilli pods. Integrated management practices involving proper cultivation, handling, drying, storage, and biological control methods can significantly improve food safety and storage quality.

6.1 Pre-Harvest Measures

Disease-Resistant Varieties: Cultivation of disease-resistant and stress-tolerant chilli varieties helps reduce fungal infection and minimizes susceptibility to Aspergillus contamination. Resistant cultivars possess better defense mechanisms against fungal invasion and environmental stress (Pitt and Hocking, 2009).

6.2 Good Agricultural Practices (GAP)

Implementation of Good Agricultural Practices such as proper irrigation, balanced fertilizer application, field sanitation, timely harvesting, and pest management reduces fungal infestation in the field. Avoiding mechanical injury during harvesting also decreases contamination risks (Magan and Aldred, 2007).

6.3 Post-Harvest Measures

Proper Drying Techniques: Freshly harvested chillies should be dried immediately using sun drying, solar drying, or mechanical drying methods to reduce moisture content. Uniform drying prevents fungal growth and enhances shelf life.

6.4 Moisture Reduction Below Safe Limits

Dry chilli pods should be maintained below 10–12% moisture content before storage, as higher moisture levels favor fungal growth and aflatoxin production (Klich, 2007).

6.5 Hygienic Handling: Proper sanitation during harvesting, transportation, packaging, and storage is essential to prevent contamination. Storage containers, drying yards, and handling equipment should be kept clean and dry.

6.6 Improved Cold-Storage Conditions: Cold-storage facilities should maintain controlled temperature, low relative humidity, and proper air circulation. Moisture-proof packaging materials and proper stacking methods help reduce fungal proliferation.

6.7 Regular Monitoring of Fungal Load: Routine inspection and periodic monitoring of stored chilli batches for fungal contamination and aflatoxin levels are necessary to ensure food safety and prevent spoilage during long-term storage.

6.8 Biological and Eco-Friendly Control

Use of Antagonistic Microbes: Biological control agents such as Trichoderma spp., Bacillus spp., and non-toxigenic strains of Aspergillus can suppress the growth of aflatoxin-producing fungi through microbial competition.

Natural Preservatives: Natural food preservatives derived from plant and microbial sources help inhibit fungal growth without harmful chemical residues.

Plant Extracts and Essential Oils

Essential oils and plant extracts from neem, clove, cinnamon, garlic, oregano, and thyme exhibit strong antifungal activity against storage fungi and may serve as eco-friendly alternatives to synthetic fungicides (Bennett and Klich, 2003).

7. Future Perspectives

Future research and technological advancements are essential for improving the safety and storage quality of chilli products. Rapid urbanization, climate change, and increasing global trade demand advanced approaches for controlling fungal contamination and aflatoxin risks.

7.1 Need for Advanced Detection Systems

Sensitive and rapid detection technologies are required for early identification of *Aspergillus* contamination and aflatoxin presence in stored chillies. Modern analytical tools can improve monitoring efficiency and food safety management.

7.2 Development of Toxin-Resistant Chilli Varieties

Breeding and biotechnological approaches should focus on developing chilli varieties resistant to fungal infection and aflatoxin accumulation under storage conditions.

7.3 Nanotechnology and Biosensors in Food Safety

Nanotechnology-based biosensors and smart packaging systems offer promising applications for real-time monitoring of fungal growth, moisture levels, and toxin contamination in food commodities.

7.4 Awareness Programs for Farmers and Storage Managers

Training and awareness programs on proper drying, hygienic handling, storage management, and aflatoxin prevention are essential for farmers, traders, and storage operators to reduce contamination risks and economic losses.

8. Conclusion

Aspergillus contamination and aflatoxin production in cold-stored chilli pods represent serious concerns for food safety, public health, and international trade. Monitoring fungal contamination during harvesting, drying, storage, and transportation is essential to prevent quality deterioration and toxin accumulation. Effective post-harvest storage management practices including proper drying, moisture control, hygienic handling, improved cold-storage facilities, and regular monitoring can significantly reduce fungal growth and aflatoxin contamination.

The prevention of aflatoxin contamination is highly important because aflatoxins are toxic, carcinogenic, and harmful to both humans and animals. Adoption of integrated management strategies, eco-friendly biological control methods, and awareness programs for farmers and storage managers can help maintain chilli quality and ensure consumer safety. Continuous research, advanced detection technologies, and strict food safety regulations are necessary for safe storage, improved export quality, and sustainable management of chilli product.

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