

HEALTH RISK ASSESSMENT OF AFLATOXIN *ASPERGILLUS FLAVUS* IN FOOD CROPS IN SOUTHEAST ASIA: A SYSTEMATIC REVIEW**Leighanna Ryielle B. Blanco¹****Ryan S. Cacacho¹****Kristale Mae E. Laquindanum¹****Gecelene C. Estorico^{1,2}**

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¹Technological University of the Philippines – Taguig, Metro Manila, 1630, Philippines²De La Salle University – Dasmariñas, Cavite, DBB-B, 4115 West Ave., Dasmariñas**ABSTRACT**

Aflatoxin contamination is a major food safety concern in tropical regions where environmental conditions favor the growth of toxigenic fungi. One of the primary fungi responsible for aflatoxin production is *Aspergillus flavus*, which produces toxins associated with serious health risks such as liver cancer, immune suppression, and chronic toxicity in humans. In Southeast Asia, staple crops including rice, maize, peanuts, and corn are widely consumed and are highly susceptible to fungal contamination due to warm temperatures, high humidity, and seasonal rainfall. These environmental conditions, combined with inadequate post-harvest handling and storage practices, increase the risk of aflatoxin accumulation in food systems. This systematic review synthesized findings from ten peer-reviewed studies published between 2016 and 2026 that examined the occurrence, detection methods, and health risks associated with aflatoxin-producing *Aspergillus flavus* in food crops across Southeast Asia. The reviewed studies were conducted in several countries, including Malaysia, Vietnam, Cambodia, and the Philippines, and primarily focused on staple crops such as rice, maize, peanuts, and corn. Reported contamination prevalence varied among crops, ranging from 10–33% in rice, 20–45% in maize, 30–60% in peanuts, and 15–40% in corn. In Malaysia, approximately 45% of analyzed maize samples were reported to contain detectable levels of aflatoxins, highlighting significant contamination risks in the region. Several laboratory methods were used to detect aflatoxins, including enzyme-linked immunosorbent assay (ELISA), high-performance liquid chromatography (HPLC), liquid chromatography–mass spectrometry (LC–MS), and molecular identification techniques. Across the reviewed studies, high moisture content during storage, prolonged storage duration, and insufficient post-harvest drying practices were consistently identified as major factors promoting fungal growth and toxin production. The findings indicate that aflatoxin contamination remains a persistent food safety challenge in Southeast Asia, emphasizing the need to strengthen monitoring systems, improve crop drying and storage infrastructure, and implement stricter food safety regulations to reduce aflatoxin exposure and protect public health.

Keywords:

Contamination, Fungi, Harvest, Moisture, Toxin

INTRODUCTION

Food contamination caused by toxigenic fungi represents a major challenge to food safety, public health, and agricultural sustainability worldwide. Among the most significant fungal contaminants of food crops is *Aspergillus flavus*, a filamentous fungus capable of producing aflatoxins, highly toxic secondary metabolites that frequently contaminate staple commodities such as maize, rice, peanuts, and other cereals. These toxins are particularly problematic in tropical and subtropical regions where warm temperatures and high humidity promote fungal growth and toxin production (Liu & Wu, 2017).

Aflatoxins are among the most potent naturally occurring carcinogens known. The most toxic compound, aflatoxin B₁ (AFB₁), has been classified as a Group 1 human carcinogen by the International Agency for Research on Cancer due to its strong association with hepatocellular carcinoma and other severe health effects (World Health Organization, 2018). Chronic exposure to aflatoxins through contaminated food can result in

liver cancer, immune suppression, growth impairment in children, and increased vulnerability to infectious diseases (Wu et al., 2019).

Southeast Asia is particularly vulnerable to aflatoxin contamination due to climatic conditions characterized by high humidity, elevated temperatures, and seasonal monsoon patterns. These environmental factors provide ideal conditions for the proliferation of *Aspergillus* species both in agricultural fields and during post-harvest storage. In addition, agricultural systems in many Southeast Asian countries rely heavily on smallholder farming, where limited access to drying facilities, proper storage infrastructure, and food safety monitoring systems increases the risk of fungal contamination.

Previous studies conducted in countries such as Vietnam, Indonesia, Malaysia, Thailand, and the Philippines have documented the presence of aflatoxin contamination in staple crops, including rice, maize, peanuts, and corn. For example, Phan et al. (2021) reported that aflatoxin contamination in the rice production chain in Vietnam ranged from 10% to 33%, depending on seasonal conditions and post-harvest practices. Similarly, studies in Indonesia and Malaysia have indicated that inadequate storage conditions, including high moisture levels and poor ventilation, significantly increase the likelihood of aflatoxin contamination in peanuts and maize (Lim et al., 2019; Rahman et al., 2018).

Given the serious public health implications of aflatoxin exposure and the widespread occurrence of *A. flavus* in food systems, there is a need for a comprehensive synthesis of existing scientific evidence. This systematic review aims to evaluate current research on the occurrence, distribution, and health risks associated with aflatoxin-producing *Aspergillus flavus* in food crops across Southeast Asia and to identify key strategies for mitigating contamination and protecting public health.

OBJECTIVES

This systematic review aims to comprehensively synthesize and evaluate scientific evidence regarding the occurrence, exposure pathways, and health risks associated with aflatoxin-producing *Aspergillus flavus* in food crops across Southeast Asia. Specifically, the study seeks to identify and critically assess peer-reviewed research that reports the presence and contamination levels of aflatoxin-producing *A. flavus* in major staple crops, including rice, maize, peanuts, and corn, and examine their implications for human health exposure. The review also aims to analyze patterns in the prevalence, concentration levels, and geographic distribution of aflatoxin contamination across different agroecological and climatic environments within the region, in order to evaluate potential dietary exposure risks. Furthermore, it examines the methodological approaches used in previous studies, including sampling strategies, laboratory detection and quantification techniques, dietary exposure assessment models, and risk characterization frameworks used in aflatoxin health risk assessments. Finally, the study synthesizes available evidence on risk management and mitigation strategies, such as improved pre- and post-harvest practices, biological control technologies, food safety regulations, and storage management systems, that have been proposed or implemented to reduce aflatoxin contamination and minimize its associated public health impacts in Southeast Asia.

METHODOLOGY

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which provide a standardized framework for identifying, screening, and synthesizing relevant scientific literature in a transparent and reproducible manner. The PRISMA approach was applied to ensure methodological rigor in the selection and evaluation of studies related to aflatoxin-producing *Aspergillus flavus* in food crops across Southeast Asia.

Literature Search Strategy

A comprehensive literature search was conducted to identify peer-reviewed studies investigating the occurrence and health risks associated with aflatoxin-producing *Aspergillus flavus* in food crops within Southeast Asia. The search was performed across several academic databases, including Scopus, Web of Science, PubMed, ScienceDirect, and Google Scholar. These databases were selected due to their extensive coverage of environmental science, food safety, toxicology, and public health research.

The search strategy involved the use of relevant keywords and Boolean operators to capture studies addressing aflatoxin contamination and fungal occurrence in agricultural commodities. The main search terms included:

- "*Aspergillus flavus*"
- "aflatoxin contamination"
- "food crops"
- "mycotoxins"
- "health risk assessment"
- "Southeast Asia"

These keywords were combined using Boolean operators such as AND and OR to refine the search results. An example of a search query used in the databases was:

(*Aspergillus flavus* AND aflatoxin AND "food crops" AND "Southeast Asia" AND contamination AND risk assessment)

Only articles published between 2016 and 2026 were included in the search to ensure that the review reflects recent developments in aflatoxin research and food safety risk assessment.

Study Selection Process

The study selection process followed the PRISMA screening procedure, which consists of four main stages: identification, screening, eligibility, and inclusion. Initially, all articles retrieved from the database search were compiled and duplicate records were removed. The remaining studies were then screened based on their titles and abstracts to determine their relevance to the topic of aflatoxin-producing *Aspergillus flavus* contamination in food crops.

Articles that appeared relevant during the initial screening were further assessed through full-text evaluation to determine their eligibility for inclusion in the systematic review. Studies that met all inclusion criteria were retained for detailed analysis and synthesis. After completing the screening and eligibility assessment process, ten studies were selected for inclusion in the final review.

Inclusion Criteria

Studies were included in the systematic review if they met the following criteria:

1. Published between 2016 and 2026.
2. Peer-reviewed journal articles.
3. Investigated aflatoxin-producing *Aspergillus flavus*.
4. Focused on food crops intended for human consumption, such as rice, maize, peanuts, and corn.
5. Conducted within Southeast Asian countries.
6. Provided empirical data on aflatoxin occurrence, contamination levels, or health risk assessment.

Exclusion Criteria

Studies were excluded from the review if they met any of the following conditions:

1. Focused exclusively on animal feed contamination without relevance to human food systems.
2. Conducted outside Southeast Asia.
3. Did not include quantitative or qualitative measurements of aflatoxin contamination.
4. Were review articles, editorials, conference abstracts, or non-peer-reviewed publications.

Data Extraction

Data from the selected studies were systematically extracted and organized using a structured data extraction framework. The information collected from each study included the study location, crop type, detection methods used for aflatoxin analysis, contamination levels, identified causes of fungal growth, associated health risks, and

mitigation strategies recommended by the authors. This information was subsequently synthesized into summary tables to facilitate comparative analysis across studies.

Data Synthesis and Analysis

The extracted data were analyzed using a qualitative synthesis approach to identify common trends, contamination patterns, and risk factors associated with aflatoxin-producing *Aspergillus flavus* in Southeast Asian food crops. The findings were organized according to the objectives of the study, including the occurrence of contamination, geographic distribution patterns, methodological approaches used in detection and risk assessment, and strategies proposed for mitigating aflatoxin exposure.

Tables and descriptive analyses were used to summarize the findings and highlight similarities and differences across the reviewed studies. This approach enabled a comprehensive evaluation of the current scientific evidence regarding aflatoxin contamination and its potential implications for food safety and public health in Southeast Asia.

The study utilizes a systematic approach structured around three fundamental components: Input, Process, and Output. The Input phase is characterized by the identification and gathering of pertinent data from high-credibility sources, including peer-reviewed journals and academic databases, specifically focusing on the occurrence of *Aspergillus flavus* and subsequent aflatoxin levels in food crops across the Southeast Asian region. The Process phase involves a rigorous methodological workflow beginning with the application of the PRISMA screening procedure to ensure study eligibility. This stage encompasses systematic data extraction, organization into structured comparative matrices, and a qualitative synthesis aimed at identifying critical environmental risk factors and contamination patterns. Furthermore, the process includes an evaluation of existing detection methods and their efficacy in diverse agricultural contexts.

Finally, the Output provides a comprehensive synthesis of evidence, resulting in an organized database of contamination levels and a thematic summary of public health risks. This systematic research structure culminates in a final review document that presents actionable mitigation strategies and evidence-based recommendations for enhancing food safety and regulatory frameworks within Southeast Asia. This IPO paradigm serves as a transparent and replicable model for understanding the intersection of fungal ecology, agricultural health, and consumer safety.

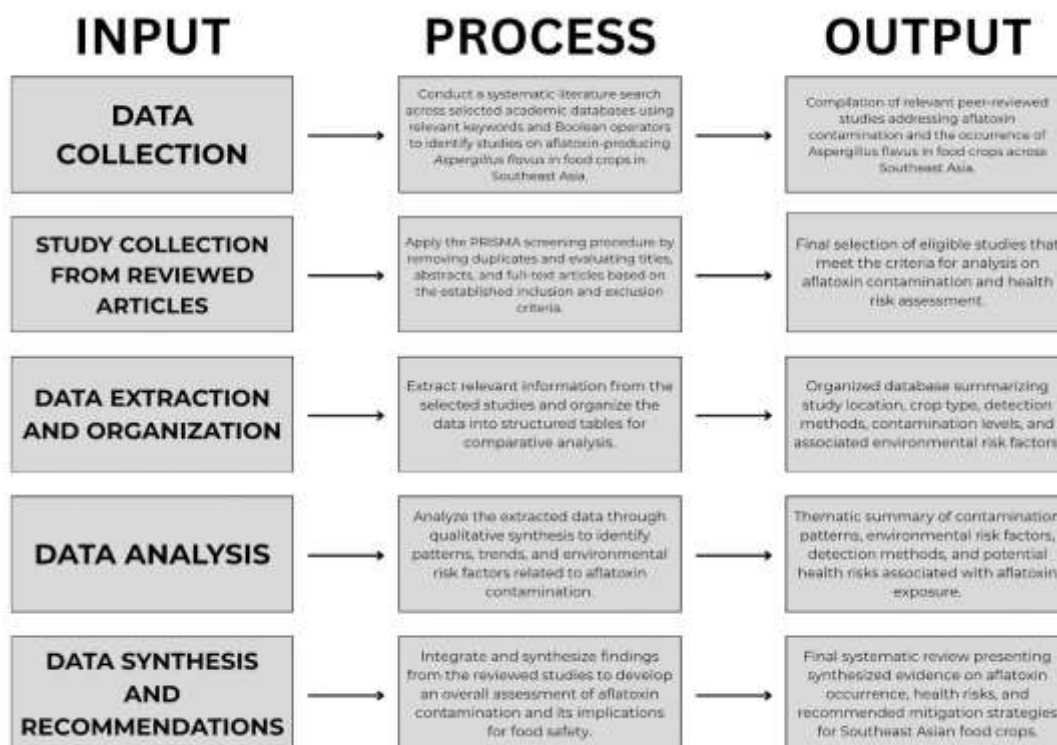


Figure 1. IPO Diagram

RESULTS AND DISCUSSION

This section presents the synthesized findings derived from the systematic review of ten peer-reviewed studies that investigated the occurrence and health risks associated with aflatoxin-producing *Aspergillus flavus* in food crops across Southeast Asia. The selected studies were conducted in several countries within the region, including Vietnam, Malaysia, Indonesia, Thailand, Cambodia, and the Philippines, where climatic conditions such as high temperature, high relative humidity, and seasonal rainfall create favorable environments for fungal proliferation and mycotoxin production. These environmental conditions, combined with agricultural practices and post-harvest handling methods, significantly influence the growth of toxigenic fungal species and the accumulation of aflatoxins in staple crops (Liu & Wu, 2017; Wu et al., 2019).

The results are presented through a series of summary tables and analyses that correspond to the objectives of the study. The section begins with a summary of the reviewed studies, followed by analyses of contamination prevalence in major crops, geographic distribution patterns, laboratory detection methods used in aflatoxin analysis, and mitigation strategies recommended by researchers. Particular attention is given to staple food commodities such as rice, maize, peanuts, and corn, which are widely consumed throughout Southeast Asia and therefore represent important pathways for human dietary exposure to aflatoxins.

In addition to presenting empirical findings, this section provides a critical interpretation of the data in order to identify key contamination trends, environmental risk factors, and methodological patterns across the reviewed literature. The discussion also examines the implications of these findings for food safety management and public health risk assessment in tropical agricultural systems. Through the integration of evidence from multiple studies, this section aims to provide a comprehensive understanding of the magnitude and drivers of aflatoxin contamination in Southeast Asian food systems and to highlight areas where improved monitoring, agricultural practices, and policy interventions are needed.

Table 1. Summary Table of Reviewed Studies on Aflatoxin-producing *Aspergillus flavus* in Food Crops across Southeast Asia

Country	Causes	Crop	Detection Method	Health Effects	Risk Level	Author's Recommendations	Study
Cambodia	High humidity and improper storage	Rice	LC-MS	Liver toxicity and increased cancer risk	Moderate	Strengthen regulatory monitoring	Chai et al. (2022)
Malaysia	Prolonged storage duration	Peanuts	ELISA	Chronic aflatoxin exposure risk	High	Improve storage duration management	Kamarulza man et al. (2018)
Malaysia	High moisture levels in storage	Maize, Peanut, Rice	ELISA	Hepatotoxic effects	High	Implement moisture control systems	Lim et al. (2019)
Malaysia	Tropical climate and poor drying practices	Maize	LC-MS/MS	Liver cancer risk	High	Improve drying and storage practices	Ezekiel et al. (2019)
Vietnam	Seasonal climate and farming practices	Rice	Molecular Identification	Long-term dietary exposure risk	Moderate	Improve supply-chain monitoring	Phan et al. (2023)
Philippines	Presence of toxigenic fungi in soil	Corn	Molecular Identification	Hepatotoxicity and immune suppression	Moderate	Monitoring fungal contamination	Balendres et al. (2019)
Malaysia	Humid environmental conditions	Maize	HPLC	Carcinogenic health risks	High	Strengthen food safety monitoring	Rahim Khan et al. (2020)
Malaysia	Moisture during storage and feed	Corn	ELISA/HPLC	Chronic toxicity	High	Strict moisture control	Nasaruddin (2021)

	processing						
Malaysia	Supply chain contamination	Peanuts	HPLC	Liver damage	High	Crop and soil monitoring	Norlia et al. (2018)
Southeast Asia	Tropical climate conditions	Cereals	Review Synthesis	Long-term dietary exposure	Moderate	Improve drying and storage	Umar et al. (2023)

Table 1 summarizes ten empirical studies that investigated the occurrence of aflatoxin-producing *Aspergillus flavus* in food crops across Southeast Asia. The studies were conducted in countries including Cambodia, Malaysia, Vietnam, the Philippines, and other parts of Southeast Asia. The table highlights several key variables including the country where the study was conducted, causes of contamination, crop type, detection methods used, potential health effects, risk levels, and author recommendations. Organizing the findings in this manner allows for a clearer comparison of contamination patterns, contributing factors, and mitigation strategies across the region.

The findings show that Malaysia accounts for the majority of the reviewed studies, indicating strong research attention to aflatoxin contamination in maize, peanuts, and corn within the country. Other countries such as Vietnam, Cambodia, and the Philippines also reported contamination in staple crops including rice and corn. These crops are widely consumed across Southeast Asia, making them important pathways for potential dietary exposure to aflatoxins.

In terms of detection methods, several laboratory techniques were employed across the reviewed studies. Analytical methods such as high-performance liquid chromatography (HPLC), liquid chromatography–mass spectrometry (LC-MS), and enzyme-linked immunosorbent assay (ELISA) were commonly used to detect and quantify aflatoxin contamination. Molecular and morphological identification techniques were also applied to confirm the presence of toxigenic *Aspergillus flavus* strains. Among these methods, HPLC and LC-MS are considered highly sensitive and reliable techniques for quantifying aflatoxin levels, particularly aflatoxin B₁, which is recognized as the most toxic and carcinogenic variant of the toxin.

The table also highlights health effects associated with aflatoxin exposure, including hepatotoxicity, immune suppression, and increased risk of hepatocellular carcinoma. Because staple crops such as rice, maize, peanuts, and corn are widely consumed across Southeast Asia, contamination in these food products can contribute to long-term dietary exposure among populations.

In addition, the reviewed studies categorize contamination risks into moderate and high risk levels, depending on environmental conditions, crop susceptibility, and storage practices. Countries with warm and humid climates, such as Malaysia and Indonesia, often reported higher contamination risks due to environmental conditions that favor fungal growth. The author recommendations consistently emphasize the need for improved storage practices, stricter food safety monitoring, and enhanced regulatory frameworks to reduce aflatoxin contamination in the food supply chain.

A. CAUSES

The synthesis of the reviewed studies indicates that aflatoxin contamination in food crops is driven by a complex interaction of environmental, biological, and post-harvest management factors that collectively influence the growth of *Aspergillus flavus*. Among these, high moisture content during storage is the most consistently reported driver of contamination. When crops are not adequately dried after harvest, residual moisture—particularly above 13–15%—creates ideal conditions for fungal germination and toxin production (Bui et al., 2016; Nasaruddin et al., 2021). This issue is further intensified in Southeast Asia's tropical climate, characterized by high temperatures (25°C–35°C), elevated humidity levels, and seasonal rainfall, which promote fungal proliferation both in the field and during storage (Wu et al., 2019). Delayed drying due to rainfall and exposure to humid environments further increases the likelihood of contamination.

In addition to environmental factors, post-harvest practices and crop characteristics significantly contribute to contamination risks. Poor storage conditions, such as inadequate ventilation, prolonged storage duration, and

reliance on traditional storage systems, allow moisture accumulation and continuous fungal growth (Lim et al., 2019; Rahman et al., 2018). The natural presence of toxigenic fungal strains in soil also plays a critical role, particularly for crops like peanuts and maize that come into direct contact with contaminated soil during growth and harvesting (Frisvad et al., 2019). Moreover, mechanical damage during harvesting and transportation exposes internal nutrients of crops, facilitating fungal invasion and colonization (Smith et al., 2019). These combined factors demonstrate that aflatoxin contamination is a multifactorial issue requiring integrated control strategies across pre-harvest, harvest, and post-harvest stages.

B. EFFECTS

The presence of aflatoxin contamination in food crops poses significant health risks to human populations, primarily affecting the liver and increasing cancer risk. Aflatoxin B₁, the most toxic variant, is metabolized in the liver where it forms reactive compounds that damage cellular DNA and proteins, leading to hepatotoxicity or liver damage (Dhakal & Sbar, 2020). Acute exposure to high levels may result in aflatoxicosis, a severe condition characterized by liver failure, jaundice, and potentially death, although such cases are relatively rare. More commonly, chronic low-level exposure occurs through daily consumption of contaminated staple foods such as maize, rice, peanuts, and corn. Over time, this prolonged exposure can lead to hepatocellular carcinoma, a type of liver cancer strongly associated with aflatoxin intake. The carcinogenic effect is due to mutations caused by aflatoxin metabolites binding to DNA, and the risk is significantly higher among individuals with hepatitis B infection (Benkerroum, 2020).

Beyond liver toxicity and cancer, aflatoxin exposure also contributes to immune suppression and long-term developmental effects, particularly in vulnerable populations. Chronic exposure has been shown to impair immune function by interfering with the production and activity of immune cells, increasing susceptibility to infectious diseases (Wu et al., 2019). In children, sustained dietary exposure is associated with growth impairment, malnutrition, and developmental delays due to disrupted nutrient absorption and protein metabolism. These effects are especially concerning in Southeast Asia, where staple crops prone to contamination are consumed regularly, leading to continuous exposure even at moderate contamination levels. Collectively, these health impacts highlight that aflatoxin contamination is not only a food safety concern but also a major public health issue requiring comprehensive prevention and control strategies across the food supply chain.

C. RISK LEVEL

The assessment of risk levels across the reviewed studies reveals that aflatoxin contamination in Southeast Asia generally falls within moderate to high categories, depending on environmental conditions, crop type, and storage practices. High-risk levels are predominantly associated with countries and commodities exposed to persistent high humidity, elevated temperatures, and inadequate post-harvest infrastructure, as observed in several studies conducted in Malaysia and Indonesia (Nasaruddin et al., 2021). Crops such as peanuts and maize consistently demonstrate higher risk classifications due to their biological susceptibility and favorable conditions for fungal colonization (Bui et al., 2016; Wu et al., 2019). These findings indicate that environmental exposure combined with crop-specific vulnerabilities significantly elevates contamination risks. Moderate risk levels, as reported in countries such as Vietnam, Thailand, and the Philippines, suggest the presence of contamination but at relatively controlled or variable levels (Balendres et al., 2019). This may be attributed to partial implementation of monitoring systems, improved agricultural practices, or differences in study methodologies and detection sensitivity. However, even moderate risk should not be underestimated, as continuous dietary exposure to low levels of aflatoxins can still result in significant long-term health impacts, including carcinogenic and immunosuppressive effects (Benkerroum, 2020). Overall, the variation in risk levels highlights the importance of localized risk assessment approaches, strengthened food safety regulations, and targeted mitigation strategies that address both environmental and systemic factors influencing aflatoxin contamination in the region.

Table 2. Prevalence of Contamination in Major Crops

Crop	Average Prevalence (%)	Countries Reported
Rice	10-33%	Vietnam, Cambodia
Maize	20-45%	Malaysia, Thailand
Peanuts	30-60%	Indonesia, Malaysia
Corn	15-40%	Philippines

Table 2 presents the prevalence of aflatoxin contamination across major food crops in Southeast Asia, including rice, maize, peanuts, and corn. The data indicate notable variations in contamination levels among crops, reflecting differences in crop composition, environmental susceptibility, and post-harvest handling practices. Among the crops analyzed, peanuts exhibited the highest contamination prevalence ranging from 30% to 60%, followed by maize with contamination rates between 20% and 45%. Corn showed moderate contamination levels between 15% and 40%, while rice generally displayed lower contamination levels ranging from 10% to 33%.

The relatively high contamination levels observed in peanuts can be attributed to several biological and structural characteristics of the crop. Peanuts grow underground and are therefore in direct contact with soil where toxigenic fungal species such as *Aspergillus flavus* naturally occur. This increases the likelihood of fungal colonization during crop development and harvesting. Additionally, peanuts have high oil and nutrient content, which creates favorable conditions for fungal growth and aflatoxin production. Previous research has shown that oil-rich crops are more vulnerable to fungal contamination because they provide a suitable substrate for fungal metabolism and toxin synthesis (Wu et al., 2019).

Maize also demonstrates relatively high contamination prevalence across the region. Maize kernels possess microstructural cracks and cavities that allow fungal spores to penetrate the grain, particularly when crops are exposed to mechanical damage during harvesting or transportation. Environmental conditions during storage further contribute to contamination. When maize is stored at moisture levels above 13–15%, fungal growth and aflatoxin production may increase significantly (Bui et al., 2016). This explains the high contamination rates reported in several Southeast Asian countries where post-harvest drying infrastructure may be limited.

Rice, on the other hand, generally shows lower contamination prevalence compared to other crops. However, rice remains a major concern in terms of food safety because it is one of the most widely consumed staple foods in Southeast Asia. Even moderate contamination levels can therefore contribute to substantial dietary exposure when rice is consumed regularly in large quantities. Studies conducted in Vietnam have shown that aflatoxin contamination in the rice supply chain may occur at multiple stages including harvesting, drying, storage, and milling (Phan et al., 2021).

Corn contamination reported in the Philippines also indicates moderate levels of aflatoxin presence. Corn is frequently used both for direct human consumption and as an ingredient in animal feed. As a result, contamination in corn may affect not only food safety but also livestock production systems, potentially introducing aflatoxins into dairy and meat products through indirect exposure pathways.

The widespread occurrence of contamination across multiple crops highlights the need for comprehensive monitoring programs and improved agricultural management practices. Regular testing of staple crops, combined with improved drying technologies and proper storage infrastructure, can significantly reduce contamination risks. Strengthening regional surveillance systems and implementing standardized aflatoxin safety limits may also help reduce public health risks associated with contaminated food products across Southeast Asia.

Table 3. Geographic Distribution of Contamination

Country	Major Crop	Risk Level
Vietnam	Rice	Moderate
Malaysia	Maize	High
Indonesia	Peanuts	High
Thailand	Maize	Moderate
Philippines	Corn	Moderate

Table 3 illustrates the geographic distribution of aflatoxin contamination across selected Southeast Asian countries and identifies the associated risk levels based on available research evidence. The data show that contamination risk varies across countries due to differences in climatic conditions, agricultural practices, storage infrastructure, and regulatory enforcement.

Malaysia and Indonesia were identified as high-risk regions, particularly in relation to maize and peanut contamination. The high contamination risk observed in these countries is largely associated with tropical environmental conditions characterized by high temperature and humidity. These conditions provide optimal environments for the growth of *Aspergillus flavus*, which thrives in temperatures ranging from 25°C to 35°C and relative humidity levels above 70%. In addition, the monsoon climate common in Southeast Asia can result in seasonal rainfall that increases moisture levels during crop harvesting and storage periods.

Another factor contributing to geographic variation is the level of agricultural infrastructure available to farmers. In many rural areas, farmers rely on traditional drying methods such as sun drying, which may not be sufficient to reduce moisture levels to safe storage conditions. Inadequate drying can allow fungal contamination to develop rapidly during storage. According to Nasaruddin et al. (2021), prolonged storage in humid conditions significantly increases the likelihood of aflatoxin accumulation in maize and corn products.

Vietnam, Thailand, and the Philippines were classified as moderate-risk regions. While these countries also experience tropical climatic conditions, some improvements in crop monitoring programs and food safety regulations may contribute to slightly lower contamination risks. For example, Vietnam has implemented monitoring programs for aflatoxin contamination in rice supply chains, particularly in major rice-producing regions (Phan et al., 2021).

However, it is important to note that contamination risk levels may also reflect differences in research intensity and monitoring capacity rather than actual contamination prevalence. Countries with stronger food safety monitoring systems may report higher contamination rates simply because more testing is conducted. Conversely, countries with limited monitoring programs may underestimate the true prevalence of aflatoxin contamination.

Overall, the geographic distribution of contamination highlights the importance of region-specific risk management strategies. Climate-responsive agricultural practices, improved storage facilities, and strengthened regulatory monitoring are essential for addressing contamination risks across Southeast Asia.

Table 4. Methodological Approaches Used in Studies

Method	Purpose
ELISA	Rapid screening of aflatoxin contamination
HPLC	Accurate quantification of toxin levels
PCR	Identification of toxigenic fungal strains
LC-MS	Highly sensitive toxin detection

Table 4 summarizes the laboratory techniques used in the reviewed studies to detect and quantify aflatoxin contamination in food crops. The main analytical methods identified include enzyme-linked immunosorbent assay (ELISA), high-performance liquid chromatography (HPLC), polymerase chain reaction (PCR), and liquid chromatography–mass spectrometry (LC-MS). Each of these methods serves a specific purpose in aflatoxin detection and contributes to improving the accuracy of contamination assessments.

ELISA is widely used as a rapid screening method for detecting aflatoxins in food samples. This technique is relatively inexpensive and allows for the analysis of large numbers of samples within a short period of time. Because of its efficiency and ease of use, ELISA is often employed as a preliminary testing method in food safety monitoring programs. However, ELISA may have limitations in terms of sensitivity and specificity compared to more advanced analytical techniques.

HPLC is considered one of the most reliable methods for the quantitative analysis of aflatoxin compounds. This technique separates chemical components within a sample and allows researchers to measure the exact concentration of aflatoxins present in food products. HPLC is commonly used in laboratory settings where precise quantification is required for regulatory compliance and risk assessment studies (Rahim Khan et al., 2020).

LC-MS represents an even more advanced analytical technique that combines chromatography with mass spectrometry for highly sensitive toxin detection. This method allows researchers to identify multiple mycotoxins simultaneously and provides highly accurate measurements even at very low concentrations. Due to its high sensitivity, LC-MS is frequently used in research laboratories and national food safety monitoring programs.

PCR and other molecular methods are also important tools for identifying toxigenic strains of *Aspergillus flavus*. Unlike chemical detection techniques that measure toxin concentrations, molecular methods focus on identifying the fungal organisms responsible for toxin production. By detecting genes associated with aflatoxin biosynthesis, researchers can determine whether specific fungal strains present in crops are capable of producing aflatoxins. According to Balendres et al. (2019), combining molecular identification with chemical detection methods provides a more comprehensive understanding of contamination pathways.

Overall, the use of multiple analytical approaches across the reviewed studies demonstrates the importance of integrating chemical, microbiological, and molecular techniques in order to accurately assess aflatoxin contamination and evaluate potential health risks.

Table 5. Risk Management and Mitigation Strategies

Strategy	Description
Biological control	Use of non-toxigenic <i>A. flavus</i> strains
Improved drying	Reduces fungal growth during storage
Storage management	Control of humidity and temperature
Food safety regulations	Monitoring contamination levels

Table 5 presents several risk management strategies that have been proposed or implemented to reduce aflatoxin contamination in food crops across Southeast Asia. These strategies include biological control methods, improved drying practices, better storage management, and strengthened food safety regulations.

One of the most promising strategies identified in the reviewed studies is biological control using non-toxigenic strains of *Aspergillus flavus*. These strains compete with toxigenic fungi for resources and can significantly reduce aflatoxin production in agricultural fields. When introduced into crop environments, non-toxigenic strains can outcompete toxin-producing fungi and prevent them from colonizing crops. Research has shown that biological control methods may reduce aflatoxin contamination by up to 70–80% under appropriate field conditions.

Improved drying techniques are also essential for reducing fungal growth. After harvest, crops must be dried rapidly to reduce moisture levels below the threshold required for fungal development. Studies indicate that maintaining grain moisture levels below 13% significantly reduces the risk of fungal proliferation during storage (Bui et al., 2016). However, many small-scale farmers in Southeast Asia lack access to mechanical drying equipment and rely on traditional sun-drying methods, which may be insufficient during periods of high humidity.

Proper storage management is another critical factor in preventing contamination. Storage facilities should maintain low humidity, adequate ventilation, and controlled temperatures to inhibit fungal growth. Hermetic storage technologies, such as airtight containers and sealed grain storage bags, have been shown to significantly reduce moisture infiltration and fungal contamination in stored crops.

In addition to agricultural practices, food safety regulations and monitoring systems play an important role in mitigating aflatoxin risks. Governments and regulatory agencies must establish and enforce maximum allowable limits for aflatoxins in food products. Routine testing and monitoring programs can help detect contaminated products before they reach consumers, thereby protecting public health.

Educational programs and farmer training initiatives are also essential components of effective risk management. Farmers, traders, and food processors should be informed about the causes of aflatoxin contamination and the preventive measures that can be implemented during crop production, harvesting, and storage.

Overall, the reviewed studies emphasize that integrated management strategies combining agricultural, technological, and regulatory approaches are necessary to effectively reduce aflatoxin contamination in Southeast Asian food systems.

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CONCLUSION

Conclusion

The systematic review of ten peer-reviewed studies highlights the widespread occurrence of aflatoxin contamination caused by *Aspergillus flavus* in major food crops across Southeast Asia. The findings indicate that contamination prevalence varies among crops, with peanuts and maize showing the highest contamination rates ranging from 30–60% and 20–45%, respectively. Rice and corn also exhibited notable contamination levels, demonstrating that staple foods consumed throughout the region may serve as important pathways for aflatoxin exposure. The results further demonstrate that environmental factors such as high humidity, elevated temperature, and inadequate post-harvest storage conditions are key drivers of fungal growth and toxin production. Detection methods including ELISA, HPLC, LC-MS, and molecular techniques were widely used to identify and quantify aflatoxin contamination, highlighting the importance of combining chemical and microbiological approaches for accurate monitoring. Overall, the evidence suggests that aflatoxin contamination remains a persistent food safety issue in Southeast Asia. Addressing this challenge requires improved agricultural practices, enhanced monitoring systems, and stronger regulatory frameworks to reduce contamination risks and protect public health.

Recommendations

Based on the findings of this systematic review, several measures are recommended to reduce the risk of aflatoxin contamination in Southeast Asian food systems. First, governments and food safety authorities should strengthen routine monitoring and testing programs for staple crops such as rice, maize, peanuts, and corn. Regular surveillance using reliable detection methods such as HPLC and LC-MS can help identify contaminated products before they enter the food supply chain. Second, improved post-harvest handling practices should be promoted among farmers and agricultural stakeholders. Proper drying techniques, moisture control, and improved storage infrastructure can significantly reduce fungal growth and toxin production. Third, increased education and awareness programs should be implemented to inform farmers, food processors, and traders about the causes and prevention of aflatoxin contamination. Training initiatives can help promote safer agricultural and storage practices. Finally, further research is needed to develop more efficient detection technologies and sustainable biological control strategies to limit the spread of toxigenic *Aspergillus flavus* strains. Collaborative efforts among researchers, policymakers, and agricultural communities will be essential for improving food safety and minimizing aflatoxin exposure in Southeast Asia.

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