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Elucidating aflatoxins profile and recommended detoxification procedures in corn, rice, and wheat

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RESEARCH ARTICLE

Abstract

Corn, rice, and wheat are the basic and fundamental foods among Pakistan's widely consumed crops. Total aflatoxins (B_1+B_2+G_1+G_2) are carcinogenic fungal species that badly deteriorate food crops. The current study is aimed to identify total aflatoxins in different samples of corn, rice, and wheat consumed in the Punjab province of Pakistan and to assess various low-cost and practical detoxification techniques for lowering aflatoxin levels found in these crops. To achieve this, 80 samples each of corn, rice, and wheat products (n = 240) were collected. The collected crop samples underwent analysis by high-performance liquid chromatography (HPLC) for the quantification of aflatoxins. Results showed that 69.58% of the crop samples were suitable, while 30.42% were not suitable for human consumption. The majority of corn samples in the Punjab province were discovered to be contaminated and unsuitable for consumption. The highest level of contamination (amounting 545µg/kg) was detected in a corn sample from district Rawalpindi, Pakistan. The highly contaminated crop sample was subjected to different detoxification methods, such as physical, chemical, and biological/natural means. After treatment with different detoxifiers, reduction in total aflatoxins was quantified by using HPLC. Results showed that maximum detoxification was obtained by cooking (physical method), by using 20% citric acid (chemical method), and by using probiotics (biological method).

Keywords: aflatoxin; corn; DAD detector; detoxification; HPLC; rice; wheat

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Introduction

Aflatoxins are deadly and carcinogenic species mainly formed by *Aspergillus flavus* and *Aspergillus parasiticus* (Nadeem *et al.,* 2025; Zahra *et al.*, 2017). Aflatoxins are of four types: aflatoxin B_1, B_2, G_1, and G_2, among which aflatoxin B_1 is highly poisonous (Krishnamurthy and Shashikala, 2006). High temperature and moisture are favorable conditions for growth of aflatoxins; nevertheless, these toxins may spoil valuable food products, which in turn damage human health. It may cause severe food poisoning and toxicological effects, such as immunodeficiency and liver cirrhosis as well as some malignancies (Nisa *et al.*, 2016). Aflatoxins are resistant species, and it is difficult to halt their growth. Thus, to ensure food safety, permissible limits were established by European Union (EU, 2010). Accordingly, the permissible limit of total aflatoxins in corn is 10 µg/kg; in white rice and brown rice, it is 4 µg/kg and 10 µg/kg, respectively, and in wheat grain and flour, permissible limit is 4 µg/kg. Furthermore, different research efforts have concentrated on the methods for deterrence of aflatoxins formation (Zahra *et al.,* 2025; Villers, 2014).

Several detoxification methods (physical, chemical, and natural/biological) were recommended to eliminate or reduce aflatoxins (Jalili, 2016). Detoxification of aflatoxins in rice was done by cooking methods in both normal cooking and cooking in pressure cooker (Hussain and Luttfullah, 2009). In a study, the contaminated rice samples were treated with 1 N citric acid, and it was found that 97.22% decontamination occurred (Safara *et al.*, 2010). Different processing methods, such as baking, roasting, steaming, and boiling, could reduce aflatoxins to a significant level (Reddy and Rani, 2000). However, it is very difficult to remove aflatoxins by simple physical methods, such as washing, because of low solubility of aflatoxins in water (Hwang and Lee, 2006). Several biological approaches were also reported in literature, such as *Lactobacillus rhamnosus* was investigated to detoxify aflatoxin contamination *in vitro* after incubating at 37°C in De Man, Rogosa and Sharpe (MRS) agar (Alrabadi *et al.*, 2018). The International Agency for Research on Cancer (IARC) has affirmed aflatoxins as powerful carcinogens. Presence of aflatoxins in food products is common these days, resulting in increased liver disease and many other health issues, such as allergies and infections. Hence, it is necessary to check quality of widely used food crops (Zahra *et al.*, 2019). The purpose of the current study is to check the presence and concentration levels of aflatoxins in Pakistan's crops (corn, rice, and wheat) and to reduce aflatoxin levels detected in studied crop samples by physical, chemical, and biological methods.

Materials and Methods

Sampling

Crop samples (n = 240) were collected from four districts of Punjab, Pakistan (namely, Bahawalpur, Faisalabad, Lahore, and Rawalpindi, as shown in Figure 1). Considering their dietary and economic significance, primary crops (corn, rice, and wheat) were chosen, and a total of 20 samples of each crop were examined. The collected samples were sourced from warehouses, agricultural fields, markets, vendors, and various retail stores. The samples were collected during the summer months of April–September within a temperature range of 25–40°C and in winter (October–March) within a temperature range of 13–22°C. Additionally, humidity levels during sample collection period were recorded as 45–69% in summer and 40–55% in winter. This collection was based on an assessment of selected crops' physical properties, storage conditions, hygiene, and potential adulteration; after collection, the samples were sent to the laboratory for quantitative analysis. Each sample, weighing 1 kg, was stored in a polyethylene bag and then processed through a sample divider. The sample size was reduced to approximately 200 g for final analysis. Each crop sample was thoroughly mixed and crunched into a fine powder for analysis (Nisa *et al.*, 2013).

Chemicals used

All the chemicals used in this study were of high-performance liquid chromatography (HPLC), analytical grade. Acetonitrile (Sigma, Darmstadt, Germany) was used for sample extraction and corresponding mobile phase.

Standard solutions preparation

A stock solution of total aflatoxins B_1+B_2+G_1+G_2 (50 µg/kg) in acetonitrile was (Romer Labs., Singapore) set at –20°C. Standard solution was created by diluting stock solution with an acetonitrile–water ratio of 20:80 (v/v) (Irakli *et al.*, 2017).

Sample preparation, analysis, and detoxification

A 5-g ground sample was combined with 50 mL of 70% acetonitrile solution and placed on a wrist action shaker for 30 min. Following shaking, the solution underwent filtration twice using Whatman 4 filter paper. The extract underwent additional filtration (0.5 µm) prior to the final HPLC analysis, which involved injecting into a C18 reverse phase Nucleosil column (dimensions: 25-cm × 4.6-mm ID,

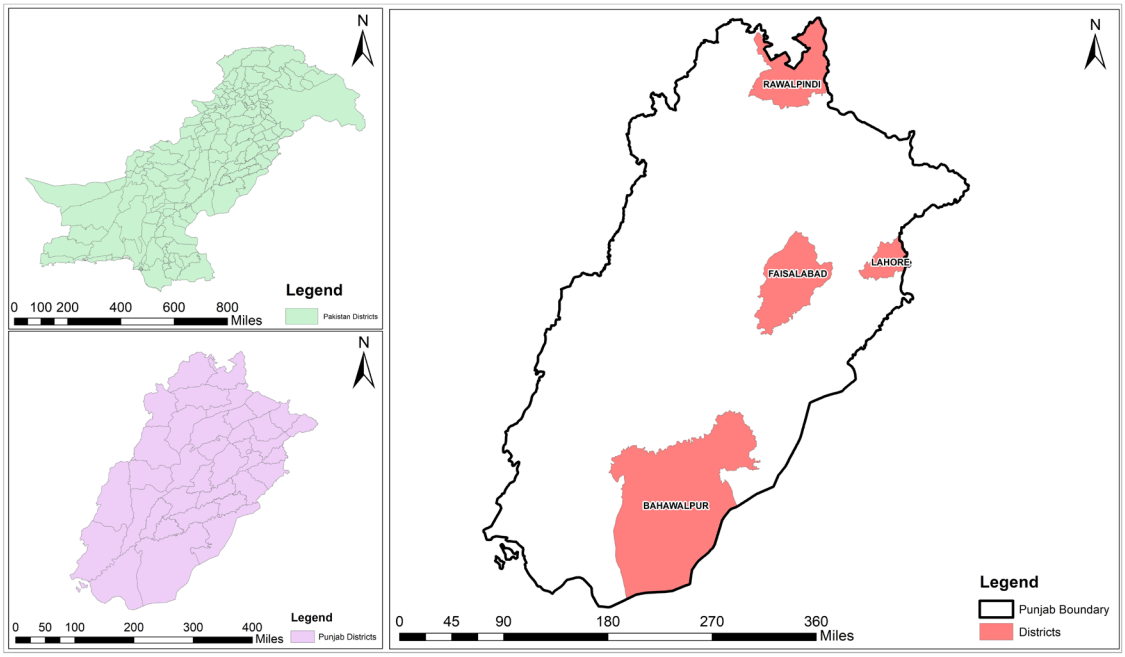

Figure 1. Map showing sample collection districts of Punjab, Pakistan.

5-mm particles) (Firdous *et al.*, 2012). The mobile phase used in this study was prepared by using acetonitrile–water ratio of 45:55 (v/v).

After quantification of aflatoxins in each product, detoxification of naturally highly contaminated corn, rice, and wheat with aflatoxins was conducted by cost-effective physical, chemical, and biological methods. The detoxification process involved various physical methods, such as washing with regular water, hot water, and cooking, beside chemical methods utilizing 10% citric acid, 10% acetic acid, 5% sodium bicarbonate ($NaHCO_3$), and 0.5% hydrochloric acid (HCl). In addition, biological detoxification was achieved through natural methods, such as 5% ginger paste, 5% garlic paste, 10% black seed oil, and probiotics derived from *Lactobacillus* bacteria found in yogurt (Aiko *et al.*, 2016; Hussain and Ali, 2012; Khosravi *et al.*, 2011; Nisa *et al.*, 2012; Shetty and Jespersen, 2006; Syukur *et al.*, 2013; Vijayanandraj *et al.*, 2014). Reduction in the concentration of total aflatoxins was checked and verified by HPLC by adopting different detoxification methods.

Physical detoxification approaches

Washing

A 50-g sample of contaminated material was placed in a beaker and mixed thoroughly with distilled water (250 mL) thrice for 20 min. The final solution was filtered and examined for reduced mycotoxins (Majeed, 2018).

Washing with hot water

An additional infected sample (50 g) was mixed with distilled water (500 mL) in a beaker. The sample beaker was placed on a hot plate. The mixture was warmed up to 100°C for 30 min. The final solution was filtered and cooled to room temperature. The targeted aflatoxins were examined using HPLC (Arshad and Ghosia, 2009).

Cooking in excess of water

A 50-g contaminated sample was mixed with 500-mL distilled water in a beaker and heated on a hot plate. The mixture was brought to a vigorous boil for 15 min and cooled at room temperature. After cooling, the sample was filtered, dried, and analyzed using HPLC (Arshad and Ghosia, 2009).

Chemical detoxification approaches

By using citric acid

Analytical grade citric acid (Merck) in diluted form was used for detoxification (Aiko *et al.*, 2016). A 50-g sample of contaminated samples was combined with 100 mL of 20% acetic acid solution and shaken for 1 h. The sample solution was filtered and tested for aflatoxins. In addition, the analysis was performed by using natural citric acid from lemon juice. A mixture of 10-mL lemon juice and 70-mL distilled water was prepared to detoxify contaminated samples. A 50-g sample of naturally contaminated crop was treated with citric acid and/or lemon

juice and incubated at 25°C for 30 min for decontamination (Rastegar *et al.*, 2016). The final extract was examined using HPLC.

By using acetic acid

A 50-g of aflatoxin-contaminated sample was mixed with 100-mL of 10% acetic acid solution and shaken for 1 h. The sample solution was then filtered and examined for mycotoxin concentration.

By using dilute hydrochloric acid

In all, 50-g of corn, rice, and wheat aflatoxin-positive samples were crunched and placed in different 500-mL conical flasks. Then, 0.5% HCl solution was added to each flask and shaken on a wrist action shaker for 1 h. The resulting solution was filtered through filter paper and dried at room temperature (Nisa *et al.*, 2013).

By using sodium bicarbonate

To detoxify, 5 g of $NaHCO_3$ was dissolved in 100 mL of distilled water. A 50 g sample was left at room temperature for one hour in a $NaHCO_3$ solution. The sample was filtered and dried prior to analysis for mycotoxins (Samarajeewa *et al.*, 1990).

Biological/natural methods

By using ginger paste

The fresh ginger (*Zingiber officinale)* was bought from the Allama Iqbal town locally situated market city Lahore. The ginger was crunched to a paste; 10-g ginger pasted was added to 100-mL water and mixed meticulously by shaking. Aflatoxin-contaminated sample (50 g) was weighed and immersed in ginger paste solution for 24 h. Then the final sample was filtered and rinsed with distilled water, dried, and analyzed for decrease in aflatoxin levels (Hussain and Ali, 2012).

By using garlic paste

Garlic (*Allium sativum*) was sourced from Johar Town supermarket, Lahore. It was ground into a paste, and 10-g of garlic paste was mixed in distilled water (10 mL) using a mixer and strained using a muslin cloth. The resulting extract was again diluted with 100-mL of distilled water (Vijayanandraj *et al.*, 2014). Crop samples, 50-g each, with natural contamination were processed with prepared garlic extract and incubated for 24 h at 25°C.

By using Kalonji *oil*

Nigella sativa (*kalonji* seeds) oil was acquired from the supermarket located in Johar Town, Lahore. The polluted sample was purified by using kalonji seed oil (Maraqa *et al.*, 2007). Kalonji seed oil (10 mL) was mixed with distilled water to prepare 100-mL solution, which was combined with 50 g of purified sample at 25°C for 6 h.

By using probiotics

Lactobacilli strains were obtained from yogurt using De Man, Rogosa, and Sharpe (MRS) agar. Yogurt samples were diluted serially from 10^1 to 10^{14} in MRS broth under sterile conditions. The diluted yogurt (10 µL, n = 3) was taken from chosen dilutions for the spread plate method, and streaking was performed on plates of MRS agar inside a laminar flow cupboard. Bacteria were evenly distributed and swabbed across MRS agar. To enhance the proliferation of lactobacillus, cysteine (0.05%) was incorporated into MRS agar (Hartemink et al, 1997) at a pH of 6.5.

Anaerobically (the ideal temperature for the growth of *lactobacillus*), the plates were incubated at 37°C (De Man *et al.*, 1960) for 48 h. Additionally, bacterial colonies were noted on plates. The subsequent procedure involved selecting specific colonies and subculturing them in MRS broth for 48 h at 37°C under anaerobic conditions. Following subculture, streaking of *lactobacillus* was conducted on MRS agar to isolate a single *lactobacillus* colony for morphological examination. The bacterial cultures in pure form were stored on MRS slants at 4°C in a refrigerator. The lactobacillus bacteria isolates were recognized by examining their morphological characteristics via biochemical tests, that is, motility test, catalase test, gram staining, and carbohydrate fermentation test (Holt *et al.*, 1994).

The optical density (OD) of selected lactobacillus, cultivated overnight on MRS agar, was measured against a blank to ascertain a concentration of 1×10^8 cells/mL of probiotics. Each contaminated sample, weighing 50 g and in crunched form, underwent treatment with lactobacillus suspension at a concentration of 1×10^8 cells/mL in a 500-mL flask. The infected samples received 17 mL of lactobacillus suspension, while the control group was treated with MRS broth without bacterial suspension. The experiment involved applying bacterial suspensions to samples. Following immunization, the flasks containing selected cultures were incubated at 32°C for 7 days. The injection of aflatoxins in selected crops is illustrated in Figure 2.

Both the control and investigational groups were observed for fungal growth after 5 and 7 days. The positive samples that had received LAB treatment were evaluated for percentage of reduced aflatoxins.

Instrumentation

The analysis was performed utilizing a reversed-phase HPLC system equipped with a quaternary pump and a Rheodyne injector valve (20-µL loop) from Agilent 1200 series (Agilent Technologies, Urdorf, Switzerland) (Irakli *et al.*, 2017). The HPLC setup included a diode array detector (DAD) and a fluorescent detector (FLD) arranged in series. A sample extract volume of 20 µL

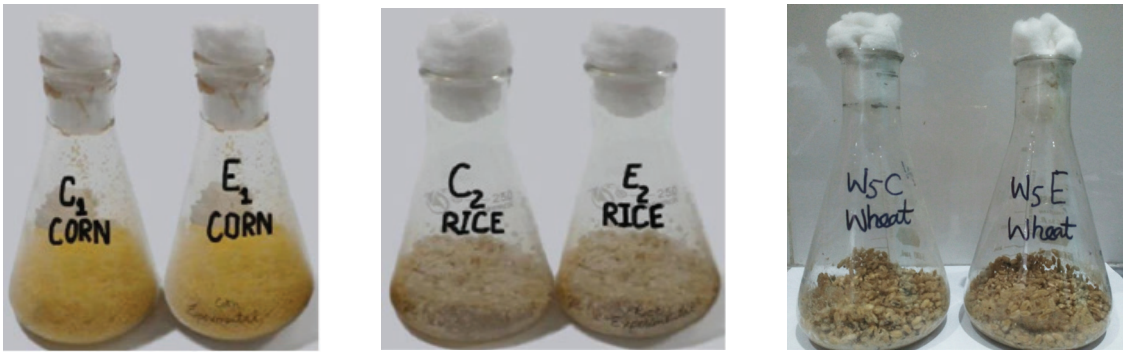

Figure 2. Inoculation of infected samples of corn, rice, and wheat with aflatoxins with and without lactic acid bacteria (LAB, probiotics).

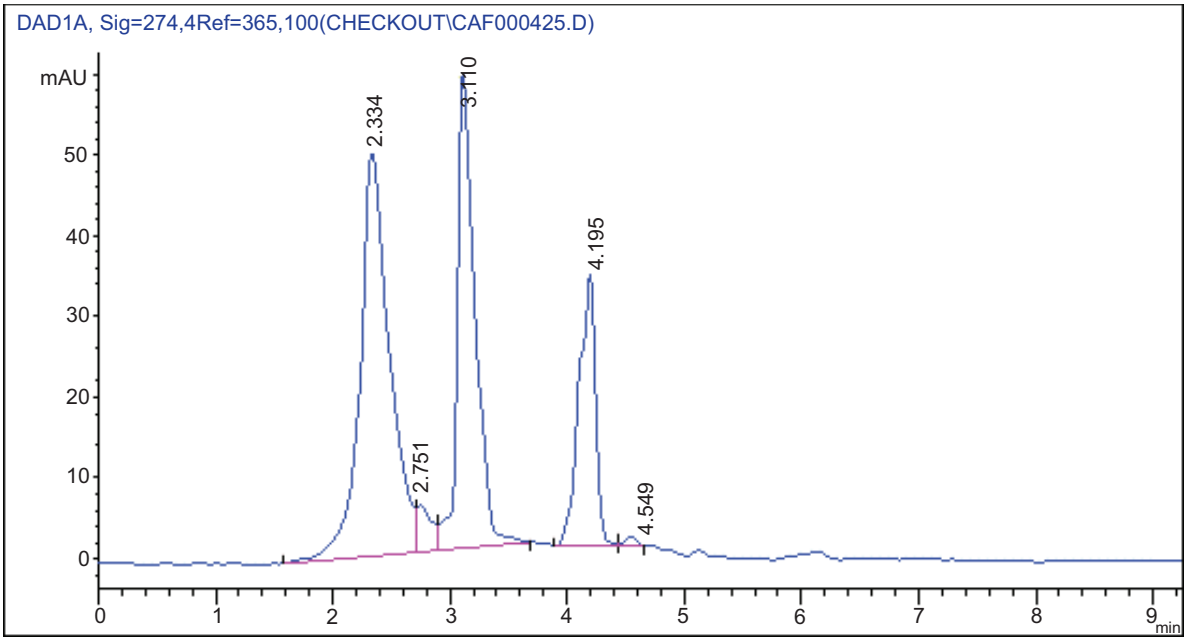

Figure 3. HPLC chromatogram of aflatoxins.

was injected into HPLC at a flow rate of 1 mL/min, utilizing a mobile phase of acetonitrile and distilled water in a 45:55 ratio. The analysis lasted for 15 min, and the chromatograms were recorded and analyzed using the Agilent Chemstation software (version B.04.01; Agilent Technologies). The amounts of aflatoxin-infected crops were analyzed statistically using the SPSS software (SPSS Statistics20, IBM, USA), and mean values and standard deviation (SD) were computed (Steel *et al.*, 1997).

Results and Discussion

Contamination status of selected food products

Aflatoxin contamination of different crops was studied to evaluate the present scenario of safety and security of crops in Punjab, Pakistan. The concentration of aflatoxin B_1, B_2, G_1, and G_2 in the standard mixture with acetonitrile was 1.96 µg/mL, 0.52 µg/mL, 2.40 µg/mL, and 0.53 µg/mL, respectively.

HPLC chromatogram of aflatoxins is shown in Figure 3.

The aflatoxins profile in selected samples (n = 240) showed that 62.08% (n = 149) of food products were infected, and only 91 samples (37.92%) were fit with no infectivity of aflatoxins. In all, 76 samples of the total aflatoxin-contaminated samples were within permissible levels, while 73 samples were unfit for human consumption. Among the contaminated samples, 69.58% were within the permissible limit, and 30.42% exceeded the permissible level. The overview of aflatoxin contamination of crops collected in the selected districts of Punjab, Pakistan, is shown in Table 1.

The aflatoxin contamination of cereals such as rice could be the basis of different diseases in humans. A similar study was done to detect 24 mycotoxins in rice samples (n = 170).

A study was conducted to assess dietary exposure to mycotoxins, aiming to collect data about rice consumption before evaluating health risks in individuals of all ages in both southern and northern regions of Punjab, Pakistan. The analysis revealed the presence of AFB1 (56%), AFB2 (28%), fumonisin (43%), deoxynivalenol (9%), zearalenone (16%), and ochratoxin (7%) in rice samples, with average concentrations ranging from 0.61 g/kg to 23.89 g/kg. It was observed that local cooking methods used in Pakistan reduce aflatoxin levels by 42–62% (Majeed *et al.*, 2018). In a study by Sani et al., (2014), it was observed that aflatoxins were reduced in rice samples by 24.80% by cooking in pressure cooker. Table 2 presents the descriptive statistical analysis of aflatoxin contamination in different food products.

Descriptive statistics of aflatoxins contamination in crop of districts in Punjab, Pakistan depicted that maximum aflatoxin contamination was found to be 545 µg/kg in corn of Rawalpindi district given in Table 3.

Detoxification approaches

The physical methods utilized in this study included cold water rinsing, hot water rinsing, and cooking the samples in excess of water. The washing of contaminated samples of corn, rice, and wheat resulted in reduced aflatoxin levels by 39.15%, 43.50%, and 39.89%, respectively (see Table 4). Notably, the most significant reduction was found after washing of the rice sample. Specifically, treating infected rice samples with hot water led to a decrease in aflatoxins by as much as 44.97%, while cooking of corn resulted in aflatoxin reduction by up to 49.40%. Preparation of food could lessen the levels of aflatoxins in final products. Washing and heating reduce certain mycotoxins, but cooking at temperatures above 100°C significantly decreases mycotoxin levels (Kamimura, 2000).

Citric acid, a mild organic chemical, serves as a stabilizer and preservative. Its acidic properties help to protect food from contamination. Lemon juice contains approximately 5% citric acid (Saidan *et al.*, 2004). Various studies have indicated that organic acids are effective in detoxifying aflatoxins. For instance, Méndez-Albores *et al.* (2005) reported a 96.7% reduction of AFB1 in corn treated with aqueous citric acid. Similarly, a study demonstrated that soaking contaminated red chillies in lemon juice resulted in a 90% reduction of AFB1. Additionally, recent research has indicated a 90% reduction of AFB1 in pistachio nuts treated with lemon juice and citric acid (Rastegar *et al.*, 2016).

Table 1. Summary showing aflatoxin contamination of different food products collected in Punjab, Pakistan.

Commodities	Total no. of samples	Uncontaminated samples	Contaminated samples	Contaminated samples within allowed levels	Contaminated samples beyond allowed levels
Corn	80	28	52	24	28
Rice	80	28	52	28	24
Wheat	80	35	45	24	21
Total	240	91	149	76	73

Table 2. Descriptive statistics of aflatoxin contamination in total crop samples of Punjab, Pakistan.

Districts	N	Range	Minimum	Maximum	Mean		Std. deviation (SD)	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
04	240	545	0	545	13.22	2.927	45.351	2,056.705

Table 3. Descriptive statistics of aflatoxin contamination of crops in four districts of Punjab, Pakistan.

Districts	N	Range	Minimum	Maximum	Mean		Std. deviation (SD)	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. error	Statistic	Statistic
BWP	60	18	0	18	3.24	0.603	4.669	21.796
FSD	60	186	0	186	15.03	5.325	41.251	1,701.632
LHR	60	137	0	137	9.39	3.502	27.125	735.776
RWP	60	545	0	545	25.21	9.666	74.876	5,606.446

BWP: Bahawalpur; FSD: Faisalabad; LHR: Lahore; RWP: Rawalpindi.

Table 4. Aflatoxin detoxification in extremely contaminated samples by physical approaches.

Sr. No.	Approaches used for detoxification	Contaminated sample ID	Initial levels (µg/kg)	Levels after detoxification (µg/kg)	Reduction (%)
1.	Washing	Corn	69.59	42.34	39.15
2.		Rice	136.69	77.27	43.50
3.		Wheat	115.19	69.24	39.89
4.	Washing with hot water	Corn	69.59	39.39	43.39
5.		Rice	136.69	75.21	44.97
6.		Wheat	115.19	66.77	42.03
7.	Cooking with excess water	Corn	69.59	35.21	49.40
8.		Rice	136.69	74.35	45.60
9.		Wheat	115.19	62.11	46.08

Table 5. Detoxification of aflatoxins in extremely infected samples by chemical approaches.

Sr. No.	Approaches used for detoxification	Contaminated sample ID	Initial levels (µg/kg)	Levels after detoxification (µg/kg)	Reduction (%)
1.	20% Citric acid	Corn	69.59	7.14	89.74
2.		Rice	106.72	10.29	90.36
3.		Wheat	115.19	15.54	86.51
4.	10% Acetic acid	Corn	10.66	2.13	80.01
5.		Rice	176.12	31.28	82.24
6.		Wheat	185.66	44.66	75.94
7.	5% $NaHCO_3$	Corn	10.66	6.24	41.46
8.		Rice	176.12	64.29	63.49
9.		Wheat	185.66	79.81	57.01
10.	0.5% HCl	Corn	10.66	3.39	68.19
11.		Rice	176.12	33.18	81.16
12.		Wheat	185.66	59.68	67.85

It was noticed in the current study that $NaHCO_3$ is effective for aflatoxin decontamination of red chillies. When contaminated red chilies were washed with $NaHCO_3$ solution for three times, a significant reduction in aflatoxins was observed (Jalili *et al.*, 2011). A study done of Montville and Goldstein (1989) revealed that aflatoxins in corn are reduced by $NaHCO_3$ solution used for washing. Safara *et al.* (2010) in Iran examined degradation of aflatoxins by up to 97.22% in contaminated rice samples treated with 1 N citric acid. The current study observed a significant reduction in aflatoxins in contaminated rice samples, with the proportions of 90.36%, 82.24%, 63.49%, and 81.16% with the application of citric acid (20%), acetic acid (10%), $NaHCO_3$ (5%), and hydrochloric acid (0.5%), respectively. Notably, citric acid solution (20%) demonstrated superior efficacy in reducing aflatoxins in rice, compared to corn and wheat, as detailed in Table 5.

The most significant reduction of aflatoxins (83.03%) was observed in the rice sample treated with LAB (probiotics). The remaining total aflatoxins in rice were reduced in the following order: black seed oil, garlic paste, and ginger paste. In corn, the highest reduction (54.22%) was achieved with black seed oil. For wheat, the highest reduction of aflatoxins (77.22%) was also noted with the application of probiotics (Table 6). There is an urgent necessity to decrease harmful fungi that result in aflatoxin formation in food products. Consequently, isolated LAB (probiotics) was employed for the inhibition of fungal growth and detoxification of aflatoxins. LAB transforms mycotoxins into less harmful substances through fermentation (Javed *et al.,* 2024; Shetty and Jespersen, 2006). Black seeds contain different antioxidants and bioactive chemicals having useful inhibitory properties (Zahra *et al.,* 2025; Khosravi *et al.*, 2011) and showed 100% detoxification when used for contaminated food products. Black seed oil is effective against all tested fungal species due to its antifungal properties (Saladino *et al.*, 2016). According to Khosravi *et al.* (2011), a significant reduction was observed in aflatoxins when treated

Table 6. Aflatoxin detoxification in extremely infected samples of corn, rice, and wheat by biological methods.

Sr. No.	Approaches used for detoxification	Contaminated sample ID	Initial levels (µg/kg)	Levels after detoxification (µg/kg)	Reduction (%)
1.	5% Ginger *(Zingiber officinale)* paste	Corn	10.66	5.72	46.34
2.		Rice	176.12	71.82	59.22
3.		Wheat	185.66	83.29	55.13
4.	5% Garlic (*Allium sativum*) paste	Corn	10.66	5.16	51.59
5.		Rice	176.12	69.28	60.66
6.		Wheat	185.66	81.77	55.95
7.	10% Black seed (*Nigella sativa)* oil	Corn	10.66	4.88	54.22
8.		Rice	176.12	67.99	61.39
9.		Wheat	185.66	78.72	57.59
10.	Probiotics (lactic acid bacteria)	Corn	10.66	4.98	52.28
11.		Rice	176.12	29.88	83.03
12.		Wheat	185.66	42.29	77.22

with *N. sativa* oil. A significant proportion of reduction was observed in AFB1 (94.2%), AFB_2 (100%), AFG_1 (98.9%), and AFG_2 (97.5%) ($p < 0.05$).

The garlic (*Allium sativum*) extract was found to be efficient for the aflatoxin detoxification of up to 98%. The results of different studies showed effective antifungal activity of garlic against Aspergillus species. Results concluded by Reddy *et al.* (2009) showed that *A. sativum C* effectively inhibited the growth of *Aspergillus flavus* by 65–78%, while AFB_1 was reduced by 72.2–85.7%. Hacıseferoğulları *et al.* (2005) studied the reduction of aflatoxins in cinnamon, pepper, and rosemary, and found that garlic paste was effective up to 0.25% (v/v) to inhibit the growth of *Aspergillus flavus*. A similar study conducted by Gowda *et al.* (2004) found that 0.1%, 0.2%, 0.5% and 1% garlic extract showed anti-fungal activity ($p < 0.01$). Kshemkalyani *et al.* (1990) reported 84% reduction in *asprgillus* species ($p < 0.01$). Two organosulfur compounds in garlic, diallyl sulfide and ajoene, hinder the binding of DNA with aflatoxins; thus, garlic is an effective anticancer food (Tadi *et al.*, 1991). The antioxidant properties of garlic were studied, and which may be helpful in different health issues, such as cardiovascular irregularities, thrombus formation, and hyperlipidemia (Rahman *et al.*, 2006). According to Yin and Tsao (1999), who studied the reduction of concentration of Aspergillus species, *Allium* plants have good antifungal properties. Percentage reduction of aflatoxins by biological methods in corn, rice, and wheat is shown in Table 6.

Conclusion

Food security and safety is a burning issue these days because of increase in various diseases, especially liver diseases. The presence of aflatoxins in different crops beyond allowed limits severely affects the safety and security of crops cultivated in Pakistan. Presence of aflatoxins reduces the worth and marketability of different crops (e.g., corn, rice, and wheat). In present study, aflatoxin contamination beyond permissible limits showed a great threat to crops in Pakistan. Aflatoxin contamination is a great risk for the deterioration of stock crops. Nonetheless, physical methods (cooking), chemical methods (20% citric acid), and biological methods (application of probiotics) were identified as effective techniques for mycotoxin detoxification of contaminated samples. Although different detoxification methods can lower levels of aflatoxin contamination, they cannot achieve complete decontamination. Organoleptic properties, texture, and the overall quality of products are compromised by using chemical methods of decontamination, whereas although biological methods are considered safe, achieving 100% decontamination remains unattainable. It is essentially required to manage aflatoxin contamination of selected crops by appropriate check and management at both familial and global trade echelons. Extra care is required in both pre- and post-harvesting methods to reduce the menace of aflatoxins. Aflatoxin contamination is induced in fields and increases spectacularly during crop storage. Proper supervision is needed for crop preservation. Hence, careful management and appropriate storage of crops are essential for evading aflatoxin contamination.

Competing Interests

The authors had no relevant financial interests to disclose.

Author Contributions

Conceptualization, Naseem Zahra; methodology, Naseem Zahra and Nadia Jamil; software, Abid Sarwar;

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Conflicts of Interest

The authors declare no conflict of Interest.

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