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MITIGATION OF AFLATOXIN IN BUSH MANGO SEEDS (*IRVINGIA* SPP.) USING SPICES AND PACKAGING MATERIALS

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Abstract: *Bush mango seeds (Irvingia spp.), a staple soup thickener in Nigeria, are prone to aflatoxin contamination from fungal growth during processing and storage. This study quantified aflatoxins (AFB1, AFB2, AFG1, AFG2) in bush mango seeds (BMS) from vendors and processors in Oyo and Osun States, Southwest Nigeria, across fresh, dried, and stored stages using HPLC. We evaluated moisture content and tested the efficacy of 10% and 15% w/w turmeric or basil combined with plastic or sack packaging over 5 weeks. Data was analyzed using ANOVA and MANOVA. Total aflatoxins in dried, stored, and vendor BMS ranged from 4.00 to 72.00 µg/kg, with 96% exceeding Nigeria's adopted EU limit of 4 µg/kg. Treatments significantly reduced aflatoxin levels ($p < 0.05$). The combination of 15% turmeric in plastic packaging (P15%T) was most effective, achieving up to an 84.8% reduction in total aflatoxins (e.g., from 33 to 5 µg/kg in vendor 4 BMS after 5 weeks). These natural spices and proper packaging offer a practical, low-cost aflatoxin control strategy for handlers, enhancing BMS safety.*

Keywords: *bush mango seeds, aflatoxin, spices, packaging material, aflatoxin control*

1. Introduction

Bush mango (*Irvingia* spp.) seeds are a seasonal oilseed (54 to 67% fat) used to thicken *ogbono* soup across Nigeria [1]. Processors ferment fruits, extract seeds, sun-dry them, and store them in sacks or pots for up to 8 months to meet off-season demand [2]. Nigeria's humid tropical climate favours *Aspergillus* proliferation, causing aflatoxin build-up. Beyond free aflatoxins, the presence of plant-conjugated "masked" mycotoxins, which can be released during digestion, adds a further layer of complexity to food safety assessments [3]. Aflatoxins are group 1 carcinogens linked to liver cancer [4]. Given these risks, there is a global push to develop localized mitigation strategies that can effectively bridge the gap between current food safety status and international regulatory requirements [5]. Prior studies confirm high aflatoxin levels in Nigerian bush mango seeds, often exceeding EU limits of 4 µg/kg total aflatoxin [2, 6]. While spices like turmeric (*Curcuma longa*; curcumin antifungal) and basil (*Ocimum basilicum*; antioxidant/antimicrobial) show promise against aflatoxigenic fungi, and packaging reduces oxygen for toxin production, no research tests their combined efficacy in bush mango supply chains [7, 8, 9].

Study objectives:

(1) Quantify aflatoxins (AFB1, AFB2, AFG1, and AFG2) and moisture across fresh, dried, stored, and vendor stages in

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Oyo and Osun bush mango seeds;
(2) Evaluate 10-15% w/w turmeric or basil with plastic or sack packaging for a 5-week aflatoxin control. These address critical points of fungal/toxin accumulation, enhancing safety for local consumption and export.

2. Materials and methods

2.1. Sample collection

A total of 32 bush mango seed (BMS) samples were collected from vendors and processors across Oyo and Osun States, Nigeria. Using a simple random sampling technique, 20 samples were obtained from local vendors. Additionally, 12 samples were collected from four specific processors; at each processing site, samples were taken across three distinct stages (fresh, dried, and stored) to monitor aflatoxin throughout the value chain. For the laboratory control, fresh bush mango fruits were procured directly from local markets.

2.2. Sample handling and preparation

All collected samples were secured in clean, sterile zip-lock bags to prevent cross-contamination and moisture loss during transport. Each sample was divided into three analytical portions: Part A: Utilized for immediate moisture content determination, Part B: Processed for aflatoxin assessment, and Part C: Reserved for aflatoxin control (treatment) studies using basil and turmeric.

2.3. Processing and treatment storage conditions

To ensure consistency and prevent post-sampling degradation, the following conditions were maintained:
Drying: Laboratory control samples and fresh samples were oven-dried at 60 °C until a constant weight was achieved, mimicking optimal commercial drying while minimizing thermal degradation of potential toxins.
Storage: Samples were stored in a cool, dry environment (approximately 25 ± 2 °C) in airtight zip-locks to prevent secondary fungal growth prior to analysis. For the treatment phase, samples were stored with spices (basil and turmeric) in high-density polyethylene (HDPE) containers with airtight lids and sterile polypropylene woven sacks to standardize storage conditions.
Handling of Spices: Basil leaves sourced from home gardens and turmeric rhizomes from local markets were thoroughly rinsed with sterile distilled water. Turmeric rhizomes were sliced and air-dried at room temperature under aseptic conditions before being pulverized into powder for treatment application.

2.4. Experimental treatments

The portion of samples identified with the highest aflatoxin levels (Part C) was subjected to treatment with basil and turmeric powder. These spices were applied to evaluate their efficacy in inhibiting fungal growth and reducing aflatoxin concentrations under controlled laboratory conditions.

2.5. Moisture content determination

The moisture content of the samples was determined using a digital halogen moisture analyzer (Ohaus MB25, Ohaus Corp., Parsippany, NJ, USA). For each analysis, approximately 4 g of ground bush mango seeds were uniformly spread on a sample pan and weighed. The samples were heated at a constant temperature of 105 °C using the standard drying profile [10]. The analysis was conducted in Auto-Shut-Off mode, where the device automatically concluded the process once the weight change was less than 1 mg over a 60-second interval. Readings were taken in triplicate per sample, and the mean values were recorded.

2.6. Aflatoxin quantification of bush mango seeds and HPLC conditions

Aflatoxin quantification was performed following established analytical protocols at the National Agency for Food and Drug Administration and Control (NAFDAC)

laboratory. Ground bush mango seed (BMS) samples (25 g) were combined with 5 g of NaCl and extracted with 150 mL of a methanol:water (80:20 v/v) solution via high-speed blending for 30 minutes. The resulting extract was filtered and subsequently purified using an AflaTest™ Immunoaffinity Column (Waters Corp, Milford, MA, USA) to isolate the aflatoxin fractions. Analytical quantification was performed using a Waters High-Performance Liquid Chromatography (HPLC) system equipped with a 6000A solvent delivery system and a WISP 710B autosampler.

The system was coupled with a Model 420C Fluorescence Detector, operating at an excitation wavelength of 365 nm and an emission wavelength of 425 nm. Chromatographic separation was achieved isocratically on a C18 column (Waters Associates) using a mobile phase consisting of acetonitrile:methanol:water (15:15:70, v/v/v) at a constant flow rate of 0.8 mL/min. These procedures were carried out in accordance with the official methods for mycotoxin analysis [11].

2.7. Method validation and quality assurance

The analytical method was verified for linearity, recovery, and sensitivity to ensure compliance with international food safety performance criteria [11]. Quality assurance was maintained throughout the study by adhering to standardized operating procedures for mycotoxin analysis. Linearity: A 5-point calibration curve was constructed for aflatoxins B1, B2, G1, and G2 over a concentration range of 2.0–20.0 µg/kg, yielding a correlation coefficient (R^2) of 0.998. Recovery (Accuracy): Recovery studies were performed by spiking blank bush mango seed samples at three concentrations (5.0, 10.0, and 20.0 µg/kg).

Mean recoveries ranged from 88.4% to 95.6%, which are within the acceptable NAFDAC and EU performance range (70–110%).

LOD and LOQ: The limit of detection (LOD) and limit of quantification (LOQ) were determined at a signal-to-noise ratio of 3:1 and 10:1, respectively. The LOD for total aflatoxins was 0.25 µg/kg, while the LOQ was 0.75 µg/kg.

2.8. Evaluation of spices for aflatoxin control

Bush mango seed samples with the highest aflatoxin content were further worked on by co-storing them with spices using the method described by [9] with slight modification. The spice concentration was varied, and different packaging materials were used. The concentration of spices (turmeric and basil) used was varied as 10% weight/weight (W/W) and 15% W/W, respectively, in the two packaging materials. For 10% W/W, 2 g of each spice was introduced to 20 g of bush mango seed samples, whose aflatoxin content was the highest; for 15% W/W, 3 g of each spice was introduced to 20 g of bush mango seed samples.

All treated samples were stored at room temperature, and aflatoxin quantification was repeated at 3 weeks (21 days) and 5 weeks (35 days) post-treatment. This was conducted to assess the potential reduction or elimination of aflatoxins previously quantified in the bush mango seed samples.

2.9. Statistical analysis

Data were analyzed using IBM SPSS Statistics version 20.0 [12]. Mean values of moisture content and aflatoxin levels in bush mango seeds were compared across locations using one-way analysis of variance (ANOVA). Differences in aflatoxin levels across storage periods and treatments were assessed using multivariate analysis of variance (MANOVA).

Results are presented as mean ± standard deviation, and a *p*-value of <0.05 was considered statistically significant.

3. Results and Discussion

3.1. Moisture content of bush mango samples

The moisture content of bush mango seed (BMS) samples varied significantly across processing stages and locations. For samples obtained from Osun State vendors, moisture levels ranged from 4.25% to 9.65% (Figure 1). Similarly, Oyo State vendor samples ranged from 5.20% to 10.12% (Figure 2), where samples from Vendor 6 exceeded the 10% safety threshold commonly associated with fungal inhibition in oilseeds. The processing stage was the most critical factor influencing moisture levels (Table 1). Fresh BMS recorded high moisture levels between 57.87% and 69.56%, which dropped significantly to 6.25%–11.05% upon drying. Notably, stored samples showed a relative increase in moisture (7.25% to 13.05%) compared to dried samples. This trend suggests moisture reabsorption (hygroscopicity) during storage in humid environments or poor packaging integrity. Laboratory-dried control samples maintained a stable moisture content of 8.47%, serving as a benchmark for optimal drying.

These findings highlight that several commercial stored and vendor samples remain at moisture levels (>10%) which are conducive to *Aspergillus* growth and subsequent aflatoxin accumulation.

3.2. Aflatoxin level in vendors' bush mango seeds

Table 2 shows aflatoxin quantity in BMS samples from Oyo State. BMS from vendor 9 had the highest aflatoxin B1 and total aflatoxin concentration of 55.00 ± 2.10 µg/kg, respectively, and BMS from vendor 7 had 0.00 ± 0.00 µg/kg for all groups of aflatoxin.

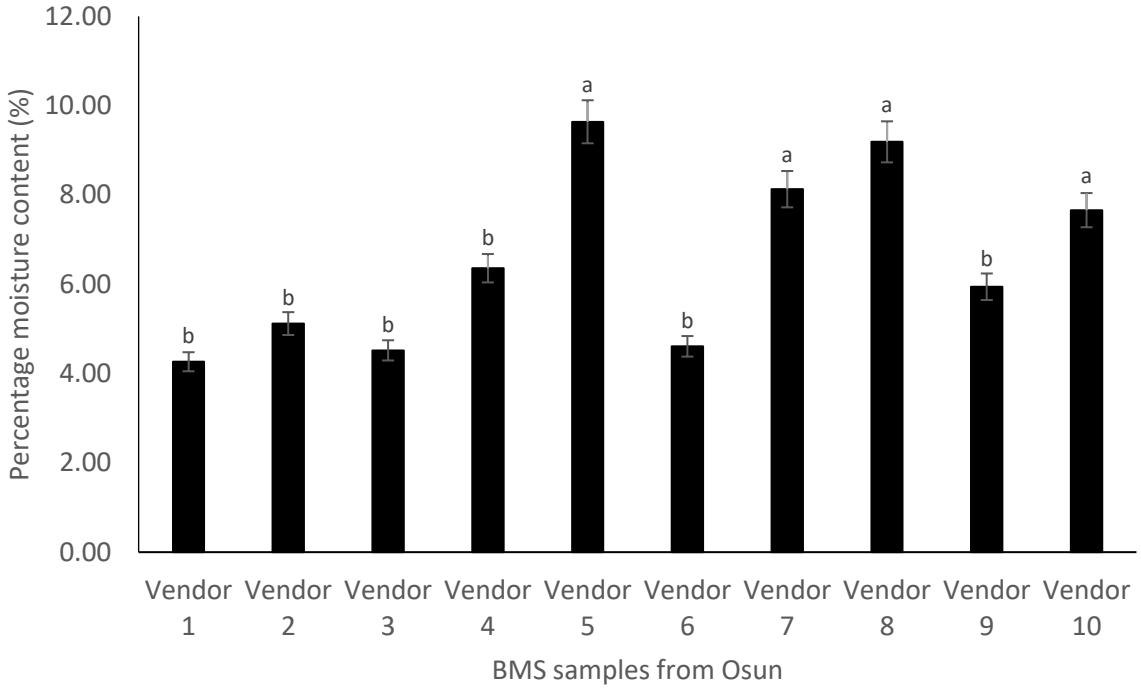

Fig. 1. Percentage moisture contents of vendors' bush mango samples from Osun
[abcd]Bars with similar alphabets are not significantly different ($p > 0.05$);
Error bars represent Standard deviation

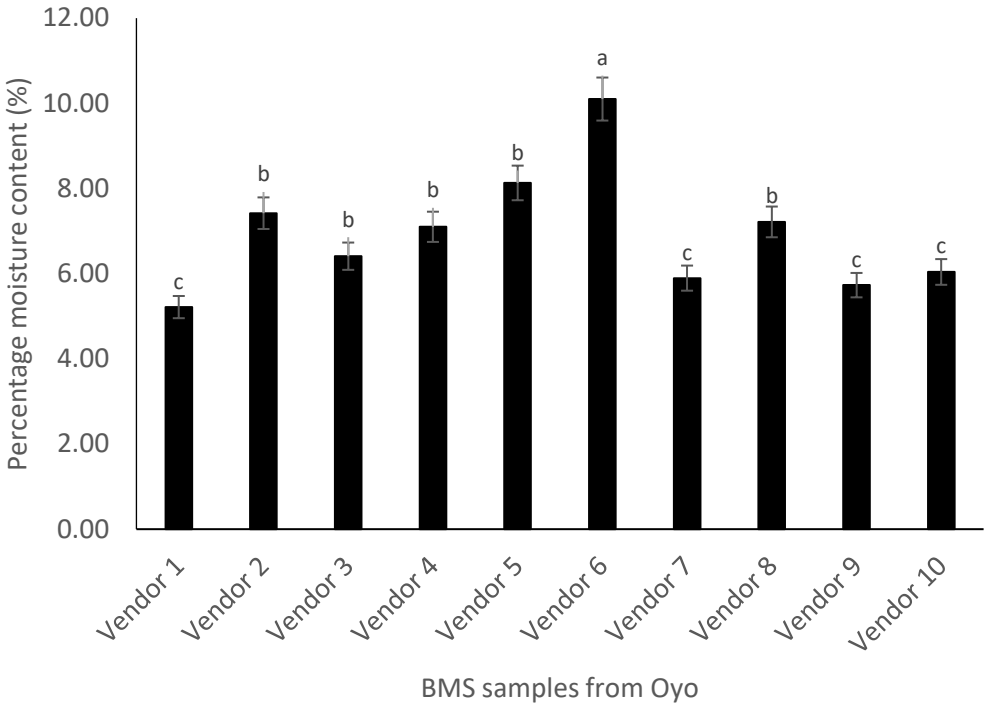

Fig. 2. Percentage moisture contents of vendors' bush mango samples from Oyo
[abcd]Bars with similar alphabets are not significantly different ($p > 0.05$);
Error bars represent standard deviation

Table 1.

Percentage moisture contents in processors' bush mango samples from Oyo and Osun (%)

Samples	Fresh	Dried samples	Stored Samples
Processor 1	65.05±0.05[b]	8.03±0.04[b]	7.25±0.07[b]
Processor 2	63.38±0.05[b]	6.51±0.01[c]	7.53±0.04[b]
Processor 3	69.56±0.05[a]	11.05±0.06[a]	9.05±0.07[a]
Processor 4	57.87±0.08[c]	8.19±0.04[b]	8.06±0.08[a]
Control	65.00±0.04[b]	8.47±0.04[b]	

[abcd]Means (± standard deviation) in the same column sharing identical superscripts do not differ significantly ($p > 0.05$).

Table 3 shows aflatoxin quantity in BMS samples from Osun State. BMS from vendor 6 had the highest aflatoxin B1 and total aflatoxin of 31.00 ± 2.00 µg/kg, respectively, while BMS from vendor 1 had the lowest aflatoxin B1 and total aflatoxin of 4.00 ± 0.20 µg/kg, respectively. Table 4 shows the aflatoxin quantity in processors' BMS (Fresh, dried, and stored) and laboratory-processed samples. From the fresh BMS samples, the sample from processor 3 had the highest total aflatoxin of 1.00 ± 0.80 µg/kg. From dried samples, BMS from processor 1 had the highest aflatoxin quantity of 16.00 ± 0.90 µg/kg. The stored BMS sample from processor 3 had the highest total aflatoxin of 72.00 ± 2.00 µg/kg among the stored samples. The control samples had no aflatoxin. The impact of antioxidant spices (turmeric and basil) combined with specific packaging materials on aflatoxin reduction over a five-

week storage period is presented in Table 5. Samples with the highest initial contamination, Oyo Vendors 3, 4, 6, 9, and Processor 3, were selected for treatment. The most significant mitigation was consistently observed in samples treated with 15% Turmeric in Plastic packaging (P15%T). For instance, in BMS from Vendor 3, the total aflatoxin concentration was reduced from an initial 41.00 ± 0.50 µg/kg to 9.00 ± 1.00 µg/kg by Week 5, representing a 78.0% reduction. Similarly, the P15%T treatment for Vendor 4 resulted in a decrease from an initial 33.00 ± 0.90 µg/kg to 5.00 ± 1.00 µg/kg, achieving the highest recorded reduction of 84.8%. The overall effectiveness of the P15%T treatment at Week 5 across the high-risk samples is summarized as follows:

Vendor 4: 84.8% reduction (from 33.00 to 5.00 µg/kg)
Vendor 3: 78.0% reduction (from 41.00 to 9.00 µg/kg)
Vendor 9: 49.1% reduction (from 55.00 to 28.00 µg /kg)
Processor 3: 36.1% reduction (from 72.00 to 46.00 µg/kg)
Vendor 6: 30.8% reduction (from 52.00 to 36.00 µg/kg).

The superior performance of turmeric over basil, particularly when utilized with plastic packaging, suggests a synergistic effect.

The distribution of aflatoxins in bush mango seed (BMS) samples followed a clear escalation based on the processing stage: Stored BMS > Dried BMS > Fresh BMS. This finding supports the observations of Atanda et al. [13], confirming that storage duration and environmental conditions are the primary drivers of toxin accumulation in the BMS value chain. Aflatoxin B1, the most toxic analogue, was detected in nearly all vendor samples across Oyo and Osun States.

These concentrations frequently exceeded the EU regulatory limit of 2 µg/kg, with total aflatoxins also surpassing the 4 µg/kg threshold, which represents a significant public health concern.

This widespread contamination confirms that aflatoxin presence is not restricted by location but is a systematic issue related to handling and environmental exposure. These concentrations frequently exceeded the EU regulatory limit of 2 µg/kg, with total aflatoxins also surpassing the 4 µg/kg threshold, which represents a significant public health concern.

Table 2.

Quantity of aflatoxins in vendor's Bush mango samples from Oyo state (µg/kg)

Vendors	AFB1	AFB2	AFG1	AFG2	Total Aflatoxin
Vendor 1	9.00 ± 0.20^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	9.00 ± 0.20^{e}
Vendor 2	7.10 ± 0.10^{d}	2.00 ± 0.20^{b}	0.00 ± 0.00^{c}	1.90 ± 0.20^{a}	11.00 ± 0.50^{e}
Vendor 3	41.00 ± 0.50^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	41.00 ± 0.50^{b}
Vendor 4	31.00 ± 0.80^{c}	2.00 ± 0.10^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	33.00 ± 0.90^{c}
Vendor 5	2.00 ± 0.20^{e}	12.10 ± 0.30^{a}	3.00 ± 0.30^{a}	0.00 ± 0.00^{b}	17.10 ± 0.80^{d}
Vendor 6	52.00 ± 1.40^{a}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	52.00 ± 1.40^{a}
Vendor 7	0.00 ± 0.00^{f}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{f}
Vendor 8	28.50 ± 0.20^{c}	0.01 ± 0.01^{c}	0.50 ± 0.05^{b}	0.00 ± 0.00^{b}	29.01 ± 0.26^{c}
Vendor 9	55.00 ± 2.10^{a}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	55.00 ± 2.10^{a}
Vendor 10	26.00 ± 2.00^{c}	3.00 ± 1.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	29.00 ± 3.00^{c}

^{abcd}Means (± standard deviation) in the same column sharing identical superscripts do not differ significantly ($p > 0.05$)

Table 3.

Quantity of aflatoxins in Vendors' Bush mango samples from Osun state (µg/kg)

Vendor	AFB1	AFB2	AFG1	AFG2	Total Aflatoxin
Vendor 1	4.00 ± 0.20^{f}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	$4.0\ 0\pm 0.20^{d}$
Vendor 2	9.00 ± 0.40^{e}	0.10 ± 0.05^{c}	3.00 ± 0.30^{a}	1.90 ± 0.30^{a}	14.00 ± 1.05^{c}
Vendor 3	27.00 ± 0.80^{a}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	27.00 ± 0.80^{a}
Vendor 4	11.20 ± 1.00^{e}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	11.20 ± 1.00^{c}
Vendor 5	18.00 ± 2.00^{c}	4.50 ± 0.40^{a}	0.40 ± 0.20^{b}	0.10 ± 0.05^{b}	23.00 ± 2.65^{b}
Vendor 6	31.00 ± 2.00^{a}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	31.00 ± 2.00^{a}
Vendor 7	22.90 ± 2.00^{b}	0.10 ± 0.06^{c}	0.10 ± 0.08^{c}	0.00 ± 0.00^{b}	23.10 ± 2.14^{b}
Vendor 8	14.00 ± 1.00^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	14.00 ± 1.00^{c}
Vendor 9	10.00 ± 0.50^{e}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	10.00 ± 0.50^{c}
Vendor 10	11.33 ± 1.53^{e}	1.93 ± 0.45^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	13.27 ± 1.98^{c}

^{abcd}Means (± standard deviation) in the same column sharing identical superscripts do not differ significantly ($p > 0.05$)

Table 4.

Aflatoxin levels in processors (fresh, dried and stored) bush mango samples (µg/kg)

Sample Type	Location	AFB1	AFB2	AFG1	AFG2	Total Aflatoxin
Fresh	Processor 1	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
	Processor 2	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
	Processor 3	1.00 ± 0.80^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	1.00 ± 0.80^{a}
	Processor 4	0.00 ± 0.00^{b}	0.09 ± 0.08^{a}	0.00 ± 0.00^{a}	0.61 ± 0.20^{a}	0.70 ± 0.28^{a}
	Control	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
Dried	Processor 1	16.00 ± 0.90^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	16.00 ± 0.90^{a}
	Processor 2	13.33 ± 1.04^{b}	1.00 ± 0.40^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	14.33 ± 1.44^{b}
	Processor 3	4.00 ± 1.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	4.00 ± 1.00^{d}
	Processor 4	5.00 ± 0.70^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	1.00 ± 0.50^{a}	6.00 ± 1.20^{c}
	Control	0.00 ± 0.00^{d}	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{e}
Stored	Processor 1	30.00 ± 2.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	30.00 ± 2.00^{b}
	Processor 2	25.00 ± 1.40^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	25.00 ± 1.40^{c}
	Processor 3	72.00 ± 2.10^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	72.00 ± 2.10^{a}
	Processor 4	19.20 ± 0.80^{d}	0.81 ± 0.20^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	20.01 ± 1.00^{d}

^{abcd}Means (±Standard deviation) in the same column having similar superscripts are not significantly different ($p > 0.05$)

This widespread contamination confirms that aflatoxin presence is not restricted by location but is a systematic issue related to handling and environmental exposure. These high levels align with regional findings by Ezekiel et al. and Zhang et al. [2, 14], emphasizing the urgent need for the localized mitigation strategies explored in this study.

A major finding in this study was the exceptional efficacy of the 15% Turmeric in Plastic packaging (P15%T) treatment.

Both turmeric and basil demonstrated significant reduction capabilities that were consistent with previous reports on spices like ginger and cinnamon [9] and basil in various grains [15].

Table 5.
Effect of concentrations, spices, and packaging materials on the control of aflatoxin in bush mango seeds during 5 weeks of storage (µg/kg)

Weeks	Treatment	Vendor 6 BMS	Vendor 9 BMS	Vendor 3 BMS	Processor 3 stored BMS	Vendor 4 BMS
	Initial	52.00±1.40^{a}	55.00±2.10^{b}	41.00±0.50^{b}	72.00±2.10^{a}	33.00±0.90^{a}
3 weeks	P10%T	41.00±1.00^{b}	46.00±0.50^{c}	33.00±0.20^{c}	65.00±0.40^{a}	28.00±0.50^{a}
	P15%T	37.00±0.30^{c}	29.00±0.40^{d}	21.00±0.50^{d}	47.00±1.00^{b}	19.00±0.30^{b}
	S10%T	50.00±0.30^{a}	49.00±1.00^{c}	38.00±0.50^{b}	70.00±0.40^{a}	30.00±0.10^{a}
	S15%T	48.00±1.00^{a}	55.00±0.50^{b}	34.00±0.40^{c}	68.00±0.60^{a}	28.00±0.30^{a}
	P10%B	43.00±0.50^{b}	55.00±0.50^{b}	41.00±0.25^{b}	67.00±0.10^{a}	30.00±0.20^{a}
	P15%B	38.00±0.45^{c}	48.00±1.00^{c}	40.00±0.15^{b}	49.00±0.40^{b}	24.00±0.45^{b}
	S10%B	50.00±0.40^{a}	55.00±0.10^{b}	39.00±0.35^{b}	69.00±0.30^{a}	30.00±0.65^{a}
	S15%B	49.00±0.10^{a}	54.00±0.60^{b}	36.00±0.15^{c}	53.00±0.50^{b}	29.00±0.30^{a}
	Sco	54.00±0.10^{a}	60.00±1.00^{a}	45.00±1.00^{a}	70.97±0.35^{a}	33.00±0.40^{a}
	Pco	51.00±1.00^{a}	53.00±0.50^{b}	40.67±0.49^{b}	70.00±2.00^{a}	32.00±0.60^{a}
	Initial	52.00±1.40^{b}	55.00±2.10^{b}	41.00±0.50^{b}	72.00±2.10^{a}	33.00±0.90^{a}
5 weeks	P10%T	40.00±1.00^{b}	44.00±0.50^{c}	33.00±0.10^{b}	65.00±0.45^{b}	28.00±0.30^{a}
	P15%T	36.00±1.00^{b}	28.00±0.35^{d}	9.00±1.00^{d}	46.00±0.30^{c}	5.00±1.00^{c}
	S10%T	49.00±0.80^{b}	48.00±0.40^{c}	23.00±0.10^{c}	62.00±0.50^{b}	29.00±0.20^{a}
	S15%T	47.00±1.00^{b}	46.00±0.10^{c}	26.00±1.00^{c}	50.00±0.45^{c}	28.00±0.65^{a}
	P10%B	42.00±0.30^{b}	53.00±0.50^{b}	38.00±0.25^{b}	67.00±0.90^{b}	30.00±0.40^{a}
	P15%B	38.00±1.00^{b}	45.00±0.70^{c}	36.00±1.00^{b}	48.00±0.10^{c}	23.00±0.30^{b}
	S10%B	50.00±0.25^{b}	54.00±1.00^{b}	39.00±0.65^{b}	68.00±0.20^{b}	30.00±0.15^{a}
	S15%B	47.97±0.29^{b}	53.00±0.50^{b}	35.00±0.63^{b}	53.00±0.10^{c}	28.30±0.26^{a}
	Sco	57.00±0.25^{a}	60.00±0.30^{a}	46.00±0.50^{a}	73.00±1.00^{a}	34.00±0.50^{a}
	Pco	52.00±0.50^{b}	54.00±0.60^{b}	40.00±0.10^{b}	71.00±0.40^{a}	32.00±0.50^{a}
Time*Trt	F value	4.013	14.180	142.399	61.701	101.984
	p value	0.01*	0.01*	0.01*	0.01*	0.01*

^{abcd}Means (±Standard deviation) in the same column for 3 weeks and 5 weeks respectively sharing similar superscripts are not significantly different ($p > 0.05$); Initial = Initial Total Aflatoxins concentration, P10%T = 10%Turmeric in Plastic, P15%T = 15% Turmeric in Plastic, S10%Turmeric = 10% Turmeric in Sack, S15%T = 15% Turmeric in Sack, P10%B = 10% Basil in Plastic, P15%B = 15% Basil in Plastic, S10%B = 10% Basil in sack, P15%B = 15% Basil in Sack, Pco = Plastic control, Sco = Sack Control

Turmeric was substantially more effective. Specifically, the P15%T treatment achieved an 84.8% reduction in the most contaminated samples (from 33.00 ± 0.90 to 5.00 ± 1.00 µg /kg in Vendor 4) and a 78.0% reduction in Vendor 3 samples (from 41.00 ± 0.50 to 9.00 ± 1.00 µg /kg) by the fifth week. This superior performance can be attributed to the high concentration of natural polyphenolics and curcuminoids in turmeric, which possess potent antioxidant and antifungal properties. These compounds likely inhibit key precursors in the aflatoxin biosynthetic pathway. Furthermore, the use of plastic packaging served as a critical variable; the airtight environment likely prevented the volatilization of the spice's bioactive compounds and shielded the seeds from ambient moisture ingress. This synergistic effect between the 15% turmeric concentration and plastic barriers provides a specific, highly effective protocol for significantly mitigating AFB1-induced

toxicity and total aflatoxin load in stored bush mango seeds.

4. Conclusion

This study confirms that bush mango seeds in Oyo and Osun, Southwest Nigeria, are highly susceptible to aflatoxin contamination, particularly during the storage phase, where levels frequently exceed international safety limits. The identification of AFB1, AFB2, AFG1, and AFG2 across multiple vendor locations highlights a significant chronic health risk for consumers.

The findings specifically demonstrate that the application of 15% w/w turmeric powder combined with airtight plastic packaging (P15%T) is the most effective mitigation strategy, achieving a total aflatoxin reduction of up to 84.8% over a five-week storage period. While basil and sack packaging also showed reduction capabilities, they were less effective than the turmeric-plastic synergy, which likely preserved bioactive curcuminoids and prevented moisture ingress.

Consequently, we recommend the adoption of the P15%T protocol as a practical, low-cost, and non-toxic intervention for local processors and vendors to safeguard the safety of bush mango seeds. Future research should focus on the long-term sensory attributes of spice-treated seeds to ensure continued consumer acceptance alongside improved chemical safety.

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6. References

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