Chapter

Influence of Indigenous Processing Methods on Aflatoxin Occurrence in Africa

Abdul Rashid Hudu, Mahunu Gustav Komla and Nelson Opoku

Abstract

Aflatoxin is a major mycotoxin naturally produced in plants. Various postharvest treatments such as drying, storage materials and storage conditions have shown to influence the accumulation of this toxin in food crops. Beside indigenous processing methods including fermentation, roasting, and cooking have contributed to the reduction in aflatoxin expression. Although these methods are not used in exclusion, each stage has an inherent impact on the levels of aflatoxin in the final products. This chapter reviewed studies on the use of indigenous processing methods in African against aflatoxin occurrences in traditional foods and beverages.

Keywords: aflatoxin, *Aspergillus* species, postharvest, indigenous processing methods, Africa

1. Introduction

Aspergillus species and its derivative mycotoxins are involved in numerous postharvest losses and health threaten conditions in plants and human. Among *Aspergillus* toxins, aflatoxin is known to carry the most potent carcinogenic activity as a natural product. The isomers aflatoxin B1 (AFB1), aflatoxin B2 (AFB2), aflatoxin G1 (AFG1) and aflatoxin G2 (AFG2) are curial for their varied biological activities [1–3], whereas the transcriptional regulators climate, soil properties, genotype of crops, and daily net evaporation exert their occurrences in food crops [3, 4]. Globally, their negative impact on health, social life and economy are more pronounced in developing countries. Consequently, it has been estimated that more than 5 billion people in developing countries are exposed to aflatoxin-associated diseases [5, 6].

Because aflatoxins are xenobiotic to animals and humans, they must consume diet with contaminated aflatoxins. Cereals, spices, oilseeds, tree nuts, and dried fruits exhibits greater susceptibility to aflatoxin contamination with maize and groundnuts being the widely consumed staple foods throughout Africa [7, 8]. Contaminations are influenced by many factors and can occur at any stage of food production (preharvest, harvest, and postharvest storage).

To protect consumers from the harmful effects of aflatoxins, a number of nations and International recognized organizations have established regulations for aflatoxins in food and animal feed. In United States and European Union, the Food and Drug Administration has established maximum limits of 20 μg/kg and 4 μg/kg

respectively. At the moment few regulations on aflatoxin exit in Africa, as a result majority of these countries live on the Joint FAO/WHO Expert Committee on Food Additive (JECFA) recommendation of 2 μg/kg body-weight per day [9, 10].

Processing methods and conditions, which are heavily influenced by multitudinous intrinsic and extrinsic factors are supposed to be involved in degrading and reducing aflatoxins levels in foods and beverage to safe and standards levels. Therefore, this review focuses on advances in the elucidation of activities of aflatoxin by indigenous processing methods. Furthermore, it summarizes the impact of variations in indigenous processing conditions in aflatoxins degradation [10, 11].

2. Postharvest factors affecting *Aspergillus* and aflatoxin production in grain

2.1 Water activity and temperature

Fungal growth and their corresponding mycotoxin production are controlled by several factors including temperature, water availability, pH, light and nature of substrate, which vary among species to species and isolated strains. Although it has become difficult to describe a set of optimum conditions for growth and production of mycotoxins, it has generally been agreed that adequate amount of moisture and temperature are crucial for aflatoxin biosynthesis in cereal and legumes during storage [12].

Reports on minimum and optimum water activity levels required for aflatoxin production differs among authors, but are within the range of 0.78 to 0.84 for *Aspergillus flavus*; and 0.81 to 0.82 for *Aspergillus parasiticus*, with 0.95 to 0.99 optimum for both strains [10–15]. Regarding to temperature, data suggest aflatoxin production occur at a range of 28 °C to 35 °C [15].

2.2 Storage methods on aflatoxin occurrence

It is well documented that storage systems and the length of storage increase fungal infestation of grains and their subsequent production of mycotoxins [14, 15]. Despite the suggestion that there is a limited increase in aflatoxin contamination of grain from field to storage [16], it has been argued that more than 6 months storage length assures efficient growth of *Aspergillus* species and significant production of Aflatoxin in maize under Africa's storage methods through increase moisture level [17, 18].

Although it is arguable that the increased aflatoxin occurrence in stored grains is simply due to the increased favorable environmental conditions for *Aspergillus* activities, it has clearly been shown that storage structure and material types affects *Aspergillus* species activities and aflatoxin occurrence (**Figure 1**). Conventional to most traders and rural households in Africa, grains are stored in jute sack or plastic sack. *Aspergillus flavus* prevalence was 51% and 56% higher in maize stored in plastic sack (18%) or hanging shed (13%) compared to those stored in jute sacks [19]. Consequently in Ghana, aflatoxin occurrence in maize grains stored in jute sack was higher (about 55%) compared to grains stored in polyethylene sack [20]. This was also indicated for groundnut stored in jute sacks for 2 months that demonstrate a higher aflatoxin occurrences (148.21 ppb) than their counterpart stored in interlaced polyethylene jute sack [21]. Another study conducted in Tanzania to determine the occurrence of *Aspergillus* species and aflatoxin in maize stored in room (n = 32) and sacks (n = 8) showed that aflatoxin concentration was high in maize stored in room (334.33 μg/kg) than their counterpart stored in sacks (305.76 μg/kg) though the difference was not significant [22].

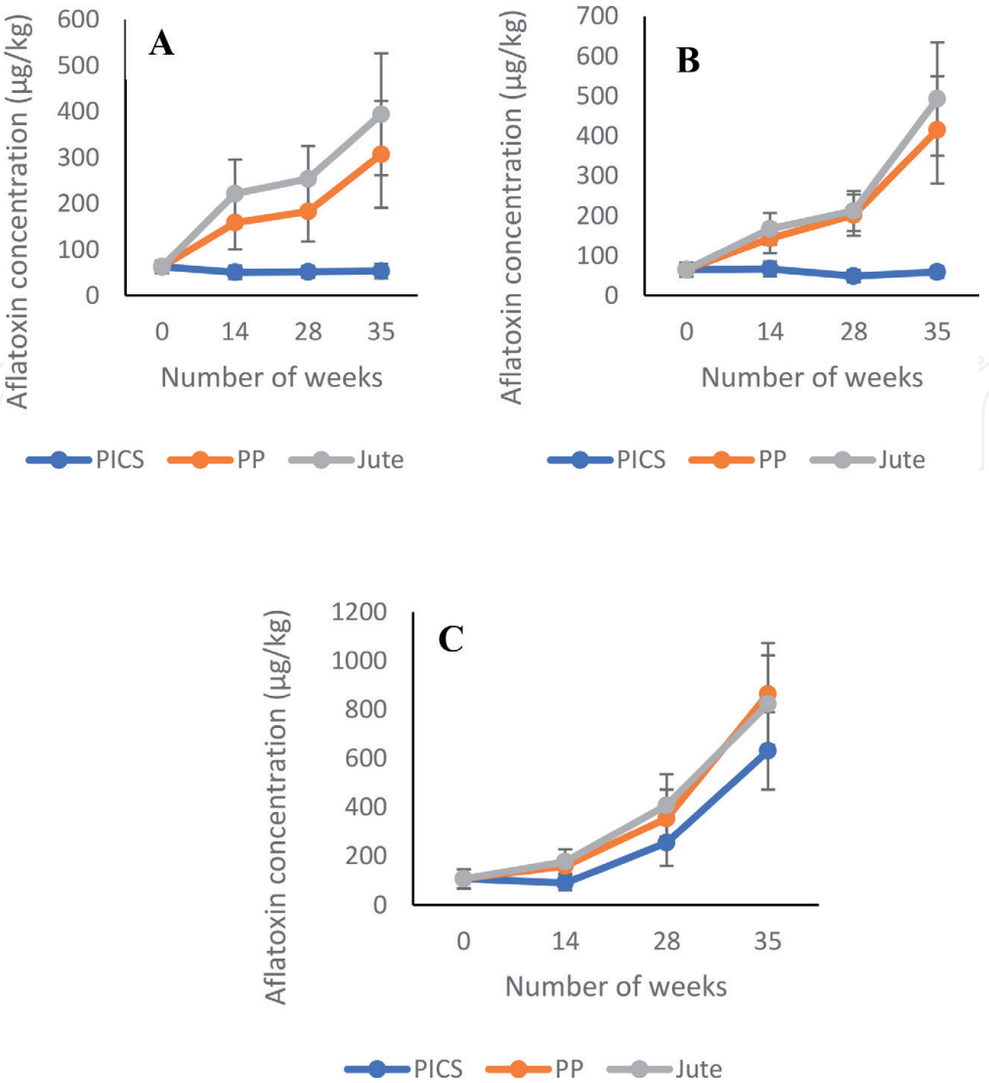

Figure 1.
Total aflatoxin concentration (µg/kg) of maize grain stored in triple layer hermetic bags (PICS), polypropylene (PP) and jute sack for 35 weeks. A = moisture level < 13%, n = 7; B = moisture level between 13% and 14%, n = 13; C = moisture level > 14%, n = 7. Source: Ng'ang'a et al. [17].

Another study conducted by Ng'ang'a et al. [17] to determine the impact of three storage materials on aflatoxin levels under three moisture levels (moisture level < 13%, n = 7; moisture level between 13% and 14%, n = 13; and moisture level > 14%, n = 7) showed that jute sacks and polyethene promoted aflatoxin production in grains stored for 35 weeks under all the moisture levels (**Figure 1**). Similarly, total mold counts in the maize grain was higher in maize grain stored in jute sack and polypropylene sacks [17].

In contrast, a study conducted by Worku et al. [23] did not find significant increased aflatoxin in maize (n = 149) stored in mud mix with teff straw, (13.1 ± 2.3–14.7 ± 2.8 ng/g; n = 33), polypropylene bag (13.7 ± 3.4 ng/g; n = 116). Similar to this distribution of aflatoxin in storage structure, it was shown that highest aflatoxin levels were found in maize stored in polypropylene and nylon sacks compared to those stored in granaries [24].

3. Effect of processing methods on aflatoxin reduction in food

A variety of indigenous processing methods have shown to influence aflatoxin content in food and feed. These methods could be physical (cleaning and

segregation; roasting; boiling; and milling), chemical or biological (fermentation). Although these methods are not used in exclusion, each stage have an inherent impact on the levels of aflatoxin in the final products [25–28].

3.1 Postharvest drying methods on aflatoxin occurrences

Drying methods affects aflatoxin status in grain and is possibly the most important factor that determine subsequent fungal contamination and production of aflatoxin in grain under storage [21, 29]. Regardless of the moisture levels of harvested grains and source of drying energy, the level and rate of production of mycotoxin would partly be influence by drying methods. Indigenous dry methods used in Africa are broadly categories into three main groups; in-field drying, on-platform drying and on-ground drying. In sub-Saharan Africa especial in West Africa, the tradition on-field drying methods where maize cobs and other cereal grains are allowed to dry on the maize plants before harvest has resulted in significant increased fungal infestation, insect damage and aflatoxin concentration [30].

Despite the suggestion that groundnuts dried on clean tarpaulin could reduce aflatoxin concentration compared to the traditional on-ground drying [21], it was recently shown that tarpaulin increased aflatoxin levels of three different varieties of groundnut during dried at two different locations in Ghana [31].

3.2 Physical separation

Physical separation (cleaning, and sorting) affects aflatoxin status in processed or raw kernels. Hand picking coupled with floating and density techniques are the most widely home-based indigenous separation methods employed in Africa to remove unwanted and mycotoxin contaminated kernels, while willowing is involved in removing dust and fine particles. The efficacy of these methods varies, depending on the level of contamination of raw materials, maturity of grains and on the percentage of removed grains [26–30, 32, 33]. Physical cleaning and separation procedures, where mycotoxin contaminated kernels are removed from good kernel, can result in 40–80% reduction in aflatoxin levels [26]. Immature shrivelled kernels and dehulled shrivelled immature kernels if not removed can increase total aflatoxin, AFG1, AFB2 and AFB1 levels in processed peanuts kernels by up to 67%, 92%, 94% and 57% respectively [33]. Similarly, Phillips et al. [31] after separating denser peanuts from less dense ones using tap water mentioned that less dense peanuts contain higher aflatoxin contents (21 out of 29 samples) and may increase total aflatoxin levels of processed kernels by 95% (mean aflatoxin concentration decreased from 301 to 20 μg/kg).

Though time consuming, the study of Matumba et al. [34] indicated that hand sorting of maize kernel had greater positive impact on the removal of aflatoxin (97.9%) than separation using the floatation technique (63.4%). Galvea et al. [35] also revealed that blanching of peanuts at 140 °C for 25 minutes facilitated the manual sorting process of aflatoxin-contaminated kernels (86%; discolored and broken kernels) after dehulling. Also it was reported that manual sorting of raw peanuts with baseline aflatoxin content of 300 μg/kg resulting in peanut kernels with no detectable concentration (< 15 μg/kg) [35].

3.3 Roasting

Roasting, mainly as dry or oil, are the main types employ in Africa by rural households and communities. Studies have established that initial aflatoxin concentration has a correlational link to aflatoxin reduction during roasting [36]. The

results of Martins et al. [37] showed that aflatoxin degradation of roasted groundnut was 81%, 64% and 55% when the baseline aflatoxin concentration was 695 μg/kg, 332 μg/kg and 35 μg/kg respectively. Arzandeh and Jinap [38] observed similar trend in groundnuts with initial aflatoxin concentration of 237 ng/g (% reduction = 78.4), 215 ng/g (% reduction = 73.9%), 68 ng/g (% reduction = 57.3%). This was also indicated for soybeans that malted and roasted aflatoxin contaminated soybeans with initial AFG1 concentrations of 56 μg/g, 45 μg/g and 38 μg/g reduced by 73%, 62% and 61% respectively [39].

Information on the effect of indigenous roasting methods on mycotoxin occurrence is limited in Africa. However, there are some studies on final food products mainly from cereal and legumes processed using indigenous roasting methods. In Sudan, traditionally prepared peanuts better was reported to have AFB_1 concentrations ranging from 54.5–101 μg/kg, followed by peanut better from retail stores (14.5 μg/g) and then laboratory prepared peanut butter of 3.3 μg/g [40]. Aflatoxins in Nigerian dry-roasted peanuts sampled from markets, retail shops and street hawkers at different locations exhibited high AFB_1 (5–165 μg/g), AFG2 (6–26 μg/g) and AFG1 (2–20 μg/g) [41].

More importantly, Lee et al. [36] pointed out that there is no significant effects in degrading aflatoxins in contaminated grains either by dry roasting or oil roasting as the two method produced uniform effect. Therefore, irrespective of the dominance of a roasting method in a particular locality, consumption of these contaminated food may be minimal.

3.4 Boiling, parboiling and bran removal

Kpodo et al. [42] examined aflatoxin reduction among cooked kenkey made from aflatoxin fermented corn dough. Ga kenkey (a sourdough dumpling from Ga and Fante-inhabited regions of West Africa) degrade about 80% and AFB2 and 35% of AFG2 after 30 minutes of cooking. Mtega et al. [43] reported 68.12%, 51.48% and 85.21% reduction in cooked porridge from un-dehulled maize flour, dehulled maize flour and maize meal (*kande*) respectively.

Aflatoxin expression in parboiled samples, mostly rice, have been studied under different experimental condition with resulting conflicting data. Aflatoxin level were reported to be higher in parboiled rice than in raw milled rice, with AFB1 (185 μg/kg) and AFG1 (963 μg/kg) recording higher occurrence rate. With regard to the migration of aflatoxins from the outer layer to the inner layer of rice during parboiling, it was demonstrated that AFB1, AFB2, AFG1 and AFG2 may be transferred from the outer layer into the starchy endosperm of rice [44, 45]. Therefore, there is some indication that soaking time and temperature of soaking promote movement of mycotoxins from one define region to another. More importantly slow heat during parboiling process might enhance the availability of aflatoxins in foods. **Table 1** present data on the influence of boiling, parboiling and bran removal on aflatoxin (μg/kg) occurrence in indigenous African foods.

3.5 Effect of fermentation on aflatoxin occurrence

Majority of Africa fermented foods and beverages are obtained through spontaneous fermentation, with varied degree of aflatoxin levels. Assohoun et al. [27] screened for AFB1 (initial level; 2.52 μg/kg); AFG1 (initial level; 2.52 μg/kg); and AFG2 (initial level; 0.33 μg/kg) in raw maize and after fermenting maize for 72 hours. The authors reported aflatoxin levels below detectable limited in all the three aflatoxin variants after 24, 48 and 72 hours of fermentation. Another study conducted by Adelekan and Nnamah [49] to assess the effect of fermentation on aflatoxin content of moldy maize showed 65% reduction in total aflatoxin content

		Cooking condition			
Treatment	**Product**	**Time (temp °C)**	**Before**	**After**	**Ref**
Un-dehulled maize flour	Stiff porridge	- (90)	4.36	1.39	[43]
Dehulled maize flour			1.01	0.49	
Maize meal			4.26	0.63	
Rice cooker	Plain rice	-(—)	1.49	1.12	[46]
Local method		1 h:10 min	1.49	1.23	
Ordinary cooked rice	Plain rice	20 min (160 °C)	2.37	1.63	[47]
Pressure cooked rice			2.37	0.31	
Parboiled with bran		—	—	70000	[48]
Polished without bran		—	—	39000	
Raw milled with bran		—	—	21000	
Polished without bran		—	—	Trace	

—; not reported.

Table 1.
Influence of boiling, parboiling and bran removal on aflatoxin (μg/kg) occurrence in indigenous African foods.

Aflatoxin	**Detoxifying microorganism**	**Strain origin**	**Place of fermentation**	**Reduction (%)**	**Ref**
AFB1	Indigenous microbial communities	Ogi	Ogi	40–60.8	[52]
		Maize meal	Maize meal	27.5	
	Lactobacillus brevis	Kutukutu	kutukutu	63	
	Lactobacillus bucheneri	Kutukutu	Kutukutu	64.2	
	Lactobacillus rhamnosus, Saccharomyces thermophilus	Commercial strain	Kwete	92–100	[52]
	Sacharromyces lactis and Lactobacillus delbrueckii	Commercial strain	Maize meal	75	[50]
AFB2	*Indigenous microbial communities*	Ogi	Ogi	68–82.8	[50]
	Lactobacillus rhamnosus, Saccharomyces thermophilus	Commercial strain	Kwete	91.8–100	[52]
AFG1	*Lactobacillus brevis*	Milk	—	33–53	[53]
	Lactobacillus acidophilus	Food Research Institute, Canada	Milk	33–53	
AFG2	*Lactobacillus acidophilus*	Food Research Institute, Canada	—	46–68	[53]
	Lactobacillus casei	Lab strain	—	46–68	

Aflatoxin	Detoxifying microorganism	Strain origin	Place of fermentation	Reduction (%)	Ref
Total aflatoxin	*Indigenous microbial communities*	Mawe	Mawe	>92	[54, 55]
		Ogi	Ogi	80	[51]
	Lactobacillus acidophilus	Ogi	Maize	37.5	[51]
	Lactobacillus brevis	Ogi	Maize	75	[51]
	Lactobacillus casei	Ogi	Maize	62.5	[51]
	Lactobacillus delbrueckii	Ogi	Maize	56.3	[51]
	Lactobacillus plantarum	Ogi	Maize	95	[51]

Ref; Reference.

Table 2.
Binding capacity of Lactobacillus spp. and yeast to aflatoxins during fermentation.

Treatment	Product	Aflatoxin type and levels (μg/kg)					Ref
		AFB1	AFB2	AFG1	AFG2	Total	
No fermentation	Raw maize kernel	2.25	ND	2.25	0.33	0.77–4.59	[27]
24 hours fermentation	Dough	ND	ND	ND	ND	0.5	
48 hours fermentation	Dough	ND	ND	ND	ND	ND	
72 hours fermentation	Dough	ND	ND	ND	ND	ND	
No fermentation	Raw maize kernels	69.80	4.5	—	—	—	[42]
24 hours fermentation	Steeped kernel, wet milled	117	11.50	—	—	—	
24 hours fermentation	Fermented Dough (Lab fermentation)	206	18.90	—	—	—	
48 hours fermentation	Fermented Dough (Lab fermentation)	270	22.20	—	—	—	
72 hours fermentation	Fermented Dough (Lab fermentation)	290	25.50	—	—	—	
24 hours fermentation	Fermented dough (sample from processing site)	106.1	6.7	21.7	2.4	135.4	
No treatment	Raw sorghum	—	—	—	—	1.70–3.0	[25]
	Malted sorghum for *thobwa*	—	—	—	—	6.10–54.6	
	Thobwa	—	—	—	—	2.1–7.1	

Treatment	Product	Aflatoxin type and levels (μg/kg)					Ref
		AFB1	AFB2	AFG1	AFG2	Total	
	Malted sorghum for beer	—	—	—	—	4.3–1138.8	
	Beer	—	—	—	—	8.8–34.5	
No spike, no starter	*Kwete*	0	0	0	0	0	[50]
No spike, starter	*Kwete*	0	0	0	0	0	
Spike, no starter	*Kwete*	2.40	1.10	2.4	1.1	7	
Spike, starter, no fermentation	*Kwete*	2.40	1.20	2.40	0.90	6.90	
Spike, starter, 12 hours fermentation	*Kwete*	0.20	0.10	0.20	0.10	0.60	
Spike, starter, 24 hours fermentation	*Kwete*	0	0	0	0	0	

ND; not detected, --; not analyzed, Ref.; reference.

Table 3.
Summary of studies on aflatoxin levels as influenced by fermentation.

after 24 hours of fermentation, subsequent fermentation (48 and 72 hours) yield levels below detectable limits. On the other hand, Kpodo et al. [42] reported 40.3% and 60.9% increase in AFB1 and AFB2 contents respectively, in maize dough after 24 hours of fermentation. Subsequent fermentation of this 24-hour fermented dough also led to increase AFB1 and AFB2.

In recent times, the use of starter cultures aimed at reducing aflatoxin concentrations in indigenous fermented foods and beverage have been investigated. Since these cultures could exclusively bind to specific toxins [39, 40], *Lactobacillus rhamnosus* have shown to have as high as 83% binding affinity for AFB1, resulting significant reduction of AFB1, AFB2, AFG1 and AFG2 in *kwete* [50]. Chaves-López et al. [51] reviewed several studies that have isolated various microbial populations from indigenous fermented foods and beverages, majority of which belong to *Saccharomyces* and *Lactobacillus* species. **Table 2** present summary of binding capacities of *Lactobacillus* spp. and yeast commonly isolated from indigenous foods to aflatoxins during fermentation.

Aflatoxin detoxification during fermentation is achieved through microbial binding and/or biotransformation of aflatoxin into less toxic substances. This binding capacity of microbial consortium to aflatoxins are influenced by acidic medium (optimum pH of 6) and temperature (30 °C) associated with noncovalent binding of aflatoxins to cell wall of bacteria and yeast [56]. Aflatoxin degradation and/or biotransformation of aflatoxin during fermentation of indigenous food and beverages have been reported and summarized in **Table 3**.

4. Conclusions

There are many indigenous approaches to reduce aflatoxins occurrence in food, feed and beverage. If prevention techniques during postharvest treatments do

not fully avoid aflatoxins contamination, indigenous decontamination methods such as cleaning, milling, roasting, cooking, dehulling and fermentation can help remove significant part of aflatoxins. Microbial fermentation is the most promising technology as it enhances consumer acceptability and limit nutrients losses. This chapter has highlighted the link between diverse indigenous processing methods used by rural households and communities with aflatoxin degradation and reduction of toxicity in processed foods and beverages.

Conflict of interest

The authors declare no conflict of interest.

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