Chapter

Nutrient Composition and Aflatoxin Contamination of African Sourced Peanuts and Cashew Nuts: Its Implications on Health

Modupeade C. Adetunji, Stephen A. Akinola, Nancy Nleya and Mwanza Mulunda

Abstract

Edible nuts are popular worldwide based on their varied attributes such as desirable taste, high nutritional value as well as some health benefits. Globally, the most popular edible nuts are groundnuts or peanuts, almond, cashew nut among others. Due to the rich nutritional composition of nuts, they tend to be prone to contamination by toxigenic fungi which could ultimately results in the release of fungal metabolites known as mycotoxins into nuts. In view of the nutritional composition of nut and its high susceptibility to fungal attack, this chapter looks at the nutritional profile, mycotoxigenic fungi and aflatoxins contamination of peanuts, cashew nuts and their products with a central focus on Africa where the effect of aflatoxin contaminations is more prominent.

Keywords: public health, peanut, cashew nut, aflatoxigenic fungi, aflatoxin, mycobiota diversity, food safety, Africa

1. Introduction

Edible nuts are popular worldwide based on their varied attributes such as desirable taste, high nutritional value as well as some health benefits. Moreover, production of edible nuts can be done under various growing conditions and climates [1], however edible nut production is mainly in the tropical and subtropical regions of the world.

Globally, the most popular edible nuts are groundnuts or peanuts (*Arachis hypogaea*) and are classified as legumes [2] with several other tree nuts such as almond (*Prunus dulcis*), cashew (*Anacardium occidentale*), Brazil nut (*Bertholetia excelssa*), hazelnut (*Corylus avellana*), macadamia (*Macadamia integrifolia*), pecan (*Carya illinoinensis*), pine nut (*Pinus pinea*), pistachio (*Pistachia* Vera), and walnut (*Juglansregia*) [1, 3]. Although nuts are considered as food with numerous health benefits, they are prone to contamination by toxigenic fungi which could ultimately results in the release of fungal metabolites known as mycotoxins into nuts [4].

Contamination of food commodities by mycotoxins has become a global food safety concern [5, 6]. Aflatoxins are secondary metabolites produced by members of the genus *Aspergillus* mainly *A. flavus*, *A. parasiticus* and *A. nomius* [7]. This genus is very ubiquitous and is known as a primary inhabitant of soil that contaminate a variety of agricultural commodities especially cereal grains and oil seeds including nuts [8]. Consumption of aflatoxin contaminated food results in a condition known as aflatoxicosis. The severity of aflatoxicosis symptoms ranges from vomiting, abdominal pains and liver damage in acute aflatoxicosis as a result of ingesting large doses of the toxin. Whereas ingestion of smaller doses leads to chronic aflatoxicosis which is asymptomatic and may result in hepatocellular carcinoma [9]. There over 20 aflatoxins but only four of them occur naturally i.e. aflatoxins (B_1, B_2, G_1, G_2). These aflatoxins are identified based on their fluorescence (B-blue or G-green) under ultraviolet light [10].

Aflatoxin contamination has led to reduced international markets especially in the developed nations, thereby advocating for stringent measures requiring import products to have very low concentrations of aflatoxins. Since nuts are used as food as well as food ingredients, regulatory limits have been established and set at 4 μg/kg for total aflatoxin ($B_1 + B_2 + G_1 + G_2$) and $\leq$ 2 μg/kg for aflatoxin B_1 by the European Commission [11, 12]. Implementation of good manufacturing practices in the nut production chain is very important so that the nuts comply with limits of the importers [13]. As a result, many countries have conducted research on the diversity of aflatoxigenic fungi as well as the extent of aflatoxin contamination in edible nuts as well as their products to ensure that their produce meets the required standards [14]. This chapter looks at the nutritional profile, mycotoxigenic fungi and aflatoxins contamination of peanuts, cashew nuts and their products with a central focus on Africa where the effect of aflatoxin contaminations is more prominent.

2. Nutritional profile of peanut

Peanut (*Arachis hypogaea* L.), groundnut or monkey nut (**Figure 1**) is the fourth oilseeds crop and 13th food crop grown worldwide because of its nutritional, medicinal and economic values [17, 18]. Several delicacies could be prepared from peanut ranging from products like roasted peanuts, peanut butter, peanut oil, peanut paste, peanut sauce, peanut flour, peanut milk, peanut beverage, peanut snacks (salted and sweet bars) and peanut cheese analog (**Figure 2**). Raw peanut is subjected to different processing which could alter or determine the nutritional composition of the end products. Processing such as roasting of peanut enhance its colour, flavour, taste, aroma and crunchy texture [20]. It also reduces the bacteria load and aflatoxin-producing fungi in raw peanut [21].

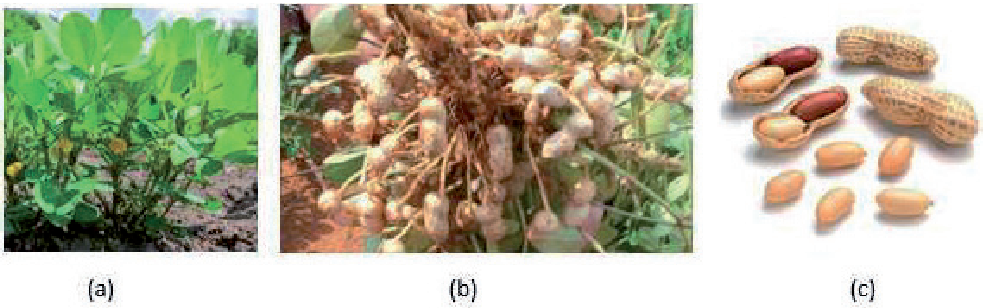


Figure 1.
Showing (a) the groundnut plant in the field, (b) harvested plant and (c) unshelled and shelled groundnuts [15, 16].

Figure 2.
Various forms in which ground nut can be consumed, adopted from market insider with modifications [19].

3. Proximate composition of peanut

Peanut is an excellent source of nutrients similar to other nuts with a substantial amount of lipid, protein and fibre content along with some amount of carbohydrate, vitamins, and minerals. The nutrient constituents and content of peanut have been previously reported; protein 20.7%–25.3%, crude fat 31–46%, ash 1.2%–2.3%, crude fibre 1.4%–3.9%, carbohydrate 21–37%, and moisture 4.9%–6.8%) [22]. Nuts including peanuts provide over 10% of the recommended dietary allowance of nutrients (protein, iron, thiamine and vitamin E) for adult males [23]. The nutritional composition of peanut is shown in **Table 1**.

Principle	Nutrients	Nutrient value	Percentage of RDA
Macro nutrients	Energy	567 Kcal	29
	Carbohydrates	16.13 g	12
	Protein	25.80 g	46
	Total Fat	49.24 g	165
	Cholesterol	0 mg	0
	Dietary Fibre	8.5 g	22
Vitamins	Folates	240 μg	60
	Niacin	12.066 mg	75
	Pantothenic acid	1.767 mg	35
	Pyridoxine	0.348 mg	27
	Riboflavin	0.135 mg	10
	Thiamin	0.640 mg	53
	Vitamin A	0 IU	0
	Vitamin C	0	0
	Vitamin E	8.33 mg	55.5
Minerals	Sodium	18 mg	1
	Potassium	705 mg	15
	Calcium	92 mg	9
	Copper	1.144 mg	127
	Iron	4.58 mg	57
	Magnesium	168 mg	42
	Manganese	1.934 mg	84
	Phosphorus	76 mg	54

Principle	Nutrients	Nutrient value	Percentage of RDA
	Selenium	7.2 μg	13
	Zinc	3.27 mg	30

Source: USDA 2014.

Table 1.
Nutritional composition of groundnut.

4. Nutritional benefits of peanut on human health

The major components of peanut are Protein, fats, and fibre (**Table 1**), and are present in their most beneficial forms. The protein is plant-based, while the fat is unsaturated, and the fibre is composed of a complex carbohydrate that are beneficial for human nutrition.

4.1 Peanut protein

The nutritional value of a food protein is determined by its essential amino acid contents and its digestibility. The protein content in the cake could reach 50% after the peanut oil has been extracted [24]. Peanuts contain all the 20 amino acids in variable proportions [25]. According to its Protein Digestibility Corrected Amino Acid Score (PDCAAS) peanut proteins and other legume proteins such as soy proteins are nutritionally equivalent to meat and eggs and ideal for human growth and health [26]. The true protein digestibility of peanuts is comparable with that of animal protein [27].

4.2 Fatty acid composition of peanut oil

Although peanuts and tree nuts have high lipid contents, peanut oil is rich in unsaturated fat, predominantly, monounsaturated fats (MUFA which have been associated with lower cardio-vascular risk) [28]. The MUFA of the regular US peanuts is 49–57% while a medium (66–69%) and high oleic (78–80%) rich peanuts have been reported [29]. The consumption of MUFA promotes artery-clearing which keeps the flow of blood and lowers the risk of atherosclerosis, heart attack or stroke [30]. Clinical studies demonstrated that intakes of MUFAs and PUFAs are associated with low risk of cardiovascular diseases (CVD) and death, whereas saturated fat and trans-fat intakes are associated with high risk of CVD [28].

4.3 Dietary Fibre

There are soluble and insoluble dietary fibres which have health benefits such as lowering the risk of heart diseases, diabetes and maintenance of a healthy weight [31]. Other health benefits includes, the lowering of blood cholesterol, improvement of bowel movement and reduced risk of metabolic syndrome [32]. The dietary fibre content of dry roasted peanut was reported as 8.4 g per 100 g of peanut similar to that in soybean (9.3 g per 100 g) while the total dietary fibre of defatted peanut flour (15.8%) was comparable to that of defatted soybean flour (17.5%) [33]. This substantial amount of dietary fibre could help individuals reach their recommended daily allowance of 38 g for men and 25 g for women.

4.4 Vitamins and minerals

Peanut has been recognised as a great source of niacin, which is important for the proper functioning of the digestive systems, skin and the nerves. It helps in the conversion of food to energy and supposed to protect against Alzheimers disease and cognitive decline [34]. Peanut is an excellent source of vitamin E whose consumption in good quantities could lead to benefits against coronary heart disease [35]. Peanut also contains good amounts of folates which are important during infancy and pregnancy for the production and maintenance of cells. It was reported that a 100 g of peanut can provides the Recommended Dietary Allowance [36] levels of copper (127%), manganese (84%), iron (57%), phosphorus (54%) and magnesium (42%) intake which is associated with reduced inflammation [37, 38] decreased risk of metabolic syndrome [38] and type II diabetes [39]. They are also referred to as a nutrient dense food, rich in multiple natural micronutrients (**Table 1**) including bioactive compounds such as resveratrol, phytosterols, phenolic acids and flavonoids that are beneficial to health. This makes them a viable option for improving the nutrition status of the malnourished, neonates, growing, or those in need of critical nutrients [40].

5. Health benefits of peanuts

Peanuts lipid profile is high in unsaturated fatty acids than the saturated fatty acids, trans- fat-free, cholesterol-free. Its low saturated fats thus qualify it as safe and desirable. Apart from basic benefits of daily nutrition, peanut consumption leads to long term health benefits such as the management of cancer [41], effective weight management [42] and lower body Mass Index [43] and management of hunger [44].

6. Cashew nut

Cashew (*Anacardium occidentale* L.) is one of the most traded processed tree nuts on the global market [45] and has become a source of income to people in the producing countries through export markets [13]. Cashew nuts are among tree nuts which are known to possess many health benefits such as reduced chances of cardiovascular diseases, diabetes, metabolic syndrome, weight gain and obesity as well as mental instability [46, 47]. This is mainly because tree nuts contain several nutrients needed for the proper functioning of the human body such as unsaturated fatty acids, proteins, mineral, vitamins, phenolic compounds and fibre [47, 48].

Following an analysis of raw cashew nuts from Brazil, India, Vietnam, East and West Africa, Rico, Bulló [47] highlighted fat as the major constituents of cashew nuts with an average of 48.3% of its total weight. However, in another study, Abubakar, Abubakar [46] reported a much higher percentage of total fats (56.4%) in raw cashew nuts from Nigeria. Nevertheless their findings were within the range (40–57%) reported in literature [49]. Fats are known to play several roles in the diet such as provision of energy, essential fatty acids as well as fat soluble vitamins [50].

The cashew tree produces the nut (kidney shaped) as the main fruit and an accessory fruit known as the cashew apple (**Figure 3**) [52, 53]. The main traded cashew products are the raw nut, the seed and the cashew nut shell liquid (CNSL) whereas the apple is converted into various beverages [54].

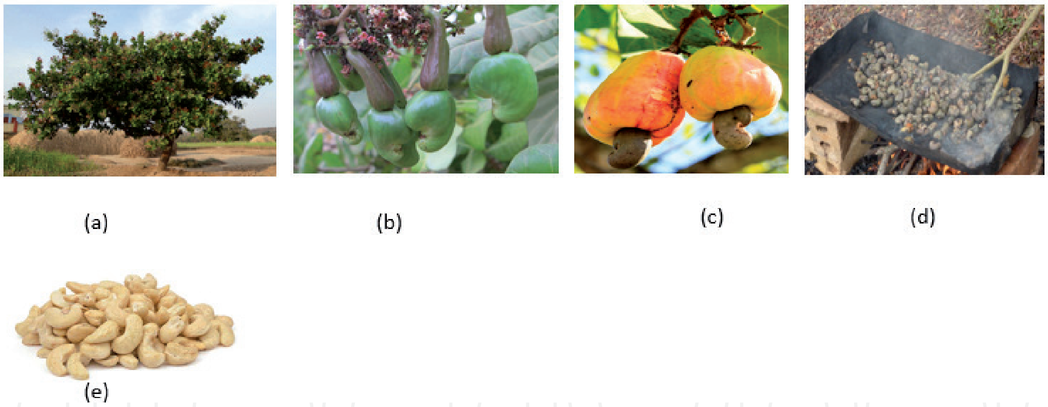


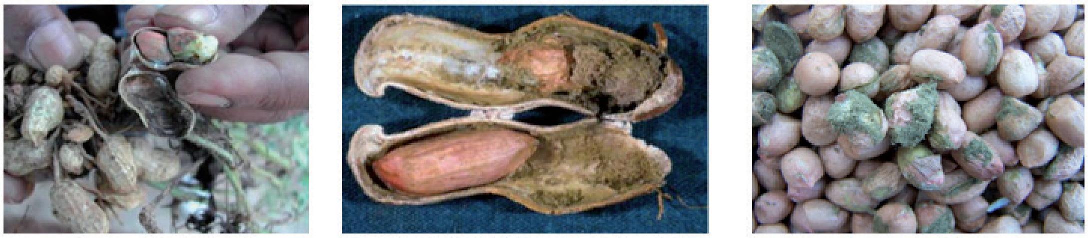
Figure 3.
Showing (a) cashew tree, (b) developing fruit, (c) cashew nut and apple, (d) roasting of shelled nuts, (e) raw shell nuts [51].

7. Contamination of peanuts and cashew nuts by toxigenic *Aspergillus* species

Despite the fact that developing countries cover the world's greatest peanut producing area, yield is very low especially in Africa because of poor socio-economic factors as well as the prevailing weather conditions [55]. The climatic conditions in the tropics and subtropics promote the proliferation of diverse pathogenic fungi capable of producing aflatoxins [56–58]. Extensive research on aflatoxins began in the 1960s with analysis on peanuts after poultry deaths in the United Kingdom, Kenya and India. This death was linked to the consumption of contaminated peanut meal [59]. The analysis of mould contaminants in peanut meals from various countries, implicated *Aspergillus flavus* [58] as the chief mould contaminant. *Aspergillus* species are ubiquitous group of soil borne fungi that can be found in agricultural soils, storage and food processing facilities as well as in the distribution systems [7, 60]. *Aspergillus parasiticus* is a soil inhabitant normally associated with pod and seed contamination whereas *A. flavus* thrives well in aerial environment and are therefore more likely to contaminate tree nuts [61]. Nuts can be colonised by fungi before harvest (**Figure 4**). Several authors have reported the presence of diverse *Aspergillus* species in the groundnuts and cashew nuts (**Table 2**).

Initially aflatoxin production was linked to *A. flavus* [85], therefore most researchers use *A. flavus* as an indicator of possible aflatoxin contamination in food commodities. For example, Sultan and Magan, [11] isolated several *Aspergillus* species from *Flavi, Circumdati* and *Nigri* sections, but performed aflatoxin producing potential tests only on the isolates from section *Flavi*. Similarly, Oyedele and co-workers [77] also isolated three *Aspergillus* species (*A. flavus, A. parasiticus* and *A. tamarii*) from peanut samples. However, determination of the toxigenicity of the isolates was carried out on those identified as *A. flavus* only. In another survey by Riba and colleagues [64] isolated species belonging to *Flavi, Circumdati, Terrei* and *Nigri* sections from shelled peanuts. Despite the fact that species from section *Nigri* had the highest incidence of occurrence, toxigenicity tests were done only for isolates from *Flavi* section. However some authors have reported aflatoxin production by species outside the section *Flavi* [86–89]. Therefore, it is important for researchers to determine the aflatoxigenicity of all isolates even if they do not belong to the *Flavi* section.

The high prevalence of the black *Aspergillus* i.e. section *Nigri* has been reported in many peanuts samples. Mohammed and Chali [55] reported the prevalence rates of *A. niger* ranging from 35 to 66% in peanut samples from the fields, storages and



(a) (b) (c)

Figure 4.
Colonisation of peanuts by Aspergillus at different production stages, (a) showing pods and kernels already contaminated before harvesting, (b) contaminated unshelled peanuts and (c) contaminated shelled peanuts in storage [36, 62, 63].

Country	Product	Sample size	Number of strains	Isolates' Identity	Aflatoxigenic (%)	Reference
Algeria	Shelled peanuts	8	55	*Aspergillus* section *Flavi*	40	[64]
	Cashew nuts	84	—	*Apergillus* section *Flavi* and *Nigri*	n.c	[65]
Benin	Cashew nuts	—	150	*A. tubingensis, A. niger, A. brasiliensis, A. carbonarius, A. luchuensis, A. aculeatus, A. aculeatinus.*	0	[66]
Botswana	Peanuts	120		*A flavus* and *A. parasiticus*	69	[67]
Egypt	Peanuts (raw, roasted and roasted with salt)	60	170	*A. niger, A. flavus, A. fucuum, A. oryzae and A parasiticus*	23	[68]
	Peanuts	45	88	*Aspergillus* section *Flavi*	90	[11]
	Peanuts	10	15	*A. flavus, A. niger, A. terreus* and *A.candidus*	80	[69]
	Peanuts	8	—	*A. flavus* and *A. niger*	—	[70]
	Peanuts	40	17	*A flavus* and *A. parasiticus*	29	[71]
Kenya	Peanuts and peanut butter	82	—	*A. flavus S strain, A. flavus L strain, A. parasiticus, A. niger, A. tamarii, A. alliaceus and A. caeletus*	n.c	[2]
	Peanuts (raw, roasted coated and roasted decoated)	228	—	*Aspergillus flavus L strain, A. flavus S strain, A. parasiticus, A. tamarii, A. caelatus, A. alliaceus* and *A.niger*	n.c	[72]

Country	Product	Sample size	Number of strains	Isolates' Identity	Aflatoxigenic (%)	Reference
	Peanuts (roasted, shelled raw, spoilt, fried, boiled podded, spoiled podded, peanut butter and peanut flour.	705	1027	*A. flavus S-strain, A. flavus L-strain, A. niger, A. tamari, A. alliaceus, A. parasiticus* and *A. caelatus*	73	[73]
Nigeria	Cashew nuts	32	14	*A. niger, A. restrictus, A. flavus, A. fumigatus* and *Aspergillus sp.*	n.c	[74]
	Cashew nuts	10	8	*A. flavus, A. glaucus, A. niger*	30	[75]
	Peanut kernels, Peanut cake, Peanut oil	189		*A. niger, A. flavus* and *A. fumigatus*	n.c	[76]
	Peanuts	84	140	*A. flavus*	64–88	[77]
	Peanuts cake	48	48	*A. flavus, A. parasiticus, A. niger, A. tamarii, A. fumigatus*	n.c	[78]
	Cashew nuts Peanuts	15 9	9 7	*A. carbonarius, A. niger* and *A. flavus.*	56 -	[79]
	Cashew nuts	—	—	*A. niger, A. flavus, A. tereus*	—	[80]
South Africa	Cashew nuts	36		*A. flavus, A. fumigatus, A. oryzae, A. niger* and other *Aspergillus spp*	15	[81]
Uganda	Peanuts (clean) Peanuts (rejects)	- -	45	*A flavus, A. parasiticus, A. niger, A. ochraceus, A. tamarii.*	24	[82]
	Peanuts	240	96	*A flavus, A. parasiticus* and section *Nigri*	34	[83]
Zambia	Soils cropped to peanuts	499	91	*A. flavus (S) and (L) strains), A. parasiticus, A. nomius.*	56–100	[84]

Keys: n.c – not counted, 0 = none was aflatoxin positive.

Table 2.
Incidence of Aflatoxigenic Aspergillus spp. in peanuts and cashew nuts from Africa.

in market places. According to Riba and colleagues [64], *A. niger* is mainly used in fermentations. Riba and associates [64] also reported high incidence of *A. niger* in analysed peanut samples. Although there are no reports on aflatoxin production by *A. niger,* there have been reports on ochratoxin A production by some *A. niger* strains [90, 91]. On the other hand, Akinola and co-workers [92] highlighted the possibility of gene transfer between toxigenic and atoxigenic strains in feedlots resulting in strains previously known as non aflatoxigenic becoming toxigenic. Acquisition of aflatoxin producing genes by *A. niger* may become a threat to the fermentation industry where it is mainly used.

The quality of the edible part of cashew nut is of great importance as it is used as either as food or ingredients in processed products. However, like others cashew nuts are also prone to fungal contamination with consequent mycotoxin production. **Table 2** shows the presence of *Aspergillus* species especially the section *Nigri* being present in most of the samples. Lamboni and others [65] highlights the implication of this section in food deterioration. The same author reported production of mycotoxins by some isolates from cashew nuts in Benin belonging to the section *Nigri* such as *Aspergillus tubingensis, A. niger, A. brasiliensis, A. carbonarius, A. luchuensis, A. aculeatus, A. aculeatinus*, however none of the isolates were able to produce aflatoxins in culture. A similar observation was noted by El-Samawaty and colleagues [93] where the majority of the *Aspergillus* species in cashew nuts from Saudi Arabia belonged to section *Nigri*. Adeniyi and Adedeji [94], emphasised the importance of moisture in the kernels during storage as it may contribute to the colonisation of the nuts by mycotoxigenic fungi.

8. Aflatoxin contamination of groundnut and cashew nut

Aflatoxin B_1 is the most potent and commonly produced naturally occurring aflatoxin [95], hence its presence in most of the samples and the most reported by researchers (**Table 3**). African countries especially those in Southern Africa namely Botswana [98], Democratic Republic of Congo [100, 101], Malawi, Mozambique [56], South Africa [101], Zambia [123, 124] and Zimbabwe [125–128] had the highest incidence of aflatoxins in the samples analysed. Most batches had more than 50% of the samples testing positive to one or more of the naturally occurring aflatoxins (**Table 3**).

In samples from Northern Africa, aflatoxins were detected though incidences of contamination were less than those reported in Southern Africa. Most samples from the batches analysed had less than 50% aflatoxin contamination occurrence rate with a few exceptions like Sudan in peanut butter. Weather conditions in Northern African countries are characterised by high temperature and humidity [129], due to being surrounded by the Mediterranean Sea and the Atlantic Ocean which promotes growth, occurrence of toxigenic moulds and subsequent aflatoxin production [130].

From West African States, Nigeria and Benin had majority of their peanuts and cashew nuts contaminated with aflatoxins and with almost 100% incidence rates. Total aflatoxin contamination in peanut cake from Benin exceeded the stipulated EC regulatory limit (4 μg/kg) whereas in cashew nuts the concentration was below the limit of detection (LOD). Studies have shown that peanut production in Africa is faced with so many challenges such as poor resources and field management which resulted to the nut being neglected. Peanuts harvest and marketing are often delayed thereby exposing the peanuts to high levels of aflatoxin contamination [95]. Contamination of nuts by aflatoxin can either be before or after harvest and a gradual increase in aflatoxin content with prolonged storage [131] could be expected. In an analysis of aflatoxin levels in peanuts at farms and markets in Uganda, Kaya and co-workers [132] reported the presence of aflatoxins at farm level in ≥60% of the peanuts. Results from analysis of raw peanuts, peanut flour, roasted peanuts and peanut butter [73, 109] showed a

Country	Product	Sample size	Positive (%)	Total Aflatoxin (range μg/kg)	Aflatoxins Detected (μg/kg)				Analysis Method	Reference
					B_1	B_2	G_1	G_2		
Algeria	Shelled peanuts	37	49	0.34–26	LOD-175	10–193	n.d	n.d	HPLC	[96]
	Unshelled peanuts	12	83		0.53–47	-	n.d	n.d		[64]
	Shelled nuts	8	100		0.2–21					
Benin	Peanut cake	15	100	33–346	<LOQ282	<LOD-31	<LOD-79	6–96	LC–MS/MS	[97]
	Cashew nuts	84	—	<LOD	<LOD	<LOD	<LOD	<LOD	UHPLC–MS/MS	[65]
Botswana	Peanuts	120	78	12.0–329	1.3–223	0.5–203	0.6–259	1.0–164	HPLC	[67]
	Peanuts	29	52	3.2–48	0.8–16	1.6–16	1.6–8	1.6–16	TLC & HPLC	[98]
	Peanut Butter	21	71	1.6–64	3.2–16	0 1.6–20	3.2–20	1.6–20		
Cameroon	Peanuts	90	29	n.d	6–125	n.d	n.d	n.d	LC–MS/MS	[99]
DRC	Peanuts	60	72	n.d	1.5–937	n.d	n.d	n.d	TLC	[100]
	Peanuts	20	100	2.19–1258	2.19–543	0–211	0–310	0–193	HPLC	[101]
Egypt	Peanuts (roasted)	36	75	0–39	0–33	0–4	0–3	0–0.2	HPLC	[102]
	Peanuts	8	100	n.d	210–600	—	250–400	n.d	TLC	[70]
Ethiopia	Peanuts	120	76	15–11,900	n.d	n.d	n.d	n.d	ELISA	[103]
	Peanut cake	50	50	n.d	0–158	0–158	—	—	UPLC	[104]
Gambia	Peanuts	3	67	n.d	2–31	n.d	n.d	n.d	HPLC	[105]
Ghana	Raw peanuts	240	—	0–1546	n.d	n.d	n.d	n.d	ELISA	[106]

Country	Product	Sample size	Positive (%)	Total Aflatoxin (range μg/kg)	Aflatoxins Detected (μg/kg)				Analysis Method	Reference
					B_1	B_2	G_1	G_2		
Kenya	Peanuts [121]	63	74	0–365	n.d	n.d	n.d	n.d	ELISA	[2]
	Peanuts (roasted)	8	50	2–298	n.d	n.d	n.d	n.d		
	Peanut butter	11	73	0–2377	n.d	n.d	n.d	n.d		
	Peanuts (raw, roasted coated and roasted decoated)	228	81	0–2345	n.d	n.d	n.d	n.d	ELISA	[72]
	Peanuts	769	36	0–7525	n.d	n.d	n.d	n.d	ELISA	[107]
	Shelledraw peanuts	705	41	0–820	n.d	n.d	n.d	n.d	ELISA	[73]
	Spoilt peanuts			2.2–1628	n.d	n.d	n.d	n.d		
	Roasted peanuts			0–757	n.d	n.d	n.d	n.d		
	Fried peanuts			0–22	n.d	n.d	n.d	n.d		
	Peanut butter			0–582	n.d	n.d	n.d	n.d		
	Peanut flour			0–820	n.d	n.d	n.d	n.d		
	Peanuts	204	99	0.1–591	0.0–510	0–48	0–44	0.1–26	HPLC	[108]
Malawi	Raw peanuts	28		LOD-1200	-	-	-	-	Vicam-Fluorometer	[109]
	Peanut flour	26		LOD-820	-	-	-	-		
	Peanut butter	13		LOD-180	-	-	-	-		
Mozambique	—	57	100	n.d	0–73	n.d	n.d	n.d	ELISA	[56]
Morocco	Peanuts	20	5	0.3	0.17	n.d	n.d	n.d	LC	[110]

Country	Product	Sample size	Positive (%)	Total Aflatoxin (range μg/kg)	Aflatoxins Detected (μg/kg)				Analysis Method	Reference
					B_1	B_2	G_1	G_2		
Nigeria	Peanut kernels (A*)	-	100	Max 600	+	+	+	+	TLC	[111]
	Peanut kernels(B*)	-	100	Max 450	+	+	-	-		
	Peanut pellets	-	100	Max 860	+	+	+	+		
	Peanut oil (crude)	-	100	Max 98	+	+	+	+		
	Peanut oil (refined)	-	100	Max 9	±	±	±	±		
	Peanut cake	—	—	—	20–455	—	—	—	TLC	[112]
	Peanut kernels	-	-	-	281–680	135–782	182–502	217–590	TLC	[113]
	Peanut pellets	-	-	-	389–793	391–513	218–530	196–320		
	Peanut oil (crude)	-	-	-	16–26	14–18	14–19	11–13		
	Peanut oil (refined)	-	-	-	0–7	0	0	0–5		
	Dry roasted peanut	106	64		5–165	6–26	5–20	7–10	TLC	[114]
	Cashew nuts (roasted)	10		0–0.4	n.d	n.d	n.d	n.d	ELISA	[115]
	Peanut (roasted)	10		0->20	n.d	n.d	n.d	n.d		
	Peanut (hulled)	7		0–0.2	n.d	n.d	n.d	n.d		
	Peanut (dehulled)	7		0->20	n.d	n.d	n.d	n.d		
	Peanut	84	100	0.4–2076	0.9–710	0.4–129	0.4–1202	18.3–123	LC–MS/MS	[77]
	Peanut	9	—	29–34	n.d	n.d	n.d	n.d	ELISA	[79]
	Cashew nuts	15		0.1–6.8						
	Cashew nuts	39	—	0.01–0.28	n.d	n.d	n.d	n.d	HPLC	[81]
South Africa	Peanut	20	90	0–73	0–35	0–16	0–10	0–8	HPLC	[101]
	Cashew nuts	36	—	0.03–0.77	n.d	n.d	n.d	n.d	HPLC	[81]

DOI: http://dx.doi.org/10.5772/intechopen.95082

Country	Product	Sample size	Positive (%)	Total Aflatoxin (range μg/kg)	Aflatoxins Detected (μg/kg)				Analysis Method	Reference
					B_1	B_2	G_1	G_2		
Sudan	Peanut butter	120	100	n.d	17–170	n.d	n.d	n.d	Vicam fluorometer	[116]
	Peanut	60	58	n.d	17.57–404	n.d	n.d	n.d	TLC	[117]
	Peanut oil (unrefined)	8	13	n.d	0.2	-	-	-	HPLC	[118]
	Peanut oil (semi-refined)	18	0	n.d	-	-	-	-		
	Peanut oil (refined)	2	0	n.d	-	-	-	-		
	Peanut	400	2		3–8	-	-	-	TLC & HPLC	[119]
	Peanut (roasted)	400	11		4–12	-	+	-		
	Peanut butter	400	64		32–54	+	+	+		
	Peanut cake	400	14		7–10	+	+	-		
Tunisia	Peanut	—	42	5	—	—	—	—	HPLC	[120]
Uganda	Peanut	152	57	n.d	0.3–11	n.d	n.d	n.d	TLC	[121]
	Peanut	152	18	1–1000	+	+	+	+	TLC	[122]
Zambia	Peanut butter	24	100	n.d	≤20–10,740	n.d	n.d	n.d	ELISA	[123]
	Raw peanuts	92	55	0.014–48.67	0.015–46.60	0.006–13	0.005–0.5	0.006–0.04	HPLC	[124]
Zimbabwe	Peanut	441	79	n.d	0–25	n.d	0–25	n.d	TLC	[125]
	Peanut	18	17	6.6–622	6.3–528	n.d	n.d	n.d	HPLC	[126]
	Peanut butter	11	91	0–247	0–186	0–25	0–47	0–9		
	Peanut	202	13	9–698	0.7–176	1.3 to 320	21--272	29–378	HPLC	[127]

Keys: - = absent, + = present, n.d = not determined, LOD = limit of detection, LOQ = limit of quantification, Max = maximum, A = kernels from government supply, B* = kernels from miscellaneous supply.*

Table 3.
Aflatoxin contamination of groundnuts, cashew nut and their products in African countries.

decrease in aflatoxin concentration in the order raw peanuts ˃ peanut flour ˃ roasted peanuts ˃ peanut butter. These results are in agreement with those of Siwela and colleagues [133] who reported a 51% reduction in aflatoxin after roasting of peanuts during large scale peanut production.

Peanut oil is the most utilised oil by people in the tropics due to its affordability [134, 135]. Analyses of peanut oil samples have shown the presence of aflatoxins especially in the unrefined oils. It has also been reported that oils extracted from peanuts often have higher aflatoxin contamination [136]. Abalaka [113], highlighted the use of crude oils by the majority of the Nigerian population hence their exposure to aflatoxins [113]. Most of the analyses in oils were from Nigeria and Sudan. Sudan is known as a major vegetable oil producer.

Cashew nut production in Africa is dominated by West African countries [137] hence the high number of reports from this quarters. Most of the studies in Africa were from Nigeria as it is one of the leading producers of cashew nuts worldwide. The result of analyses on aflatoxins in cashew nuts showed that they were within the EU and FDA regulatory limit of 15 μg/kg for total aflatoxin in nuts intended for further processing. However Milhome and associates [14] highlighted some samples from Brazil having total aflatoxins greater than this limit.

9. Impact of Aflatoxin on health

Mycotoxins finds their way into human and animal body through the consumption of mycotoxin contaminated foods [138]. Mycotoxins causes significant decline in animal productivity and general health performance. Out of the over 400 mycotoxins identified in food and animal feeds, those capable of causing significant health effect in humans and animals includes aflatoxin (AFs), fumonisins (FUM), zearalenone (ZEA), T-2/HT-2, deoxynivalenol [139] and ochratoxin A [15], they are of great concern for their effects on animal and human health [140]. Aflatoxins are naturally occurring chemical contaminants of foods such as cereals, legumes and nuts; groundnuts and cashew nuts [141], *Aspergillus parasiticus* and *Aspergillus flavus* are the primary producers of aflatoxin in crops [142]. The consumption of contaminated peanuts and cashew nuts which serves the function of food ingredients and as snacks could results in mycotoxicosis in humans and animals. Similarly, the detection of aflatoxin in animals carcases have been related to the ingestion of aflatoxin contaminated feed ingredients such as peanut [143]. Aside food substrates, mycotoxin occurrence have been reported in animal feed, animal feedlots and animal derived food products [92, 144, 145]. Aflatoxin is regarded as the chief of mycotoxins based on their degree of toxicities [146]. They have been classified as class 1 human carcinogens based on their deleterious effect on the health of both humans and animals [147, 148].

Human exposure to aflatoxin occurs due to the consumption of contaminated agricultural produce and animal derived food product [143]. Aflatoxin ingestion have been reported to cause teratogenic, mutagenic, carcinogenic immunosuppressive, hepatotoxic, nephrotoxic, and genotoxicity effect in humans and animals [144]. The degree of toxicity of mycotoxins on health of animals or humans is a function of the aflatoxin type, species and sex [149]. The liver is the major target organs for aflatoxin toxicity and could show symptoms such as liver lesions and tumour upon exposure to low and moderate doses of aflatoxin [146, 150]. The consumption of aflatoxin contaminated nuts could impair the immunity, feed efficiency and cause a teratogenic and mutagenic effect in animals [151–153]. The consumption of this nuts could pose a threat to consumer's health causing ill-health, immunosuppression, cancer and liver and kidney damage in humans and animals [150]. The consequences of aflatoxicosis accounts for more than 40% of the diseases in developing countries [9]. In tropical and subtropical countries with less or lack of regulatory activities governing the acceptable level of aflatoxin in food and feeds, the risk of human aflatoxicosis is huge. [154, 155]. The study of Ibeh *et al.* [156] reported the effect of aflatoxin on male fertility. In their study, males with high aflatoxin levels in their serum had abnormal sperm morphology, motility and sperm count. There are also evidence to the transfer of aflatoxin from mothers to babies. Authors [157–159] have reported the detection of aflatoxin M1 in breast milk of mothers exposed to aflatoxin contaminated foods in Gambian and United Arab Emirates respectively. Neonatal jaundice was reported in foetus exposed to aflatoxin in Nigeria and Iran [160, 161]. Studies have also shown the negative effect of aflatoxin on birth weight, gestational age, birth height, in blood samples obtained from mothers [158, 159].

Yousef and Lamplugh [162] have also reported mobility and mortality cases as a result of aflatoxin ingestion in humans. Chronic aflatoxicosis can results from the continuous exposure to aflatoxin contaminated foods and could cause reduction in life expectancy, cancer, immunosuppression and stunting in children [154].

10. Aflatoxin regulation

After the discovery of aflatoxins and their effects on health of both humans and livestock, regulatory limits were set in the late 1960s [163]. The United States of America was the first country to set the aflatoxin limit of 20 μg/kg [164] and the EU limit (4 μg/kg) for total aflatoxin and 2 μg/kg for aflatoxin B1. However there was harmonisation of aflatoxin standards for the EU countries which took place in 1997 and implemented in 1998. Total aflatoxin for peanuts needing further processing which was previously set at 10 μg/kg was changed to 15 μg/kg and 4 μg/kg for nuts intended for human consumption. Aflatoxin B1 was set at 8 μg/kg and 2 μg/kg for nuts that required further processing and direct human consumption respectively [165]. Not all countries adopted the harmonised standards, for examples in Asia, China and the Philippines limit of aflatoxins set by these countries were 20 μg/kg while Indonesia set 15 μg/kg for aflatoxin B1 [166].

11. Conclusion

Nuts and nut products and specially peanuts and cashew nuts have long been recognised for their nutritional content and contribution to good health. One of the limitations to the role of these nuts in human nutrition and health is their susceptibility to *Aspergillus* species and related aflatoxins. Aflatoxins have continued to be a problem from the time of discovery as their presence in nuts especially in African countries is still above the limits. Nuts are sources of livelihood to most people in developing countries as they can be used in nutrition as well as for income generation but its high susceptibility to aflatoxin contamination poses a huge threat to the consumers as well as reducing its value economically especially at the International market [139]. As aflatoxins are not really a threat to the developed countries, because of their stringent rules on acceptable limits in foods meant for human consumption.

This chapter revealed that a larger percentage of the nuts produced in Africa are contaminated with aflatoxin concentration above the regulated permissible level, hence consumers of nuts especially peanuts in Africa are at risk of aflatoxicosis despite the nutritional importance of the nut. Hence, strategies to reduce the proliferation of aflatoxigenic fungi in nuts while on the field and at post-harvest level should be harnessed. Some suggested strategies to achieve this includes:

- Good Agricultural practices such as planting of improved varieties of nuts that are resistant to drought and stress, good storage practices, proper drying of produce before storage, prevention of kernel damage during harvesting etc. should be encouraged.

- Appropriate controls of storage parameters that could aid impedes *Aspergillus* spp. growth, contamination and aflatoxin production.

- Application of biological techniques such as use of atoxigenic strains of *Aspergillus* to control the toxigenic strains.

It is recommended that future research should focus on the nutritional advantages of peanuts and cashew nuts and their related health benefits beyond the ones that have been identified in this chapter.

DOI: http://dx.doi.org/10.5772/intechopen.95082

Author details

Modupeade C. Adetunji[1]*, Stephen A. Akinola[2], Nancy Nleya[3,4] and Mwanza Mulunda[3]

1 Department of Biological Sciences, Trinity University Yaba, Lagos, Nigeria

2 Department of Microbiology, North West University, Mmabatho, South Africa

3 Department of Animal Health, Northwest University, Mmabatho, South Africa

4 Department of Applied Biology and Biochemistry, National University of Science and Technology, Bulawayo, Zimbabwe

*Address all correspondence to: modupe.adetunji@trinityuniversity.edu.ng

References

[1] Venkatachalam, M. and S.K. Sathe, Chemical composition of selected edible nut seeds. Journal of agricultural and food chemistry, 2006. 54(13): p. 4705-4714.

[2] Ndung'u, J., et al., *Prevalence and potential for aflatoxin contamination in groundnuts and peanut butter from farmers and traders in Nairobi and Nyanza provinces of Kenya.* Journal of Applied Biosciences, 2013. **65**.

[3] Ros, E., *Health benefits of nut consumption.* Nutrients, 2010. **2**(7): p. 652-682.

[4] Diella, G., et al., *Aflatoxin contamination in nuts marketed in Italy: preliminary results.* Ann Ig, 2018. **30**(5): p. 401-9.

[5] Gong, Y.Y., S. Watson, and M.N. Routledge, *Aflatoxin exposure and associated human health effects, a review of epidemiological studies.* Food safety, 2016. **4**(1): p. 14-27.

[6] Abbas, M., et al., *Pervasiveness of aflatoxin in peanuts growing in the area of Pothohar, Pakistan.* World Academy of Science, Engineering and Technology, 2012. **69**: p. 624-627.

[7] Tola, M. and B. Kebede, *Occurrence, importance and control of mycotoxins: A review.* Cogent Food & Agriculture, 2016. **2**(1): p. 1191103.

[8] Udomkun, P., et al., *Mycotoxins in Sub-Saharan Africa: Present situation, socio-economic impact, awareness, and outlook. Food Control*, 2017. **72**: p. 110-122.

[9] Williams, J.H., et al., *Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences, and interventions.* The American journal of clinical nutrition, 2004. **80**(5): p. 1106-1122.

[10] Klich, M.A., *Aspergillus flavus: the major producer of aflatoxin.* Molecular plant pathology, 2007. **8**(6): p. 713-722.

[11] Sultan, Y. and N. Magan, *Mycotoxigenic fungi in peanuts from different geographic regions of Egypt.* Mycotoxin Research, 2010. **26**(2): p. 133-140.

[12] Uçkun, O. and V. Işıl, *Monitoring of aflatoxins in peanuts.* Türk Tarım ve Doğa Bilimleri Dergisi, 2014. **1**(Özel Sayı-1): p. 1310-1314.

[13] Kujbida, P., et al., *Risk assessment of the occurrence of aflatoxin and fungi in peanuts and cashew nuts.* Brazilian Journal of Pharmaceutical Sciences, 2019. **55**.

[14] Milhome, M., et al., *Occurrence of aflatoxins in cashew nuts produced in northeastern Brazil.* Food control, 2014. **42**: p. 34-37.

[15] Ajeigbe, H., et al., *A Farmer's guide to groundnut production in Nigeria.* Patancheru, 2014. **502**(324): p. 36.

[16] Olayinka, B., et al., *Traditional preparations and uses of groundnut in Nigeria.* Annuals Food Science and Technology, 2014. **15**(1): p. 29-34.

[17] Akram, N.A., F. Shafiq, and M. Ashraf, *Peanut (Arachis hypogaea L.): A prospective legume crop to offer multiple health benefits under changing climate.* Comprehensive Reviews in Food Science and Food Safety, 2018. **17**(5): p. 1325-1338.

[18] Bediako, K.A., et al., *Aflatoxin contamination of groundnut (Arachis hypogaea L.): Predisposing factors and management interventions.* Food Control, 2019. **98**: p. 61-67.

[19] Market-Insider, *Edible Nuts - Groundnuts*, in *Groundnut Quarterly Bulletin* 2015, Market Insider.

[20] Chang, S.K., et al., *Nuts and their co-products: The impact of processing (roasting) on phenolics, bioavailability, and health benefits–A comprehensive review.* Journal of functional foods, 2016. **26**: p. 88-122.

[21] Ostadrahimi, A., et al., *Aflatoxin in raw and salt-roasted nuts (pistachios, peanuts and walnuts) sold in markets of Tabriz, Iran.* Jundishapur journal of microbiology, 2014. 7(1).

[22] Alhassan, K., *Proximate Composition and Functional Properties of Some New Groundnut Accessions*. 2018.

[23] King, J.C., et al., *Tree nuts and peanuts as components of a healthy diet.* The Journal of nutrition, 2008. **138**(9): p. 1736S–1740S.

[24] Zhao, G., et al., *Enzymatic hydrolysis and their effects on conformational and functional properties of peanut protein isolate.* Food Chemistry, 2011. **127**(4): p. 1438-1443.

[25] (USDA), U.S.D.o.A., *Food Components* http://www. nal.usda.gov/fnic/foodcomp/search/. Accessed 21 Aug 2014, 2014.

[26] Joint, W., *Protein and amino acid requirements in human nutrition.* World health organization technical report series, 2007(935): p. 1.

[27] Singh, U. and B. Singh, *Functional properties of sorghum-peanut composite flour.* Cereal chemistry, 1991. **68**(5): p. 460-463.

[28] Sacks, F.M., et al., *Dietary fats and cardiovascular disease: a presidential advisory from the American Heart Association.* Circulation, 2017. **136**(3): p. e1-e23.

[29] Shin, E.C., et al., *Commercial Runner peanut cultivars in the USA: Fatty acid composition.* European journal of lipid science and technology, 2010. **112**(2): p. 195-207.

[30] NHLBI (National Heart, L., and Blood Institute), *Atherosclerosis.* Retrievedfrom https://www.nhlbi.nih.gov/health-topics/atherosclerosis, 2019.

[31] Lattimer, J.M. and M.D. Haub, *Effects of dietary fiber and its components on metabolic health.* Nutrients, 2010. **2**(12): p. 1266-1289.

[32] Wei, B., et al., *Dietary fiber intake and risk of metabolic syndrome: A meta-analysis of observational studies.* Clinical Nutrition, 2018. **37**(6): p. 1935-1942.

[33] Dhingra, D., et al., *Dietary fibre in foods: a review.* Journal of food science and technology, 2012. **49**(3): p. 255-266.

[34] Morris, M.C., et al., *Dietary intake of antioxidant nutrients and the risk of incident Alzheimer disease in a biracial community study.* Jama, 2002. **287**(24): p. 3230-3237.

[35] Bramley, P., et al., *Vitamin E-review.* J Sci Food Agric, 2000. **80**: p. 913-938.

[36] Jordan, D., et al., *Preventing mycotoxin contamination in groundnut cultivation.* Achieving sustainable cultivation of grain legumes, 2018. **2**.

[37] King, D.E., et al., *Dietary magnesium and C-reactive protein levels.* Journal of the American College of Nutrition, 2005. **24**(3): p. 166-171.

[38] Song, Y., et al., *Magnesium intake, C-reactive protein, and the prevalence of metabolic syndrome in middle-aged and older US women.* Diabetes care, 2005. **28**(6): p. 1438-1444.

[39] Larsson, S. and A. Wolk, *Magnesium intake and risk of type 2 diabetes: a meta-analysis.* Journal of internal medicine, 2007. **262**(2): p. 208-214.

[40] Gülçin, İ., *Antioxidant properties of resveratrol: a structure–activity insight.* Innovative Food Science & Emerging Technologies, 2010. **11**(1): p. 210-218.

[41] González, C.A. and J. Salas-Salvadó, *The potential of nuts in the prevention of cancer.* British Journal of Nutrition, 2006. **96**(S2): p. S87-S94.

[42] Mattes, R.D., P.M. Kris-Etherton, and G.D. Foster, *Impact of peanuts and tree nuts on body weight and healthy weight loss in adults.* The Journal of nutrition, 2008. **138**(9): p. 1741S–1745S.

[43] Kirkmeyer, S. and R. Mattes, *Effects of food attributes on hunger and food intake.* International journal of obesity, 2000. **24**(9): p. 1167-1175.

[44] Schwartz, G.J., et al., *The lipid messenger OEA links dietary fat intake to satiety.* Cell metabolism, 2008. **8**(4): p. 281-288.

[45] Sajeev, M. and P. Saroj, *Social and economic benefits of cashew (Anacardium occidentale) cultivation in Dakshina Kannada, Karnataka: An analysis of the impact, its determinants and constraints.* Indian Journal of Agricultural Sciences, 2015. **85**(6): p. 821-826.

[46] Abubakar, S.M., et al., *Evaluation of nutrient content of raw and roasted cashew nut (Anacardium occidentale) kernel.* Biological and Environmental Sciences Journal for the Tropics 2018. **15**(1).

[47] Rico, R., M. Bulló, and J. Salas-Salvadó, *Nutritional composition of raw fresh cashew (Anacardium occidentale L.) kernels from different origin.* Food science & nutrition, 2016. **4**(2): p. 329-338.

[48] Dias, C.C., et al., *Cashew nuts (Anacardium occidentale L.) decrease visceral fat, yet augment glucose in dyslipidemic rats.* Plos one, 2019. **14**(12): p. e0225736.

[49] Ogunwolu, S., et al., *Production of protein concentrate and isolate from cashew (Anacardium occidentale L.) nut.* African Journal of Food, Agriculture, Nutrition and Development, 2010. **10**(5).

[50] Roche, H.M., *Unsaturated fatty acids.* Proceedings of the Nutrition Society, 1999. **58**(2): p. 397-401.

[51] Costa, S. and S. Bocchi, *Manual for small-scale cashew cultivation in Sierra Leone.* Milan, Italy, 2017.

[52] Dendena, B. and S. Corsi, *Cashew, from seed to market: a review.* Agronomy for sustainable development, 2014. **34**(4): p. 753-772.

[53] Catarino, L., Y. Menezes, and R. Sardinha, *Cashew cultivation in Guinea-Bissau–risks and challenges of the success of a cash crop.* Scientia Agricola, 2015. **72**(5): p. 459-467.

[54] Yomichan, S., *Case Study: Opportunities and Potential of Cashew Trade Between India and Guinea Bissau 2018.* Acta Scientific Agriculture, 2020. **4**(3).

[55] Mohammed, A. and A. Chala, *Incidence of Aspergillus contamination of groundnut (Arachis hypogaea L.) in Eastern Ethiopia.* African Journal of Microbiology Research, 2014. **8**(8): p. 759-765.

[56] Hlashwayo, D.F., *Aflatoxin B1 contamination in raw peanuts sold in Maputo City, Mozambique and associated factors.* Journal of Stored Products and Postharvest Research, 2018. **9**(6): p. 58-67.

[57] Yilmaz, I. and M. Aluc. *Determination of aflatoxin levels in cashews on Turkish markets*. in *Proceedings of the 9th Baltic Conference on Food Science and Technology "Food for Consumer Well-Being*. 2014.

[58] Benkerroum, N., *Retrospective and prospective look at aflatoxin research and development from a practical standpoint.* International Journal of Environmental

Research and Public Health, 2019. **16**(19): p. 3633.

[59] Keenan, J. and G. Savage, *Mycotoxins in groundnuts, with special reference to aflatoxin*, in *The Groundnut Crop: A scientific basis for improvement*, J. Smartt, Editor. 1994, Chapma & Hall: London. p. 509-551.

[60] Waliyar, F., et al., *Pre-and post-harvest management of aflatoxin contamination in peanuts.* Mycotoxins: detection methods, management, public health and agricultural trade. CABI, Wallingford, UK, 2008: p. 209-218.

[61] Diener, U.L., *Preharvest aflatoxin contamination of peanuts, corn and cottonseed: A review*, in *Biodeterioration Research 2*. 1989, Springer. p. 217-244.

[62] Janila, P. and M. Mula, *Cultural Management Practices of Groundnut: Scaling-up of Improved Groundnut Varieties through Established Seed System in Various Cropping Systems of Smallholder Farmers in Odisha.* 2015.

[63] Vabi, M.B., et al., *Understanding and Managing Aflatoxin Contamination in the Groundnut Value Chain in Nigeria*. 2016, ICRISAT.

[64] Riba, A., et al., *Investigations on aflatoxigenic fungi and aflatoxins contamination in some nuts sampled in Algeria.* African Journal of Microbiology Research, 2013. **7**(42): p. 4974-4980.

[65] Lamboni, Y., et al., *Occurrence of Aspergillus section Flavi and section Nigri and aflatoxins in raw cashew kernels (Anacardium occidentale L.) from Benin.* LWT, 2016. **70**: p. 71-77.

[66] Lamboni, Y., et al., *Diversity in secondary metabolites including mycotoxins from strains of Aspergillus section Nigri isolated from raw cashew nuts from Benin, West Africa.* PLoS One, 2016. **11**(10): p. e0164310.

[67] Mphande, F.A., B.A. Siame, and J.E. Taylor, *Fungi, aflatoxins, and cyclopiazonic acid associated with peanut retailing in Botswana.* Journal of Food Protection, 2004. **67**(1): p. 96-102.

[68] Youssef, M., O. El-Maghraby, and Y. Ibrahim, *Mycobiota and mycotoxins of Egyptian peanut (Arachis hypogeae L.) seeds.* International journal of Botany, 2008.

[69] Ismail, M.A., et al., *Biodiversity of mycobiota in peanut seeds, corn and wheat grains with special reference to their aflatoxigenic ability.* Journal of Microbiology, Biotechnology and Food Sciences, 2016. **9**(4): p. 314-319.

[70] El-Shanshoury, A.E.-R.R., *Occurrence of moulds, toxicogenic capability of Aspergillus flavus and levels of aflatoxins in maize, wheat, rice and.* Int. J. Curr. Microbiol. App. Sci, 2014. **3**(3): p. 852-865.

[71] El-Gohary, A., *Study on aflatoxins in some foodstuffs with special reference to public health hazard in Egypt.* Asian-Australasian Journal of Animal Sciences, 1995. **8**(6): p. 571-575.

[72] Nyirahakizimana, H., et al., *Occurrence of Aspergillus species and aflatoxin contamination in raw and roasted peanuts from formal and informal markets in Eldoret and Kericho towns, Kenya.* Advances in Microbiology, 2013. **3**(4): p. 333-342.

[73] Wagacha, J.M., et al., *Fungal species isolated from peanuts in major Kenyan markets: Emphasis on Aspergillus section Flavi.* Crop Protection, 2013. **52**: p. 1-9.

[74] Adebajo, L. and S. Diyaolu, *Mycology and spoilage of retail cashew nuts.* African journal of Biotechnology, 2003. **2**(10): p. 369-373.

[75] Lawal, O.U. and E.D. Fagbohun, *Studies on biodeterioration, aflatoxin contamination and nutritive values of processed cashew (Anacardium occidentale*

L) nuts during Storage. Nature and Science, 2014. **11**(9): p. 127-133.

[76] Salau, I., K. Shehu, and A. Kasarawa, *Morphological Characterization of Mycotoxigenic Fungi Contaminating Groundnut Products in Sokoto State.* International Journal of Research in Pharmacy and Biosciences, 2017. **4**(4): p. 1-7.

[77] Oyedele, O.A., et al., *Mycotoxin risk assessment for consumers of groundnut in domestic markets in Nigeria.* International Journal of Food Microbiology, 2017. **251**: p. 24-32.

[78] Gbolagade, S., et al., *Characterization and detection of aflatoxigenic genes in fungi associated with kulikuli (groundnut cake) from Nigeria.* Lincoln University Journal of Science, 2019. **8**: p. 1-13.

[79] Adetunji, M.C., et al., *Microbiological quality and risk assessment for aflatoxins in groundnuts and roasted cashew nuts meant for human consumption.* Journal of Toxicology, 2018. **2018**.

[80] Ambrose, F., *Studies on Mycotic Contamination of Cashew Nuts (anarcadium occidentale l.) in Abakaliki, Ebonyi State and the Impacts on their Nutritional Qualities.* IDOSR journal of biochemistry, biotechnology and allied fields . 2018. **3**(2): p. 71-77.

[81] Adetunji, M.C., et al., *A polyphasic method for the identification of aflatoxigenic Aspergilla from cashew nuts.* World Journal of Microbiology and Biotechnology, 2019. **35**(1): p. 15.

[82] Sebunya, T.K. and D.M. Yourtee, *Aflatoxigenic Aspergilli in foods and feeds in Uganda.* Journal of Food Quality, 1989. **13**(2): p. 97-107.

[83] Acur, A., et al., *Genetic diversity of aflatoxin-producing Aspergillus flavus isolated from selected groundnut growing agro-ecological zones of Uganda.* BMC microbiology, 2020. **20**(1): p. 1-12.

[84] Njoroge, S., et al., *Identification and toxigenicity of Aspergillus spp. from soils planted to peanuts in Eastern Zambia.* Peanut Science, 2016. **43**(2): p. 148-156.

[85] World Health Organization, *Safety evaluation of certain contaminants in food: prepared by the eighty-third meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA)*. 2018.

[86] Pandey, M.K., et al., *Mitigating aflatoxin contamination in groundnut through a combination of genetic resistance and post-harvest management practices.* Toxins, 2019. **11**(6): p. 315.

[87] Varga, J., et al., *Mycotoxin producers in the Aspergillus genus: an update.* Acta Biologica Szegediensis, 2015. **59**(2): p. 151-167.

[88] Baranyi, N., et al., *Current trends in aflatoxin research. Acta Biologica Szegediensis*, 2013. **57**(2): p. 95-107.

[89] Cary, J., M. Klich, and S. Beltz, *Characterization of aflatoxin-producing fungi outside of Aspergillus section Flavi*. Mycologia, 2005. **97**(2): p. 425-432.

[90] Frisvad, J.C., et al., *Fumonisin and ochratoxin production in industrial Aspergillus niger strains.* PLoS One, 2011. **6**(8): p. e23496.

[91] Schuster, E., et al., *On the safety of Aspergillus niger–a review.* Applied microbiology and biotechnology, 2002. **59**(4-5): p. 426-435.

[92] Akinola, S.A., C.N. Ateba, and M. Mwanza, *Polyphasic Assessment of Aflatoxin Production Potential in Selected Aspergilli*. Toxins, 2019. **11**(12): p. 692.

[93] El-Samawaty, A., et al., *Contamination of cashew nut with myco-toxigenic fungi*. Journal of Pure

and Applied Microbiology, 2013. **8**: p. 3923-3393.

[94] Adeniyi, D. and A. Adedeji, *Evaluation of fungal flora and mycotoxin potential associated with postharvest handlings of Cashew Nut.* Arch Appl Sci Res, 2015. **7**(2): p. 30-33.

[95] Brown, L.R., *Aflatoxins in food and feed: Impacts risks, and management strategies*. Vol. 9. 2018: Intl Food Policy Res Inst.

[96] Ait Mimoune, N., et al., *Aspergillus section Flavi and aflatoxins in dried figs and nuts in Algeria.* Food Additives & Contaminants: Part B, 2018. **11**(2): p. 119-125.

[97] Njumbe Ediage, E., et al., *A validated multianalyte LC–MS/MS method for quantification of 25 mycotoxins in cassava flour, peanut cake and maize samples.* Journal of agricultural and food chemistry, 2011. **59**(10): p. 5173-5180.

[98] Siame, B.A., et al., *Occurrence of aflatoxins, fumonisin B1, and zearalenone in foods and feeds in Botswana.* Journal of Food Protection, 1998. **61**(12): p. 1670-1673.

[99] Njumbe Ediage, E., K. Hell, and S. De Saeger, *A comprehensive study to explore differences in mycotoxin patterns from agro-ecological regions through maize, peanut, and cassava products: A case study, cameroon.* Journal of agricultural and food chemistry, 2014. **62**(20): p. 4789-4797.

[100] Kamika, I. and L.L. Takoy, *Natural occurrence of Aflatoxin B_1 in peanut collected from Kinshasa, Democratic Republic of Congo. Food Control*, 2011. **22**(11): p. 1760-1764.

[101] Kamika, I., et al., *Mycological and aflatoxin contamination of peanuts sold at markets in Kinshasa, Democratic Republic of Congo, and Pretoria, South Africa.* Food Additives & Contaminants: Part B, 2014. **7**(2): p. 120-126.

[102] Abdel-Rahman, G.N., et al., *Identify the natural levels of mycotoxins in Egyptian roasted peanuts and the destructive effect of gamma radiation.* Journal of Microbiology, Biotechnology and Food Sciences, 2019. **2019**: p. 1174-1177.

[103] Chala, A., et al., *Natural occurrence of aflatoxins in groundnut (Arachis hypogaea L.) from eastern Ethiopia.* Food control, 2013. **30**(2): p. 602-605.

[104] Mohammed, A., et al., *Aspergillus and aflatoxin in groundnut (Arachis hypogaea L.) and groundnut cake in Eastern Ethiopia.* Food Additives & Contaminants: Part B, 2016. **9**(4): p. 290-298.

[105] Jallow, E.A., et al., *Assessment of aflatoxin-producing fungi strains and contamination levels of aflatoxin B1 in groundnut, maize, beans and rice.* Journal of Agricultural Science and Food Technology, 2018. **4**(4): p. 71-79.

[106] Sugri, I., et al., *Integrated peanut aflatoxin management for increase income and nutrition in Northern Ghana.* Cogent Food & Agriculture, 2017. **3**(1): p. 1312046.

[107] Mutegi, C., et al., *Prevalence and factors associated with aflatoxin contamination of peanuts from Western Kenya.* International journal of food microbiology, 2009. **130**(1): p. 27-34.

[108] Menza, N.C., M.W. Margaret, and K.M. Lucy, *Incidence, types and levels of aflatoxin in different peanuts varieties produced in Busia and Kisii Central Districts, Kenya.* Open Journal of Medical Microbiology, 2015. **5**(04): p. 209.

[109] Magamba, K., et al., *Aflatoxin risk management in commercial groundnut products in Malawi (Sub-Saharan Africa): a call for a more*

socially responsible industry. Journal of Consumer Protection and Food Safety, 2017. **12**(4): p. 309-316.

[110] Juan, C., et al., *Aflatoxins levels in dried fruits and nuts from Rabat-Salé area, Morocco.* Food Control, 2008. **19**(9): p. 849-853.

[111] Abalaka, J. and J. Elegbede, *Aflatoxin distribution and total microbial counts in an edible oil extracting plant. I. Preliminary observations.* Food and Chemical Toxicology, 1982. **20**(1): p. 43-46.

[112] Akano, D. and O. Atanda, *The present level of aflatoxin in Nigerian groundnut cake ('kulikuli').* Letters in Applied Microbiology, 1990. **10**(4): p. 187-189.

[113] Abalaka, J., *Aflatoxin distribution in edible oil-extracting plants and in poultry feedmills.* Food and chemical toxicology, 1984. **22**(6): p. 461-463.

[114] Bankole, S., B. Ogunsanwo, and D. Eseigbe, *Aflatoxins in Nigerian dry-roasted groundnuts.* Food chemistry, 2005. **89**(4): p. 503-506.

[115] Ubwa, S., et al., *Assessment of total aflatoxins level of two major nuts consumed in Makurdi Benue State, Nigeria.* International Journal of Nutrition and Food Sciences, 2014. **3**(5): p. 397-403.

[116] Elzupir, A.O. and A.S. Alamer, *Quantitative cancer risk of aflatoxin in peanut butter and vegetable oils: Sudan case study.* Toxin Reviews, 2014. **33**(4): p. 202-205.

[117] Bakhiet, S.E.A. and A.A.A. Musa, *Survey and determination of aflatoxin levels in stored peanut in Sudan.* Jordan Journal of Biological Sciences, 2011. **147**(614): p. 1-16.

[118] Idris, Y.M., et al., *Determination of aflatoxin levels in Sudanese edible oils.* Food and Chemical Toxicology, 2010. **48**(8-9): p. 2539-2541.

[119] Younis, Y.M. and K.M. Malik, *TLC and HPLC assays of aflatoxin contamination in Sudanese peanuts and peanut products.* Kuwait J Sci Eng, 2003. **30**(1): p. 79-93.

[120] Ghali, R., et al., *Aflatoxin determination in commonly consumed foods in Tunisia.* Journal of the Science of Food and Agriculture, 2010. **90**(14): p. 2347-2351.

[121] Lopez, A. and M. Crawford, *Aflatoxin content of groundnuts sold for human consumption in Uganda.* The Lancet, 1967. **290**(7530): p. 1351-1354.

[122] Alpert, M., et al., *Association between aflatoxin content of food and hepatoma frequency in Uganda.* Cancer, 1971. **28**(1): p. 253-260.

[123] Njoroge, S.M., et al., *A case for regular aflatoxin monitoring in peanut butter in sub-Saharan Africa: lessons from a 3-year survey in Zambia.* Journal of food protection, 2016. **79**(5): p. 795-800.

[124] Bumbangi, N., et al., *Occurrence and factors associated with aflatoxin contamination of raw peanuts from Lusaka district's markets, Zambia.* Food Control, 2016. **68**: p. 291-296.

[125] Siwela, A.H. and A. Caley, *Aflatoxin Contamination of Stored Groundnuts in Zimbabwe*, in *International proceedings of the International Crops Research Institute Workshop, 6-9 Oct 1987,ICRISAT for the Semi-Arid Tropics)*. 1989: ICRISAT Center, India. Patancheru.

[126] Mupunga, I., et al., *Natural occurrence of aflatoxins in peanuts and peanut butter from Bulawayo, Zimbabwe. Journal of Food Protection*, 2014. **77**(10): p. 1814-1818.

[127] Maringe, D.T., et al., *Natural postharvest aflatoxin occurrence in food*

legumes in the smallholder farming sector of Zimbabwe. Food Additives & Contaminants: Part B, 2017. **10**(1): p. 21-26.

[128] Mupunga, I., P. Mngqawa, and D.R. Katerere, *Peanuts, Aflatoxins and Undernutrition in Children in Sub-Saharan Africa. Nutrients*, 2017. **9**(12): p. 1287.

[129] Lahouar, A., et al., *Incidence, legislations and strategies of control of mycotoxins in North African countries.* International Food Research Journal, 2018, vol. 25, núm. 6, p. 2229-2247, 2018.

[130] Tantaoui-Elaraki, A., et al., *Toxigenic fungi and mycotoxin occurrence and prevention in food and feed in northern Africa–a review.* World Mycotoxin Journal, 2018. **11**(3): p. 385-400.

[131] Siriacha, P. *Minimizing aflatoxin production in grains in the tropics*. in *JIRCAS International Symposium Series (Japan)*. 1999.

[132] Kaaya, A., C. Harris, and W. Eigel, *Peanut aflatoxin levels on farms and in markets of Uganda.* Peanut Science, 2006. **33**(1): p. 68-75.

[133] Siwela, A.H., K.J. Mukaro, and N. Nziramasanga, *Aflatoxin Carryover during Large Scale Peanut Butter Production. Food and Nutrition Sciences*, 2011. **2**: p. 103-108.

[134] Prasad, P.V., V.G. Kakani, and H.D. Upadhyaya, *Growth and production of groundnut.* UNESCO Encyclopedia, 2010: p. 1-26.

[135] Anyasor, G., et al., *Chemical analyses of groundnut (Arachis hypogaea) oil.* Pakistan Journal of Nutrition, 2009. **8**(3): p. 269-272.

[136] Mariod, A.A. and Y.M.A. Idris, *Aflatoxin B1 levels in groundnut and sunflower oils in different Sudanese states.* Food Additives & Contaminants: Part B, 2015. **8**(4): p. 266-270.

[137] Monteiro, F., et al., *Cashew as a high agricultural commodity in West Africa: insights towards sustainable production in Guinea-Bissau.* Sustainability, 2017. **9**(9): p. 1666.

[138] CAST, *Mycotoxins: risks in plant, animal, and human systems*. 2003: Council for Agricultural.

[139] Diao, E., et al., *Factors influencing aflatoxin contamination in before and after harvest peanuts: a review.* Journal of Food Research, 2015. **4**(1): p. 148.

[140] Hassan, Z.U., et al., *Detection of toxigenic mycobiota and mycotoxins in cereal feed market.* Food Control, 2018. **84**: p. 389-394.

[141] Shuaib, F.M., et al., *Reproductive health effects of aflatoxins: a review of the literature.* Reproductive Toxicology, 2010. **29**(3): p. 262-270.

[142] Klich, M.A., *Environmental and developmental factors influencing aflatoxin production by Aspergillus flavus and Aspergillus parasiticus.* Mycoscience, 2007. **48**(2): p. 71-80.

[143] Flores-Flores ME, L.E., de Cerain AL, González-Peñas E. , *Presence of mycotoxins in animal milk: A review.* Food Control, 2015. **53**: p. 163-76.

[144] Völkel, I., E. Schröer-Merker, and C.-P. Czerny, *The carry-over of mycotoxins in products of animal origin with special regard to its implications for the European food safety legislation.* Food and Nutrition Sciences, 2011. **2**(8): p. 852.

[145] Smith, M.-C., et al., *Natural co-occurrence of mycotoxins in foods and feeds and their in vitro combined toxicological effects.* Toxins, 2016. **8**(4): p. 94.

[146] EFSA, *Opinion of the scientific panel on contaminants in the food chain on a*

request from the commission related to aflatoxin B1 as undesirable substance in animal feed. EFSA J, 2004. **39**: p. 1-27.

[147] Humans, I.W.G.O.T.E.O.C.R.T., I.A.F.R.O. Cancer, and W.H. Organization, *Occupational Exposures of Hairdressers and Barbers and Personal Use of Hair Colourants: Some Hair Dyes, Cosmetic Colourants, Industrial Dyestuffs and Aromatic Amines*. Vol. 57. 1993: World Health Organization.

[148] Rodrigues, P., et al., *A polyphasic approach to the identification of aflatoxigenic and non-aflatoxigenic strains of Aspergillus section Flavi isolated from Portuguese almonds.* International journal of food microbiology, 2009. **129**(2): p. 187-193.

[149] Marin, S., et al., *Mycotoxins: Occurrence, toxicology, and exposure assessment.* Food and chemical toxicology, 2013. **60**: p. 218-237.

[150] Akinola, S.A., *Interaction of Salmonella Typhimurium and Aspergillus spp in gut of host*, in *Department of Microbiology*. 2020, North West University, South Africa. p. 1-477.

[151] Wogan, G.N., *Chemical nature and biological effects of the aflatoxins.* Bacteriological reviews, 1966. **30**(2): p. 460.

[152] D'Mello, J.P. and A.M. Macdonald, *Mycotoxins A.* Feed Sci. Technol. , 1997. **69**: p. 155-166.

[153] Bryden, W.L., *Mycotoxins in the food chain: human health implications.* Asia Pacific journal of clinical nutrition, 2007. **16**(S1): p. 95-101.

[154] Shephard, G.S., *Impact of mycotoxins on human health in developing countries.* Food Additives and contaminants, 2008. **25**(2): p. 146-151.

[155] Wild, C.P. and Y.Y. Gong, *Mycotoxins and human disease: a largely ignored global health issue.* Carcinogenesis, 2010. **31**(1): p. 71-82.

[156] Ibeh, I., N. Uraih, and J. Ogonar, *Dietary exposure to aflatoxin in human male infertility in Benin City, Nigeria.* International journal of fertility and menopausal studies, 1994. **39**(4): p. 208-214.

[157] Turner, P.C., et al., *Aflatoxin exposure in utero causes growth faltering in Gambian infants.* International journal of epidemiology, 2007. **36**(5): p. 1119-1125.

[158] Sadeghi, N., et al., *Incidence of aflatoxin M1 in human breast milk in Tehran, Iran.* Food control, 2009. **20**(1): p. 75-78.

[159] Abdulrazzaq, Y.M., et al., *Aflatoxin M1 in breast-milk of UAE women.* Annals of tropical paediatrics, 2003. **23**(3): p. 173-179.

[160] Abulu, E., et al., *Preliminary investigation on aflatoxin in cord blood of jaundiced neonates.* West African Journal of Medicine, 1998. **17**(3): p. 184-187.

[161] Abdulrazzaq, Y.M., N. Osman, and A. Ibrahim, *Fetal exposure to aflatoxins in the United Arab Emirates.* Annals of tropical paediatrics, 2002. **22**(1): p. 3-9.

[162] Abdulrazzaq, Y.M., et al., *Morbidity in neonates of mothers who have ingested aflatoxins.* Annals of Tropical Paediatrics, 2004. **24**(2): p. 145-151.

[163] Van Egmond, H. and M. Jonker, *Worldwide regulations for mycotoxins in food and feed in 2003.* Food Agric Organiz United Nations, 2004.

[164] Van Egmond, H.P. and M.A. Jonker, *Worldwide regulations on aflatoxins—The situation in 2002.* Journal of Toxicology: Toxin Reviews, 2004. **23**(2-3): p. 273-293.

[165] Sowley, E.N.K., *Aflatoxins: A silent threat in developing countries.* African Journal of Biotechnology, 2016. **15**(35): p. 1864-1870.

[166] Anukul, N., K. Vangnai, and W. Mahakarnchanakul, *Significance of regulation limits in mycotoxin contamination in Asia and risk management programs at the national level.* Journal of Food and Drug Analysis, 2013. **21**(3): p. 227-241.