



Aflatoxin contamination in cereals and legumes to reconsider usage as complementary food ingredients for Ghanaian infants: A review

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ABSTRACT

Cereals and legumes, being the major staples of many African communities, frequently used for complementary foods for infants and young children. However, aflatoxin contamination is a threatening issue in these staples and its negative effects on human health, most especially infants and young children, are very alarming. Thus, this review sought to highlight the risk of aflatoxin contamination in cereals and legumes so as to reconsider their usage in complementary feeding. Factors such as temperature, relative humidity/moisture, soil properties, type and length of storage as well as nutrient composition of the food produce greatly influence fungal growth and aflatoxin production in cereals and legumes. Consumption of such contaminated food ingredients could expose many infants and young children to poor growth and development. Nonetheless, the toxin, though seemingly inevitable, can be minimized if not curbed completely through awareness creation/education, good agricultural practices and proper storage practices. Moreover, consumption of root and tuber crops such as sweetpotato, especially the orange-fleshed sweetpotato, can be a sustainable approach to reduce aflatoxin ingestion in children. Thus, to control the adverse effects of aflatoxin in infants and young children, cereal-legume blends could be substituted with root and tuber-based blends in complementary feeding.

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1. Background

Healthy growth and development in infants or young children

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has been the desired goal of many worldwide, mostly mothers [1]. Infant and young child health is worth more attention especially on the African continent where growth impairment is a big issue [1,2]. Growth impairment has rendered many African children physically and mentally defective while many others have lost their lives as result of it [1,3]. This growth problem in infant and young children in Africa, is largely as a result of exposure to mycotoxin contaminated foods at very tender ages through complementary feeding [1,2].

Cereals and legumes, though widely and frequently consumed in Africa and beyond due to their nutritional complementary value and potential to reduce malnutrition, have not been spared of mycotoxin contamination [4,5]. Cereals such as maize, rice, millet and wheat among others are staple foods for many localities globally [2,4]. Legumes such as groundnut (peanut) and beans have also gained frequent use in many African diets to complement cereal diets [6]. Cereals and legumes are by far the main ingredients for complementary foods in Ghana and Africa at large [2,4,7,8]. These food commodities, however, are very susceptible to mycotoxin contamination, mostly aflatoxin contamination, at different stages of the agricultural chain such as pre-harvest, harvest, and post-harvest handling [1,9,10]. Thus, cereals and legumes amply expose humans to ingestion of harmful naturally-produced toxicants, example, microbial toxins, through diet if not handled appropriately during cultivation and storage [4].

Microbial toxins are toxic secondary metabolites produced by fungal species. *Aspergillus species* produce aflatoxins (AF) and ochratoxin A (OTA); *Penicillium species*, also produce ochratoxin A (OTA); and *Fusarium species*, produce deoxynivalenol (DON), zearalenone (ZEA), fumonisins (FB), HT-2 and T-2 [1,10,11]. Unfortunately, their effect on health is seriously unnoticed in developing countries including Ghana [12,13]. Factors such as high temperature, relative humidity, poor storage conditions, and pest damage have made mycotoxin contamination a major challenge in tropical and sub-tropical areas as the organisms thrive well in such conditions [5,10,12,14].

There is thus a need to regularly track the changes that occur in food, especially the most consumed foods, like cereals and legumes, to allow for rapid interventions to prevent or minimize related health issues. Thus, this present work seeks to highlight the risk of aflatoxin contamination in cereals and legumes so as to reconsider their usage most especially in complementary feeding.

2. Factors promoting fungal growth and aflatoxin production

Aflatoxin contamination is becoming more or less inevitable in food commodities because of the promoting factors that are involved in its production [15,16]. These factors could be extrinsic: temperature; relative humidity; soil properties; mechanic injury on food commodity; insects and rodents attack; or intrinsic (pH, nutrient composition, moisture content/water activity) [16,17]. These factors, however, do not work in isolation [16]. Therefore, two or more factors may have to be met before fungal growth and corresponding toxin production can be effected.

2.1. Temperature

It has been reported that whether there is high or low temperature, fungal growth and its resultant mycotoxin production are inevitable [16]. Atanda et al. [16] observed that temperatures below 20 °C favored *Penicillium* and *Cladosporium* whereas above 20 °C enhanced growth of *Aspergillus* species. The researchers also reported that food products such as cereals and legumes were more prone to *Aspergillus species* than any other toxin-producing fungi, more so at storage due to the temperatures involved [16].

However, fungal activity and toxin production have been reported elsewhere to be optimum at 25–37 °C [15,18–20] in the presence of other favoring conditions. This range of temperature is the ambient temperature in Ghana [18]. Abdel-Hadi et al. [20] reported maximum *Aspergillus* growth rate of 6.9 mm/day at 35 °C and maximum aflatoxin production rate of 2278–3082 µg/g at 37 °C in maize. Nonetheless, the effect of temperature and that of moisture are inseparable [21].

2.2. Moisture content

Water content is an important factor that affects both the grade and storability of grains and legumes as it significantly influences microbial growth and toxin production [21]. It is thus, a key determinant of aflatoxin development in food crops. Storage fungi like *Aspergillus* require about 13% moisture or relative humidity of 65% (water activity, a_w , of 0.65) for growth and toxin production [16]. However, 77% or above is optimum for growth and proliferation [19,21].

Abdel-Hadi et al. [22] observed a maximum growth of *Aspergillus flavus* at 0.95 a_w with maximum aflatoxin production at 0.90 a_w and 0.95 a_w after three weeks of storage when investigating the effect of water activity on both *A. flavus* and aflatoxin (AFB₁) production in peanuts at 25 °C. The researchers [22] realized a significant ($P = 0.000$) positive correlation between *A. flavus* population and aflatoxin production, *A. flavus* population and water activity, and aflatoxin production and water activity with respective correlation coefficients of 0.849, 0.75 and 0.68. Water activity is however shown to increase with storage time [4]; this, coupled with improper drying predisposes stored cereals and legumes to fungal infestation, growth and aflatoxin development.

With maturity and harvest of food crops at the end of the raining season, the risk of *A. flavus* and metabolites accumulation could be high in Ghana. Traditional drying techniques involve field- and bare ground-drying; and this immensely contributes to fungal contamination [21]. These techniques are labour-intensive and time-consuming, involving lots of crop handling that may not adequately accomplish efficient drying. This issue is sometimes compounded by continuous downpour during harvesting and drying, and makes it difficult to attain the recommended moisture level for safe storage [21].

2.3. Effect of soil properties on aflatoxin contamination in food

Soil is another factor that has a key influence on fungal contamination in agricultural produce [23]. Thus, crops cultivated in different soil types may have significantly varying levels of aflatoxin prevalence. According to Codex Alimentarius Commission [24], light sandy soils accelerate growth of the fungi in peanuts, particularly under dry conditions, whereas heavier soils result in less contamination owing to their high water retention capacity that helps in the reduction of drought stress. Though Ghana is made of different soil types such as sandy, loamy and clayey, the specific type of soil of a particular area may depend on the part of the country it is located. The northern part of the country has mainly sandy and sandy loamy soils while the southern part is made of soil types ranging from clayey loamy to dark loamy [25–27]. However, most of the soils of Ghana where cereals and legumes such as maize, millet, groundnuts, bambara beans, and beans are grown range from light sandy to sandy loamy [25,26]. This could partly be the reason for the high aflatoxin contamination in some of these crops. Fuseini [28] also reported that light sandy soils promote the rapid proliferation of *Aspergillus flavus* especially in adverse dry conditions.

Soil moisture stress has also been observed to have a great

influence on pre-harvest aflatoxin contamination of produce [21]. This was supported by findings of more *A. flavus* infected kernels when groundnuts were exposed to drought stress in the field as compared to that in irrigated plots [21]. It was explained that excessive drought causes strains on pods and seed coats that serve as entry points for fungi while excessive moisture weakens the pods and seed coats causing a similar effect. Droughts are common in Ghana, especially in the northern part of the country, where rainfall is between May and September while the remaining part of the year forms the dry season [26]. This long period of no rain may exert drought stress on legumes such as groundnuts and bambara beans, which most often are harvested within the periods of little or no rainfall, causing strains on their pods and seed coats which may serve as access points to fungi. However, those leguminous crops which sometimes happen to be harvested within the period of severe rains may face pod and seed coat weakening as a result of excessive moisture. This could as well make the seeds highly susceptible to fungal infestation [21].

2.4. Impact of nutrient composition of food on aflatoxin contamination

Regardless of the fact that moulds have the genetic potential to produce a particular mycotoxin, the level and rate of production would partly be influenced by available nutrients [23]. As such, different food substrates may have different effects on aflatoxin production due to difference in nutrient content [16,29].

Findings on effect of nutrients in substrates (corn, wheat, peanut, soybean, corn germ and corn endosperm) on aflatoxin B₁ production showed a slight *A. flavus* contamination and a relatively low levels of AFB₁ in defatted substrates [29]. However, AFB₁ levels sharply increased with the addition of corn oil. The levels of AFB₁ in full-fat substrates were also higher than in the defatted substrates. Therefore processing complementary foods from full-fat cereals and legumes may increase the potential of aflatoxin contamination. A survey conducted in Ghana showed that cereal-legume blends containing maize and groundnuts had high levels of total aflatoxin contamination with some samples having values above 500 ppb [30].

Liu et al. [29] also revealed that low concentrations of soluble sugars (stachyose, raffinose, sucrose, fructose, maltose, and glucose) could not enhance AFB₁ production. However, when the soluble sugar concentration reached 3.0% and 6.0%, AFB₁ production was significantly enhanced [29]. Also, it was reported specifically that at a concentration of 3.0% for each of the sugars, sucrose markedly influenced AFB₁ production (39782.61 ng/30 mL), followed by maltose (23687.29 ng/30 mL), and fructose with the least effect [29].

However, the enhancing effects of sucrose (4471.97 ng/30 mL), raffinose (5.50 ng/30 mL), and stachyose (120.61 ng/30 mL) decreased at a concentration of 6.0%. Meanwhile at 6.0% concentration, maltose recorded the highest aflatoxin production of 74848.68 ng/30 mL, in the study, followed by glucose (35860.57 ng/30 mL). Among the six soluble sugars, raffinose exhibited the weakest enhancement.

In contrast, increasing amino acid concentration generally decreased aflatoxin production [29]. Nevertheless, 0.5% concentration of glutamic acid, aspartic acid and glycine and all concentrations of arginine significantly promoted AFB₁ production [29].

With regard to effect of trace elements (copper, iron, zinc and manganese) on the AFB₁ production, it was observed that only zinc had a significant positive impact on AFB₁ synthesis: as the zinc concentration increased, AFB₁ production correspondingly increased [29]. Specifically, at 20, 50, and 100 mg/L concentrations of zinc, the contents of AFB₁ respectively increased by 4-, 5-, and

19-fold. Contrarily, the other three trace elements markedly inhibited AFB₁ production at all concentrations examined.

Results from the aforementioned work clearly show that there is a close relationship between oil content and aflatoxin production and that sucrose, maltose, glucose, arginine, aspartic acid, glutamic acid as well as zinc contents of food may predispose it to aflatoxin contamination. Thus, the levels of aflatoxin prevalence in cereals and legumes could partly be attributed to the varying contents of the nutrients mentioned above since these grains have relatively high concentrations of these nutrients [29].

A lot of food products made from cereals and legumes are available in the Ghanaian community. Some of these food products include *kenkey* (made from maize), *banku* (made from maize) and *Tuo Zaafi* (TZ) (made from maize or millet) that could be eaten with groundnut soup [31]. For the “kenkey” and *banku*, the maize is soaked in water for at least 24 h and wet-milled into dough [32]. The dough is then fermented for 48 h and then used to prepare the kenkey or banku. Unfermented maize or millet flour is used to prepare TZ. These foods are eaten across the various age groups.

Other local products such as *koko* (porridge made usually from millet or maize flour), *koose* (fried bean cake), *maasa* (fried millet or maize cake), *kulikuli* (fried groundnut cake prepared from groundnut paste) and *tubaani* (steamed cowpea or bambara beans pudding) [33,34]. *Koko* is taken with *koose*, *maasa*, *kulikuli* or bread as accompaniments. Infants and young children are particularly fed with *koko* more often because of their inability to take solid foods. “Tom brown” (prepared from a blend of groundnuts, maize and soybeans), rice mix (prepared from a blend of rice, soybeans and groundnuts), weannimix (made from blends of maize, millet, wheat, groundnuts and soybeans), *ceresoya* (made from soybeans, wheat and milk), and wheat mix (made from wheat, groundnuts and soybeans) among others have also been developed indigenously as infant foods [35]. A review published earlier indicates that cereals and legumes are the major ingredients used in complementary food formulation [36].

2.5. Effect of storage on fungal infestation and aflatoxin production

Very paramount among postharvest operations are method and length of storage [21,37]. The quality of stored foods markedly depends on the storage conditions they have been subjected to [4]. However, methods and duration of storage of food commodities seem to differ from one agro-ecological area or ethnic group to another [38]. Cost and availability of storage units largely dictate the method of storage patronized by a particular group of people [37].

Most of the storage structures commonly used by farmers in Africa are traditional and may not: provide the right internal atmosphere; give maximum protection from water, insects and rodents; and be easy to clean [21]. Storage can be done on the farm for produce like legumes and cereals right after harvest, most especially when transport and storage structures are not ready; or in rooms or courtyards, often in heaps [38]. All these conditions promote growth of fungi and aflatoxin production in stored legumes and cereals.

A study conducted in four different locations in Benin on the influence of storage practices on aflatoxin contamination in maize showed that farmers stored their produce in structures such as giant woven baskets made from raffia palms, tree branches or bamboo, or on platforms of about 30 cm above the ground or 80 cm when placed over kitchen fire, bags, clay stores and roof tops [38]. However, for the six months period of storage [38] (regardless of the storage type), there was severe insects and rats' invasion as well as increased aflatoxin contamination with a range of 2.2–5.8% (at the beginning of the storage) to 7.5–24% (at the end of the storage)

period) of the samples recording as high as above 100 ppb. The increased aflatoxin concentration could be attributed to microbial infestation stemming from the invasion of insects and rodents during storage due to the general deplorable nature of the storage facilities used.

Another study conducted in the Northern Region of Ghana showed that drying groundnuts on clean tarpaulins could reduce aflatoxin levels to about 50% compared to drying on bare ground [39].

In Ghana, it was confirmed that length of storage actually predisposes food commodities to aflatoxin contamination as all long-stored samples of groundnuts registered aflatoxin levels above 88.0 ppb [40]. Makun and co-workers [23] explained that mechanical injury caused by pests during storage destroys the seed coat of grains and accelerates fungal inoculum penetration to interior parts of the grains. The researchers added that not only do storage pests cause physical damage to grains and other food commodities, they also inoculate the already infected food with spores transmitted from other sources, thus aggravating the contamination [23]. Mechanical damage caused during harvesting and shelling of groundnuts also makes them susceptible to *Aspergillus species* invasion both on the field and during storage [21].

3. Aflatoxin levels in cereals and legumes and their products

Cereals and legumes, though widely cultivated and consumed in Africa, are known to be highly sensitive to aflatoxin contamination. A study conducted in Kenya showed that 60% of total household maize samples (269) across the study tested positive for aflatoxin with a range of 0.17–5.3 ppb while all 39 millet samples recorded aflatoxin levels ranging from 0.14 to 6.4 ppb, none of which exceeded the country's regulatory limit of 10 ppb [41]. On the contrary, sorghum samples recorded aflatoxin levels ranging from 0.15 to 210.1 ppb (overall mean of 26.0 ppb), out of which the Kilibwoni sub-location registered the highest percentage (46%) of samples exceeding the maximum tolerable limit of 10 ppb, suggesting possible variation in aflatoxin prevalence with geographical location [41]. Magembe et al. [42] also found that aflatoxin levels in groundnut ranged from 72.97 to 195.17 µg/kg. Makun et al. [43] also recorded 63.5–106.2 µg/kg of AFB1 in 29 out of the 50 bean samples analyzed and 102.9–198.4 µg/kg AFB1 in 27 out of 50 marketed wheat samples.

Aflatoxin contamination in maize grains from a total of 38 major store markets in Benin, Ghana and Togo was monitored and the results showed that aflatoxin concentration in contaminated samples ranged from 24 to 117.5 ng/g in Benin, from 0.4 to 490.6 ng/g in Ghana, and from 0.7 to 108.8 ng/g in Togo [44]. A study also conducted in three districts in Ghana, namely Ejura-Sekyedumase, North-Kwahu and Nkoranza, showed aflatoxin contamination levels in maize ranging from 12 to 30 ppb. Sugri et al. [37] reported aflatoxin prevalence range of 0.011–308 ppb in maize samples (240) in six districts in the Upper East and Upper West regions of Ghana.

Besides, an earlier study in Ghana [40] showed that locally produced groundnut products such as *nkati* cake, *dakwa*, pounded raw groundnut, butter and *kulikuli* all recorded aflatoxin contents above the EU limit for processed food products, 4 ppb. Amongst these products, the butter and *kulikuli* registered relatively higher levels of aflatoxin, 42.49 ppb and 76.91 ppb, respectively. Aside these, it was also observed very high levels of aflatoxin in cereal-legume blends with a range of 104 ppb–296 ppb. Another study also in Ghana conducted on cereal-legume blends showed similar copious contamination with aflatoxin [45].

Additionally, Kpodo [46] also observed that all maize samples taken from silos and warehouses in Ghana contained 20 µg/kg to

355 µg/kg levels of aflatoxin while 31 out of 32 fermented maize dough samples taken from key processing areas across the nation also were contaminated with up to 310 µg/kg of the toxin. Furthermore, 15 maize samples taken from major processing sites in the capital of Ghana, Accra, were analyzed and reported to contain aflatoxin levels ranging from 2 to 662 µg/kg [47]. Awuah and Kpodo [48] also reported an average aflatoxin contamination level of 3276 µg/kg in market groundnut samples in Ghana. In the Ejura-Sekyedumase district of Ghana, a range of 7.9–500 ppb aflatoxin was detected in 36 food samples locally prepared as infant foods from a proportional blend of groundnut, beans and maize [49]. Out of this, 30 (83%) of the samples exceeded the 20 ppb limit for aflatoxin.

All these findings clearly show that cereals and legumes as ingredients are highly prone to aflatoxin contamination. Consumption of these contaminated foods thus undoubtedly remains a reality in the Ghanaian community since some of the highly susceptible food crops such as maize and groundnut are consumed across the nation daily by infants and young children.

4. Aflatoxin exposure and consequences during infancy and early childhood

Aflatoxin contamination does not only affect crops, but also humans as contaminated crops are consumed by humans. Aflatoxin exposure in humans, though more prevalent in children and pregnant women, cuts across all gender and age groups [7,13,50,51]. Gong and co-workers [52], in a study conducted in Benin and Togo, reported that 99% (475 out of 479) of old infants and young children (9 months–5 years) were exposed to aflatoxin, and aflatoxin-albumin (AF-alb) concentration increased with age during early childhood as a result of introduction of complementary foods. A geometric mean of 32.8 pg/mg aflatoxin exposure while 95% of the children had exposure levels ranging from 25.3 to 42.5 pg [52]. It was found, in this study, that the exposure level increased with age up to 3 years, with the levels recorded within the 1–3-year age group significantly ($P = 0.0001$) correlating with weaning status: weaned children had about twice higher mean exposure levels (38 pg/mg) than those fed with a mixture of breast milk and solid foods. A positive correlation was also observed between the frequency of consumption of maize and aflatoxin exposure levels [52].

Subsequent studies in Benin, Kenya and Tanzania had similar findings among young children using maize-based porridges for complementary feeding [50,52–54]. Aflatoxin exposure was reported to have reached 100% with levels at 40.4 pg/mg, and with 5.4% recording levels above 200 pg/mg in a study conducted in nine countries in Africa [1]. The study also showed that aflatoxin was present in umbilical cords indicating that this microbial contaminant crosses the placenta. Additionally, maternal exposure were also reported to positively correlate with breast milk aflatoxin concentration [1].

Aflatoxin, depending on the level of exposure, contributes to low birth weight [1,18], growth impairment [9,54], immune-suppression as well as mental retardation in children by inducing changes in insulin-like growth protein factor and inhibiting mineral bioavailability [3,53,55]. Lombard [1] observed that infants who were affected by the toxin through maternal exposure had low height-for-age and low weight-for-age scores. It was disclosed in this study that infants and young children who had the toxin's exposure greater than the provisional maximum tolerable daily limit were noticeably shorter and lighter. It also causes various kinds of cancer and resultant deaths depending on the type, period and amount of exposure [9].

A current review has also shown that aflatoxin exposure has the potential of contributing to infertility in male humans [56]. The

aflatoxin exposure in humans and its health repercussions however cannot conclusively be attributed to only the consumption of affected cereals and legumes as other foods, if affected, may pose similar effects when consumed.

Another study conducted in Ghana to determine aflatoxin in human breast milk as well as the human placental membrane showed that 34% ($n = 90$) of 264 milk samples contained aflatoxin (AFM2) with a concentration of 16 ng/l–2075 ng/l [57]. It was also reported that 34% ($n = 63$) of the umbilical cord blood specimens had aflatoxin (AFB1) concentration of 185 ng/l–43,822 ng/l [57]. A cross-sectional study conducted among 785 pregnant women in Kumasi in Ghana revealed aflatoxin B1-lysine adduct (AF-ALB) levels range of 0.44 pg/mg to 268.73 pg/mg albumin in the women [19]. Aflatoxin (AFB1) levels ranging from 0.12 to 2.995 pmol/mg albumin were reported among 140 participants in the Ashanti region of Ghana [58].

In another study conducted by Shuiab et al. [53] to determine the association between aflatoxin and anaemia in pregnant women in Ghana found a 0.44–268.73 pg/mg range of the toxin that was observed to have a very strong positive association with anaemia. A range of 24.7–8368.9 pg/mg creatinine of AFM1 was detected in urine samples taken from twenty-eight (28) children in the Ejura-Sekyedumase district of Ghana [49].

5. Socio-economic determinants of aflatoxin levels in humans

Aflatoxin prevalence in humans is largely due to difference in socio-economic or demographic factors such as level of education, employment/income status, family size, age group, ethnic group and residential location [19,59,60]. Some people consume aflatoxin-contaminated food because they perhaps have no knowledge about the adverse effect of aflatoxin on health [61].

A study carried out in India reported that about 74% of farmers (180) interviewed were not aware of aflatoxin [61]. The study also showed that 55% of the farmers interviewed believed that even if there was aflatoxin, it had no negative effect on the quality of food. Similarly, an interview with 2416 respondents revealed poor baseline knowledge of the toxin and its related health problems [44]. In Tanzania, it was also noted that 97% of respondents (72) were not aware of mould infection in stored produce such as cereals and groundnut [42]. These suggest that agricultural produce bought from farmers of such caliber may, to a large extent, most likely be contaminated with aflatoxin. Such farmers and their families may face a greater risk of aflatoxin exposure since they consume mostly what they themselves produce. These statistics are an indication that knowledge on the toxin and its repercussions has not been far spread.

Income status is another factor that markedly affect aflatoxin exposure in humans: low-income earners, would patronize cheaply-sold foods that most often, are the contaminated ones resulting in high prevalence of the toxin in them than their well-to-do counterparts [19,56]. Amongst the less costly but widely consumed foods in Africa are maize and groundnuts that are known to be highly prone to mycotoxin contamination [2,4,7,8]. Most farmers, in dire need of money, turn to consume the defective produce while the more quality ones are sold [56].

Ethnicity, though not very significant, is another determinant of aflatoxin level in humans as some ethnic groups are associated with the routine consumption of certain foods like maize that may predispose them to aflatoxin prevalence [56,59].

6. Possible ways of reducing aflatoxin exposure

Though challenging, aflatoxin occurrence in foods can be

reduced if not completely eradicated [56]. Certain strategies have been proven effective in the fight against the canker and have thus been recommended. Very key amongst them is public awareness campaign [44,62]. Creating public awareness on the toxin, its health risks and control methods might help minimize its prevalence while extending scientific findings to the wider public for tremendous national and personal development [44,59].

Educating food dealers as well as the general public in a language they can easily comprehend using appropriate features and food materials would enhance easy dissemination of the information [44,62]. This awareness creation would be more effective and the information well taken if agricultural, research, and medical professionals who have adequate knowledge about the toxin are collaboratively and actively involved [62].

Additionally, management practices such as timely planting, drought stress control, weed and pest control, early harvesting, good sanitation, proper cleaning and sorting of agricultural produce should be greatly encouraged [9,14]. These practices would help eliminate or reduce to the lowest degree conditions and factors that promote fungal infestation and aflatoxin infection.

Crop rotation also helps to reduce aflatoxin prevalence in crops by breaking the cycles and build-ups of toxin-producing microorganisms, and thus could be employed [24]. Furthermore, cultivation of resistant varieties would help control the spread of the toxin. This is particularly possible when aflatoxin inhibitory compounds are identified and used in the breeding of new cereal and leguminous varieties [14]. Knowledge of resistant varieties should also be sought from plant breeders before cultivation [24].

Quick and proper drying of cereals and legumes soon after harvest to moisture level of about 10% may help limit *Aspergillus flavus* proliferation and toxin production [14,16]. Besides, storage conditions such as temperature and relative humidity should be well controlled to minimize fungal activity and aflatoxin development in cereals and legumes [14]. This calls for investment for building appropriate storage structures to control temperature and relative humidity to ensure effective drying of food crops. As mentioned earlier, traditional drying techniques involving field and bare ground drying immensely contribute to fungal contamination [21].

The role of food regulatory bodies cannot be neglected as far as controlling aflatoxin contamination in agricultural produce is concerned [63]. These regulatory bodies must ensure that food commodities on the market with aflatoxin contamination above the maximum allowable limits are brought to book without any compromise of set standards. This can be realized through routine inspection of aflatoxin levels in foods on the market and those stored by farmers, along with timely availability of data [56]. Such data may help to ensure that rapid and appropriate measures are taken to prevent the occurrence aflatoxin-related problems and may also serve as a tool for checking contamination levels over time. This, in turn, will aid in assessing control efforts and development of climate-based models to enhance better prediction of aflatoxin levels ahead of time.

More favorably, researchers and food professionals should work around the clock to come out with better ways of utilizing aflatoxin contaminated food produce, so that the effort of the farmer and food vendors does not go waste. Aflatoxin-contaminated food produce such as groundnuts could be processed into oil for human consumption or addition of food grade aflatoxin binders to defective foods [56]. However, reducing the frequency and quantity of consumption of aflatoxin-prone food products such as maize and groundnut products may most effectively help control its prevalence in humans.

Cereals and legumes such as millet, rice, guinea corn, beans, bambara beans and soybean which are relatively less susceptible to

the toxin as compared to maize and groundnut could reasonably be consumed while the frequency of consuming maize and groundnut seriously revised to reduce, to a bearable level, exposure to the toxin [64,65]. For complementary feeding, alternative food crops such as root and tuber food crops should be encouraged. Example, is the proposed complementary food blend based on orange-fleshed sweetpotato [66]. The elimination of maize and groundnut in sweetpotato-based recipes may lead to reduction in the dietary intake of aflatoxin by infants and young children in developing countries. Sweetpotato-based complementary food as a better alternative baby food has been discussed elsewhere [67–69]. However, due to the poor shelf life of the storage root of orange-fleshed sweetpotato cultivars, efforts should be intensified to ensure all-year supply.

7. Conclusion

Aflatoxin prevalence is becoming increasingly inevitable due to the inability to absolutely control factors that enhance the growth of the *Aspergillus species*. Aflatoxin contamination in cereals and legumes cannot be overlooked as far as the African community is concerned since these are the staples of many localities in the continent, of which Ghana is not exempted. However, with appropriate measures such as awareness creation and proper management practices, the prevalence of the toxin can be minimized, if not eradicated. Finding alternative food crops less prone to mycotoxin contamination, such as root and tuber crops, due to how they are used in culinary preparation should be harnessed for complementary feeding for infants and young children.

Conflict of interest

The authors declare no conflict of interest.

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