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

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A B S T R A C T

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 *Cladosporiwn* 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 ($AFB_1$) 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