International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 18, No. 6, p. 204-216, 2021

INNSPUB

RESEARCH PAPER OPEN ACCESS

Monotonous Cereal-based Complementary Feeding Contribute to Aflatoxin Exposure in Children

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Key words: Complementary feeding, Dietary diversity, Dietary-aflatoxins exposure.

http://dx.doi.org/10.12692/ijb/18.6.204-216 Article published on June 29, 2021

Abstract

This study assessed the diversity of food used in complementary feeding, their risk to aflatoxins (AF) contamination and subsequent children's exposure. A total of 290 children aged between 6-24 months from ten villages in Singida District, Tanzania was studied. Their mothers were interviewed on infant feeding practices and handling of food crops using a structured questionnaire, weight of index child was taken and up to 3 cereals-based food samples used in complementary feeding were collected in a subsample of 180 households to make a total of 218 samples. Food samples were analyzed for aflatoxins using High-Performance Liquid Chromatography (HPLC). The results indicated that the majority of children were monotonously feeding on thin and thick porridge made from maize (78.3%), sorghum (12.7%) or millet (9.0%) flour, and sometimes sorghum-based fermented drink (14.5) locally known as *Magai*. Aflatoxin B1 (AFB1) was detected in 80 (36.7%) flour and drink samples with the levels ranging from 0.33 to 23.75 µg/kg whereas, total aflatoxins were detected in 185 (84.9%) samples with the range from 0.47 to 289.28 µg/kg**.** *Magai* drink and maize flour were the leading complementary food materials responsible for the high aflatoxin exposure to AFB1 in children with the mean exposure of 133.3 and 111.7 ng/kg body weight per day respectively. These findings highlighted a need for integrated nutrition interventions to the entire population with the inclusion of strategies for improving dietary diversity and mitigating mycotoxins contamination of staple food crops thereby reducing exposure among infants and the general population.

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Introduction

Low dietary diversity in complementary feeding is still of public health concern to children below the age of five years, whereby it stands as contributing factor to undernutrition. Child undernutrition is mainly caused by the deficiency in macro-nutrients and micro-nutrients where dietary diversification has not been realized. In Tanzania, the majority (90%) of the rural population depends on agriculture and their diet is full of cereal-based staple food (Anitha *et al.*, 2020). In the central part of the country, maize seems to be the major ingredient in porridge, a common complementary food that is fed to children with little or no vegetables or proteins rich products included in daily meals (Muhimbula and Issa-Zacharia, 2010).

A study conducted in rural Tanzania reported that infants' consumption of maize was relatively high at 43 g/day, as a single staple with limited diversification (Kimanya *et al.* 2009). Although there are some production and availability of diverse nutrient-dense crops in central Tanzania such as groundnut, pigeon pea, cowpea, bambara nuts and pearl millet, their inclusion in complementary foods remains low on average as maize forms the major proportion of complementary food (Kimanya *et al.*, 2009). Not only that but also products from small animals raised by these societies such as eggs are sold out for money to sort out other essential needs like maize milling costs, buying cooking oil, salt and exercise books for school children. In general, rural households produce nutrient-dense crops in relatively low quantities as compared to staple cereals. These earlier case crops are sold out benefiting affluent urban consumers and distant markets leaving the local-undernourished communities to rely on staple cereals (Anitha *et al.*, 2020). This limited inclusion of nutritious food crops in diets leads to high reliance on monotonous staple cereals for both family and complementary feeding. Of a critical disadvantage, cereals in the tropical region are prone to fungal contamination due to favorable climate, inadequate pre-and post-harvest technologies, and may result in mycotoxins contamination and ultimately human exposure to unacceptable levels (Ezekiel *et al.*, 2018).

Mycotoxins are toxic secondary metabolites produced by organisms of the fungus kingdom. Of a wide range of mycotoxins known, Aflatoxins rank the first in the list of mycotoxins of public health concern, and are produced by *Aspergillus flavus* and *Aspergillus parasiticus* which contaminate cereal crops (Gong *et al.*, 2016). Cereal and legume crops are usually highly susceptible to these contaminants due to the hot and humid climate as well as poor field management and storage practices (Wild and Gong, 2009). There are four types of aflatoxins namely; aflatoxin B1 (AFB1), aflatoxin B2 (AFB2), aflatoxin G1 (AFG1) and aflatoxin G2 (AFG2) which are commonly found in cereal-based foods and feeds (Gong *et al.*, 2016). Of the four types, aflatoxin B1 is the most toxic and identified as carcinogenic by the International Agency for Research on Cancer (IARC) (Loprieno, 1975). Although national and international regulatory bodies have set maximum tolerable limits for these toxins in trade and baby foods (Brown *et al.*, 1999; Gong *et al.*, 2016) aiming at consumers protection, it has been a challenge for developing countries to meet these standards due to poor strategies and policies on management practices as well as lack of technological resources for constant monitoring (Strosnider *et al.*, 2006). In addition, subsistence and rain-fed agriculture practiced by populations living in rural particularly semi-arid areas with a high risk of food insecurity (Kulwa *et al.*, 2015), are known to contribute to high levels of aflatoxin exposure (Gong *et al.*, 2016). This long-term residential-related exposure leads to chronic exposure to more than 5 billion people (including children) worldwide particularly in developing countries through an accumulation of toxins from contaminated cereal-based foods that are frequently consumed as the main staple and weaning foods (Wu, 2014). Aflatoxins exposure in children can be critical compared to adults due to their small body size (Magoha *et al.*, 2016) and monotonous complementary food mainly composed of cereals with maize constituting the largest portion (Shirima *et al.*, 2014).

Aflatoxin exposure in children may result in undernutrition particularly stunting as a result of immune suppression leading to susceptibility to recurrent infections with a complex mechanism of action. Various studies have reported different mechanisms of action due to aflatoxins exposure such as; disruption of insulin-like growth factors (IGF) which lead to toxicity in the liver (Castelino *et al.*, 2015), immunosuppressive effect in children which expose the child to infection thereby decreasing appetite and nutrients bioavailability (Gong *et al.*, 2008), and inhibition of protein synthesis which may damage the intestinal walls hence reduce nutrients absorption (Smith *et al.*, 2012) and cause growth impairment.

In this fact, there is a need for assessing the safety of cereals in disadvantaged communities where they are used as main staples and especially monotonously fed to children who are the most vulnerable to both nutrient inadequacy and aflatoxins exposure. Therefore, this study was conducted to assess the diversity in which cereals are used in complementary feeding among children aged less than two years in the Singida region of the central semi-arid part of Tanzania, and specifically to estimate dietary aflatoxins exposure through cereal-based complementary foods. In addition, feeding practices were assessed to find out dietary diversity and exposure to aflatoxins through cereal-based complementary feeding.

Methodology

Study design and recruitment of participants

A cross-sectional study was conducted in 10 villages of Singida District council in Singida region of central Tanzania. The region was selected due to low dietary diversity and stunting among children aged 6-24 months as reported in 2016 by Singida Nutrition and Agroecology project (SNAP), (Unpublished data). It was designed to ascertain other factors contributing to undernutrition reported by the Demographic Health Survey (DHS, 2018) and thereafter the SNAP, a cohort study that found out low dietary diversity and stunting prevalence of 24.7% (Unpublished data). Ten villages; namely Ikhanoda, Mrama, Mkimbii, Kihunadi, Ngamu, Mnung'una, Mudida, Mwanyonye, Mitula and Kinyagigi, five from each of the highest and lowest dietary diversity reported by the SNAP project were selected for the current study. The sample size was calculated based on $n=z^2*p(1-p)/e^2$, where; n sample size, z is a constant (1.96) level of confidence, p is the prevalence of stunting (24.7%) obtained from SNAP baseline survey (Unpublished data) and e is a precision (0.05) (Kothari, 2004). Calculated sample size was 287 which was approximated to 290 children (29 from each village).

A pre-survey was conducted with help from a community guide to list households with children of the required inclusion criteria, and then the respondents were recruited randomly. Households with children aged between 6-24 months and who had been introduced to complementary food were randomly selected. Also, living in the village from the time of the mother's conception of the index child to the date of the survey was considered. Twins, disabled children and those who have been sick in the past two weeks before the survey or have a history of suffering from chronic diseases such as Human Immunodeficiency Virus (HIV), Tuberculosis (TB), cardiovascular diseases (CVD) and the like were excluded from the study. Information on demographic, infant and young child feeding practices was collected using a semi-structured questionnaire, and samples of cereals-based complementary food were collected for determination of aflatoxins contamination.

Ethical clearance

Ethical clearance certificate number NIMR/HQ/R.8a/Vol.IX/2739 was obtained from the National Institute for Medical Research (NIMR) in Tanzania. Also, local administrative permission to conduct the study was obtained from the Singida District council and respective villages. Mothers/caregivers of the recruited children were informed of the study and those who were willing to participate in the study signed a written consent form. However, for the participants who did not know how to read and write, consent was provided orally and translated to their language by the community guide and then a thumbprint was used for those who consented.

Household Interviews, body weight measurements and dietary diversity

Structured questionnaires were used to collect information on demography, infant and young child feeding practices from the mothers/ primary caregivers. Children's body weight was measured using calibrated instruments according to WHO standards by using weighing scale (874, SECA, Hamburg, Germany) to the nearest accuracy of 0.1kg. Food frequency questionnaires were also used to assess dietary habits and frequency of consumption of aflatoxins susceptible foods and drinks. Mothers/ primary caregivers were asked to recall and report all foods that were repeatedly given to the child as complimentary food (including family food if offered to the index child) a week before the survey. According to (Arimond and Ruel, 2004; Brown *et al.*, 2002; WHO, 2008), food consumed in a week before the interview were grouped into seven (7) groups of; cereal/tubers/roots, flesh foods, eggs, dairy, legumes, vitamin A fruits and vegetables and other fruits and vegetables, and mothers were requested to recall intake of these food groups by the index child in seven days to ascertain food dietary diversity. For susceptible cereal-based foods, the amount of flour used to prepare a child's food per day was estimated by mothers using local utensils like spoons, cups and bowls then weighed on a kitchen digital scale and recorded in grams. Furthermore, information on the handling and management of cereals that are normally used in the preparation of complementary and /or family foods offered to the child was collected. Sources, post-harvest handling practices of cereals including storage, pre-processing preparation of raw ingredients before milling were among the information collected.

Dietary diversity scores were computed by counting the frequency of food groups fed to the child in a week as recorded in the food frequency questionnaire. Food groups consumed by a child for 3 or more days in a week were given "1" and those which were not consumed by the same child for 3 or more days in a week were given "0"(Arimond and Ruel, 2004). Finally, food groups that scored 1 were counted to find out dietary diversity scores for every child. In this case, the highest score for a child would be 7 with a score of 1 for every food group consumed for ≥3 days in a week. Therefore, if the child was fed 4 or more food groups for ≥3 days a week, the child would have met the minimum Dietary Diversity (DD) (Kennedy *et al.*, 2011).

Collection of food samples

Samples of crop produce commonly used in complementary feeding and which are susceptible to aflatoxin contamination were sought from all 290 interviewed households. However, only180 households were found to have at least one of the whole or form of food products used in the preparation of complementary food. Therefore, based on availability, up to 3 samples of the susceptible whole or form of food produces were collected from 180 households making a total of 218 food samples. Samples varied from maize and maize flour, sorghum, and sorghum flour, millet flour, composite flour, "*magai*" flour (milled germinated sorghum), to "*magai* drink" (a fermented drink prepared from *magai* flour). Each sample was thoroughly mixed for homogenization, and a minimum of 200 g or 100 ml of solids and liquid samples respectively were collected. Dried samples were packed in khaki bags and kept in a dry place, liquid samples were collected into sterile plastic containers and kept at 4°C and then frozen at -20°C within six hours of collection until analysis.

Analysis of aflatoxins in food samples

Liquid samples were thawed at room temperature (Nemati *et al.*, 2010; Song *et al.*, 2013), and then both liquid and solid samples were thoroughly mixed before measuring a portion for analysis. Aflatoxins contamination of the collected samples was determined by the method described by Stroka *et al.* (2000) with a slight modification made by Kimanya *et al.* (2008). Briefly, 25 g or ml of each food sample was measured in a blender, added with 100 ml of 60%

methanol as an extraction solution and blended at high speed for 3 minutes. The extract was filtered immediately through Whatman filter paper No. 1 (Sigma-Aldrich) followed by dilution of 4 ml of the extract with 8 ml of phosphate-buffered saline (PBS) at pH 6.8. Then, the mixture was passed through the immuno-affinity column placed on a vacuum manifold at the flow rate of 3 ml/min. The column was then rinsed with 10 ml of HPLC grade water with air forced through the column to ensure runoff. Then, elution of bounded aflatoxins was done by using 1 ml of acetonitrile into a glass amber vial. Four hundred microliter of the eluent was mixed with 600 µl of derivatizing reagent (70:20:10 v/v/v of water: trifluoroacetic acid: acetic acid) and then heated in a water bath at 65°C for 15 min. The mixture was allowed to cool and then injected into the HPLC system. A high-performance liquid chromatography (HPLC) (Shimadzu, Tokyo, Japan) with pump LC 20AD and fluorescence detector model RF-10AXL was set at a wavelength of 365 nm (excitation) and 450 nm (emission). HPLC column C_{18} (Spherisorb 80-3 ODS-1, 5 µm, 4.6 × 150 mm) was used at 40°C with a mobile phase composed of water: methanol: acetonitrile at a ratio of 60:30: 10 v/v/v and a flow rate of 1.5 ml/min. The running time was set at 11 minutes.

Ascertaining the risk of dietary exposure to aflatoxins among children

Mothers or caregivers were asked to estimate using household utensils the amount of the major raw ingredient such as flour used to prepare food consumed by the index child in a day, and then the ingredient was measured on a kitchen digital scale and recorded. For each child, exposure to aflatoxin B1 and total aflatoxins was calculated by multiplying aflatoxin contaminations (µg/kg) by an estimated amount of flour consumed (kg) per day and then dividing by the child's body weight (kg) (Magoha *et al.*, 2016).

$$D_e(ng/kgbw/day) = Consumption(g/day) * C_o(ng/kg) / BW_{ic}(kg) \quad ..1$$

Where; D_e= Dietary exposure, C_o = Concentration, and BW_{ic} = Body weight of the index child.

The child whose exposure was found to be above the margin of exposure (MOE) of 0.017ng/kg BW per day was considered at risk of being exposed to unacceptable levels of aflatoxin through complementary feeding, thus indicates public health concern (EFSA 2007).

Data analysis

Statistical analysis was done by using Statistical Package for Social Science (SPSS) version 20 software. Descriptive statistics were performed to determine the frequency, mean, median, percentage of feeding practices and aflatoxin contamination which was presented in tables and graphs. Multivariate analysis was used to find the association between feeding practices and dietary exposure to aflatoxins. A ninety-five percent confidence interval (CI) was used to assess the strength of association with a statistical significance of $p<0.05$.

The Kruskal-Wallis test, a non-parametric alternative to a one-way between-groups analysis of variance was conducted to compare the scores on AFB1 exposure in six groups of complementary food samples.

Results

Demographic information and feeding practices

Out of 290 children recruited in the study, 52.4% were male, whereby 19.7%, 17.6 and 62.8% were aged between 6-8, 9-11 and 12-24 months respectively. Children's body weight ranged from 6.2 kg to 14.6 kg with a mean of 8.79±1.42kg. The vast majority of households (96.6%) were smallholder farmers who depend on rainfed agriculture as the main occupation.

Mother's level of education was mainly standard seven (91%), secondary education (5.5%) and a few (2.4%) did not attend a formal school. About 86% of the children were still breastfeeding in addition to complementary feeding (Table 1). Moreover, the majority (94.2%) of the children consumed foods below the minimum dietary diversity of not less than 4 food groups in a week. Thus, only 5.8% of the children were consuming at least 4 food groups in a week before the survey (Fig.1).

Table 1. Infants and young child feeding practices.

Variable	N	%
Breastfeeding		
Yes	249	85.9
No	41	14.1
Introduction of complementary feeding		
Early introduction	12	4.1
Timely introduction	278	95.9
Dietary diversity score		
Minimum DDS	17	5.9
Below minimum DDS	273	94.1
Common food		
Porridge	174	60.6
Ugali	112	39.0
Milk	1	0.3
Meal frequency		
1	2	0.7
2	30	10.3
3	204	70.3
4	35	12.1
5	15	5.2
>5	4	1.4

Food source, handling and preparation

The majority (99%) of the studied households rely on homegrown cereals for complementary feeding as well as family food. On preparation of cereals before milling, 95.2% of the mothers/caregivers prepared maize by only winnowing and 99.4% of the households stored cereals in ordinary sacks for a maximum of 1 year (Table 2).

Aflatoxins contamination of food samples

Table 3 results show that aflatoxin B1 contamination was detected in 80 (36.7%) of flour and magai drink used in complementary feeding and the levels ranged from 0.33 to 23.75 µg/kg where total aflatoxins were detected in 185 (84.9%) food samples with the range of 0.47 to 289.28 µg/kg. However, 6 (2.7%) of the samples exceeded the limit of 5 µg/kg for aflatoxin B1 in food set by Tanzania Bureau of Standards (TBS, 2014) and 14 (6.4%) were above the European Union (EU) limits for processed cereals which is 2 µg/kg (EC, 2010) (Table 4). Furthermore, 36.7% of the samples exceed the level of 0.1 µg/kg set by the EU for AFB1 in baby foods. About 13% of the samples were above the limit of 10 µg/kg set by Tanzania for total aflatoxins in food (Table 4).

The highest and lowest AFB1 range of contamination of up to 289.28 µg/kg and 0.47 µg/kg respectively were detected in samples of maize-based flour used in complementary feeding. The highest median value of 1.03 µg/kg for AFB1 was found in composite flour compared to the median of AFB1 from other types of foods (Table 3).

Child dietary exposure to aflatoxins

Child consumptions of key food products from 180 households ranged from 50 to 456 g per day, with a mean of 117.11±79.8 g. The margin of exposure (MOE) to aflatoxins B1 was below 10,000 (1.0 to 963.0) or above 0.017 ng kg^{-1} BW per day. The median dietary exposure to AFB1 and total aflatoxins were found to be 3.0 ng/kg body weight per day and

34.0 ng/kg body weight per day with the range of 1.0 to 963.0 ng/kg body weight per day and 1.0 to 11,732 ng/kg body weight per day, respectively.

The mean dietary exposure to AFB1 for children who consumed *"magai"* flour as part of *"magai"* drink was higher (157.94 ng/kg body weight per day) compared to their counterparts. The mean dietary exposure due to consumption of susceptible food produce was; *magai* drink (133.36 ng/kg body weight per day), composite flour (106.0 ng/kg body weight per day), maize flour (111.70 ng/kg body weight per day), sorghum flour (94.68 ng/kg body weight per day) and millet flour (92 ng/kg body weight per day). However, there was an insignificant difference (p=0.085) in dietary exposure to AFB1 between children who consumed *magai* compared to those who were using other types of food materials.

Table 2. Food handling in households.

Variable	N	Percentage (%)
Food sources		
Home grown	287	99.0
Market	3	1.0
Cereal preparation		
Sorting	9	3.1
Winnowing	276	95.2
Washing & dried on mats	5	1.7
Storage time (months)		
2-5	13	4.5
6-9	80	27.7
10-12	180	62.3
>12	16	5.5
Storage facility		
Floor and silos	2	0.6
Sacks	288	99.4

The mean ranks suggest that *magai* flour, *magai* drink, maize and composite flour had the highest exposure to AFB1, with the millet and sorghum ranking the lowest **(**Table 5).

Discussion

The study found out very low dietary diversity among infants and young children aged between 6 to 24 months. This could be contributed by a high level of food insecurity as observed earlier by the research conducted in 2016 by SNAP project in the same location. In the current study, 94.2% of the children received less than four food groups per week contrary to the WHO recommendations (WHO, 2008) while 52.8% received an average of 2 food groups per week. The two food groups consumed by this later case were mainly stiff porridge made from maize, sorghum, or millet flour accompanied with green leafy vegetables. This monotonous diet could cause not only inadequate intake of nutrients but also the risk of chronic exposure to aflatoxins due to multiple consumptions of these susceptible cereals daily. To ensure adequate complementary food intake, it is recommended to balance with all food groups necessary to supply adequate nutrients, for growth and reduce chances of exposure to undesired substances such as mycotoxins. Low dietary diversity may have resulted from the inadequate harvest of non-cereal-based crops possibly due to reliance on rain-fed agriculture, lack of prioritization by cultivation or selling out non-cereals crops for income, as well as negligence and slow adoption of nutrition-sensitive agriculture (Ochieng *et al.*, 2017). Also, inadequate education on appropriate, nutritionally enriched and safe foods for infants and young children (Chen, 2016).

Table 3. Occurrence of aflatoxins in different food materials used in complementary feeding (n=218).

Type of food	Number of samples	Positive (%) for AFB1	Positive (%) for total AF	AFB1(µg/kg		Total aflatoxin (µg/kg)	
				Median values	Range	Median values	Range
Maize flour	100	40(40.0)	87(87.0)	1.02	0.33-23.75	2.17	0.47-289.28
Millet flour	16	0(0.0)	10(62.5)	0.00	0.00-0.00	1.66	0.82-3.83
Sorghum flour	20	5(25.0)	17(85.0)	0.39	0.37-7.99	1.71	1.46-39.52
Composite flour	62	20(32.25)	51(82.23)	1.03	0.37-4.48	2.73	0.48-50.84
"Magai" flour	9	6(66.7)	9(100)	1.01	0.65-6.16	18.59	1.67-36.54
"Magai" drink	11	9(81.8)	11(100)	0.65	0.60-0.79	3.38	1.11-4.92

This was supported by another study conducted in the semi-arid Dodoma region, which revealed the effect of food insecurity on low dietary diversity in children's diet as a result of dependence on rain-fed agriculture (Kulwa *et al.*, 2015). Low dietary diversity especially reliance on monotonous cereal-based diets commits significant low nutrient intake and susceptibility to mycotoxins exposure (Makori *et at.* 2018).

This study is one of the first to reveal the high level of dietary exposure to aflatoxins in multiple cereal-based complementary foods in Singida rural communities, particularly among young children past the exclusive breastfeeding age. This is in conformity to the findings reported in Benin and Togo which showed that the majority of children at this age were no longer breastfed and their complementary food were susceptible to aflatoxins contamination at levels higher than that of the breast milk (Gong *et al.*, 2003). Increased exposure to aflatoxins is parallel to the high consumption of the susceptible food produce as the consumption rate of children at the age group of 12 to 24 months in this study was high as 456g per day compared to other age groups of 6-8 and 9-11 months which were 350g and 390g respectively.

Table 4. Prevalence of aflatoxins contaminations of food above regulatory limits (n=218).

Types of food materials	EU limits			Tanzania limits	
	>0.1 µg/kg for AFB1 in baby foods[a]	>2 µg/kg for AFB1[b]	>4 µg/kg for total AF[b]	>5 µg/kg for AFB1	>10 µg/kg for total AF
Maize flour	40	7	27	4	13
Millet flour	0	0	0	0	0
Sorghum flour	5	2	3	0	2
Composite flour	20	3	16	1	8
"Magai" flour	6	2	6	1	6
"Magai" drink	9	0	4	0	0

Among other food, *Magai* and maize were detected with high aflatoxins contamination. *Magai,* a local soft drink made from milled germinated sorghum is a common drink in the study area used by families as a refreshment and in-between meals. Hand in hand, *magai* was consumed by children as complementary food (Nyamete *et al.*, 2016; Ezekiel *et al.*, 2018) where there is no other cereal flour for baby's porridge which is the traditional complementary food. Of a disadvantage, *magai* was found to expose children to AFB1 above tolerable levels. This study found that dietary exposure to AFB1 from *magai* flour consumed as *magai* drink was very high with the mean of 157.94 ng/kg body weight per day as compared to those who consumed other flour as part of complementary food. *Magai* drink was positive for AFB1 by 81.8% and the first before maize flour (in causing high dietary exposure to this potent AF with the mean of 133.36 ng/kg and 111.7 ng/kg body weight per day respectively. This high level of aflatoxins contamination of *magai* and the resultant dietary exposure could be due to the processes involved during its preparation whereby the dried sorghum is washed and soaked for 2 days, allowed to germinate in 3 days and later on sun-dried on a bare ground/soil or a mat. Sun-drying cereals on the bare ground have been widely associated with high levels of mycotoxins contamination (Waliyar *et al.*, 2014) as many fungi are harbored in the soil. The washing and soaking processes expose the prior dried sorghum to high moisture content, which favors fungal growth and mycotoxins production if not rapidly dried to the acceptable moisture content. In addition, weather condition and unawareness of mycotoxins contamination of cereals in the study area might contribute to delayed re-drying of such cereals followed by poor storage of the malt which both favors fungal growth, mycotoxins production and ultimate unacceptable high dietary exposure of these toxins in children and the general population (Ezekiel *et al.*, 2018). Furthermore, during the preparation of *magai* drink there could be a carry-over effect resulting in cross-contamination of aflatoxins between batches of *magai* drink as they practiced back-slopping fermentation. This is supported by the fact that, in some cases, the *magai* flour was less contaminated compared to the *magai* drink collected from the same households. For instance, a case where *magai* flour was undetected for AFB1 but its product *magai* drink was found to be contaminated with AFB1 at 0.68 µg/kg. On the other hand, high levels of aflatoxin contamination in *magai* flour seem to reduce after fermentation of *magai* drink. This was revealed in the samples of *magai* flour and *magai* drink collected from the same household where total aflatoxins in *magai* flour were reduced from 4.04 µg/kg to 0.46 µg/kg in *magai* drink. This is an indication that, when clean culture is used, levels of aflatoxins in the follow-up batch (if contaminated flour used) could be reduced. Reducing aflatoxin levels in fermented products has been reported to be facilitated by the presence of lactic acid bacteria by fighting the growth of fungus and by detoxifying the toxins (Nyamete *et al.*, 2016).

Table 5. Mean ranks to AFB1 exposure in different types of food samples.

Type of food	N	Mean Rank (ng/kg body weight per day)
Maize flour	100	111.70
Millet flour	17	92.12
Sorghum flour	20	94.68
Composite flour	62	106.00
Magai flour	9	157.94
Magai drink	11	133.36

The majority of the children (71.1%) were commonly fed daily with thin or stiff porridge originating from maize, millet and sorghum flour, and the cereal-based meals were accompanied by green vegetables particularly jute mallow. Cereals preparation before milling was poorly handled like the majority (95.2%) of the families reported to only winnow the cereals particularly maize and no dehulling (97.6%), explaining the 40% of AFB1 contamination found in the non-dehulled maize flour with the range of 0.33-23.75 µg/kg. However, the levels were lower compared to those reported in other studies conducted in Tanzania by (Geary *et al.*, 2016) who reported contaminations ranging from 0.15 to 34.5 µg/kg. Though debatable and a tradeoff between food safety and nutrition, removal of the bran and another part of cereal outer layer have shown a significant decrease in the levels of aflatoxins and a promising solution in areas where there are less diversified diets.

This is supported by (Siwela *et al.*, 2005) who reported a 92% reduction of aflatoxins in dehulled maize. Furthermore, dietary exposure of all studied children to aflatoxin B1 and total aflatoxins is of public health concern, with MoE (EFSA, 2007) below 10,000 (above 0.0017ng/kg BW per day) for both AFB1 and total aflatoxins. Complementary flour used for preparing complementary food for children was contaminated with AFB1 by 36.7% above the maximum limit (ML) of 0.1 µg/kg set by the EU for AFB1 in baby foods. Another study conducted in Dodoma observed high contaminations (42.5%) of the samples with AFB1 above the ML of 0.1 µg/kg set by the EU (Makori *et al.*, 2019). Integrated intervention strategies including the creation of awareness of aflatoxins contamination of agricultural products and their associated health effect are critical to addressing the problem. Poor management of crops in the field especially in low fertile land can stress plants and lead to the risk of fungal growth and mycotoxins contamination of the grain. On the other hand, high temperature and humidity are the main factors favoring fungal growth and mycotoxin contamination of crops during storage (Gong *et al*., 2016). Being the semi-arid region, Singida is highly affected by low (435 mm per year) (Lal *et al*., 2015) and erratic rainfall, subjecting the plants to water stress throughout the production time such could be the reason for fungal infestation and high aflatoxins contamination of these susceptible food crops.

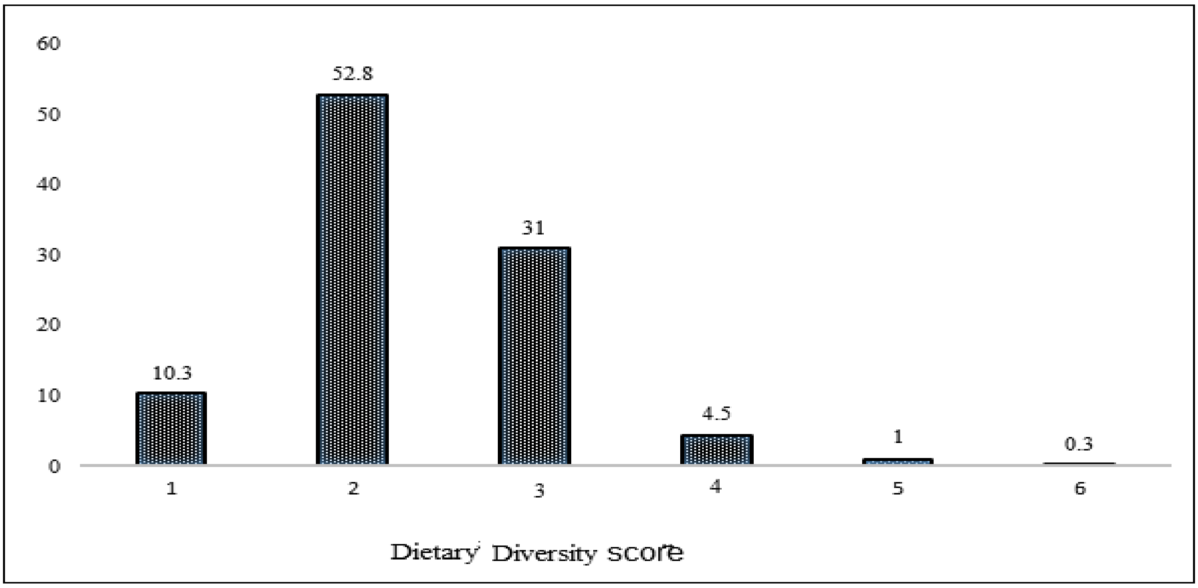

Fig. 1. Infants and young child dietary diversity score.

The majority (99.4%) of the households in this study stored their produce in sacks for about 12 months (62.3%). Longer time storage of crops, especially in inadequate or poorly managed storage facilities, has been associated with high mycotoxins contamination (Makori *et al*., 2019; Torres *et al*., 2014).

Conclusion

This study reported very low dietary diversity among young children with high consumption of cereals-based flour in its wholesome, which are inadequate in essential nutrients and susceptible to aflatoxins contamination. Furthermore, longer time storage of crops, especially in inadequate or poorly managed storage facilities, could be among the reasons for these high levels of mycotoxin contamination *Magai* drink and maize flour contaminated beyond tolerable limits and the leading complementary food materials responsible for the high aflatoxins exposure in children, posing a public health concern. These findings highlighted a need for integrated nutrition interventions to the entire population with the inclusion of strategies for improving dietary diversity and mitigating mycotoxins contamination of staple food crops thereby reducing exposure among infants and the general population.

Acknowledgment

This research collaboration between Nelson Mandela Institution of Science and Technology (NM-AIST) Arusha, Tanzania and Michigan State University, USA was funded by USAID under Feed the Future Programme through Sustainable Intensification Innovation Lab (SIIL) of Kansas State University, USA. The Authors acknowledge the fundamental work by Singida Nutritional and Agroecological project (SNAP) which is the basis for this follow-up research work. SNAP was funded by Mcknight Foundation and implemented in collaboration between NM-AIST and Cornell University, USA.

Declaration

The authors declare no conflict of interest.

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