2023-02

# Infant and Young Child Feeding Practices and Mycotoxin Contamination of Complementary Food Ingredients in Kongwa District, Tanzania

Ngure, Francis

Elsevier

https://doi.org/10.1016/j.cdnut.2023.100030

Current Developments in Nutrition 7 (2023) 100030

journal homepage: www.journals.elsevier.com/current-developments-in-nutrition

Original Research

# Infant and Young Child Feeding Practices and Mycotoxin Contamination of Complementary Food Ingredients in Kongwa District, Tanzania

Francis M. Ngure [1,*], Neema Kassim [2], Erica L. Phillips [1], Paul C. Turner [3]

[1] *Division of Nutritional Sciences, Cornell University, Ithaca, NY, USA;* [2] *Department of Food Biotechnology and Nutritional Sciences, School of Life Science and Bio-Engineering, The Nelson Mandela African Institution of Science and Technology (NM-AIST), Arusha, Tanzania;* [3] *Maryland Institute for Applied Environmental Health, School of Public Health, University of Maryland, College Park, MD, USA*

ABSTRACT

**Background:** Inadequate infant and young child feeding (IYCF) practices in low income countries contribute to poor child growth and development.

**Objectives:** To assess IYCF practices and mycotoxin contamination in complementary food ingredients across 2 seasons in Kongwa District, Tanzania.

**Methods:** Early feeding practices in 115 rural households from 25 villages in Kongwa District, Dodoma region, Tanzania, were assessed. The primary caregiver for the index child (6–18 mo of age) was interviewed using a structured dietary questionnaire at recruitment (October/November 2017), and revisited 6 mo later. The questionnaire included questions on typical food consumption in the past 24 h. This study reports 7 of the revised and new IYCF indicators, including minimum dietary diversity (MDD). Aflatoxins (AF) and fumonisins (FUM) were analyzed in complementary food ingredients for pooled household samples to broadly establish patterns of contamination at the village level.

**Results:** The MDD was not met for 80% of infants at recruitment (survey 1) as compared with 56% in survey 2 ($P < 0.05$). Changes in MDD between the 2 surveys were dependent on season but not age. Maize was consumed by >90% of households in both surveys, whereas groundnut was consumed by 44% and 64% of households in surveys 1 and 2, respectively. AF concentrations in maize and groundnuts were found to be higher in survey 1 than in survey 2. Overall, AF exceeded the legal limit in 18% of maize and 61% of groundnut pooled samples in both surveys. Maize was also contaminated with significant FUM concentrations.

**Conclusions:** Poor diets were common among children in Kongwa District. Reliance on maize and groundnuts exposes this vulnerable age group to AF (also to FUM in maize). Inadequate diet and exposure to AF and FUM have separately been linked to linear growth retardation. Low diet diversity and mycotoxins contamination are plausible causes for poor growth and development among infants in Central Tanzania. *Curr Dev Nutr 20XX;x:xx.*

*Keywords*: infant and young child feeding, nutrition, minimum dietary diversity, maize, groundnuts, mycotoxins, Tanzania

## Introduction

Adequate infants and young child feeding practices (IYCF) is fundamental to improved nutrition, health, and development during early life [1]. In many low and middle income countries, IYCF varies and remains a significant risk factor for undernutrition, including wasting, stunting, underweight, and micronutrient deficiencies [2, 3, 4]. Among several IYCF practices, dietary diversity is associated with improved child growth in multiple low income countries [5–7].

*Abbreviations:* AF, aflatoxins; ASFs, animal source foods; CBF, continued breastfeeding; EFF, eggs and flesh foods; EvBF, ever breastfed; FUM, fumonisins; IYCF, infants and young child feeding practices; IYC, infants and young children; MDD, minimum dietary diversity; MeOH, methanol; SSA, sub-Saharan Africa; SwB, sweet beverage consumption; UFC, unhealthy food consumption; ZVF, zero vegetable and fruit consumption.

* Corresponding author *E-mail addresses:* fmn9@cornell.edu, fmngure@gmail.com (F.M. Ngure).

https://doi.org/10.1016/j.cdnut.2023.100030

Received 31 August 2022; Received in revised form 4 January 2023; Accepted 4 January 2023; Available online 9 January 2023

Globally, stunting remains a significant public health problem. Africa and Asia have the largest burden of child stunting at 39% and 55%, respectively [8]. Although steady progress has been made in reducing the global prevalence of stunting, the pace has been slow among sub-Saharan African (SSA) countries. In Tanzania, stunting among children aged <5 y is similar to other SSA countries and remains high at 32% compared with the global average of 22% [8]. The prevalence has only declined by 6% in the last 20 y, compared with 12% in SSA and 11% globally. The prevalence of stunting varies across various regions in Tanzania. The Dodoma region in Central Tanzania has 37% prevalence [9], which is higher than the national average.

Assessment of IYCF practices is commonly performed using IYCF indicators, which have been validated in 10 countries [10]. One IYCF indicator is the minimum dietary diversity (MDD) previously defined as the consumption of ≥4 of the 7 food groups [10]. Based on nationally representative data from Tanzania Demographic Health Survey, the percentage of meeting the MDD declined from 46% in 2004 to 30% in 2016 among children aged 6–23 mo [11]. Low diet diversity has also been reported among 6–23-mo-old children across Tanzania and in an urban population in Dar es Salaam [6]. Poor dietary diversity was associated with a 29% higher risk of stunting among 6–24-mo-old children in urban Moshi, Tanzania [12].

Infants and young children (IYC) in Tanzania are also at a risk of exposure to mycotoxins during complementary feeding. Mycotoxins are toxic secondary metabolites that are produced by various fungal species, and are of concern in several dietary staples. In tropical regions, maize is frequently contaminated with AFs and FUMs [13, 14]. Groundnuts are also a common source of aflatoxins [14]. AFs are potent carcinogens [14], and early-life ingestion has also been associated with growth faltering in several studies conducted in sub-Saharan Africa [15, 16, 17]. FUM exposure has also been associated with poor linear growth among rural children in Tanzania [18, 19]. AFs have previously been detected in Tanzanian maize and/or groundnuts [18, 20, 21]. The outbreak of acute aflatoxicosis in 2016 in Dodoma and Manyara region, Central Tanzania, was attributed to the consumption of highly contaminated maize [22].Understanding mycotoxin exposure in the background of poor IYCF and how these vary with season and child age is important in elucidating health risks in early life.

This formative study on IYCF in the Kongwa District of Dodoma region, Tanzania, was conducted to *1*) compare IYCF practices among the same infants at 2 survey time points to determine whether the practices vary with the age of the child and/or season and *2*) capture mycotoxin contamination at the village level in various complementary food ingredients at the 2 time points. The 2 surveys were conducted 6 mo apart to explore seasonality with regard to the harvest and rainy season. The study also captures the age of IYC when linear growth declines steadily, and adequate IYCF is critical [23]. Exploring the synergistic or independent effects of factors such as season, child age, and gender on IYCF is important in informing future interventions. The research was formative in the implementation of a randomized control trial to assess the effect of aflatoxin on infant linear growth [24]. This article reports the use of some of the revised and new IYCF indicators [1] in a Tanzanian context.

# Methods

## Study site and sampling

This study was conducted in 25 villages in Kongwa, a rural semiarid district that comprises 90 villages, in Dodoma, Central Tanzania. The food system is characterized by small holder farming of food crops such as maize, groundnuts, sunflower, pearl millet, and sorghum. Purposive sampling of 4–6 households per village was conducted to provide a balance of breadth and depth in representing feeding practices across the district. The eligibility criteria were as follows: *1*) being mothers of 6–18-mo-old children with no feeding or swallowing difficulties, *2*) a survey household was separated by ≥6 households from the next one, and *3*) ≤50% of the households in a village were enrolled from one subvillage (the smallest geographic unit of a village).

## Field survey

Two dietary surveys of infant feeding were conducted in each household. Survey 1 was conducted toward the end of October and early November 2017 just before the onset of the rainy season, when there is less variety of food in Kongwa. Survey 2 revisited the families 6 mo later, at the end of April 2018 to early May 2018, and at the end of the rainy season when there is typically more food variety. Survey 2 was conducted during the groundnut harvesting season. Maize is harvested in June and July. Maize and groundnuts are common complementary food ingredients in Kongwa.

A total of 115 households in 25 villages were recruited for survey 1; 11 of these households (9.6%) were lost to follow-up for survey 2. The primary respondent (mothers) in these 11 households had either traveled or relocated to other villages and could not be reached within the 2 wk of data collection for this survey. Each household visit involved administering a questionnaire on *1*) maternal and household characteristics, *2*) foods fed to the index child within the last 24 h, and *3*) pre- and postharvest practices for maize and groundnuts. The survey data collected was relevant to 3 of the revised and 4 of the new WHO IYCF indicators defined below [1].

## Definition of IYCF indicators

The revised IYCF indicators are as follows: *1*) ever breastfed (EvBF)–children born in the last 24 mo who were breastfed at one time point; *2*) continued breast feeding (CBF)–percentage of children aged 12–23 who were breastfed the previous day; and *3*) the MDD–percentage of children aged 6–23 mo who consumed foods and beverages from ≥5 out of 8 defined food groups the previous day [1]. The 8 food groups include the 7 described previously [10] and the recently added breast milk. All children in survey 1 were between 6 and 23 mo of age and were included in MDD score; however, 3 of the 104 children in survey 2 were excluded because they were 24 mo old.

The new IYCF indicators were as follows: *1*) egg and/or flesh food consumption (EFF)–the percentage of children aged 6–23 mo who consumed egg and/or flesh food the previous day, *2*) unhealthy food consumption (UFC)–the percentage of children aged 6–23 mo who consumed selected sentinel unhealthy foods (that is, foods high in sugar, salt, and/or unhealthy fats) the previous day, *3*) zero vegetable and fruit consumption (ZVF)–the percentage of children aged 6–23 mo who did not consume any vegetables or fruits during the previous day, and *4*) sweet beverage consumption (SwB)–the percentage of children aged 6–23 mo who consumed sweet beverages the previous day [1].

## Sampling of complementary food ingredients for mycotoxins

The study attempted to collect food samples that were representative of complementary feeding ingredients that are prone to AF and/or FUM contamination. Pantry level food sampling was preferred for ingredients fed in the previous 3 d. Approximately 250–500 g of each ingredient was collected. Flours of the food ingredients were collected to obtain a homogeneous mixture and to save milling time. In households with limited quantities of groundnuts and the maize/groundnut composite (Lishe) flours, a sample of ~100 g was collected.

In households where flours were not available in pantries, sampling was conducted for the food ingredients in stock. Five random subsamples of ~200 g were drawn from different sections of the stock bag of >25 kg of maize kernels in stock. The subsamples were combined into 1 kg and mixed thoroughly. Half of the aggregated sample was taken and carefully sealed in a food grade, clean zip lock bag. The same procedure and principles were applied in sampling sunflower oil seeds and cereals such as pearl millet, sorghum and finger millet. In households where groundnuts were stored in pods, random subsamples were taken to fill up a 1-kg zip lock bag. Compensation was given for each sample of food at between USD 0.50–0.90 depending on the quantity and type of food. All food samples were transported to a field laboratory within the same day and stored at −20°C. At the end of each survey, all food samples were transported to Nelson Mandela African Institute of Science and Technology (NM-AIST) for milling and laboratory analysis. All samples were stored at −20°C and analyzed within 1 mo after sample collection.

## Aflatoxins and fumonisins analyses

A minimum of 30 g of individual milled food samples, for example, maize, from each of the 4–6 households in a village were pooled and thoroughly mixed to obtain an approximate village level sample. In pooled village samples, an equal weight of food from each household was contributed to the pool. For other food items, AF was analyzed in fewer numbers of pooled samples, as well as in some, at the individual household level, where only one sample was collected within that village (Supplemental Table 1). A 5-g subsample of the flour was used for extraction. Extraction of AF involved thorough mixing of the subsample with 25 mL of solvent, 75% MeOH for maize flour, and 80% MeOH for sorghum, pearl millet, finger millet, groundnuts, and Lishe. FUMs were extracted only from maize flour and used 25 mL of 90% MeOH for 5 g of flour.

AF and FUM concentrations were quantified using commercially available ELISA kits (Helica Biosystems Inc.) according to manufacturer's protocols. AFs in maize were analyzed using total AF ELISA (catalog number: 941AFL01M-96). AFs in other food matrices were analyzed using low matrix total aflatoxin ELISA (catalog number: 981AFL01LM-96); kit choices were directed by manufacturer's recommendations for food types. FUMs in maize were analyzed using FUM ELISA (catalog number: 951FUM01C-96). Results from each ELISA plate were accepted on the basis of a coefficient of variation of ≤10% of duplicates absorbance values and an R-square value of the standard curve of ≥0.97. An assay was repeated if the results were >1 SD of the mean for the AF quality control reference material (that is, 6.1 ± 1.1 μg/kg). The limit of detection was 0.1 μg/kg for low matrix and total aflatoxin ELISA, and 10 μg/kg for FUM ELISA.

## Data analysis

Data were analyzed using STATA 15.1. Descriptive statistics for household characteristics are presented. The proportion of children consuming each food group or meeting each of the IYCF indicators was compared using the chi-square test. Interactions between age, gender, season, and tribe were examined using a logistic regression model with IYCF indicator as the dependent variable. Each IYCF indicator was coded as either 0 (no) or 1 (yes). Some terms were dropped in a 3-factor interaction model between age, season, and tribe because of few children in the age category (older children). Finally, a logistic model with 2-factor interaction was analyzed to test either season and age or age and gender.

Descriptive statistics were analyzed for the AF and FUM data. As AF and FUM data in maize for the 2 surveys were not normally distributed, log transformation was performed before paired t-

**TABLE 1**
Household characteristics at recruitment (survey 1)

| Characteristics | Survey 1 ($n$ = 115) |
|---|---|
| Age of caregiver (y): Mean (SD) | 28 (7) |
| Number of children alive: Mean (SD) | 3 (2) |
| Age of index child (mo): Mean (SD) | 12 (3) |
| Children age category (mo) | |
| 6–11 | 55 (48%) |
| 12–17 | 50 (43%) |
| 18–23 | 10 (9%) |
| Sex of child, $n$ (%) | |
| Male | 64 (56%) |
| Female | 51 (44%) |
| Relationship of child and caregiver | |
| Mother | 113 (98%) |
| Others | 2 (2%) |
| Education | |
| Secondary school and college | 13 (11%) |
| Primary school (standard 7) | 67 (58%) |
| Primary school (standards 1–6) | 17 (15%) |
| Not attended school | 18 (16%) |
| Marital status | |
| Married | 92 (80%) |
| Single | 18 (16%) |
| Separated or divorced | 5 (4%) |
| Employment status | |
| Caregiver ($n$ = 115) | |
| Farmer | 96 (83%) |
| Business | 11 (10%) |
| Others | 8 (7%) |
| Spouse ($n$ = 92) | |
| Farmer | 78 (84%) |
| Business | 7 (8%) |
| Others | 7 (8%) |
| Major tribes | |
| Wagogo | 52 (45%) |
| Wakaguru | 39 (34%) |
| Others | 24 (21%) |

Eleven of the households (9.6%) were lost to follow-up for survey 2. The primary respondent (mothers) in these 11 households had either traveled or relocated to other villages, and could not be reached within the 2 wk of data collection.

**TABLE 2**
Number (proportion) of children by food group fed in the last 24 h

| Food group | Survey 1 ($n = 115$) | Survey 2 ($n = 101$) | Chi-Square $P$ value |
|---|---|---|---|
| Breast milk | 108 (94%) | 78 (77%) | 0.000 |
| Grains, roots, tubers, and plantains | 115 (100%) | 100 (99%) | 0.285 |
| Legumes, nuts, and seeds | 85 (74%) | 83 (82%) | 0.145 |
| Dairy products[1] | 16 (14%) | 13 (13%) | 0.823 |
| Flesh foods (meat, fish, poultry) | 27 (23%) | 14 (14%) | 0.072 |
| Eggs | 2 (2%) | 1 (1%) | 0.639 |
| Vitamin-A–rich fruits and vegetables | 64 (56%) | 72 (72%) | 0.018 |
| Other fruits and vegetables | 23 (20%) | 56 (56%) | 0.000 |
| Sentinel sweet foods | 9 (8%) | 11 (11%) | 0.438 |
| Sentinel fried and salty foods | 17 (15%) | 25 (25%) | 0.065 |

[1] Dairy products include any mammal's milk, infant formula, yogurt, and cheese.

test mean comparison. Geometric means and 95% CIs are presented for AF and FUM in maize. Half the value of the limit of detection (LOD) was used for AF or FUM values less than the LOD. The distribution of AFs in groundnuts was skewed even after log transformation. Pearson's chi-square test for categorical data (≤10 and >10 μg/kg) was used to compare differences in the distribution of AF in groundnut samples.

## Ethical considerations

Ethical approval for the study was granted by the National Institute for Medical Research, Tanzania (protocol ID: NIMR/HQ/R.8a/Vol.IX/2526) and the Institutional Review Board, Cornell University (protocol ID: 1703007043). Mothers provided written informed consent prior to the start of the study.

# Results

## Household characteristics

Household characteristics at recruitment are summarized in Table 1. The respondent to the questionnaire (caregiver) was predominantly the mother (98%), and the caregivers were on average 28 y old (range: 15–48 y). Farming was the most common economic activity for both the caregiver ($n = 96$, 83%) and, when married ($n = 92$), the spouse ($n = 76$; 85%). Most of the caregivers had attended school (84%), and among them, 58% completed primary school (standard 7). The majority of the respondents were from 2 ethnic groups –Wagogo: 45%; Wakaguru: 34%. The mean age of the IYC at recruitment was 12 mo (SD: 3 mo) and the range was 6–18 mo. Fifty six percent of the IYC were male. The mean age at survey 2 was 17 mo (SD: 3 mo) and the range was 10–24 mo.

## Food consumption patterns

Individual foods consumed by the index child in the previous 24 h were grouped into 10 food groups (Table 2). The first 8 food groups were used in defining the MDD. Breastfeeding within the last 24 h was almost universal in survey 1 (94%) and this reduced to 77% in surveys 21 and 2, respectively). In both surveys, all IYC had consumed starchy foods such as grains and tubers, with the exception of one sick child in survey 2. Other common foods were legumes and nuts (primarily beans and groundnuts) and vitamin A–rich fruits and vegetables. Consumption of dairy products was low (14% in survey 1 and 13% in survey 2). The proportion of children who consumed vitamin A–rich fruits and vegetables increased significantly from survey 1 to survey 2 ($P <$ 0.05; Table 2). The proportion of children who consumed other fruits and vegetables in survey 2 was more than twice that of survey 1 ($P < 0.05$; Table 2). Overall, most IYC consumed 3 or 4 food groups in survey 1 (77%) and 4 or 5 food groups in survey 2 (72%; Figure 1).

## IYCF indicators

All IYC were breastfed at some point (Table 3). In the first survey, 3 children had stopped breastfeeding at 1, 2, and 9 mo of age. In the second survey, 15 children had stopped breastfeeding at a mean age of 18 mo and range of 7–24 mo. In survey 1, the majority (95%) of the older infants (12–23 mo) continued breastfeeding beyond the first year. This proportion decreased to 86% in survey 2 ($P = 0.068$).

The proportion of children who met the MDD increased from 20% in survey 1 to 44% in survey 2 ($P < 0.001$). Egg and flesh food consumption was low (25%) in survey 1 and decreased further (14%) in survey 2 ($P < 0.05$). Twenty percent of the children consumed unhealthy food in survey 1 compared with 33% in survey 2 ($P < 0.05$). Slightly over one-third of the children (37%) consumed no vegetables and fruits and this proportion decreased to 18% in survey 2 ($P < 0.05$). The proportion of children who drank sweet beverages was low (15%) in survey 1 and almost doubled (27%) in survey 2 ($P < 0.05$).

## IYCF indicators by season and age

The odds of the index child meeting the MDD increased by 3.1 (95% CI: 1.7–5.6) from survey 1 to survey 2 ($P < 0.001$). This relationship did not change with age ($P$ value for the interaction term = 0.836). Age and tribe were NS predictors of MDD. The interaction between season and age was significant for UFC ($P <$ 0.05). The odds of UFC were 0.54 times higher for the oldest children (18–24 mo) compared with the youngest ones (6–11 mo) in survey 1 ($P < 0.05$). The odds of UFC were 0.21 times higher for 6–11 mo old in survey 2 than those of children of the same age in survey 1 ($P < 0.05$). The odds of UFC were 0.26 times higher for 12–18-mo olds in survey 2 than for 6–11-mo olds in survey 1 ($P < 0.05$). The interaction between season and age was NS for SwB and EFF ($P > 0.05$). The interaction terms were not tested for ZVF owing to few observations.

## Consumption of mycotoxin-susceptible foods

Consumption of maize was >90% in both surveys (Table 4). Other starchy foods were rice, wheat, sorghum, pearl millet, finger millet, potatoes, and cassava. Groundnut consumption

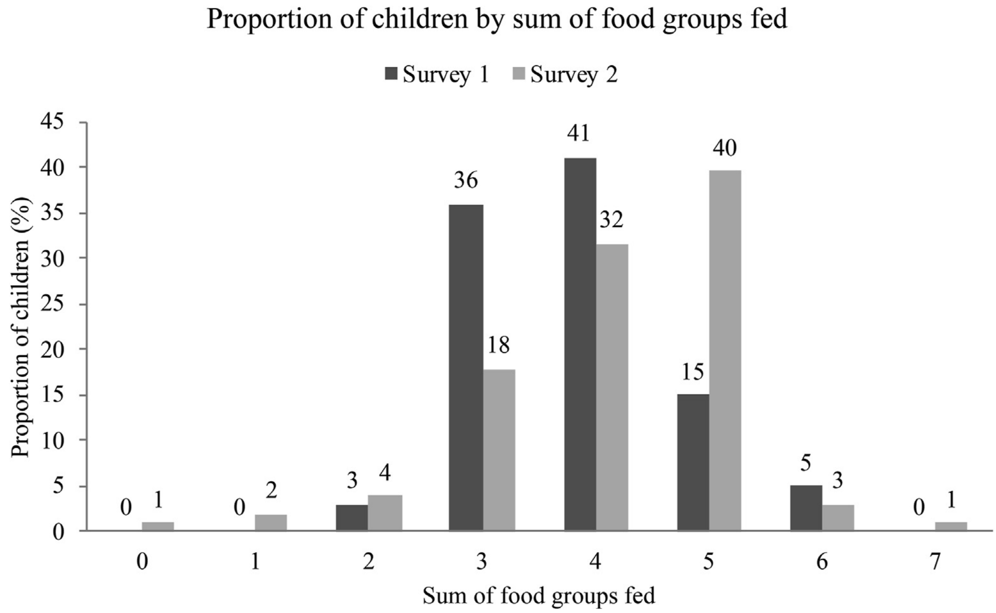


**FIGURE 1.** Distribution of children in both surveys by the sum of food groups fed in the last 24 h.

**TABLE 3**
Number (proportion) of children by IYCF Indicator

| WHO IYCF Indicator | Survey 1 | Survey 2 | *P* value[1] |
|---|---|---|---|
| Ever breastfed (<24 m)[2] | 115 (100%) | 104 (100%) | |
| Continued breastfeeding (12–23 m)[3] | 57 (95%) | 84 (86%) | 0.068 |
| Minimum dietary diversity (MDD) (6–23 m)[4] | 23 (20%) | 44 (44%) | <0.001 |
| Eggs and/or flesh foods (EFF) (6–23 m)[4] | 29 (25%) | 14 (14%) | 0.037 |
| Unhealthy food consumption (UFC) (6–23 m)[4] | 23 (20%) | 33 (33%) | 0.034 |
| Zero vegetable and fruit (ZVF) (6–23 m)[4] | 43 (37%) | 18 (18%) | 0.001 |
| Sweet beverage consumption (SwB) (6–23 m)[4] | 17 (15%) | 27 (27%) | 0.030 |

IYCF, infants and young child feeding practices.
[1] Chi-square test was used to compare the proportions across the 2 surveys.
[2] $n = 115$ in survey 1 and $n = 104$ in survey 2.
[3] $n = 60$ in survey 1 and $n = 98$ in survey 2.
[4] $n = 101$ in survey 2 as 3 children were 24 mo old.

was common and increased from 44% to 64% of the households between surveys 1 and 2 (Table 4). Other pulses and nuts fed to children were beans, cowpeas, peas, and Bambara nuts.

Maize was predominantly consumed as a porridge (thin gruel) or Ugali (a stiff porridge; Table 5). Consumption of porridge decreased from 96% in survey 1 to 74% in survey 2. This was accompanied by an increase in consumption of Ugali from 77% in survey 1 to 85% in survey 2. Consumption of maize in Lishe flour porridge was reported among 20% and 13% of IYC in surveys 1 and 2, respectively. Consumption of porridge or Ugali prepared using pearl millet and sorghum was not common (≤10%) in either survey (Table 5).

Groundnuts were fed to children as an ingredient of the composite (Lishe) flour and/or an addition to vegetable and bean relishes to improve taste. The relishes were fed with Ugali. Overall, groundnuts were consumed by 50% of the IYC in survey 1, and this increased to 67% by survey 2. All the 36 Lishe flours consumed in both surveys had groundnuts, except for 2 in survey 1, which had soybeans. Consumption of groundnuts in relishes increased from 31% in survey 1 to 55% in survey 2 (Table 5).

## Mycotoxin contamination of complementary food ingredients

Complementary food ingredients, especially maize and groundnuts, were frequently contaminated with AF (Table 6). The geometric mean AF in survey 1 (5.0 μg/kg) was more than twice that of survey 2 (2.1 μg/kg; paired t-test, $P < 0.05$). Only 8 maize samples (32%) in survey 1 and 1 sample (4%) in survey 2 exceeded the legal limit of AFs in Tanzania, that is, 10 μg/kg [25]. There were significant differences in AF distribution in groundnuts between the 2 surveys. Seventy six percent of

**TABLE 4**
Number and proportion of children fed mycotoxin-susceptible food ingredients within the previous 24 h

| Food ingredient | Survey 1 ($n = 115$) | Survey 2 ($n = 101$) | Chi-Square *P* value |
|---|---|---|---|
| Grains, roots, tubers, and plantains | 115 (100%) | 100 (99%) | 0.285 |
| Food with maize | 107 (93%) | 93 (92%) | 0.787 |
| Food with no maize | 8 (7%) | 8 (8%) | |
| Legumes, nuts, and seeds | 85 (74%) | 83 (82%) | 0.145 |
| Food with groundnuts | 51 (44%) | 65 (64%) | 0.003 |
| Food with no groundnuts | 64 (56%) | 36 (36%) | |

**TABLE 5**
Number and proportion of children who fed on food with maize and groundnuts in the last 24 h

| Food | Main ingredients | Survey 1 | Survey 2 |
|---|---|---|---|
| Porridge[1] (total *n*) | | 110 (96%) | 77 (74%) |
| | Total for maize | 69 (60%) | 56 (54%) |
| | Whole maize (Dona) | 26 (23%) | 16 (15%) |
| | Sifted maize (Sembe) | 24 (21%) | 38 (37%) |
| | Maize (undefined) | 19 (17%) | 2 (2%) |
| | Sorghum | 11 (10%) | 6 (6%) |
| | Pearl millet | 7 (6%) | 2 (2%) |
| Composite f lour porridge (Lishe) | Lishe ingredients | 23 (20%) | 13 (13%) |
| | Maize | 23 (20%) | 13 (13%) |
| | Rice | 17 (15%) | 9 (9%) |
| | Finger millet | 14 (12%) | 8 (8%) |
| | Pearl millet | 5 (4%) | 2 (2%) |
| | Sorghum | 2 (2%) | 3 (3%) |
| | Soybeans | 2 (2%) | 2 (2%) |
| | Wheat | 2 (2%) | 2 (2%) |
| Groundnuts (total *n*) | | 57 (50%) | 70 (67%) |
| | Groundnuts in *Lishe* | 21 (18%) | 13 (13%) |
| | Groundnuts in relishes | 36 (31%) | 57 (55%) |
| Ugali[2] (total *n*) | | 100 (87%) | 97 (93%) |
| | Total for maize | 89 (77%) | 88 (85%) |
| | Whole maize (*Dona*) | 24 (21%) | 22 (21%) |
| | Sifted maize (*Sembe*) | 49 (43%) | 62 (60%) |
| | Maize (undefined) | 16 (14%) | 4 (4%) |
| | Sorghum | 7 (6%) | 7 (7%) |
| | Pearl millet | 4 (3%) | 2 (2%) |
| | *n* | 115 | 104 |

Percentages overlap in several households because children consume porridge and Ugali, or each of them twice, in the past 24 h.
[1] Porridge in this context refers to a soft food (thin gruel) made by boiling cereal or composite flour in water and fed using a spoon from a cup or bowl.
[2] Ugali is a stiff porridge commonly eaten with accompaniments such as vegetables, meat, and/or bean relishes or gravy.

groundnut samples in survey 1 exceeded 10 μg/kg of AFs compared with 45% of samples in survey 2 (Pearson's chi-square = 4.1881, $P = 0.041$).

Among less commonly used food ingredients, 36/43 (84%) had detectable AF (range: 0.2–36 μg/kg) in survey 1. Of these, 6/43 (14%) had AF concentrations >10 μg/kg. In survey 1, the only sample of Bambara nuts had 36 μg/kg of AFs and 1 out of 12 samples of sunflower seeds had 14 μg/kg of AFs. For pearl millet, 1 out of 7 samples had 26 μg/kg of AFs and 3 out of 10 samples of sorghum had 14, 20, and 35 μg/kg of AFs. In survey 2, 27/30 (90%) of such ingredients had detectable AF concentrations (range: 0.2–20). Only one of the 6 sorghum samples had AF concentrations >10 μg/kg. The majority of the other samples in both surveys had AF concentrations of <5 μg/kg (Table 4). Overall, AF contamination in groundnuts was variable over several logs and significantly higher than that in maize and other ingredients.

The geometric mean FUM concentrations in maize were not significantly different across the 2 surveys ($P > 0.05$). Over 60% of the maize samples in each survey had FUM concentrations >155 μg/kg. Only one maize sample had FUM concentrations above the legal limit in Tanzania (2000 μg/kg) [25] in both surveys.

**TABLE 6**
Mycotoxin in main food ingredients (μg/kg)

| Mycotoxins | Survey 1 | Survey 2 |
|---|---|---|
| AF in maize | | |
| Mean (SD) | 11 (15) | 3 (3) |
| Median (range) | 4 (0.6–56) | 2 (0.4–12) |
| Samples with >10 μg/kg | 8 (32%) | 1 (4%) |
| *n* (villages) | 25 | 24 |
| Geometric mean (95% CI)[1] | 5.0 (2.8–9.1) | 2.1 (1.4–3.1) |
| *n* (villages) | 24 | 24 |
| AF in groundnuts | | |
| Mean (SD) | 373 (507) | 535 (1003) |
| Median (range) | 172 (3–2120) | 5 (0.6–3600) |
| Samples with >10 μg/kg[2] | 16 (76%) | 9 (45%) |
| Geometric mean (95% CI) | 100 (38–260) | 19 (4–84) |
| *n* (villages) | 21 | 20 |
| AF in composite flour (*Lishe*) | | |
| Mean (SD) | 10 (10) | 22 (35) |
| Median (range) | 8 (0.6–24) | 3 (0.5–76) |
| Samples with >10 μg/kg | 3 (50%) | 2 (29%) |
| *n* (villages) | 6 | 7 |
| AF in other ingredients[3] | | |
| Range | ND–36 | ND–20 |
| Samples with >10 μg/kg[4] | 6 (14%) | 1 (3%) |
| *n* (villages) | 43 | 30 |
| FUM in maize | | |
| Mean (SD) | 386 (560) | 283 (262) |
| Median (range) | 247 (11–2770) | 200 (ND–950) |
| Samples with >155 μg/kg[5] | 17 (68%) | 15 (63%) |
| *n* (villages) | 25 | 24 |
| Geometric mean (95% CI)[6] | 214 (129–347) | 178 (112–282) |
| *n* (villages) | 24 | 24 |

AF, alfatoxins; FUM, fumonisins; ND, not detectable.
[1] Mean AF concentrations in maize for the 2 surveys were significantly different (paired t-test: $P < 0.05$).
[2] The distribution of AF concentrations in groundnuts (categories ≤10 and >10 μg/kg) for the 2 surveys were significantly different (Pearson chi-square = 4.1881, Pr = 0.041).
[3] Others include Bambara nut, sunflower seeds, rice, wheat, pearl millet, finger millet, and sorghum.
[4] In survey 1, the only sample of Bambara nuts had 36 μg/kg of AF, one (out of 12) sample of sunflower seeds had 14 μg/kg of AF, one (out of 7) pearl millet sample had 26 μg/kg of AF, and 3 (out of 10) samples of sorghum had 14, 20, and 35 μg/kg of AF. In survey 2, only 1 out of 6 sorghum samples had 20 μg/kg of AF. The majority of the other samples had below 5 μg/kg of AF.
[5] Concentrations of AF in maize that can result in exposure above PMTDI of 2-μg/kg body weight based on the recommended daily per capita intake of maize (771 g) for an adult of 60-kg body weight in Tanzania [49].
[6] Mean FUM concentrations in maize for the 2 surveys were not significantly different (paired t-test: $P > 0.05$).

## Discussion

IYC in Kongwa consume diets that are generally poor and characterized by low diversity. Only 20% of them met the MDD in survey 1. This proportion is slightly lower than that reported in the recent national data in Tanzania, which showed that 24% of breastfed children aged 6–23 mo met the MDD [9]. The proportion of breastfed children who met the MDD was also lower than what was reported in national surveys in Uganda (27%) and Kenya (38%) [26, 27]. Dietary diversity is a good predictor of micronutrient density and children's diet intake [28, 29]. A diverse diet was associated with a lower risk of child stunting among 6–23-mo-old children in sub-Saharan Africa [30] and improved linear growth across several countries in Africa, Asia, and the Caribbean [5].

Seasonal variation in MDD was observed. The proportion of households that met the MDD in survey 2 was at least twice that of survey 1, an effect that was not statistically associated with age. The seasonality was driven by the increase in consumption of vitamin A–rich fruits and vegetables and other vegetables. Survey 2 (April–May) was at the end of the rainy season in Kongwa, and green leafy vegetables were more easily available than in survey 1. Consumption of green maize accounted for the substantial increase in other vegetables, unlike in survey 1, when maize was already harvested and stored for 3–4 mo. These changes in consumption were also reflected in the significant decline in the proportion of children who consumed no vegetables and fruits (ZVF) between the 2 seasons. ZVF is a newly added IYCF indicator that represents an unhealthy practice [1]. Low fruit and vegetable intake in young children was associated with the low intake of fruits and vegetables in later period of life in a cohort of US children [31]. Infants who do not frequently consume fruits and vegetables might fail to develop the taste preference and familiarity for such foods later in life.

In terms of other nutrient-rich food groups, consumption of animal source foods (ASFs) in this study, (39% and 28% for the 2 seasons, respectively) was generally lower than that observed in Eastern and Southern Africa (49%) for the same age group [32]. ASFs, which include dairy, are associated with a reduction in stunting, with significant lower risk for children who ingest >1 ASF [32]. Low consumption of eggs and/or flesh foods was observed in Kongwa where poultry husbandry is common. EFF consumption was only reported in a quarter of the households in survey 1 and this decreased by nearly half in survey 2. It is likely that EFF consumption was replaced with more affordable seasonal green leafy vegetables as an accompaniment for Ugali. Consumption of flesh foods in survey 1 (23%) was comparable but lower than the prevalence reported in Eastern and Southern Africa region (25%) and globally (28%) [33]. In both seasons, egg consumption was very rare and much lower than 11% reported in Eastern and Southern Africa region and 17% globally [33]. Infrequent consumption of eggs has also been widely reported in similar semiarid rural areas in Central Tanzania [34]. In a nationally representative survey in Tanzania, households that rely on income from agriculture consumed less ASFs than those that rely on nonagricultural income, similar to rural households compared with urban households [35].

The inadequate diets in Kongwa were also characterized by unhealthy food (UFC) and sweet beverage consumption (SwB) across the 2 seasons. Such foods are often energy-dense but poor in micronutrients. Commonly consumed unhealthy foods in Kongwa include biscuits and deep-fried wheat dough (mandazi). Common sweetened beverages include black tea with sugar and commercially packaged juice made of fruit concentrate. Chronic food insecurity and the convenience of acquiring or preparing such foods in a context where the primary caregivers spend much time on farming activities are likely to have driven the consumption of such foods, especially among older children in this study. These foods can frequently displace nutritious foods in contexts where diets are inadequate and the burden of child malnutrition is high [36]. Excessive consumption of sweet beverages and unhealthy foods is associated with overnutrition [37, 38]. Such foods have penetrated the diets of the rural poor in sub-Saharan Africa [39, 40, 41] where the triple burden of malnutrition is on the rise [42].

Monotonous cereal-based diets were common and protein-rich foods were scarce. Almost all children consume either maize as Ugali or regular porridge. Maize is high in carbohydrates but low in protein, fat, and micronutrients [43]. Nearly 50% of the children consume groundnuts in survey 1 and almost two-thirds of them in survey 2. Although a legume, groundnuts (or peanuts) are considered as oilseeds because of the high oil content. They are rich in high quality protein, oil, and fiber [44]. However, maize and groundnuts are sources of mycotoxins in children's diets, especially in highly unregulated food systems, characterized by minimal food processing before consumption, such as the case of Kongwa District in Tanzania.

The food system in rural Kongwa is characterized by small scale subsistence farmers who generally lack awareness and capacity for mycotoxin control [45]. Suboptimal preharvest conditions such as drought stress and rains prior to and during harvest, exacerbated by poor drying and storage practices (Supplemental Table 2), contribute to postharvest mycotoxin accumulation [46, 47]. Homestead farming is common for maize and groundnuts. However, homegrown reserves are sold out within the course of the year for some households and purchasing is common. In survey 1, 54% of maize samples collected from households were from purchased stock and this rose to 61% in survey 2. Groundnuts purchasing was more common in both surveys (72%).

In both surveys, 18% (9/45) of maize and 61% (25/41) of groundnut samples had AF concentrations above the legal limit for Tanzania. Fourty four percent (18/41) of groundnut samples had >10 times the AF legal limit in both surveys. Groundnuts were contaminated with over 100 times higher AF concentrations than maize for the most contaminated samples. However, consumption of maize was higher than groundnuts. AF concentrations in maize and groundnuts in this study are comparable with concentrations reported in other studies where AF exposure has been associated with growth faltering in West Africa [15, 16, 48]. AF concentrations in maize and groundnuts were frequently higher in survey 1 when 48% of the children were between 6 and 11 mo of age. FUM concentrations in maize were comparable with the concentrations in a study in Northern Tanzania, which found that exposure levels above the PMTDI of 2 μg/kg body weight were inversely associated with linear growth (18). Daily consumption of 771 g of maize with FUM concentrations >55 μg/kg for an adult of 60-kg body weight in Tanzania can result in exposure levels above PMTDI [49]. Exposure of infants aged <6 mo to AFs and FUMs is likely because of introduction of complementary food in Tanzania has been reported as early 1–3 mo of age [9]. In the demographic health survey 2015–2016, 15% and 44% of the 2–3 and 4–5-mo-old infants consumed foods made with cereals [9].

It is important to rethink nutrition education and IYC diets in such low income settings and consider caregivers' time commitments in labor-intensive farming communities. Groundnuts are an important source of a complete protein [50] in this context where ASF consumption is low. One hundred grams of raw groundnuts provides 567 Kcal of energy, 26% protein, 49% total fat, 8.5% fiber, and several vitamins and minerals [51]. Before consumption of groundnuts by children, they should be preceded by rigorous sorting to remove moldy and spoiled kernels to reduce AF exposure. Further research on effective strategies to promote groundnut sorting at the community level and subsequent removal of highly contaminated kernels from the food system is recommended. Consumption of nutrient-dense foods such as ASFs should be promoted for such low income rural households that hold onto cattle and poultry as a source of financial security. Agroprocessing of green leafy vegetables holds potential in improving the shelf life and ensuring availability across seasons.

This study has several strengths and limitations. Purposive sampling of households may limit the generalizability of these findings. However, the wide geographical coverage of a quarter of the villages in Kongwa District provides significant insights into IYCF practices in this region. Panel data on the same children (households) provide robust findings on the otherwise complex and variable IYCF practices, and shed light on the importance of seasonality in the adequacy and diversity of child diets. This study also corroborates other studies that have reported AF and FUM contamination of food ingredients used in complementary feeding. However, pooled food samples limited the ability to link IYCF indicators to toxin exposure at the individual level. Pooling samples may have masked the true variation in individual food contamination because of reduced heterogeneity in toxin concentrations. However, these data indicate a very high frequency of contamination, often at high concentrations.

In conclusion, diets of IYC in Kongwa District are generally characterized by low diet diversity, low consumption of ASFs (dairy, eggs, and flesh foods), and reliance on maize and groundnuts. Low diet diversity puts these children at a great risk of malnutrition, especially micronutrient malnutrition and stunting. Reliance on maize and groundnuts suggests that this population is at a high risk of mycotoxin exposure, especially to AFs (and FUMs from maize). Poorer diet diversity and significantly higher frequency and concentrations of mycotoxin in dietary staples were observed in survey 1. It is predicted that both contribute to stunting and thus seasonal windows of these risk factors require further awareness to better inform intervention studies seeking to improve infant growth. There is a great opportunity and need for culturally appropriate nutrition education and postharvest interventions to improve IYCF practices, food safety, and diets in this context. Primarily, promotion of animal based foods, such as eggs, poultry, and dairy products will improve children's diets and nutrients intake. Understanding IYCF practices and mycotoxin contamination of common food ingredients was critical in informing the design of a dietary intervention for a mycotoxin mitigation research trial in Kongwa [24].

## Author disclosures

FMN, NK, ELP, and PCT, no conflict of interest.

## Acknowledgments

The authors acknowledge the technical advice provided during the study by Dr. Rebecca Stoltzfus and Dr. Rebecca Nelson, the principal investigators of the cluster randomized control trial, to assess the effect of aflatoxin on infant linear growth.

## Author contributions

The authors' responsibilities were as follows–FMN, NK, and ELP: designed the research; FMN and ELP: designed the survey tools; FMN: led data collection activities and data analysis and wrote initial and subsequent drafts of the manuscript; PCT and ELP: provided critical review of the manuscript; and all authors: read and approved the final manuscript.

## Funding

This study was funded by the Bill & Melinda Gates Foundation, as part of a larger study, under grant number OPP1155626. The supporting source had no involvement in study design, implementation, or analysis and has no restrictions regarding publication.

## Data Availability

Data described in the manuscript will be made available upon request.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cdnut.2023.100030.

## References

[1] Indicators for Assessing Infant and Young Child Feeding Practices: Definitions and Measurement Methods [Internet], World Health Organization and the United Nations Children's Fund (UNICEF), Geneva, 2021 [Updated: April 12, 2021; Cited: August 31, 2021].
[2] R.E. Black, C.G. Victora, S.P. Walker, Z.A. Bhutta, P. Christian, M. de Onis, et al., Maternal and child undernutrition and overweight in low-income and middle-income countries, Lancet 382 (9890) (2013) 427–451.
[3] C.K. Lutter, B.M.E.G. Daelmans, M. de Onis, M.T. Kothari, M.T. Ruel, M. Arimond, et al., Undernutrition, poor feeding practices, and low coverage of key nutrition interventions, Pediatrics 128 (6) (2011) e1418–e1427.
[4] A.W. Onyango, E. Borghi, M. de Onis, C. Casanovas Mdel, C. Garza, Complementary feeding and attained linear growth among 6–23-month-old children, Public Health Nutr 17 (9) (2014) 1975–1983.
[5] M. Arimond, M.T. Ruel, Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys, J Nutr 134 (10) (2004) 2579–2585.
[6] A.G. Khamis, A.W. Mwanri, J.E. Ntwenya, K. Kreppel, The influence of dietary diversity on the nutritional status of children between 6 and 23 months of age in Tanzania, BMC Pediatr 19 (1) (2019) 518.
[7] B.P. Marriott, A. White, L. Hadden, J.C. Davies, J.C. Wallingford, World Health Organization (WHO) infant and young child feeding indicators: associations with growth measures in 14 low-income countries, Matern Child Nutr 8 (3) (2012) 354–370.
[8] World Health Organization, United Nations Children's Fund (UNICEF) & World Bank (2021). Levels and trends in child malnutrition: UNICEF / WHO / The World Bank Group joint child malnutrition estimates: key findings of the 2021 edition. World Health Organization. https://apps.who.int/iris/handle/10665/341135. Dates cited: 2 December 2021.
[9] Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) [Tanzania Mainland], Ministry of Health (MoH) [Zanzibar], National Bureau of Statistics (NBS), Office of the Chief Government Statistician (OCGS), and ICF. 2016. Tanzania Demographic and Health Survey and Malaria Indicator Survey (TDHS-MIS) 2015–16. Dar es Salaam, Tanzania, and Rockville, Maryland, USA: MoHCDGEC,

MoH, NBS, OCGS, and ICF. [updated: October 1, 2019; Cited: October 31, 2021].
[10] Indicators for Assessing Infant and Young Child Feeding Practices: Part 1 Definitions [Internet], World Health Organization, Washington, DC, USA, 2008 [Updated: November 8, 2007: Cited: October 31, 2021].
[11] F.A. Ogbo, P. Ogeleka, A.O. Awosemo, Trends and determinants of complementary feeding practices in Tanzania, 2004–2016, Trop Med Health 46 (1) (2018) 40.
[12] R. Masuke, S.E. Msuya, J.M. Mahande, E.J. Diarz, B. Stray-Pedersen, O. Jahanpour, et al., Effect of inappropriate complementary feeding practices on the nutritional status of children aged 6–24 months in urban Moshi, Northern Tanzania: cohort study, PLOS ONE 16 (5) (2021), e0250562.
[13] M. Eskola, G. Kos, C.T. Elliott, J. Hajšlová, S. Mayar, R. Krska, Worldwide contamination of food-crops with mycotoxins: validity of the widely cited 'FAO estimate' of 25, Crit Rev Food Sci Nutr 60 (16) (2020) 2773–2789.
[14] Evaluation of Certain Contaminants in Food: Eighty-Third Report of the Joint FAO/WHO Expert Committee on Food Additives [Internet], World Health Organization, Joint FAO/WHO Expert Committee on Food Additives, Geneva, Switzerland, 2017, p. 1002 [Updated: November 17, 2017; Cited: October 31, 2021].
[15] Y.Y. Gong, K. Cardwell, A. Hounsa, S. Egal, P.C. Turner, A.J. Hall, et al., Dietary aflatoxin exposure and impaired growth in young children from Benin and Togo: cross sectional study, Br Med J 325 (7354) (2002) 20–21.
[16] Y.Y. Gong, A. Hounsa, S. Egal, P.C. Turner, A.E. Sutcliffe, A.J. Hall, Postweaning exposure to aflatoxin results in impaired child growth: a longitudinal study in Benin, West Africa, Environ Health Perspect 112 (13) (2004) 1334–1338.
[17] P.C. Turner, A.C. Collinson, Y.B. Cheung, Y.Y. Gong, A.J. Hall, A.M. Prentice, et al., Aflatoxin exposure in utero causes growth faltering in Gambian infants, Int J Epidemiol 36 (5) (2007) 1119–1125.
[18] M.E. Kimanya, B. De Meulenaer, D. Roberfroid, C. Lachat, P. Kolsteren, Fumonisin exposure through maize in complementary foods is inversely associated with linear growth of infants in Tanzania, Mol Nutr Food Res 54 (11) (2010) 1659–1667.
[19] C.P. Shirima, M.E. Kimanya, M.N. Routledge, C. Srey, J.L. Kinabo, H.U. Humpf, et al., A prospective study of growth and biomarkers of exposure to aflatoxin and fumonisin during early childhood in Tanzania, Environ Health Perspect 123 (2) (2015) 173–178.
[20] S.B. Boni, F. Beed, M.E. Kimanya, E. Koyano, O. Mponda, D. Mamiro, et al., Aflatoxin contamination in Tanzania: quantifying the problem in maize and groundnuts from rural households, World Mycotoxin J 14 (4) (2021) 553–564.
[21] H. Magoha, M. Kimanya, B. De Meulenaer, D. Roberfroid, C. Lachat, P. Kolsteren, Risk of dietary exposure to aflatoxins and fumonisins in infants less than 6 months of age in Rombo, Northern Tanzania, Matern Child Nutr 12 (3) (2016) 516–527.
[22] A. Kamala, C. Shirima, B. Jani, M. Bakari, H. Sillo, N. Rusibamayila, et al., Outbreak of an acute aflatoxicosis in Tanzania during 2016, World Mycotoxin J 11 (3) (2018) 311–320.
[23] C.G. Victora, M. de Onis, P.C. Hallal, M. Blössner, R. Shrimpton, Worldwide timing of growth faltering: revisiting implications for interventions, Pediatrics 125 (3) (2010) e473–e480.
[24] E. Phillips, F. Ngure, L.E. Smith, E. Makule, P.C. Turner, R. Nelson, et al., Protocol for the trial to establish a causal linkage between mycotoxin exposure and child stunting: a cluster randomized trial, BMC Public Health 20 (1) (2020) 598.
[25] [Internet]. 3rd Edition, East African Standard: Maize Grains–Specification, East African Community, Arusha, Tanzania, 2013 [Updated: 2011; October 31, 2021].
[26] [Internet], Uganda Demographic and Health Survey 2016, Uganda Bureau of Statistics and ICF, Kampala, Uganda, and Maryland, USA, 2016 [Updated: January, 2018; Cited: November 24, 2021].
[27] Demographic and Health Survey, Kenya National Bureau of Statistics [Internet], Ministry of Health, National AIDS Control Council, Kenya Medical Research Institute, National Council for Population and Development, ICF International, Nairobi, Kenya, and Rockville, Maryland, 2014 [Updated: December 2015; Cited: November 24, 2021].
[28] G.L. Kennedy, M.R. Pedro, C. Seghieri, G. Nantel, I. Brouwer, Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children, J Nutr 137 (2) (2007) 472–477.
[29] M.M. Moursi, M. Arimond, K.G. Dewey, S. Trèche, M.T. Ruel, F. Delpeuch, Dietary diversity is a good predictor of the micronutrient density of the diet of 6- to 23-month-old children in Madagascar, J Nutr 138 (12) (2008) 2448–2453.
[30] R.G. Aboagye, A.A. Seidu, B.O. Ahinkorah, F. Arthur-Holmes, A. Cadri, L.K. Dadzie, et al., Dietary diversity and undernutrition in children aged 6–23 months in sub-Saharan Africa, Nutrients 13 (10) (2021) 3431.
[31] K.A. Grimm, S.A. Kim, A.L. Yaroch, K.S. Scanlon, Fruit and vegetable intake during infancy and early childhood, Pediatrics 134 (Suppl_1) (2014) S63–S69.
[32] D. Headey, K. Hirvonen, J. Hoddinott, Animal sourced foods and child stunting, Am J Agric Econ 100 (5) (2018) 1302–1319.
[33] J.M. White, F. Bégin, R. Kumapley, C. Murray, J. Krasevec, Complementary feeding practices: current global and regional estimates, Matern Child Nutr 13 (Suppl_2) (2017), e12505.
[34] J. de Bruyn, B. Bagnol, I. Darnton-Hill, W. Maulaga, P.C. Thomson, R. Alders, Characterising infant and young child feeding practices and the consumption of poultry products in rural Tanzania: a mixed methods approach, Matern Child Nutr 14 (2) (2018) 1–15.
[35] P. Wang, N. Tran, D. Enahoro, C.Y. Chan, K.M. Shikuku, K.M. Rich, et al., Spatial and temporal patterns of consumption of animal-source foods in Tanzania, Agribusiness 38 (2) (2022) 328–348.
[36] A.M. Pries, S. Filteau, E.L. Ferguson, Snack food and beverage consumption and young child nutrition in low- and middle income countries: a systematic review, Matern Child Nutr 15 (Suppl_4) (2019), e12729.
[37] B.M. Popkin, T. Reardon, Obesity and the food system transformation in Latin America, Obes Rev 19 (8) (2018) 1028–1064.
[38] B.M. Popkin, Nutrition and Health in Developing Countries, in: The nutrition transition and its relationship to demographic change, Humana Press, Totowa, NJ, 2008, pp. 601–616.
[39] M. Dolislager, L.S.O. Liverpool-Tasie, N.M. Mason, T. Reardon, D. Tschirley, Consumption of healthy and unhealthy foods by the African poor: evidence from Nigeria, Tanzania, and Uganda, Agric Econ 53 (2022) 870–894.
[40] C.M. Sauer, T. Reardon, D. Tschirley, S. Liverpool-Tasie, T. Awokuse, R. Alphonce, et al., Consumption of processed food & food away from home in big cities, small towns, and rural areas of Tanzania, Agric Econ 52 (5) (2021) 749–770.
[41] D. Tschirley, T. Reardon, M. Dolislager, J. Snyder, The rise of a middle class in East and Southern Africa: implications for food system transformation, J Int Dev 27 (5) (2015) 628–646.
[42] A.K. Christian, F.A. Dake, Profiling household double and triple burden of malnutrition in sub-Saharan Africa: prevalence and influencing household factors, Public Health Nutr 25 (6) (2022) 1563–1576.
[43] [Internet], Corn grain, white (SR LEGACY, 168920), United States Department of Agriculture (USDA), 2019 [Updated: April 2018; Cited: January 22, 2022].
[44] K. Suchoszek-Łukaniuk, A. Jaromin, M. Korycińska, A. Kozubek, Nuts and seeds in health and disease prevention, in: Chapter 13, Health benefits of peanut (*Arachis hypogaea L.*) seeds and peanut oil consumption, Academic Press, 2011, pp. 873–880.
[45] M. Sasamalo, J. Mugula, C. Nyangi, Aflatoxins contamination of maize at harvest and during storage in Dodoma, Tanzania, Int J Innov Res Dev 7 (6) (2018) 10–15.
[46] A. Kamala, M. Kimanya, G. Haesaert, B. Tiisekwa, R. Madege, S. Degraeve, et al., Local post-harvest practices associated with aflatoxin and fumonisin contamination of maize in three agro ecological zones of Tanzania, Food Addit Contam Part A Chem Anal Control Expo Risk Assess 33 (3) (2016) 551–559.
[47] A. Seetha, W. Munthali, H.W. Msere, E. Swai, Y. Muzanila, E. Sichone, et al., Occurrence of aflatoxins and its management in diverse cropping systems of Central Tanzania, Mycotoxin Res 33 (4) (2017) 323–331.
[48] S. Egal, A. Hounsa, Y.Y. Gong, P.C. Turner, C.P. Wild, A.J. Hall, et al., Dietary exposure to aflatoxin from maize and groundnut in young children from Benin and Togo, West Africa, Int J Food Microbiol 104 (2) (2005) 215–224.
[49] M. Kimanya, B. de Meulenaer, B. Tiisekwa, M. Ndomondo-Sigonda, P. Kolsteren, Human exposure to fumonisins from home grown maize in Tanzania, World Mycotoxin J 1 (3) (2008) 307–313.
[50] S.S. Arya, A.R. Salve, S. Chauhan, Peanuts as functional food: a review, J Food Sci Technol 53 (1) (2016) 31–41.
[51] Peanuts, all types, raw (SR LEGACY, 172430) [Internet], United States Department of Agriculture (USDA), 2019 [Updated: April 2018; Cited: January 22, 2022].