Original Article

Strategies to reduce exposure of fumonisins from complementary foods in rural Tanzania

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Abstract

Feeding infants with maize can expose them to fumonisin mycotoxins. We assessed fumonisin exposure from complementary foods in rural Tanzania and determined strategies to reduce the exposure. We conducted a cross-sectional study in four villages of Tarakea division, Northern Tanzania. We used a repeat 24-hour dietary recall to collect data of maize consumption as complementary food for 254 infants aged 6–8 months. Fumonisin concentrations in the maize were also estimated. Fumonisin exposure was assessed using @RISK analysis software. With the software, several maximum fumonisin contamination and maize consumption patterns were combined in order to determine effective strategies for minimizing fumonisin exposure. Of the infants, 89% consumed maize at amounts up to 158 g/person/day (mean; 43 g/person/day $\pm$ 28). The maize was contaminated with fumonisins at levels up to 3201 $\mu\text{g kg}^{-1}$. Risk of fumonisin intake above the provisional maximum tolerable daily limit of 2 $\mu\text{g kg}^{-1}$ body weight was 15% (95% confidence interval; 10–19). The risk was minimized when the maximum contamination was set at 150 $\mu\text{g kg}^{-1}$. The risk was also minimized when the maximum consumption was set at 20 g/child/day while keeping the maximum contamination at the European Union (EU) maximum tolerated limit (MTL) of 1000 $\mu\text{g kg}^{-1}$. Considering the economical and technological limitations of adopting good agricultural practices in rural Tanzania, it is practically difficult to reduce contamination in maize to 150 $\mu\text{g kg}^{-1}$. We suggest adoption of the EU MTL of 1000 $\mu\text{g kg}^{-1}$ for fumonisins in maize and reduction, by replacement with another cereal, of the maize component in complementary foods to a maximum intake of 20 g/child/day.

Keywords: fumonisins, infants, maize, maximum tolerated limit, risk, Tanzania.

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Introduction

In most parts of Tanzania, maize is the main cereal used in complementary food (Mamiro *et al.* 2005; Nyaruhucha *et al.* 2006; Kimanya *et al.* 2009). Unfortunately, maize is very vulnerable to contamination by fumonisin mycotoxins (Shephard *et al.* 1996; Miller 2001). The most prevalent of the fumonisins in contaminated

maize are fumonisins B₁ (FB₁), B₂ (FB₂) and B₃ (FB₃) (Miller 2001; Fandohan *et al.* 2005).

In animals, FB₁ can cause several health effects including leucoencephalomalacia in horses (Kellerman *et al.* 1990) and liver and kidneys cancers (Riley *et al.* 1994; Gelderblom *et al.* 2001) in rats and mice. A correlation has been epidemiologically suggested between consumption of fumonisin-contaminated

maize and the high incidence of oesophageal cancer in the former Transkei region of South Africa (Rheeder *et al.* 1992), Northeastern Italy (Franceschi *et al.* 1990), China (Li *et al.* 2001) and Iran (Shephard *et al.* 2000). The International Agency for Research on Cancer (IARC) classified FB₁ as a group 2B carcinogen (IARC 2002). The Joint FAO/WHO Expert Committee on Food Additives (JECFA) recommends a provisional maximum tolerable daily intake (PMTDI) of 2 µg kg⁻¹ body weight (bw) for FB₁, FB₂ and FB₃ alone or in combination [World Health Organization (WHO) 2002]. In their review paper, Bouhet and Oswald (2007) state that available evidence indicates that fumonisins induce cytotoxicity of intestinal mucosal cells and can thus disrupt the barrier function, and that cytokine production is also affected. These effects can interfere with normal absorption mechanism.

Strategies to reduce intake of fumonisins can be based on either limiting the toxin levels in food, limiting the consumption of the food or a combination of both (Marasas 1997; Humphreys *et al.* 2001; van Egmond *et al.* 2007). The European Union (EU) (van Egmond *et al.* 2007), Iran (Yazdanpanah *et al.* 2006) and Switzerland (de Nijs *et al.* 1998) limit fumonisins in maize flour for human consumption at a maximum concentration of 1000 µg kg⁻¹. However, in view of the high maize consumption in South Africa, Marasas (1997) suggested a maximum tolerated limit (MTL) of 122 µg kg⁻¹ for people in rural areas and 202 µg kg⁻¹ for people in urban areas. In an exposure assessment for fumonisins in maize for human consumption in the United States, Humphreys *et al.* (2001) concluded that limiting maize consumption

would be more practical than limiting the concentration of fumonisins in maize.

In Tanzania, maize is grown and used as staple food for the majority of populations in rural areas. The average daily per capita maize consumption in the main maize-producing regions of Tanzania is 356 g (Nkonya *et al.* 1998). Available data show the presence of fumonisins in maize from Tanzania at concentrations of up to 21 616 µg kg⁻¹ (Kimanya *et al.* 2008a, 2009). Based on the high maize consumption and fumonisin contamination of maize in Tanzania, it has been established that adults (Kimanya *et al.* 2008a, 2009) and children (Kimanya *et al.* 2009, 2010) in this country are at a high risk of exposure to these toxins. Using a deterministic approach, we recently found that 12% of 215 infants who received a maize-based complementary food in Tanzania exceeded the PMTDI of 2 µg kg⁻¹ bw (Kimanya *et al.* 2010). Importantly, in that study, we showed that at 12 months of age, the infants with fumonisin exposures above the PMTDI were significantly shorter by 1.3 cm and lighter by 328 g than those with exposures below the limit. These findings suggest that fumonisins intake is associated with growth retardation. In view of the high fumonisin exposures and the suggested influence of these toxins on child growth, there is an urgent need to search for strategies that minimize fumonisin exposure in maize, in particular, the maize-based complementary foods consumed in Tanzania.

The objective of this study was therefore to determine a MTL for fumonisins in flour and a maximum advisory limit of maize for consumption in Tanzania as complementary foods in case the EU MTL of 1000 µg kg⁻¹ for fumonisins is adopted.

Key messages

- More than 80% of the infants consumed maize, at amounts ranging from 2 to 158 g/child/day.
- The maize consumed by the infants contained fumonisins from 21 to 3201 µg kg⁻¹.
- The risk of an infant to be exposed to fumonisins above the provisional maximum tolerable daily intake (PMTDI) of 2 µg kg⁻¹ body weight was 15% (95% confidence interval; 10–19).
- The risk of exceeding the PMTDI can be minimized by setting maximum contamination in maize at 150 µg kg⁻¹ or limiting the maximum maize consumption at 20 g/child/day and the maximum contamination at 1000 µg kg⁻¹.
- In view of the impracticality of reducing fumonisin contamination in maize to the maximum limit of 150 µg kg⁻¹, we recommend adoption of a maximum tolerated limit of 1000 µg kg⁻¹ for fumonisins in maize for Tanzania and reduction of maize intake by infants to the maximum limit of 20 g/child/day.

Methods

Study area

The study was conducted in four villages of the Tarakea division, Northern Tanzania. This division was chosen based on the outcome of a preliminary survey of fumonisins in main maize-producing areas of Tanzania. The survey found that maize from a village (Kikelelwa) in Tarakea contained contamination levels of up to $11048 \mu\text{g kg}^{-1}$ compared with levels of up to $3560 \mu\text{g kg}^{-1}$ contained in maize from other villages surveyed in other parts of the country.

Subject recruitment

The subjects were recruited as described in Kimanya *et al.* (2008b) and Kimanya *et al.* (2010). Briefly, all infants in Tarakea who attained the age of 6 months in July, August or September 2006 were eligible to participate in the study. From July to September 2006, 6-month-old infants were progressively recruited. Infants were identified using their registration number and dates of birth as recorded in registers of birth in seven reproductive child health clinics of the division. In Tanzania, all infants born in clinics are registered soon after birth. In case of home deliveries, registration is done on the day the child is taken to the clinic for immunization. The study was approved by the ethics committees of the National Institute of Medical Research in Tanzania and Ghent University in Belgium.

Collection of maize consumption data and maize flour samples

Complementary food consumption data and maize flour samples were collected as described in Kimanya *et al.* (2008b). In brief, a repeat 24-hour dietary recall technique was used to estimate consumption of complementary food for each infant. An amount of maize flour equivalent to that used in preparation of the complementary food in the previous day was packed in a khaki paper bag, sealed and then transported to the Tanzanian Food and Drugs Authority laboratory for analysis. Its weight was measured and

recorded. Two portions of the maize flour, as collected during the two visits of a family, were mixed using a laboratory mixer and were used as a sample for determination of fumonisins.

Processing of food consumption data

We entered and processed the food consumption data in a Microsoft Access-based food intake database. With the software, the amount of different ingredients of complementary foods consumed by an infant per day was calculated. Based on amounts calculated for each of the two 24-hour recalls, the average daily maize consumption ($\text{kg kg}^{-1} \text{ bw day}^{-1}$) for each infant was calculated by dividing the child's average daily maize consumption (kg day^{-1}) by his/her most recent bw, at the time of the complementary food survey, which was obtained from her monthly records of bw in his/her clinic card.

Determination of fumonisins in ready-to-cook maize flour

FB₁, FB₂ and FB₃ in the maize flour consumed by the infants were determined by using a liquid chromatographic method based on Sydenham *et al.* (1992) with slight modifications as recommended by Samapundo *et al.* (2006). The limit of detection (LOD) for the analytical method, defined as the mean value of the blank readings plus three standard deviations, was $20 \mu\text{g kg}^{-1}$ for FB₁ and FB₂ and $18 \mu\text{g kg}^{-1}$ for FB₃.

Probabilistic exposure assessment

The probabilistic exposure assessment was performed with the @RISK analysis software (@RISK 4.5.5 professional edition, Palisade, Middlesex, UK). We modelled the probable fumonisin exposure by combining the total fumonisin (FB₁ + FB₂ + FB₃) contamination data with the maize consumption data. Values of FB₁ or FB₂ and FB₃ below the LOD were replaced with the LOD value of $20 \mu\text{g kg}^{-1}$ and $18 \mu\text{g kg}^{-1}$, respectively, divided by 2 (Vose 2000; Baert *et al.* 2007). The exposure was compared with the PMTDI of $2 \mu\text{g kg}^{-1} \text{ bw}$ to estimate the risk of unacceptable exposures

among the infants as recommended by the JECFA [World Health Organization (WHO) 2002].

The variability of the maize consumption and contamination values was described by a non-parametric, discrete uniform (RiskDuniform) distribution ensuring that all values had the same probability of occurrence (Vose 2000; Baert *et al.* 2007). Second-order Monte Carlo simulation was performed for propagation of the variability and uncertainty for the values. Latin hypercube sampling procedure was used. The simulation had 500 iterations to account for the variability in the maize consumption and contamination data as the inner loop and 500 bootstrap iterations to describe the outer loop for determination of the confidence intervals (CI) (Vose 2000; Baert *et al.* 2007).

Determination of MTL for fumonisins

We evaluated the probability of exceeding the PMTDI for different assumed MTLs for fumonisin concentration in maize. Based on the fumonisin contamination pattern generated by this study, five different hypothetical contamination data sets with maximum concentrations of 1000, 500, 250, 200 and 150 $\mu\text{g kg}^{-1}$ were created and evaluated. In order to create a hypothetical contamination data set, we replaced all contaminations above the desired maximum concentration (e.g. 1000 g kg^{-1}) in the contamination pattern with this desired value (Bolger *et al.* 2001). Probabilistic exposure assessment was conducted for each of the contamination scenarios using the maize consumption pattern estimated by this study for infants in this community. For each scenario, we evaluated the probability of exceeding the PMTDI.

Determination of maximum advisory consumption level for maize

Assuming the EU MTL of 1000 $\mu\text{g kg}^{-1}$ is adopted for Tanzania, we evaluated exposure using three hypothetical maize consumption patterns by setting the maximum maize consumption levels at 80, 40 and 20 g/child/day, being, respectively, about 50, 25, 12.5% of the highest maize consumption of 158 g/child/day estimated by this study. To create a hypothetical con-

sumption data set, we replaced all maize intakes above the desired maximum level with the maximum consumption level (Baert *et al.* 2007). Probabilistic exposure assessment was conducted for each of the consumption scenarios using the fumonisins contamination data set of 1000 $\mu\text{g kg}^{-1}$ as the maximum contamination. For each maize consumption scenario, the probability of exceeding the PMTDI was evaluated.

Statistical analysis of data

The statistical package used for the descriptive statistics was Stata version 10 (Statacorp, College Station, TX, USA).

Results

Subjects

Mothers of 273 out of 563 registered infants consented for their infants to participate in the study. The mothers of six out of the 273 infants changed their minds afterwards. The mothers of 13 other infants were either living in areas which could not be easily reached or were not found at home, despite having received information in advance on the planned visit. In total, 254 infants were recruited and participated in the study. The average weight of the infants was $7.9 \text{ kg} \pm 1.04$.

Maize dishes consumed by infants

All infants received complementary foods and 89% of them consumed maize-based dishes. The maize-based dishes were consumed as a thin maize porridge, thick maize porridge, thin mixed cereal porridge, dehulled maize grits or a combination of these dishes. The thin, mixed cereal porridge was prepared using flour obtained from a mixture of rice, finger millet, groundnuts, legume beans, wheat and sorghum and/or bulrush millet at varying proportions. Table 1 shows the type of the maize-based dishes and amounts of maize calculated from different amounts of the respective dishes consumed by the infants. The infants consumed maize at amounts ranging from 2 to 158 g/child/day (mean; $43 \text{ g/child/day} \pm 28$). Maize intakes

Table 1. Proportions of infants who consumed different maize-based dishes and maize intake from the respective dish(es)

Type of maize-based dish	Percentage of infants	Mean maize intake (g/child/day) $\pm$ SD	Range of maize intake (g/child/day)
Thin maize porridge	43.4	46.9 $\pm$ 26.5	5.2–118.2
Thin cereal* porridge	13.7	23.8 $\pm$ 17.4	2.4–60.2
Thick maize porridge	4.4	17.7 $\pm$ 7.4	8.6–30.2
Thin and thick maize porridges	20.4	56.3 $\pm$ 31.5	9.5–157.6
Thin maize porridge and thin cereal porridge	6.2	33.67 $\pm$ 17.11	7.8–74.6
Thin maize porridge and dehulled maize grits	0.5	103.1	–
Thin cereal porridge and thick maize porridge	3.5	23.8 $\pm$ 18.2	3.9–56.0
Thin cereal porridge and dehulled maize grits	0.9	21.6 $\pm$ 23.4	5.1–38.2
Thin maize porridge, thick maize porridge, thin cereal porridge	3.1	41.1 $\pm$ 19.7	14.8–74.0
Thin maize porridge, thick maize porridge and dehulled maize porridge	2.5	72.1 $\pm$ 32.1	26.1–108.0
Thin maize porridge, thin cereal porridge and dehulled maize grits	0.5	27.1	–
Thin maize porridge, thick maize porridge, thin cereal porridge and dehulled maize porridge.	0.9	38.9 $\pm$ 7.9	32.2–44.5
Overall	100	43.0 $\pm$ 28.1	2.4–157.6

SD, standard deviation. *A mixture of rice, finger millet, groundnuts, legume beans, wheat, sorghum and bulrush millet or another combination.

Table 2. Concentration and occurrence of fumonisins at different ranges

Mycotoxin	Range ($\mu\text{g kg}^{-1}$)	Occurrence (%) at different ranges ($\mu\text{g kg}^{-1}$)			
		> LOD*	>150	>500	>1000**
Total fumonisins	20–3201	70	36	15	8
FB ₁	21–2375	67	25	7	6
FB ₂	20–1076	52	15	4	1
FB ₃	20–604	31	2	1	–

*Limit of detection (LOD) stands for limit of detection of 20 $\mu\text{g kg}^{-1}$ for FB₁ or FB₂ or FB₃; **MTL set for fumonisins in maize flour in the European Union.

above 100 g/day are recorded in the older infants who received predominantly the thick maize porridge.

Fumonisin in ready-to-cook maize flour

Maize flours from 178 (70%) out of the 254 families contained total fumonisins at concentrations varying from 20 to 3201 $\mu\text{g kg}^{-1}$. Percentage of samples contaminated by total fumonisins, FB₁, FB₂ or FB₃ at different ranges is shown in Table 2.

Probable fumonisin exposures

Table 3 shows probable fumonisins exposure levels and their relationships with the PMTDI at different

Table 3. Probable fumonisins exposure levels and their relationship with the PMTDI at different percentiles (mean with 95% confidence interval)

Percentile	Exposure ($\mu\text{g kg}^{-1}$ bw day ⁻¹)	Relationship with PMTDI (%)
50th	0.33 (0.28–0.43)	17
75th	1.09 (0.88–1.43)	55
80th	1.47 (1.13–1.84)	74
85th	2.04 (1.52–2.73)	102
90th	3.26 (2.04–4.59)	163
95th	6.24 (3.62–9.43)	312
99th	17.00 (9.01–32.17)	850

PMTDI, provisional maximum tolerable daily intake.

percentiles of the exposure pattern. The probable fumonisin exposures among the infants equalled the PMTDI value of 2 $\mu\text{g kg}^{-1}$ bw at the 85th percentile. The probable exposure levels for the higher consumers, at the 95th and 99th percentiles, would be more than 300% and 800 % of the PMTDI, respectively.

Limit of fumonisins in maize

Table 4 shows that when the maximum contamination in the data was set at the EU MTL of 1000 $\mu\text{g kg}^{-1}$, the probability of exceeding the PMTDI was reduced from 15% (95% CI: 10–19) to 8% (95% CI: 5–13). The risk of unacceptable exposure was reduced to

Table 4. Comparison of probabilities of exceeding the PMTDI (mean with 95% confidence interval) for different fumonisin contamination patterns

Total fumonisin concentration ^a ($\mu\text{g kg}^{-1}$)	Probability of exceeding PMTDI (%)
29–3201	15 (10–19)
29–1000 ^b	8 (5–13)
29–500 ^b	6 (3–11)
29–250 ^b	2 (0–4)
29–200 ^b	1 (0–2)
29–150 ^b	0 (0–1)

The minimum contamination value of $29 \mu\text{g kg}^{-1}$ is the minimum total fumonisin obtained by replacing contaminations below limit of detection (LOD) for FB₁, FB₂ and FB₃ by respective LOD values divided by 2; ^aTotal fumonisin contamination = $F(B_1 + B_2 + B_3)$; ^bTotal fumonisins data bearing the superscript letter 'b' are hypothetical.

Table 5. Comparison of probabilities of exceeding the PMTDI (mean with 95% confidence interval) for different maize consumption patterns for maize containing the EU MTL of $1000 \mu\text{g kg}^{-1}$

Maize consumption pattern (g/child/day)	Probability of exceeding PMTDI (%)
2.37–158	8 (5–13)
2.37–80 ^b	8 (5–11)
2.37–40 ^b	2 (0–4)
2.37–20 ^b	0 (0–1)

PMTDI, provisional maximum tolerable daily intake; EU, European Union; MTL, maximum tolerated limit. ^aMTL set for fumonisins in maize flour in the European Union; ^bMaize consumption data bearing the superscript letter 'b' are hypothetical.

minimal when the maximum contamination was set at $150 \mu\text{g kg}^{-1}$.

Limit of maize consumption in complementary foods

Table 5 shows that reduction of the maximum maize intake among the infants from 158 to 40 g/child/day does not minimize risk of exposure to the infants, even if the EU MTL of $1000 \mu\text{g kg}^{-1}$ is adopted for this community.

However, when the maximum maize intake was set at 20 g/day, the risk of exceeding the PMTDI was significantly minimized from 8 (95% CI: 5–13) to 0 (95% CI: 0–1).

Discussion

We evaluated two strategies to minimize fumonisin intake in foods for infants in rural Tanzania. The first one entails reducing the concentration of fumonisins in maize for human consumption, and the second one, simultaneously reducing the concentration of fumonisins in maize and the maize consumption in complementary foods. Results of the evaluation for the first strategy suggest that concentration of fumonisins in maize for human consumption in Tanzanian should not exceed $150 \mu\text{g kg}^{-1}$. This maximum limit of $150 \mu\text{g kg}^{-1}$ is similar to the maximum limit of $122 \mu\text{g kg}^{-1}$ suggested by Marasas (1997) for fumonisins in maize for rural South Africa. Maize consumption and fumonisin contamination patterns in rural South Africa and Tanzania are similar. Average per capita maize consumption can be as high as 397 g/day in South Africa (Shephard *et al.* 2007) and as high as 356 g/day in Tanzania (Nkonya *et al.* 1998). Fumonisin contamination concentrations in home-grown maize are up to $10\,140 \mu\text{g/kg}$ in South Africa (Shephard *et al.* 1996, 2007) and up to $11\,048 \mu\text{g kg}^{-1}$ in Tanzania (Kimanya *et al.* 2008a).

Reduction of the maximum contamination in maize grain from the present value of $11\,048 \mu\text{g kg}^{-1}$, or in maize flour from $3201 \mu\text{g kg}^{-1}$, to the maximum value of $150 \mu\text{g kg}^{-1}$ is a challenge that the available technologies, in place in Tanzania, can hardly fulfil. There is a very low rate of adoption of good maize production practices in Tanzania (Nkonya *et al.* 1998), a situation that may influence fumonisin production in the crops (Soriano & Dragacci 2004; Kabak *et al.* 2006). Sorting maize is another approach to reduce fumonisin contamination in maize (Fandohan *et al.* 2005; Kimanya *et al.* 2009), but there are reports that some resource poor farmers in rural Tanzania and other parts of Africa cannot afford discarding the visibly bad-quality maize sorted from their harvest (Jolly *et al.* 2006; Kimanya *et al.* 2008a). We reported previously that the risk of exceeding the PMTDI would be up to 24% if infants consumed unsorted maize in the year 2006 (Kimanya *et al.* 2008b). The risk of exceeding the PMTDI as estimated by this exposure assessment is still very high (15%), although mothers did not indicate to have

used unsorted maize in the complementary foods. Possibly, the mothers used whole maize flour. For various reasons, such as minimization of food losses, people in the Kikelelwa village of Tarakea prefer whole to dehulled maize flour (Kimanya *et al.* 2008a). This might be the case in the other neighbouring villages studied. Dehulling of maize as part of milling is one of the practices that reduce mycotoxin contamination in maize (Fandohan *et al.* 2005). Another technology which could be promoted to reduce fumonisin contamination in maize is steeping. Kpodo *et al.* (2006) reported that a steeping stage that precedes milling and fermentation of maize for *Kenkey* leads to significant reduction in fumonisin levels in the raw material maize. However, the authors showed that steeping alone is not capable of reducing contamination in maize to levels as low as 150/kg. One could also argue to mix maize grain or flour with different contamination levels to decrease overall contamination. This practice, however, cannot be promoted because it undermines the spirit of assuring minimal exposure of mycotoxins in food. Even if mixing could be of help at times of unpredictably high contamination, the practice is very difficult to implement in auto-subsistence farming areas like the rural Tanzania. Mixing maize batches of different contamination levels entails that batches can be analysed for contamination and that flours can be mixed centrally. Clearly, more efforts will be needed to improve the maize management practices in Tanzania to reduce mycotoxin contamination in this crop.

As preventive technologies are being searched for and as normal cooking temperatures do not have a considerable effect on the fumonisin concentration in foods (Shephard *et al.* 1996; Fandohan *et al.* 2005), reduction of maize consumption appears to be the complementary strategy for minimizing fumonisin exposure in rural Tanzania. A similar observation was made by Humphreys *et al.* (2001) for the United States.

In our evaluation for the second strategy, we demonstrated that if the maximum fumonisin concentration in maize for human consumption in Tanzania is limited to 1000 $\mu\text{g kg}^{-1}$, the risk of exceeding the PMTDI will only be minimal when the maximum

maize consumption as part of complementary food is limited to 20 g/child/day. Thus, partial replacement of maize with other cereals could be a possible option to minimize fumonisin exposure in children in the country. Mothers could be advised to replace part of the maize component in the complementary foods with a less fumonisin-contaminated cereal such as finger millet and sorghum (Munimbazi & Bullerman 1996). As was found in this study and the studies by Mamiro *et al.* (2005) and Nyaruhucha *et al.* (2006), finger millet, sorghum and rice are some of the other cereals already in use as part of complementary foods in Tanzania. However, it should be noted that this study did not determine fumonisins in the other cereals used in complementary foods in Tanzania. Thus, there is a need to examine extent of fumonisin contamination in the other cereal crops before any of the crops is advocated for gradual replacement of maize in complementary foods. Indeed, future surveys of mycotoxins in Tanzania should examine contamination of other mycotoxins in complementary foods. For instance, aflatoxins have been found to co-occur with fumonisins in maize and maize-based complementary foods (Kpodo *et al.* 2000; Kimanya *et al.* 2008a). The soundness of using the EU limits for fumonisins of 1000 $\mu\text{g kg}^{-1}$ could also be argued. Given that maize is consumed in large quantities in these populations, estimates on exposures in adults might also be needed before defining a local maximum contamination level. However, to allow some degree of evaluation, this level was used for comparisons.

Conclusions

We showed that the maximum total fumonisin contamination in maize for human consumption in rural Tanzania should be limited to 150 $\mu\text{g/kg}$. In view of the impracticability of reducing the total fumonisins in Tanzanian maize to the limit of 150 $\mu\text{g/kg}$, we suggest adoption of the EU MTL of 1000 $\mu\text{g/kg}$ for fumonisins in maize for Tanzania and reduction of maize intake as part of complementary foods to a maximum limit of 20 g/child/day. What remains to be known is how acceptable the fumonisin reduction strategies are and the extent to which they can reduce fumonisin exposure in rural communities.

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Conflict of interest

The authors declare that there were no conflicts of interest.

Contributions

MEK, BDeM, JVanC and PA designed the study. MEK was the principal field investigator, carried out the study and drafted the initial version of the manuscript with PA. MEK and KB performed the exposure assessment. All authors contributed to the interpretation of the study results, participated in the write-up and read and approved the manuscript.

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