

Household dietary exposure to aflatoxins from maize and maize products in Kenya

Robert Musyoka Kilonzo¹

P. O. Box 546 – 00202 Nairobi, Kenya

Telephone: +254 2717077

Cell phone: +254 722 688 878

Fax: +254 2710055

Jasper Kathenya Imungi²

E-mail address: imungijk@yahoo.com

P. O. Box 29053-00625 Nairobi

Cell phone: +254 721`468 181

William Maina Muiru³

E-mail address: wmmuiru27@hotmail.com

P. O. Box 29053- 00625, Nairobi

Cell phone: +254 0722 242 431

Peter Obimbo Lamuka²

E-mail address: lamukapeter@yahoo.com

P. O. Box 29053-00625 Nairobi

Cell phone: +254 724 290 616

Patrick Murigu Kamau Njage^{2,4}

E-mail: kamau.patrick@gmail.com

Private Bag X20 Hatfield 0028, Pretoria

Cell phone: +254 720 460 727

¹ Corresponding Author, E-mail address: rmkilonzo@yahoo.co.uk

² Department of Food Science, Nutrition and Technology, University of Nairobi

³ Department of Plant Science and Crop Protection, University of Nairobi

⁴ Department of Food Science, University of Pretoria

Abstract

Aflatoxicosis has repeatedly affected Kenyans, particularly in the eastern region, due to consumption of contaminated maize. However, save for the cases of acute toxicity, the levels of sub-lethal exposure have not been adequately assessed. It is believed that this type of exposure does exist even during the seasons when acute toxicity does not occur. This study, therefore, was designed to assess the exposure of households to aflatoxins through consumption of maize and maize products. Twenty samples each of maize kernels, muthokoi and maize meal were randomly sampled from households in Kibwezi District of Makueni County in Eastern Kenya and analysed for aflatoxin contamination. The samples were quantitatively analysed for aflatoxin contamination using HPLC. The uncertainty and variability in dietary exposure was quantitatively modelled in Ms Excel using Monte Carlo simulation in @Risk software. Aflatoxins were found in 45% of maize kernels at between 18 and 480 $\mu\text{g kg}^{-1}$, 20% of muthokoi at between 12 and 123 $\mu\text{g kg}^{-1}$, and 35% of maize meal at between 6 and 30 $\mu\text{g kg}^{-1}$. The mean dietary exposure to aflatoxin in maize kernels was $292 \pm 1567 \text{ ng kg}^{-1} \text{ body weight day}^{-1}$, while the mean dietary exposure to aflatoxin in maize meal and muthokoi were 59 ± 62 and $27 \pm 154 \text{ ng kg}^{-1} \text{ body weight day}^{-1}$ respectively. The results showed that the amount and frequency of consumption of the three foods is the more important contributing factor than the mean aflatoxin concentration levels, to the risk of dietary exposure to aflatoxins.

Keywords: maize kernels; githeri; muthokoi; maize meal; aflatoxins; dietary exposure

Introduction

Maize is the most important staple food for majority of Kenyans (EPZA 2005; Kimanya et al. 2008). It is consumed at an average of 400 g per person per day (Muriuki & Siboe 1995; Shephard 2008). The annual consumption per capita has been estimated to be 98 kg. This figure has for many years served as the basis for the computation of food balance sheets and other estimates of national cereal import requirements (Nyoro et al. 2004).

The FAO estimates that between 25% and 50% of agricultural crops worldwide are contaminated with mycotoxins (Fandohan et al. 2003; Lewis et al. 2005; Wagacha & Muthomi 2008). The mycotoxigenic fungi that commonly contaminate grain producing toxic metabolites include genera *Aspergillus*, *Fusarium* and *Penicillium*. The value of maize lost due to aflatoxin contamination amounts to millions of dollars. Estimates are that in countries outside the United States, more than US\$225 million per year are lost, while in the United States approximately US\$932 million are lost through mycotoxin contamination (Betrán & Isakeit 2004). It must be noted that in the United States the level of rejection of food resulting from contamination with mycotoxins is much lower than in developing countries.

Aflatoxin poisoning is very common, especially in the tropical developing countries. It has been estimated that more than 5 billion people in these countries are at risk of chronic exposure to aflatoxins through contaminated foods (Strosnider et al. 2006). The primary chronic disease associated with aflatoxins intake is hepatocellular carcinoma (liver cancer). This disease is the third leading cause of cancer deaths globally according to the WHO (2008), with about 550 000–600 000 new cases diagnosed each year. Eighty-three per cent of these deaths occur in East Asia and Sub-Saharan Africa (Kirk et al. 2006; Strosnider et al. 2006). In addition, ingestion of

aflatoxins has also been linked to stunted growth in children and immune system disorders (Gong et al. 2002, 2003, 2004; Jolly et al. 2008; Khlangwiset et al. 2011).

In Kenya outbreaks of aflatoxin poisoning are perennial, especially in the Eastern and part of the Central Provinces (Ngindu et al. 1982; CDC 2004; Azziz-Baumgartner et al. 2005; Lewis et al. 2005). Acute aflatoxin poisoning has occurred, and it is believed that each year many people receive chronic exposure to the toxin. Aflatoxin poisoning in Kenya has been associated with consumption of maize, which has been improperly stored under damp conditions (Lewis et al. 2005). The aflatoxicosis outbreak of 2004, which affected the Eastern and part of the Central Provinces, is still rated as the largest and most severe so far documented worldwide. The outbreak covered more than seven districts and resulted in 317 case-patients and 125 deaths. The maize implicated in the outbreak was harvested in February during off-season early rains. From the farms, some of the maize probably entered the local market distribution system, while containing high moisture and aflatoxins levels. These levels obviously continued to rise because of the prevailing condition of the maize. The concentrations of aflatoxins B1 in the maize was found to be as high as 4400 $\mu\text{g kg}^{-1}$ (CDC 2004; Azziz-Baumgartner et al. 2005). Muriuki and Siboe (1995) had earlier reported 100% contamination of three processed maize meal brands available commercially in Kenya with aflatoxin levels of B1 and B2 ranging from 0.4 to 2.0 $\mu\text{g kg}^{-1}$. Other smaller outbreaks occurred in 2005 and 2006, resulting in about 30 and nine deaths respectively. Therefore, efforts to curb exposure to aflatoxins during an outbreak must consider the market system especially for the urban consumer (Lewis et al. 2005). Kenya has adopted a conservative tolerance to aflatoxins of 10 and 5 $\mu\text{g kg}^{-1}$ as the total aflatoxins and aflatoxins B1 respectively (KEBS 2000).

Other documented fatal aflatoxicosis outbreaks have been reported in Western India in 1974 with 397 cases and 106 reported deaths (Krishnamachari et al. 1975); Nigeria in 2005 with more than

100 deaths (Afla-guard 2005); Kenya in 1981, 2005 and 2006 with 20 cases (Ngindu et al. 1982), 80 cases and 39 deaths (Anonymous, 2006. Personal Communication. Food Poisoning Deaths still baffle Ukambani residents in Kenya) respectively.

Considering the importance of maize as staple food for most of the communities in Kenya and the fact that outbreaks of aflatoxin poisoning have always been associated with the crop, it is therefore imperative to assess the exposure to aflatoxins through consumption of contaminated maize kernels, muthokoi (decorticated maize) and maize meal.

Materials and Methods

Study area

This study was designed to assess the exposure to aflatoxin of the households in Kibwezi District of Eastern Province, an area perennially afflicted by aflatoxin poisoning. Kibwezi District is one of the nine districts of Makueni County. The district has a total population of 158 708 (KNBS 2009) and is divided into three divisions, namely Machinery, Mtito Andei and Kibwezi. Makueni County is characterised by extreme rainfall variability. Typically wet seasons are interspersed with extremely dry seasons and variations in the onset of rainy seasons add to the difficulty of ensuring adequate food production. The county has two rainy seasons with two peaks in March–April (long rains, usually unreliable) and November–December (short rains). June–October is a long dry period, while January–March is a short one. The hilly parts of the county receive 800–1200 mm of rainfall per year. The rest of the county receives less rainfall of about 500 mm per annum. The temperature ranges are between 18 and 24°C in the cold seasons and between 24 and 33°C in the hot season. The major crop grown is maize, which is the staple food in the county. Other crops grown in order of importance include cow peas, beans, pigeon peas and green grams.

Study design

The study was cross-sectional and utilized 72 households, with 24 households being systematically sampled from each of the three divisions of the district. Of the 24 households from each division, 12 were randomly selected for collection of samples of maize products for laboratory analysis.

Collection of samples

For sample collection, 12 households were systematically selected from each division with a sampling interval of two households. Samples were collected from each household at the rate of 1 kg each of muthokoi, intact maize kernel and maize meal. For maize kernels stored in 90 or 50 kg polypropylene bags, a sample was drawn using a probe from the top, middle and bottom of the bags, combined in a bucket, mixed thoroughly and a sample of 1 kg drawn from the mixture. Twenty samples of each product were collected. Each sample was placed in a Kraft paper bag, well sealed, clearly labelled and transported to the Government Chemist laboratories for aflatoxins analysis.

Qualitative screening for aflatoxins

Qualitative screening for aflatoxins In order to identify the samples showing positive results for aflatoxin, all samples were screened as described by AOAC with modifications (AOAC 2005). In brief, ground sample (50 g) was mixed with 25 ml distilled water and 250 ml chloroform and the mixture vortexed in a shaker (Bibby Scientific Ltd, Stone, UK) at 600 oscillations per min for 30 min. The mixture was filtered through a fluted filter paper (Whatman 185 mm diameter CAT No. 1001 185) and the filtrate collected into a clean beaker. The filtrate was evaporated to near dryness on a water bath and the paste dissolved in 100 ml chloroform–methanol mixture, at a

ratio of 97:3. The solution was spotted on a TLC plate alongside aflatoxins standards B1, B2, G1 and G2. The chromatogram was developed in a 100 ml diethyl ether tank to remove fats and thereafter in a chloroform–acetone–water tank, 88:12:1.5 mixtures and then left to dry. The chromatogram was viewed under UV light (254–360 wavelength) to observe any bright blue or green fluorescence. The chromatograms were then sprayed with 25% sulfuric acid for confirmation by the fluorescence changing from blue to green. The samples that showed positive aflatoxin identification were further analyzed for aflatoxin concentration using HPLC.

Quantification of aflatoxin levels

Sample preparation

The aflatoxin positive samples were analysed using an HPLC method for analysis of corn, grains and feed in order to quantify the total aflatoxins. The positive milled samples of the maize kernels, muthokoi and maize meal were separately homogenised. A laboratory sample, 75 g of each maize product was picked and placed into a beaker, then 25 ml distilled water and 215 ml acetone were added and mixed with a shaker (Bibby Scientific) for 30 min. An aliquots of 10 g silica gel (13% calcium sulfate) was added, stirred and then filtered through a fluted filter paper (Whatman 185 mm diameter CAT No. 1001 185) and 200 ml filtrate collected into a clean vessel. A total of 100 ml of 5% sodium chloride and 100 ml of hexane was then added and the mixture shaken for 5 min. The mixture was allowed to separate in a separating funnel and the aqueous acetone layer collected. The aflatoxins were re-extracted from the aqueous acetone layer with 50 ml chloroform by shaking for 3 min and decanting.

The two chloroform portions were combined together to make a volume of 150 ml. A total of 100 ml of 5% sodium chloride was added and the mixture shaken or 3 min. The organic chloroform layer and the aqueous salt solution were separated using a separating funnel, and the

chloroform portion collected. The chloroform portion was passed through an anhydrous sodium sulfate column and the effluent (chloroform from the column) collected and concentrated by evaporation to about 10 ml. The concentrate was introduced to an acidic alumina–silica gel–sodium sulfate column (packed in column in the same sequence with ratios of 5:15:15 g respectively). The concentrate was washed with 100 ml benzene–acetic acid mixture (9:1), and hereafter by 150 ml ether–hexane mixture (3:1). The columns were eluted with 200 ml chloroform–methanol mixture (97:3) and evaporated to dryness in a nitrogen stream.

HPLC analysis

The aflatoxin residues were prepared into a test solution for loading into the HPLC according to Kimanya et al., (2008) with little modifications as follows. The residues were dissolved in 100 μ l chloroform. Then 1 μ l of elute was injected into the HPLC for analysis using reverse phase HPLC with a fluorescence detection system. A Shimadzu HPLC system consisting of Shimadzu LC 20 AT, Romer® Derivatization Unit and controller was used. The system was connected to a Shimadzu SIL-20A auto injector. A methanol–water–acetonitrile mixture (50:40:10, v/v) was used as a mobile phase with a flow rate of 0.8 ml min⁻¹. Fluorescence of the aflatoxins was recorded at wavelength of 365 nm (excitation) and 440 nm (emission). Blank maize samples were spiked with AFB1 at 10 μ g kg⁻¹ with average recovery of 96%. The LOD was 0.05 μ g kg⁻¹ for B₁, B₂, G₁ and G₂.

Estimation of dietary exposure

Model design

The uncertainty and variability in dietary exposure were quantitatively modelled in Ms Excel spreadsheet (Microsoft, Redmond, WA, USA) using Monte Carlo simulation in @Risk software

(version 4.0, Palisade Corp., Newfield, NY, USA). To measure the total dietary exposure, input parameters were varied according to the aflatoxin concentrations for each maize-based food product as determined by HPLC. The model was simulated each time and the change in exposure recorded. The lognorm distribution was used due to the number of samples that had tested positive for aflatoxin contamination and also due to the fact that its shape is flexible and is skewed to the right or to the left.

Model simulation and scenario analysis

Simulations with @Risk using automatic iterations resulted in 50 000 iterations for a random number generator seed of 1. A log-normal distribution was used to quantitatively model the mean concentrations of aflatoxins in maize kernel and maize meal (ng g^{-1}). The mean aflatoxin concentration of muthokoi was quantitatively modelled using pert statistical distribution. The effect of possible intervention strategies on the exposure scenario in the study setting was also modelled. Aflatoxin concentration levels for maize kernels and muthokoi were reduced according to secondary data by Mutungi et al. (2007) and Pietri et al. (2009). Mutungi et al. (2007) observed that when muthokoi was soaked in ammonium persulphate for 14 h, the aflatoxin content decreased by 72.2%. In the work of Pietri et al. (2009), the cleaning step in dry-milled maize fractions reduced the aflatoxin content by 57%. In this study, 72.2% and 57% decrease of aflatoxin concentration levels are used to calculate the possible aflatoxin content if the chemical was to be used prior to cooking muthokoi and if maize kernels were cleaned before cooking, respectively.

Data analysis

The descriptive statistics were carried out by use of Strata 9.0 statistical package (Strata 9.0; SAS/Strata, Institute Inc., Cary, NC, USA). The uncertainty and variability in exposure were

quantitatively modelled in MS Excel spreadsheet (Microsoft, Redmond, WA) using Monte Carlo simulation in @Risk software (version 4.0, Palisade Corp., Newfield, NY, USA) an Excel add-in program. Spearman's rank correlation was calculated between the estimated probability of exposure to different concentrations of aflatoxins and predictive factors were aflatoxin concentration, consumption levels and form of maize consumed.

Results

Consumption of maize and maize products

Data on the consumption of maize and maize products were collected. The highest amounts consumed either during breakfast, lunch or dinner were between 201 and 300 ml. The standard deviations for breakfast, lunch and dinner were also calculated. The estimated daily consumption (EDC) of maize meal, githeri, muthokoi, porridge and other foods consumed by the respondents is shown in Table 1. Githeri is a Kenyan traditional meal of maize and beans, either fresh or dry, mixed in a sufuria or pot and boiled until the food is cooked and ready to eat. Table 1 shows that maize is the most consumed food amongst the other maize products and also has the highest expected daily consumption of 195 g day^{-1} .

Aflatoxin contamination levels

The screening process showed that 45% of the maize kernels were contaminated with aflatoxins, while 20% and 35% samples of muthokoi and maize meal respectively were confirmed positive for aflatoxin contamination. These results are shown in Table 2. The aflatoxin contamination levels in maize kernels ranged from 18 to $480 \mu\text{g kg}^{-1}$, while in muthokoi and maize meal samples it was from 12 to $123 \mu\text{g kg}^{-1}$ and from 6 to $30 \mu\text{g kg}^{-1}$ respectively. Of the samples, only maize meal had few samples (5%) containing aflatoxins below the tolerable limits for the East African Region. However, 45%, 15% and 15% of maize kernels, muthokoi and maize meal,

respectively, had aflatoxin levels above the Codex Alimentarius Commission limit of $15 \mu\text{g kg}^{-1}$ and the Kenyan limits of $10 \mu\text{g kg}^{-1}$.

Dietary exposure assessment

Figure 1 shows the probability distribution for dietary exposure to aflatoxins from muthokoi, maize meal and maize kernels. Maize kernels contributed to the highest dietary exposure to aflatoxins of $292 (1-180\ 704) \text{ ng kg}^{-1} \text{ bw day}^{-1}$ as compared with maize meal of $59 (0-1144) \text{ ng kg}^{-1} \text{ bw day}^{-1}$ and muthokoi of $27 (0-864) \text{ ng kg}^{-1} \text{ bw day}^{-1}$ (Table 3). The comparison of the magnitude of the dietary exposure by the three maize-based foods is shown by the steepness of the slopes in Figure 1.

Decrease in aflatoxin concentrations

The findings by Mutungi et al. (2007) and Pietri et al. (2009) were used to calculate the possible aflatoxin levels upon use of ammonium persulfate in muthokoi and cleaning step in maize kernels respectively. The total aflatoxin concentrations in muthokoi and maize kernels were reduced accordingly. The total aflatoxin concentration in maize kernels would be reduced from 292 to $171 \text{ ng kg}^{-1} \text{ bw day}^{-1}$ resulting into exposure reduction of 41%. Exposure reduction of 26% would be recorded in muthokoi after use of ammonium persulphate from total aflatoxin concentration of 27 to $20 \text{ ng kg}^{-1} \text{ bw day}^{-1}$ (Table 4).

Relative contribution of consumption and aflatoxin concentration to exposure with aflatoxins

Regression coefficients were performed using Spearman's rank correlation and the results were presented in a tornado diagram (Figure 2). The daily consumption of muthokoi, maize meal and

maize kernels were assessed with the respective mean aflatoxin concentration in order to evaluate their contribution to the dietary exposure to aflatoxins. Regression analysis assessing the contribution of either the amount consumed or the mean aflatoxin concentration revealed that the quantities consumed of any of the three types of maize-based products contributes the highest exposure to aflatoxins compared with the aflatoxin concentration.

Discussion

The exposure in this study was higher than when the available 400 g/person day⁻¹ consumption from literature is used to calculate the total dietary exposure to aflatoxins. For example, when consumption of 400 g/person day⁻¹ is used and mean maize kernel aflatoxin content of 123 µg kg⁻¹ aflatoxin content, the exposure would be less than it could have been if it were based on raw consumption data (157 µg kg⁻¹ aflatoxin content). This study shows that it may be more accurate to collect new consumption data when computing the dietary exposure to contaminants in maize, than using available consumption data due to changes and variations in consumption patterns.

Severally, the Kenya maize consumption of 400 g/person day⁻¹ (Muriuki & Siboe 1995) has been used to compute maize consumption data for national planning on maize importation and also basis for calculation of dietary exposure due to contaminants in maize. However, this study findings shows that the 400 g/person day⁻¹ maize consumption may mislead when used to calculate the total dietary exposure to aflatoxins.

Data on the uncooked intact maize kernels showed that 45% of the households were exposed to aflatoxins at levels ranging between 18 and 480 µg kg⁻¹. At the highest aflatoxins concentrations of 480 µg kg⁻¹, the households would be exposed to 48 times higher than the tolerable levels of 10 µg kg⁻¹. In the 2004 aflatoxins outbreak in Kenya, concentrations of aflatoxins B1 in maize was found to be as high as 4400 µg kg⁻¹, which is 440 times greater than the 10 µg kg⁻¹ (CDC

2004). The aflatoxins levels in muthokoi and maize meal are lower as compared with those in the intact maize kernels. This could be due to milling that removes some of the seed coat on which the toxins are embedded. Muthokoi is usually washed and decorticated removing the kernel cover and some toxins underneath it. In commercial maize milling, the kernels are sorted, and milled into maize meal, a process that removes some of the outer cover of the maize kernels hence reducing the levels of aflatoxins. Usually, muthokoi and maize kernels in githeri are cooked in a mixture with beans and probably vegetables. This also reduces by dilution the amount of maize product directly consumed hence reduction of the aflatoxins ingested.

The high exposures to total aflatoxins by consumption of maize kernels, muthokoi and maize meal suggested that risk management of aflatoxins contamination in maize based foods is required. Regression analysis assessing the contribution of either the amount consumed or the mean aflatoxin concentration revealed that the quantities consumed of any of the three types of maize-based products contributes the highest exposure to aflatoxins compared to the aflatoxin concentration. This revealed that the consumption of the three types of maize-based products (muthokoi $p = 0.94$, maize kernels $p = 0.6$, and maize meal $p = 0.82$) (Pearson correlation coefficient) is the most important risk to dietary exposure to aflatoxins than the mean aflatoxin concentration levels (muthokoi $p = 0.06$, maize kernels $p = 0.23$, and maize meal $p = 0.49$).

Data from this study have shown that if pre-cooking strategies are used such as soaking of muthokoi in ammonium persulfate and cleaning of maize kernels before preparing githeri or other dish reduces the number of households exposed to aflatoxins contamination by 26% and 41% respectively. The reduction in aflatoxin contamination levels does not necessarily conform to reduction in dietary exposure. The data on correlation between consumption and aflatoxin contamination levels in this study showed that consumption patterns of the consumers influence aflatoxin exposure more than the aflatoxin concentration levels. Therefore, reducing the aflatoxin

concentration levels might be confounded by the dietary exposure as supported by high consumption, even of low contaminated foods.

The mean dietary intakes of aflatoxins are 0.15 ng kg⁻¹ bw day⁻¹ for Australians, 0.8 ng kg⁻¹ bw day⁻¹ for Swedes (Thuvander et al. 2001), 0.26 ng kg⁻¹ bw day⁻¹ for Americans (JECFA 1998), and 0.1 ng kg⁻¹ bw day⁻¹ for adults (> 15 ages), 0.3 ng kg⁻¹ bw day⁻¹ for children (3–14 ages) in French. Thus, considering Kenyan probable daily intakes, Kenyans consume higher amounts of aflatoxins than the above countries. However, from Chinese survey (Li et al. 2001), the average daily intake of AFB1 from maize in the high-risk area was 184.1 µg kg⁻¹, and the probable daily exposure was estimated to be 3.68 µg kg⁻¹ bw day⁻¹.

Conclusions

This study demonstrates that maize and maize products in Kibwezi are contaminated with aflatoxins. Populations consuming maize products as staple food are at risk of exposure to unacceptable levels of aflatoxins, which are higher than the national maximum tolerable limits of 10 µg kg⁻¹. The consumption patterns influences dietary exposure to aflatoxins. Among the maize products tested, intact kernels were found to have the highest level of total aflatoxins ranging from 18 to 480 µg kg⁻¹. The other maize products, muthokoi and maize meal, were found to be contaminated with aflatoxins at levels lower than maize kernels, with maize meal containing the lowest levels. According to the present results, the amount consumed of the three types of maize-based products is the most important contributing factor to the risk of dietary exposure to high levels of aflatoxins than the mean aflatoxin concentration levels. The diversification of food to include lower maize fraction of total meal is likely to reduce the aflatoxin dietary exposure levels, and therefore this study suggests diet diversification as means to reduce exposure to aflatoxins. Exposure reduction further accrued from precooking strategies

such as soaking of muthokoi in ammonium persulfate and cleaning of maize kernels before preparing githeri or other dishes and these could therefore form means to further reduce aflatoxin exposure levels.

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Table 1: Estimated Daily Consumption (EDC)* of maize meal, maize kernels, *muthokoi*, porridge and other foods consumed by the respondents

Meal	No. of Respondents and type of food consumed				
	Maize meal	Maize kernels**	<i>Muthokoi</i>	Porridge	Others
Breakfast	47	13	6	30	4
Lunch	54	37	7	1	1
Dinner	56	33	10	0	0
Total	157	83	23	31	5
Percentage of respondents	52	28	8	10	2
MDC (g day ⁻¹)	375	368	363	390	300
EDC* (g/day ⁻¹)	195	103	29	39	6

Notes:

*EDC for each type of food consumed = mean daily consumption (MDC) of the food type in a day × percentage of respondents consuming the type. The total number of respondents was 299.

**Maize kernels: together with other cereals and legumes such as beans, maize kernels are used in preparation of githeri and therefore maize kernels are not eaten separately as a dish.

Table 2: Aflatoxins contamination of maize and maize products

	Maize Kernel (n = 20)	<i>Muthokoi</i> (n = 20)	Maize Meal (n = 20)
Positive samples (%)	45	20	35
Median (µg kg ⁻¹)	43	36	15
Range (µg kg ⁻¹)	18 - 480	12 - 123	6 - 30
Mean (µg kg ⁻¹)	53	10	6
Samples below MTL of 10 µg kg ⁻¹ total aflatoxins (%)	0	0	5
Samples with 10-15µg kg ⁻¹ total aflatoxins (%)	0	5	15
Samples above of 15µg kg ⁻¹ (%)	45	15	15

Note: MTL, Maximum Tolerable level for Kenya

Tables 3: Dietary exposure to aflatoxins through consumption of *muthokoi*, maize meal and maize kernels in Kibwezi District, Kenya

	Dietary exposure (ng/kg BW/day) from aflatoxins		
	<i>Muthokoi</i>	Maize kernels	Maize meal
Minimum	0	0.22	0
Maximum	864	180704	1144
Mean \pm SD	27 \pm 154	292 \pm 1567	59 \pm 62
5%	0	6	0
95%	288	1044	176

Table 4: Probabilistic modelling of the effect of possible pre-cooking interventions on the exposure to aflatoxins in Kibwezi District, Kenya

	Maize Kernels		<i>Muthokoi</i>		Maize Meal (ng/kg BW/day)
	Before Cleaning (ng/kg BW/day)	After Cleaning (ng/kg BW/day)	Before use of ammonium persulfate (ng/kg BW/day)	After use of ammonium persulfate (ng/kg BW/day)	
Minimum	0.22	0.15	0	0	0
Maximum	180704	120871	864	700	1144
Mean \pm SD	292 \pm 1567	171 \pm 1035	27 \pm 154	19 \pm 111	59 \pm 62
5%	6	4	0	0	0
95%	1044	593	288	207	176

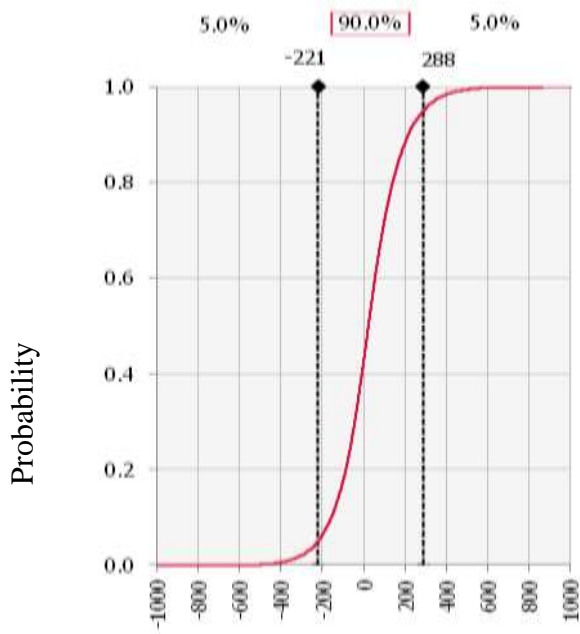


Figure 1(a): *muthokoi*

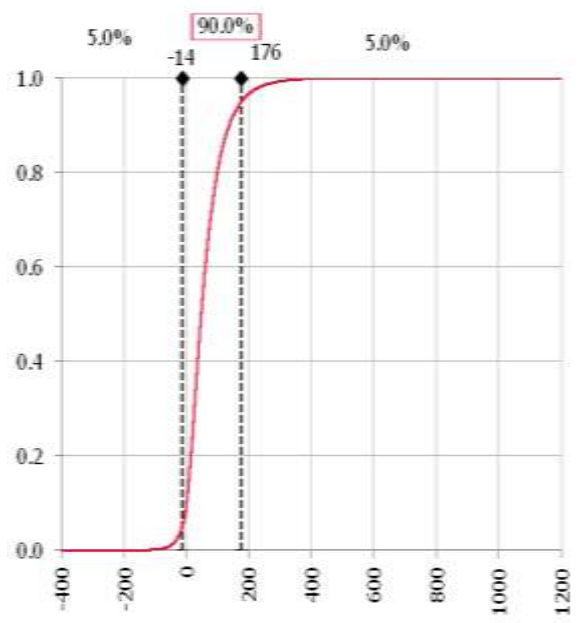


Figure 1(b): maize meal

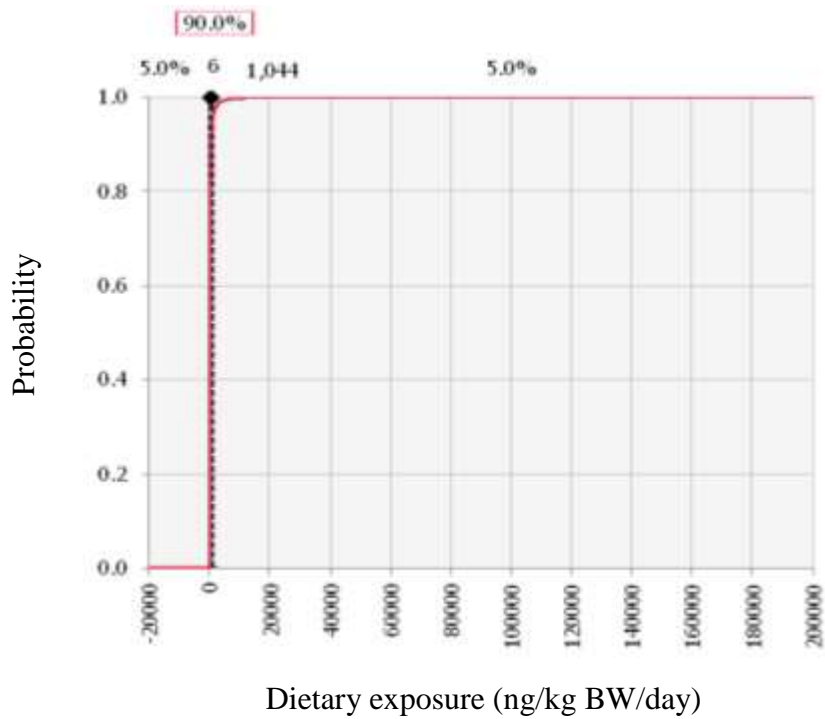


Figure 1(c): maize kernels

Figure 1: Probability distribution for probability of dietary exposure (ng/kg BW/day) to aflatoxins from *muthokoi* 1(a), maize meal 1(b) and maize kernels 1(c)

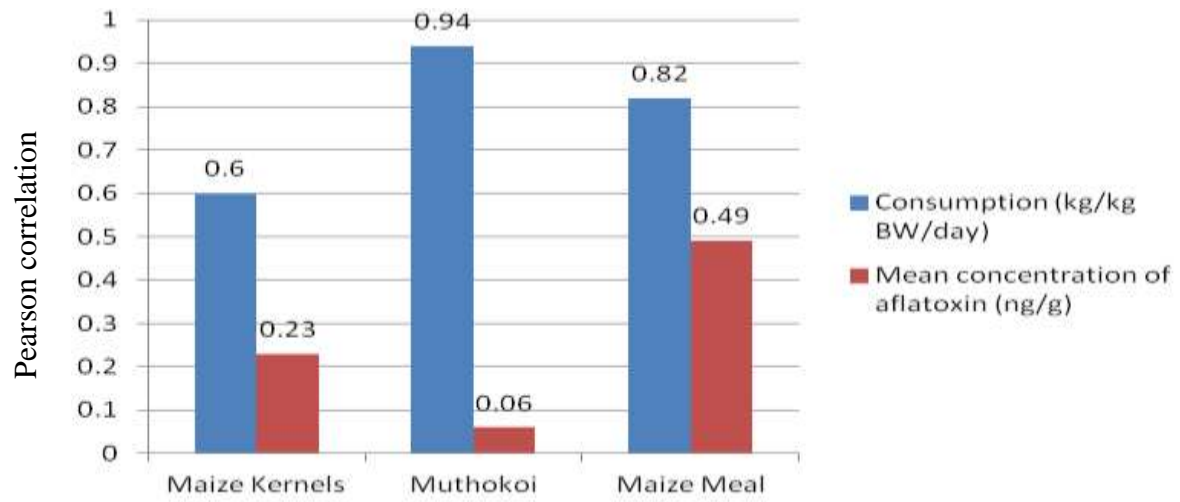


Figure 2: Contribution of the concentration, consumption levels and form of maize consumed to dietary exposure to aflatoxins

Values above the bars represent pearson correlation coefficient explaining the magnitude of effect each factor has on exposure to aflatoxins.