Quantitative Risk Assessment for Aflatoxin and Fumonisin from Maize Consumption in Northern Tanzania

Article · August 2018
DOI: 10.24940/ijird/2018/v7/i7

1 author:

Chacha Nyangi
Mbeya University of Science and Technology (MUST)

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Quantitative Risk Assessment for Aflatoxin and Fumonisin from Maize Consumption in Northern Tanzania

Chacha Joseph Nyangi
Lecturer, Department of Science and Business Management,
Mbeya University of Science and Technology
Mahamudu Mohamed Sasamalo
Agricultural Inspector, Ministry of Agriculture (Plant Health Services),
National Plant Protection Organizations, Tanzania
Joseph Runyogote
Lecturer, Department of Science and Business Management,
Mbeya University of Science and Technology, Tanzania

Abstract:
The study was on Quantitative risk assessment for population exposure to aflatoxin and fumonisin consuming maize in Northern Tanzania. This kind of assessment allow modelling maize consumption data (kg/kg body weight (bw)/day) using an estimated average weight of an adult of 60 Kg with previously collected data for total Aflatoxin (AF) and Fumonisin (FUM) contamination (µg/kg) maize samples from harvested, sorted, unsorted and maize flour from 2013/14 survey. Consumption was estimated by using national daily maize intake of 365 g/Kg BW/day and the exposure assessment was performed with the @RISK analysis software. Results from this assessment showed aflatoxin exposure was increasing from a mean value of 8.64, 8.96, 10.28 and 8.06 ng/kg BW/day for harvested, sorted, unsorted and maize flour respectively at the lower bound (LB). Maize flour had low exposure followed by sorted maize compared to unsorted and harvested maize. Fumonisin exposure was found to decrease from harvested, sorted, unsorted and maize flour with a mean value of 13.51, 6.87, 3.31 and 1.77 ng/kg BW/day respectively. Margin of Exposure (MoE) from this study were all below 10,000 for all scenarios for both AF and FUM and this is of public health concern. Even though all samples had aflatoxin and fumonisin contamination below maximum tolerable limit (MTL) of 10 µg/kg and 2 mg/kg respectively for East Africa standards, there is still a serious long-term health implication due to high levels of maize consumption in the study region. Meeting MTL will not by itself guarantee food safety, but using the data collected and available on various health effects from AF, FUM and other mycotoxins, it is important to incorporate them into a risk assessment and show how excessive consumption of foods meeting MTLs can still carry significant health risks.

Keywords: *Aflatoxin, fumonisin, risk assessment, monte carlo simulation, maize*

1. Introduction

Mycotoxins are toxic secondary metabolites produced by various fungi genera such as Aspergillus, Penicillium, Fusarium and Byssochlamys, many of which contaminate food and feed worldwide (Warth et al., 2012, Bosco and Mollea, 2012). Mycotoxin prevalence depends on several factors including; commodity, climatic conditions, agricultural practices, storage conditions and good processing and handling (Warth et al., 2012; Milani, 2013). The two most important mycotoxigenic fungi associated with maize and other crops, fruits and nuts are Aspergillus flavus, which produces aflatoxin, and Fusarium verticillioides, which produces fumonisin (Okoth and Kola, 2012; Nyinawabali, 2013).

Aflatoxins (Aspergillus flavus and Aspergillus parasiticus) are acute and chronic toxicity depending on the amount consumed, immunosuppressive, mutagenic, teratogenic, genotoxic and carcinogenic compounds and widely recognized as a major health problem (Filazi and Sireli, 2013). Optimum conditions for aflatoxin production is a temperature of 33°C and water activity of 0.99 while that for growth is 35°C and water activity of 0.95 (Milani, 2013). Fumonisins (Fusarium verticillioides and Fusarium proliferatum) was first described in 1988 by Gelderblom et al. Fumonisin were found to cause human oesophageal cancer in South Africa, Northern Italy and China (Marasas et al., 2008; Franceschi et al., 1990; Ueno et al., 1997). Fumonisin were also found to be associated with stunting and underweight in Tanzania (Kimanya et al., 2010), and cranial neural tube defects (NTD) a defect of the brain and spinal cord in the embryo that results from failure of the neural tube to close (Blom et al., 2006).

Maize is the first and most important staple food in Tanzania; other staples are sorghum, millet, cassava, sweet potatoes, bananas, pulses, paddy and wheat (Lyimo et al., 2014). Maize was the first agricultural commodity in terms of production followed by cassava, and production was 6,737,197 Tonnes, with a yield of 16,041 Kg/ha and a total of about four million hectares harvested annually and accounting for 523 KCal/Day of dietary calories to Tanzanian (FAOSTAT, 2013; 2014). The estimated annual per capita consumption of maize in Tanzania is 128 kg (which is equivalent to 365 g/day). Tanzania Food and Nutrition Centre (TFNC) recommended a daily per capital consumption of 771 g/day for non-dehulled maize flour or rice and 790 g/day for dehulled maize flour to provide enough energy intakes to adult individual in communities that rely on these cereal products for food (TFNC, 1997).

Despite the importance of maize as a staple food to most Tanzanians, it is mostly produced by small-scale farmers approximately 80% most of them own farm of up to 10 ha per household and account for about 85% of the maize produced in the country (Amani, 2004). About 85% of the maize produced is consumed at the household level. The crop is mainly cultivated during two rain seasons, short-duration rains (vuli") and long-duration rains (masika) and grown almost in all regions in the country, though the productivity is more in the high rainfall areas of Tanzania, such as, southern highlands, the Lake Victoria zone, and the northern zone (Temu et al., 2010). In study area, maize is commonly used to prepare typical meals such as uji (porridge), ugali (stiff porridge), kande (boiled maize grits and beans mixture), weaning food, alcoholic drinks and snacks.

2. Materials and Methods

2.1. Study Area

The study was conducted in three villages namely Long, Sabilo and Seloto in Babati District, Manyara Region, Tanzania in 2013/14 to assess farmers' maize pre-harvest practices, storage practices and processing techniques with aflatoxin and fumonisin levels. The villages were selected as they represented different climatic zones. The high altitude high rain zone (Long village) lies between 2150 and 2450 metres above sea levels (m.a.s.l), with relatively high annual rainfall of 1200 mm. The mid altitude low rainfall zone (Sabilo village) lies between 1500 and 1850 m.a.s.l with relatively low rainfall of 900 – 1100 mm, while the mid altitude high rain zone (Seloto village) lies between 1850 – 2150 m.a.s.l with relatively annual rainfall of 1100 – 1200 mm (Nyangi et al., 2016a).

2.2. Selection of Farmers

A total of 450 farmers (150 from each village) for harvest samples and 60 farmers (20 from each village) for storage samples were randomly selected from a list of farmers in each village generated by respective village's extension officers. Two posho mills (small scale mills) were also selected for collecting maize flour (Nyangi et al., 2016b). For storage samples each farmer provided 350 kg of maize to be stored in their household for at least 6 months.

2.3. Samples Collection

A total of 443 harvest samples were collected between June and July 2013 (Nyangi et al., 2016a), and 574 samples from storage (sorted and unsorted) between August 2013 to February 2014, storage samples were collected at an interval of 0, 90 and 180 days of storage (Nyangi et al, unpublished). Also 15 maize flour samples were collected from 2 small scale posho mills (Nyangi et al., 2016b). Collected samples were then well sealed, labelled and immediately transported to plant pathology laboratory of International Institute for Tropical Agriculture (IITA) in Dar es salaam, Tanzania.

2.4. Quantification *of Total Aflatoxin and Fumonisin*

The samples were ground using a Bunn grinder (Man: Bunn-O-Matic Corporation Springfield, Illinois, U.S.A), homogenized, and sub divided to obtain a representative sub-sample for analysis. Analysis was done according to the method used by Nyangi et al. (2016a). In brief, the samples were ground using a Bunn grinder (Man: Bunn-O-Matic Corporation Springfield, Illinois, U.S.A), homogenized, and sub divided to obtain a representative sub-sample for analysis. A 50 g of sub-sample was taken from each of the ground samples and extracted with 250 mL mixture of ethanol/water (65:35, v/v) and shaken vigorously at 150 revolutions per minute (r/min) for 3 min using a laboratory shaker (IKA® Werke, Germany). Extracts were filtered through Whatman No. 1 filter paper (Whatman International Ltd., Maidstone, UK). Then total aflatoxin (μg/kg) was quantified following the manufacturer's protocol using Reveal AccuScan® III reader (Neogen Corporation, USA), a quantitative ELISA-based analytical test designed specifically for AF and FUM.

For technical validation, random subsets of samples were re-analyzed using LC-MS/MS at the Interuniversity Department for Agro biotechnology (IFA Tulln, Austria).

2.5. Statistical Analysis

Data were analysed using SAS 9.4, SAS Institute, Cary NC. Four models were built; one with all villages, and one for each village. A stepwise linear regression in Generalised linear model (HPGENSELECT) was used to identify factors that significantly affected contamination of maize with aflatoxin. Aflatoxin levels were log (x + 1) transformed to normalize data before analysis (Nyangi et al., 2016a).

2.6. Input Setting

2.6.1. Harvest, Sorted, Unsorted and Maize Flour Data

The data for harvested, sorted and unsorted maize samples used as initial concentration for AF and FUM in this study were obtained from survey conducted in Babati District, Northern Tanzania. Four different scenarios were used from the concentration of AF and FUM, these were; harvested, sorted, unsorted and maize flour. For the risk output, calculations were utilized using an "if" logical function of the MS excels. Non-detects data were considered zero, ½ LOD and LOD for Lower bound (LB), Mid bound (MB) and Upper bound (UB) respectively. Best fit distributions were applied to the LB scenario of AF and FUM concentration in different scenarios (Table 2), using the Chi-square statistics. The type of best fit distribution selected for the LB was also applied to the MB and UB of the concentration data (Yogendrarajah et al., 2014).

Table 1 represents practices and their influence on the aflatoxin contamination of maize during pre- and post-harvest as well as processing from several studies across the globe.

Practices	Min	Mean	Max	Unit	Influence	Source
Harvesting Delay harvest for 3 to 4 weeks	4		7	fold	Increase	Kaaya et al., 2006
Drying (i) on bare ground		1.4			Increase	Own data
ii) on platform		0.7			Reduction	Own data
Sorting		53	8		Reduction	Pearson et al., 2004
	40		80	80%	Reduction	Afolabi et al. (2006)
		2.69	37	37%	Reduction	Own data
Shelling i. By hand		0.7		0	Grain damage	Fandohan et al., 2005
ii. Motorised sheller	0.9	2.2	3.5	3.5%	Grain damage	Fandohan et al., 2005
Storage (180 days) Improved bags (PICS)	2.1	2.38	4.7		Control aflatoxin levels	Own data
Polypropylene (POP) bags	2.2	3.3	10.1		-	Own data
Granaries	2.1	2.76	4.7		-	Own data
Milling i. Whole maize		0.34			-	Nyangi et al., 2016b
ii. Dehulled maize for 'Kande'		0.07	79	79%	Reduction	Nyangi et al., 2016b
iii. Maize flour for'Ugali'		0.3	11	11%	Reduction	Nyangi et al., 2016b

Table 1: Practices Influencing Aflatoxin Contamination Along the Maize Value Chain (Maize to Maize Flour)

Inputs of Exposure Assessment	Type	Best Fit Distribution Function	Min	Mean	Median	Max
Harvested maize	AF	=RiskExpon(0.83;RiskShift(1.99)	1.99	2.82	1.99	+ ∞
	FUM	=RiskInvgauss(4.62;RiskShift(79.63)	79.63	4.70	4.24	162.21
Sorted maize	AF	=RiskExpon(1;0403;RiskShift(1,993)	1.99	3.03	2.71	12.58
	FUM	=RiskLognorm(1916,5;RiskShift(0.30)	0.30	2.17	2.05	299.37
Unsorted maize	AF	=RiskExtvalue(2.91;RiskShift(1.95)	1.95	3.52	3.30	17.09
	FUM	=RiskGamma(0.88;RiskShift(0.30)	0.30	1.14	1.06	8.29
Maize flour	AF	=RiskTriang(1.65;RiskShift(1.67)	1.67	2.68	2.38	3.20
	FUM	=RiskTriang(1.76;RiskShift(-2.52)	-2.52	0.58	0.50	1.64

Table 2: Best Fit Distributions and Descriptive Statistics (Min, Mean, Median and Max) for the Lower Bound of the Mycotoxin Concentrations (μg/Kg) and the Consumption of Maize in Both Studied Regions Applied for the Probabilistic Exposure Assessment

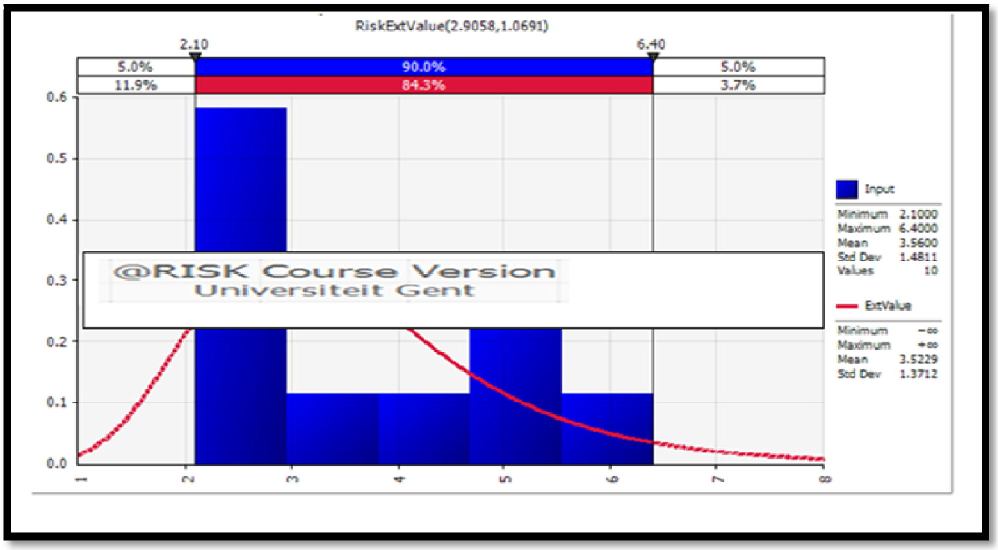

Figure 1

Probability-Probability and Quantile Plot of AFs concentration in Unsorted Maize LB
RiskExtvalue(2,9058;1,0691)

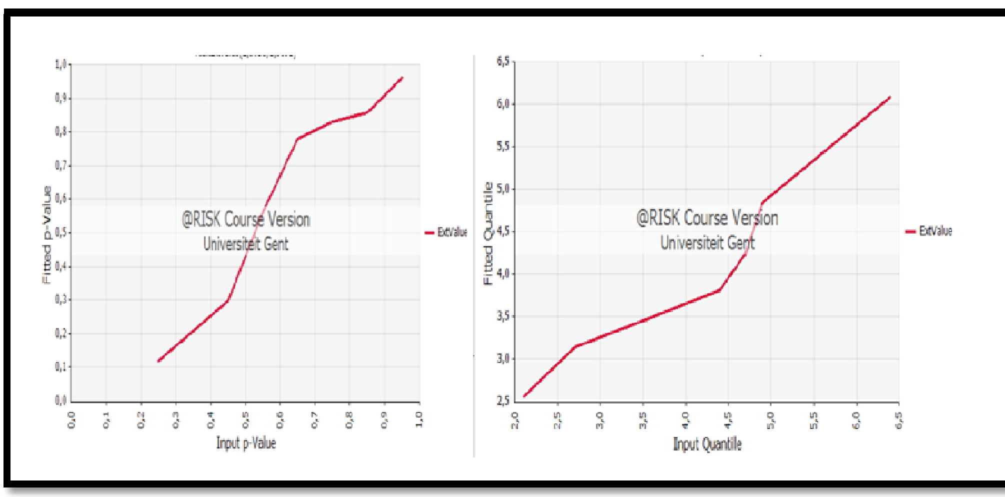

Figure 2: Graph on Best Fit Distribution of Aflatoxin Concentration in Unsorted Maize and Its Probability –Probability (P/P) and Quantile-Quantile (Q/Q) Plots

2.6.2. Probabilistic Dietary Exposure Assessment

Management of the left-censored contamination data is considered to be the main source of uncertainty in exposure models. Substitution of the non-detection (NDs) by the limit of detection (LOD), 1/2LOD and zero for the UB, MB and LB has been the most common approach in mycotoxin risk assessment studies (Yogendrarajah et al., 2014). Therefore, in this study NDs were replaced by zero, half of the LOD and LOD, for the LB, MB and UB, respectively. The exposure assessment was performed separately for harvested, sorted, unsorted and maize flour using consumption data from national dietary intake.

The most common approach to estimate the dietary exposure to mycotoxins is to integrate the contamination data obtained through the sample analysis and the consumption data generally obtained through national dietary surveys. A probabilistic ("simulated random sampling") method was used to assess the risk associated with the mycotoxins exposure (Yogendrarajah et al., 2014). The AF and FUM exposure (µg/kg BW/day) was modelled by multiplying maize meal consumption data (kg/kg Bw/day) with total AF and FUM contamination data (µg /kg). In order to evaluate different scenarios of exposure, different total AF and FUM contamination patterns were used. These were:

- Total AF and FUM contamination from harvested maize that was collected from the
- 2013/14 maize at harvest in farmers' field
- Total AF and FUM contamination from sorted maize that was collected from the
- 2013/14 maize harvest in household storage facilities
- Total AF and FUM contamination from unsorted maize that was collected from the
- 2013/14 maize harvest in household storage facilities in 2013/14

- Total AF and FUM contamination from maize flour that was collected from the 2013/14 maize harvest in small scale posho mills in 2013/14

The probabilistic exposure assessment was performed with the @RISK analysis software; (@Risk version 6.1, Palisade Corporation, USA). The simulations were performed with the add-in @RISK® for Microsoft Excel version 6.1 (Palisade Corporation, USA) and the probability/probability (P/P) and quantile/quantile (Q/Q) plots were also assessed in order to determine the best fit distribution for harvested, sorted, unsorted and maize flour consumption and AF and FUM concentration data. For the risk output calculations, the fractions of <LOD, ½LOD and LOD were utilized using an "if" logical function of the MS excel for the LB, MB and UB respectively. Best fit distributions were determined for the four scenarios of the AF and FUM concentration data using the Chi-square statistics (Yogendrarajah et al., 2014). Simulations were performed considering 5,000 iterations and three simulations to ensure stable values are maintained. The probable dietary intakes of the AF and FUM (mean, standard deviation (SD), maximum and the percentiles) was determined through the consumption of harvested, sorted, unsorted and maize flour.

The dietary exposure to a mycotoxin was calculated on a single-point basis by the following equation, which relates mycotoxin contamination level (ng/kg food) in the food consumed the daily dietary intake per day (g food day^{-1}) and the individual's body weight (kg) as follows:

- Exposure (ngkg^{-1} bodyweight/day) = (Contamination level) (Amount consumed)/ (Body weight)
- The estimated adult body weight of 60 Kg (Shephard et al., 2008) was used for this calculation

2.6.3. Risk Characterization

For the evaluation of the risk of the AF and FUM exposure, the calculated exposure values were compared with the established Provisional Maximum Tolerable Daily Intake (PMTDI) of 1 ng/kg BW/day for AFB_1 (Yogendrarajah et al., 2014), this was assumed to be the same for total aflatoxin and 2 ng/kg BW/day for fumonisin. Also, the Margin of Exposure (MoE) was estimated by combining the Bench Mark Dose Lower limit (BMDL) with the AF exposure values. Likewise, the AFB_1 $BMDL_{10}$ value of 170 ng/kg BW/day for aflatoxin and 165 ng/kg BW/day for fumonisin (EFSA, 2007; Yogendrarajah et al., 2014; JECFA, 2016) was assumed the same for AF and FUM and adopted, as a Point of Departure (PoD) to calculate the Margin of Exposure (MoE) for AF and FUM.

The MoE was calculated using the following formula:

$$MoE = \frac{BMDL_{10}\ \text{(from rodent data)}}{\text{Human Exposure}}$$

3. Results and Discussion

3.1. Exposure Assessment Due to AFS in Maize

The best fit distributions using Chi-square and the probability/probability (P/P) and quantile/quantile (Q/Q) plots and descriptive statistics obtained for the LB scenario of AF and FUM concentration in harvest, sorted, unsorted and maize flour (Fig 1). Estimated dietary exposures due to AF and FUM intake are shown in Table 3. The mean total aflatoxin intake for harvest, sorted, unsorted and maize flour of 8.64, 8.96, 10.28 and 8.06 ng/kg BW/day respectively for LB are shown in table 3. The maize flour had both lower AF and FUM intake; this is an indication that processing techniques such as milling, and sorting reduces levels of aflatoxin and other mycotoxin in food commodities. All mean exposure values were above the PMTDI of 1 ng/kg BW/day and 2 ng/kg BW/day for AF and FUM respectively, with the exception of FUM mean exposure from maize flour with a value of 1.77 (Table 3).

Mycotoxin Conc. Scenario	**Statistics Description**	**Exposure Due to Consumption of Food from Harvested Maize**		**Exposure Due to Consumption Of Food from Sorted Maize**		**Exposure Due to Consumption of Food from Unsorted Maize**		**Exposure Due to Consumption of Food from Maize Flour**	
		AF	FUM	AF	FUM	AF	FUM	AF	FUM
LB	Mean	8.64	13.51	8.96	6.87	10.28	3.31	8.06	1.77
	SD*	9.28	40.17	10.23	39.10	12.05	4.96	8.32	2.70
	P50	12.19	1.54	0.00	0.00	0.00	0.00	0.00	0.00
	P90	20.05	32.99	22.08	11.54	26.14	9.96	18.47	5.91
	P95	23.55	64.30	26.47	24.94	32.56	13.48	18.97	6.75
	P97.5	26.96	110.65	30.71	48.93	37.63	17.01	19.24	7.29
	P99	32.02	186.54	37.09	95.47	45.44	21.89	19.38	7.91
	Max	52.71	986.77	65.30	1821.16	84.98	42.35	19.46	9.37
MB	Mean	11.78	14.39	12.06	6.26	13.67	3.96	11.16	2.26
	SD*	6.63	44.83	7.53	23.32	9.71	5.04	5.38	1.93
	P50	12.27	0.912	6.08	0.91	6.08	0.91	6.08	0.91
	P90	20.32	32.37	22.17	11.08	27.46	10.27	18.50	4.81
	P95	23.87	65.97	26.18	23.70	32.23	14.49	18.96	6.10
	P97.5	27.08	115.40	30.14	42.18	37.43	18.30	18.96	7.31
	P99	32.52	192.15	36.33	88.26	43.27	23.43	19.37	9.23
	Max	59.79	1177.35	63.37	707.19	70.31	54.13	19.47	20.14

Mycotoxin Conc. Scenario	Statistics Description	Exposure Due to Consumption of Food from Harvested Maize		Exposure Due to Consumption Of Food from Sorted Maize		Exposure Due to Consumption of Food from Unsorted Maize		Exposure Due to Consumption of Food from Maize Flour	
UB	Mean	14.95	15.26	14.06	7347.42	12.67	4.47	14.39	2.65
	SD*	4.45	46.36	1.89	32.45	5.05	4.85	2.65	2.16
	P50	12.17	1.83	13.48	1.82	12.17	52.68	12.16	1.83
	P90	20.76	32.74	16.53	11.09	17.69	10.36	18.60	5.84
	P95	24.03	68.16	17.34	23.88	22.24	14.18	19.04	6.61
	P97.5	27.43	120.21	19.14	46.49	27.07	18.46	19.26	7.20
	P99	31.60	208.92	20.86	68.35	34.08	24.67	19.38	7.81
	Max	57.48	1334.42	30.88	1248.45	63.38	52.68	19.46	9.70

Table 3: Probabilistic Dietary Exposure (Ng/Kg BW/Day) Based on the Contamination Patterns for Harvested, Sorted and Unsorted Maize for AF and FUM. Values below PMTDI Are Shown in Bold

3.2. Sorting and Milling

Maize flour from milled maize had low level of dietary exposure for both AF and FUM compared to other scenarios. The model predicted that consuming food from unsorted maize had high exposure probability comparing to maize flour, sorted and harvested maize for AF. While for FUM high exposure probability was related to consumption of food from harvested maize (Table 3). It is also reported from table 1 that sorting and dehulling as part of milling reduce the level of aflatoxin and hence low dietary exposure. These results are comparables to those reported by (Kimanya et al., 2010) from fumonisin study in Tanzania, also similar results were reported by (Park, 2002; Afolabi et al., 2006). There is a need for farmers to adopt these simple and locally available good practices (Good Agricultural Practices (GAP), Good Storage Practices (GSP) and processing as well as good handling technique to lower the dietary exposure from AF, FUM and other mycotoxins. Good hygiene practices which also involve basic sanitation measures such as removal and destruction of debris from previous harvest both in the field and store proved to minimize infection and infestation of produce both in the field and in storage (Hell et al., 2005).

3.3. Risk Characterization Due to Maize Consumption

Margin of Exposure (MoE) value was determined for AF and FUM using BMDL10 of rodent data (EFSA, 2005, 2007; Shephard, 2008; Yogendrarajah et al., 2014; JECFA, 2016). The calculated value of MoE are reported in table 4 and 5, these were calculated from the value of probabilistic dietary exposure mean value (Table 3) by dividing $BMDL_{10}$ to the mean exposure value using estimates of minimum, mean, maximum and percentiles exposure to AF and FUM for four consumption scenarios; harvested, sorted, unsorted and maize flour. The MoE value of > 10,000 is considered of low health concern to the public (EFSA, 2005). The value from this study are all below 10,000 and considered as public health concern in the study area and other region with similar agro-ecological zones, agricultural practices and eating habits.

The mean MoE values 02.84 – 50.90 reported from this study are comparable to those reported in 6 different countries from Africa (0.1–850) (Shephard, 2008) and MoE values of 45 - 74 reported by Yogendrarajah et al. (2014). The results from this study are contrary to those reported in a study on AFB_1 in peanut from China with MoE of 25–1273 (Ding et al., 2012).

Consumption Level	Harvested Maize			Sorted Maize			Unsorted Maize			Maize Flour		
	LB	MB	UB	LB	MB	UB	LB	MB	UB	LB	MB	UB
Min	N/A[a]	27.70	13.97	N/A[a]	27.96	13.98	N/A[a]	50.90	28.38	21.09	15.23	11.81
Mean	19.68	14.43	11.37	18.97	14.10	12.09	16.54	12.44	13.42	20.43	31.60	64.15
P50	13.95	13.85	13.97	N/A[a]	27.96	12.61	N/A[a]	27.96	13.97	0.00	27.96	13.98
P90	8.480	8.37	8.19	7.70	7.67	10.28	6.50	6.19	9.61	9.20	9.19	9.14
P95	7.22	7.12	7.07	6.42	6.50	9.80	5.22	5.27	7.64	8.96	8.97	8.93
P97.5	6.31	6.28	6.20	5.54	5.64	8.88	4.52	4.54	6.28	8.84	8.97	8.83
P99	5.31	5.23	5.38	4.58	4.68	8.15	3.74	3.93	4.99	8.77	8.78	8.77
Max	3.23	2.84	2.96	2.60	2.68	5.51	2.00	2.42	2.68	8.74	8.73	8.74

Table 4: Margin of Exposure (MOE) Derived from Estimates of Minimum, Mean, Maximum and Percentiles Exposure to AF for Harvested, Sorted, Unsorted and Maize Flour Consumption

[A] Not Applicable; Moe Could Not Be Calculated Since the Lower Bound Minimum Is Zero Concentration

Consumption Level	Harvested Maize			Sorted Maize			Unsorted Maize			Maize Flour		
	LB	MB	UB	LB	MB	UB	LB	MB	UB	LB	MB	UB
Min	0.01	0.01	0.01	0.02	0.03	0.00	0.05	0.04	0.04	0.09	0.04	0.06
Mean	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.03	0.06	0.09	0.08
P50	0.11	0.18	0.09	0.00	0.18	0.09	0.00	0.18	0.00	0.00	0.18	0.09
P90	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03
P95	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02
P97.5	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02
P99	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.02
Max	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.02

Table 5: Margin of Exposure (MOE) Derived from Estimates of Minimum, Mean, Maximum and Percentiles Exposure to FUM for Harvested, Sorted, Unsorted and Maize Flour Consumption

3.4. Risk Management

Risk management includes the sharing of information and critical findings derived from the risk analysis to the stakeholders and turn it into a political decision. It is crucial that the social, political, and economical factors be fully taken into consideration when making decisions regarding the current global context (Ketney et al., 2014).

It is necessary that in Tanzania, risk management and risk administration take into account the results of risk assessment and, in particular, the notifications of the Regulatory Authorities and other legitimate factors regarding mycotoxins contamination of food and feed products, as well as the precautionary principle. Continuous monitoring is necessary, as well as risk reduction, to ensure that exposure does not pose any health risk (Ketney et al., 2014). Risk management presents some risk reduction priorities, and they depend mostly on the frequency and extent that Total Daily Intake (TDI) is exceeded, so that in risk management there are a variety of risk management options that can help ensure food safety conditions (Ketney et al., 2014).

3.4.1. Good Agricultural Practices (GAP)

Tillage method, and time of planting have shown to have direct influence on the contamination of grain by aflatoxin, fumonisin and other mycotoxin, early planting resulted in lower aflatoxin and fumonisin contamination and in significantly less frequent contamination above a regulatory action level than the late planting date (Lillehoj et al., 1978; Jones and Duncan, 1981; Janusauskaite et al., 2013; Abbas et al., 2007).

The general recommendation is to harvest maize grain after they attain physiological maturity and then artificially dried to a moisture content of below 13% for safe storage (Bruns, 2003). This is recommended since aflatoxin level can increase with delayed harvest interval (Kaaya et al., 2006). Kahaya and Kyamuhangire (2006) and Bankole and Adebanjo (2003) reported that early harvesting reduces fungal infection of crops in the field and consequent contamination of harvested produce.

From his study Atukwase et al. (2009) found that crop rotation is significantly associated with fumonisin production in maize. Hence care must be taken to avoid rotation of crops that can influence contamination (Alakonya and Monda, 2013; Atanda et al., 2013).

The use of resistant hybrids like AO901-25 a yellow maize variety with high yield of 7115 kg/ha, good resistance to Aspergillus and low aflatoxin level could be very promising, but commercial hybrids are not always available (Abbas et al., 2009). A biological control (bio-control) technique greatly reduced aflatoxin in all the susceptible crops in a cost-effective manner and over a broad geographic area (Bandyopadhyay, 2010). Native strains of A. flavus that do not produce aflatoxins ("atoxigenic strains") are used to competitively exclude aflatoxin-producing strains from the crop environment (Donner et al., 2010).

3.4.2. Post-Harvest Practices

The post-harvest practices which include Including Good Storage Practices (GSP) and Good Manufacturing Practices (GMP) are those practices following harvest and leading up to primary processing such as milling. They include; rapid drying on platforms to avoid direct contact with soil. A proper shelling method was reported to reduce grain damage and mycotoxin level in maize by 56 – 68% (Fandohan et al., 2005). Dehulling of maize prior to milling was also found to remove significant amounts of aflatoxin and fumonisin in maize and maize products, with a reduction of 92% and 79% aflatoxin (Fandohan et al., 2005; Nyangi et al., 2016b; Siwela et al., 2005). Milling whole maize grains to flour was found to remove 11% of aflatoxin (Nyangi et al., 2016b). Basic sanitation measures such as removal and destruction of debris from previous harvest both in the field and store also helps in minimizing infection and infestation of produce both in the field and in storage (Hell et al., 2005). Use of clean and aerated storage structures, controlling insect damage, good transportation practices and avoiding long storage periods, 8- 10 months all were found to control aflatoxin development (Hell et al., 2005).

It is well known that aflatoxin contamination of foods increases with storage period (Hell et al., 2000), while Fandohan et al. (2003) found that fumonisin level overall, was decreasing over the storage period. Sorting out physically damaged and infected grains (based on their coloration, odd shapes, shrivelled and reduced size) from the intact commodity can reduce aflatoxin levels by 40-80% (Park, 2002; Afolabi et al., 2006).

4. Conclusion

Though, most of the samples from this study had levels below Maximum Tolerable Limit (MTL) for both total aflatoxin and fumonisin for East Africa standards (EAC, 2011), the MoE showed that all scenarios had MoE value of less than 10,000 which is an indication of public health concern. High exposures in this study area can be a result of moderately contamination levels of maize consumed in high amounts. The data presented in this study can be used as a sufficient indicator that the Government needs to pay more attention to address aflatoxin and other mycotoxin contamination and exposure and its health consequences to the public. More comprehensive strategies which include risk analysis with all its components of risk assessment, risk management and risk communication are required, this is due to the fact that mycotoxins have health effect both in humans and animals and most of the foods in developing countries are consumed locally through informal market and this cause food safety compliance to be low and very challenging

5. References

i. Abbas, H. K., Shier, W. T. and Cartwright, R. D. (2007). Effect of temperature, rainfall and planting date on aflatoxin and fumonisin contamination in commercial Bt and non-Bt corn hybrids in Arkansas. Phytoprotection 88 (2): 41 – 50.

ii. Abbas, H. K., Wilkinson, J. R., Zablotowicz, R. M., Accinelli, C., Abel, C. A., Bruns, H. A. and Weaver, M. A. (2009). Ecology of Aspergillus flavus, regulation of aflatoxin production and management strategies to reduce aflatoxin contamination of corn. Toxin Reviews 28: 142 – 153.

iii. Afolabi, C. G., Bandyopadhyay, R., Leslie, J. F. and Ekpo, E. J. A. (2006). Effect of Sorting on Incidence and Occurrence of Fumonisins and Fusarium verticillioides on Maize from Nigeria. Journal of Food Protection 69(8): 2019 – 2023.

iv. Amani, H. K. R. (2004). Agricultural Development and Food Security in Sub-Saharan Africa Tanzania Country Report. Economic and Social Research Foundation, Dar es Salaam, Tanzania. 43pp.

v. Alakonya A. E. and Monda, E. O. (2013). A New Approach in Aflatoxin Management in Africa: targeting aflatoxin/sterigmatocyst in biosynthesis in Aspergillus species by RNA silencing technique. In: Aflatoxins Recent Advances and Future. (Edited by Razzaghi-Abyaneh, M.), InTech Janeza Trdine, Croatia. pp. 41 – 57.

vi. Atanda, O., Makun, H. A., Ogara, I. M., Edema, M., Idahor, K. O., Eshiett, M. E. and Oluwabamiwo, B.F. (2013). Fungal and mycotoxin contamination of Nigerian foods and feeds. In: Mycotoxin and Food Safety in Developing Countries. (Edited by Makun, H.A.), InTech Janeza Trdine Rijeka, Croatia. pp.15 – 50.

vii. Atukwase, A., Kaaya, A. N. and Muyanja, C. (2009). Factors associated with fumonisin contamination of maize in Uganda. Journal of Science and Food Agriculture 89: 2393 –2398.

viii. Bandyopadhyay, R. (2010). Aflatoxins the Invisible threat in foods and feeds. SP-IPM secretariat.

ix. Bankole, S. A. and Adebanjo, A. (2003). Mycotoxins in food in West Africa: Current situation and possibilities of controlling it. African Journal of Biotechnology 2:254 – 263.

x. Blom, H. J., Shaw, G. M., den Heijer, M. and Finnell, R. H. (2006). Neural tube defects and folate: case far from closed. Nature Reviews Neuroscience 7(9): 724 – 731.

xi. Bosco, F and Mollea, C. (2012). Mycotoxins in Food. In: Food Industrial Processes- Methods and Equipment. (Edited by Valdez B.) InTech Janeza Trdine 9, 51000 Rijeka, Croatia. pp. 169-200.

xii. Bruns, H. A. (2003). Controlling aflatoxin and fumonisin in maize by crop management. Journal of Toxicology Toxin Reviews 22(3): 153 – 173.

xiii. Ding, X., Li, P., Bai, Y., Zhou, H. (2012). Aflatoxin B_1 in post-harvest peanuts and dietary risk in China. Food Control, 23: 143–148.

xiv. Donner, M., Atehnkeng, J., Sikora, K. A., Bandyopadhyay, R. and Cotty, P. J. (2010). Molecular characterization of atoxigenic strains for biological control of aflatoxins in Nigeria. Chemistry, Analysis, Control, Exposure and Risk Assessment 27: 576 – 590.

xv. East African Community (EAC). (2011). East African Standards Maize grains - EAS 2/2011 of 2011. Available at: [https://law.resource.org/pub/eac/ibr/eas.2.2011.html] site visited on 12/02/2017).

xvi. EFSA. (2005). European Food Safety Authority. Opinion of the Scientific Committee on a request from EFSA related to A Harmonized Approach for Risk Assessment of Substances which are both Genotoxic and Carcinogenic. EFSA J. 282:1–31.

xvii. EFSA. (2007). European Food Safety Authority. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to the potential increase of consumer health risk by a possible increase of the existing maximum levels for aflatoxins in almonds, hazelnuts and pistachios and derived products. EFSA J. 446:1–127.

xviii. Fandohan, P., Hell, K., Marasas, W. F. O. and Wingfield, M. J. (2003). Infection of maize by Fusarium species and contamination with fumonisins in Africa. African Journal of Biotechnology 12: 570 – 579.

xix. Fandohan, P., Ahouansou, R., Houssou, P., Hell, K., Marasas, W. F. O. and Wingfield, M. J. (2005). Impact of mechanical shelling and dehulling on Fusarium infection and fumonisin contamination in maize. Food Additives and Contaminants 23: 451-421.

xx. Filazi, A. and Sireli, U. T. (2013). Occurrence of Aflatoxins in Food. In: Aflatoxins – Recent Advances and Future. (Edited by Razzaghi-abyaneh, M.), InTech Janeza Trdine Rijeka, Croatia. pp. 153 – 180.

xxi. Food and Agriculture Organization. (2013). FAOSTAT database: [http://faostat.fao.org/beta/en/#data/FBS] site visited on 19/11/2016

xxii. Food and Agriculture Organization. (2014). FAOSTAT database: [http://faostat.fao.org/beta/en/#data/QC] site visited on 19/11/2016

xxiii. Franceschi, S., Bidoli, E., Baron, A. E. and La Vechhia, C. (1990). Maize and the risk of cancers of theoral cavity, pharynx, and oesophagus in north-eastern Italy. Journal of National Cancer Institute 82:1407–1410.

xxiv. Gelderblom, W. C. A., Jaskiewicz, K., Marasas, W. F. O., Thiel, P. G., Horak, R., Vleggaar, M. and Kriek, N. P. J. (1988). Fumonisins novel mycotoxins with cancer promoting activity produced by Fusarium moniliforme. Applied Environmental Microbiology 54: 1806 – 1811.

xxv. Hell, K., Cardwell, K. F., Setamou, M. and Poehling, H. M. (2000). The influence of storage practices on aflatoxin contamination in maize in four climatic zones of Benin West Africa. Journal of Stored Products Research 36: 365 – 382.

xxvi. Hell, K., Fandohan, P., Bandyopadhyay, R., Kiewnick, S., Sikora, R. and Cotty, P. J. (2005). Pre- and Post-harvest Management of Aflatoxin in Maize: An African Perspective. In: Mycotoxins: Detection methods, Management, Public Health and Agricultural Trade. (Edited by Leslie, J.F. Bandyopadhyay, R. and Visconti, A.), Cromwell press, Townbridge, UK. pp. 219 – 229.

xxvii. Janusauskaite, D., Kadziene, G. and Auskalniene, O. (2013). The effect of tillage system on soil Microbiota in relation to soil structure. Polish Journal of Environmental Studies 22(5): 1387 – 1391.

xxviii. Joint FAO/WHO Expert Committee on Food Additives- JECFA. (2016). Evaluate certain contaminants in food. Eighty-third meeting, Rome, Issued 23 November 2016 [http://www.fao.org/3/a-bq821e.pdf] site visited on 16/03/2017.

xxix. Jones, R. K. and Duncan, H. E. (1981). Effect of nitrogen fertilizer, planting date, and harvest date on aflatoxin production in corn inoculated with Aspergillus flavus. Plant Diseases 65: 741 – 744.

xxx. Kaaya, A. N., Kyamuhangire, W. and Kyamanywa, S. (2006). Factors affecting aflatoxin contamination of harvested maize in the three climatic zones of Uganda. Journal of Applied Science 11: 2401 – 2407.

xxxi. Kaaya, A. N. and Kyamuhangire, W. (2006). The effect of storage time and climatic zone on mould incidence and aflatoxin contamination of maize from traders in Uganda. International Journal of Food Microbiology 110: 217 – 223.

xxxii. Ketney, O., Tita, O and Tifrea, A. (2014). Current approaches regarding analysis and assessment of risks associated with aflatoxin contamination: Review. Journal of Agroalimentary Processes and Technologies, 20(3): 275-281

xxxiii. Kimanya, M.E., Meulenaer, B. De, Roberfroid, D., Lachat, C and P Kolsteren. (2010). Fumonisin Exposure Through Maize in Complementary Foods is Inversely Associated with Linear Growth of Infants in Tanzania. Mol. Nutr. Food Res. 54(11): 1659–1667.

xxxiv. Lillehoj, E. B., Fennell, D. I., Kwolek, W. F., Adams, G. L., Zuber, M. S., Horner, E. S., Widstrom, N. W., Warren, H., Guthrie, W. D., Sauer, D. B., Findley, W. R., Manwiller, A., Josephson, L. M. and Bockholt, A. J. (1978). Aflatoxin contamination of corn before harvest: Aspergillus flavus association with insects collected from developing ears. Crop Science 18: 921 – 924.

xxxv. Lyimo, S., Mduruma, Z and De Groote, H. (2014). The use of improved maize varieties in Tanzania. Afr. J. Agric. Res. 9(7): 643-657.

xxxvi. Marasas, W. F. O., Gelderblom, W. C. A., Shephard, G. S. and Vismer, H. F. (2008). Mycotoxins: A Global Problem. In: Mycotoxins: Detection methods, Management, Public Health and Agricultural Trade (Edited by Leslie, J.F. Bandyopadhyay, R. and Visconti, A.) Cromwell press, Townbridge, UK. pp. 29 – 39.

xxxvii. Milani, J.M. (2013). Ecological Conditions Affecting Mycotoxin Production in Cereals: A Review. Vet. Med. (Praha). 58(8): 405–411.

xxxviii. Nyangi C, Beed F, Mugula JK, Boni S, Koyano E, Mahuku G, Sulyok M and B Mateete. (2016a). Assessment of Pre-harvest Aflatoxin and Fumonisin Contamination of Maize in Babati District, Tanzania. Afr. J. Food Agric. Nutr. Dev. 16(3): 11039-11053.

xxxix. Nyangi, C., Mugula, J. K. , Beed, F., Boni, S., Koyano, E and Sulyok, M. (2016b). Aflatoxins and Fumonisin Contamination of Marketed Maize, Maize Bran and Maize Used as Animal Feed In Northern Tanzania. Afr. J. Food Agric. Nutr. Dev. 16(3): 11054-11065.

xl. Nyinawabali F. (2013). A Survey of Fungi and Mycotoxins in Selected Food Commodities from Rwanda. University of Johannesburg.

xli. Okoth, S.A and Kola, M.A. (2012). Market Samples as a Source of Chronic Aflatoxin Exposure in Kenya. Afr. J. Health Sci. 20(1–2): 56–61.

xlii. Park, D. L. (2002). Effect of processing on aflatoxin. Advances in Experimental Medicine and Biology. 504: 173–179.

xliii. Pearson, T. C., Wicklow, D. T and Pasikatan, M. C. (2004). Reduction of Aflatoxin and Fumonisin Contamination in Yellow Corn by High-Speed Dual-Wavelength Sorting. Cereal Chem. 81(4):490-498

xliv. Shephard, G.S. (2008) Risk assessment of aflatoxins in food in Africa, Food Additives & Contaminants: Part A. 25 (10): 1246-1256.

xlv. Siwela, A. H., Siwela, M., Matindi, G., Dube, S. and Nziramasanga, N. (2005). Decontamination of aflatoxin-contaminated maize by dehulling. Journal of the Science of Food and Agriculture. 85(15):2535-2538.

xlvi. Tanzania Food and Nutrition Centre (TFNC). 1997. Matumizi ya kadi ya uhakika wa chakula katika kaya. Mwongozo kwa wafanyakazi wa ugani. Dar es Salaam: TFNC.

xlvii. Temu, A. E., Manyama, A. and Temu, A. A. (2010). Maize Trade and Marketing Policy Interventions in Tanzania. Food Security In Africa: Market and Trade Policy for Staple Foods in Eastern, Southern Africa. 317pp.
xlviii. Ueno, Y., Iijima, K., Wang, S. D., Sugiura, Y., Sekijima, M. and Tanaka, T. (1997). Fumonisins as a possible contributory risk factor for primary liver cancer: A 3-year study of corn harvest in Haimen, China, by HPLC and ELISA. Food Chemistry Toxicology 35: 1143 – 1150.
xlix. Warth, B., Parich, A., Atehnkeng, J., Bandyopadhyay, R., Schuhmacher, R., Sulyok, M and Kraska, R. (2012). Quantitation of Mycotoxins in Food and Feed from Burkina Faso and Mozambique Using a Modern LC-MS/MS Multitoxin Method. J. Agric. Food Chem. 60(36): 9352–9363.
l. Yogendrarajah, P., Jacxsens, L., Lachat,C., Walpita, C.N., Kolsteren, P., De Saeger, S., De Meulenaer, B. (2014). Public health risk associated with the co-occurrence of mycotoxins in spices consumed in Sri Lanka. Food Chem. Toxicol. 74: 240–248