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Levels and daily intake estimates of aflatoxin B_1 and fumonisin B_1 in maize consumed by rural households in Shamva and Makoni districts of Zimbabwe

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ABSTRACT

Levels of aflatoxin B_1 and fumonisin B_1 in maize samples collected from rural households in Shamva and Makoni districts of Zimbabwe were determined. Aflatoxin B_1 was determined using high performance liquid chromatography with fluorescence detection and post-column derivatisation. Aflatoxin B_1 was detected in 80 of the 388 samples analysed at levels ranging between 0.57 and 26.6 μg/kg (median, 3.21 μg/kg). Of the samples containing aflatoxin B_1, 18 exceeded the Zimbabwean limit for aflatoxins (5 μg/kg). Fumonisin B_1 was determined using EuroProxima™ ELISA kits. All samples analysed contained levels of fumonisin B_1 ranging between 10.43 μg/kg and 432.32 μg/kg (median, 292.15 μg/kg) and 13.84 μg/kg to 606.64 μg/kg (median, 360.18 μg/kg) for Shamva and Makoni districts respectively. In Shamva district the probable daily intake of fumonisin B_1 ranged between 0.14 and 5.76 μg/kg body weight/day and in Makoni district the probable daily intake of fumonisin B_1 ranged between 0.18 and 8.092 μg/kg body weight/day. In Shamva district fumonisin B_1 and aflatoxin B_1 were found together in 36 out of 166 samples analysed. In Makoni district fumonisin B_1 and aflatoxin B_1 were found together in 44 out of 222 samples analysed. Of the 80 samples that contained fumonisin B_1 and aflatoxin B_1, 18 samples contained levels of aflatoxin B_1 above the national maximum regulatory limit.

1. Introduction

Maize (*Zea mays* L.) is a staple crop consumed in Zimbabwe being consumed as *Sadza*, maize meal porridge or samp. Maize grain is susceptible to contamination and degradation by fungi including *Aspergillus*, *Fusarium* and *Penicillium* (Gamanya & Sibanda, 2001) Contamination affects the quality of grain through discolouration, reduction in nutritional value and production of mycotoxins. Mycotoxins are toxic fungal secondary metabolites that include aflatoxins, ochratoxins and fusarium toxins (Moreno et al., 2009). About 40% of the reduction in life expectancy in developing countries is related to the presence of mycotoxins in the food consumed by the populations (FAO, 2005).

Fumonisins are a group of potentially carcinogenic mycotoxins (IARC, 2002) that are produced by fungi of the *Fusarium* genus, especially *F. verticillioides and F. proliferatum* (Shephard, Thiel, Stockenström, & Sydenham, 1996) usually in maize. Fumonisins are designated as A, B, C and P series according to their chemical structure. Fumonisins are polar compounds, soluble in water and aqueous solutions of methanol and acetonitrile, but not in nonpolar solvents. Fumonisins B_1 (FB1), B_2 (FB2), and B_3 (FB3) are the most widespread and most frequently determined in maize. Fumonisin B_1 the most toxic is responsible for 70% of food contamination in the world (Thiel et al., 1991). Fumonisin B_1 is associated with a variety of pathological problems in animals such as

Abbreviations: ELISA, enzyme linked immunosorbent assay; bw, body weight; AFB, aflatoxin; FB, fumonisin; PDI, probable daily intake; APDI, average probable daily intake; MPDI, maximum probable daily intake; PMTDI, provisional maximum tolerable daily intake; IARC, International Agency for Research on Cancer.

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leukoencephalomalacia in horses, pulmonary oedema in swine and hepatocarcinoma in rats. The International Agency for Research on Cancer (IARC, 2002) has described FB1 as a class 2B toxin. FB1 is associated with inhibition of sphingolipid synthesis and increased risk of oesophageal cancer in humans (Marasas, 1996).

Aflatoxins are mycotoxins produced by *Aspergillus flavus* and *Aspergillus parasiticus*. The four most common aflatoxins are aflatoxin B_1 (AFB1), B2 (AFB2), G_1 (AFG1) and G_2 (AFG2). Aflatoxin B_1 (AFB1) is considered as the most potent naturally occurring genotoxic carcinogen. AFB1 has been classified as a group 1 carcinogen in humans by the International Agency for Research on Cancer (WHO and IARC, 1993). Chronic exposure to AFB1 was reported to increase the risk of liver cancer especially when associated with hepatitis B or hepatitis C (Kew, 2003).

The limits for aflatoxins in food and foodstuffs for human consumption in Zimbabwe have been set at 5 μg/kg (Siwela & Nziramasanga, 1999). The limits recommended by the European Commission Regulation Number 1126/2007, for fumonisins range from 4000 μg/kg for unprocessed maize and 200 μg/kg for processed maize-based foods for infants and young children (EC, 2007). The World Health Organization (WHO) recommends a provisional maximum tolerable daily intake (PMTDI) of 2 μg/kg body weight/day for FB1, FB2 and FB3, independently or combined, which was calculated according to the dose of no observable adverse effect level of 0.2 μg/kg/day with a safety factor of 100 (WHO, 2002).

In Zimbabwe, there is little information on typical range of fumonisins and aflatoxins concentration in maize meal and maize grain for human consumption. Although maize is a staple food for the majority of Zimbabweans, not much work has been done to determine the magnitude of the fumonisin and aflatoxin problem in maize consumed in Zimbabwean rural households. Our objective was to estimate the levels and daily intake of aflatoxin B_1 and fumonisin B_1 in maize meal and maize grain that was being consumed in rural households in Shamva and Makoni Districts of Zimbabwe.

2. Materials and methods

2.1. Site description and study design

The study was conducted in Shamva district (17.1667° S, 31.6667° E) in Mashonaland Central Province and Makoni district (18.2083° S, 32.8000° E) in Manicaland Province in Zimbabwe (Fig. 1). Shamva and Makoni districts are in Zimbabwean agricultural region II and receive average rainfall between 700 and 1050 mm/year. The two districts were chosen because farmers typically produce maize in surplus and the weather patterns favour fungal infection of maize and chances of mycotoxin contamination are high.

Six and five administrative units, referred to as wards in Zimbabwe were purposively selected from Makoni and Shamva districts respectively. The wards selected had majority of farmers that produce maize for subsistence use, consume home grown maize for at least six months in each farming season and have potential demand for storage facilities. In addition, wards that were selected are in agro ecological zone II and in one of the three smallholder farming sectors namely, communal areas, old resettlement areas and new resettlement areas and the wards are accessible by road.

The wards in each district were spread across three smallholder farming sectors namely, communal areas, old resettlement areas and new resettlement areas. The smallholder farming sectors are characterised by labour-intensive maize production systems using ox-drawn implements and is semi-commercialized. Two enumeration areas (villages) were randomly selected in each ward from which households were listed. Households relying on maize as staple food and located in an area that was accessible by road were selected for the survey.

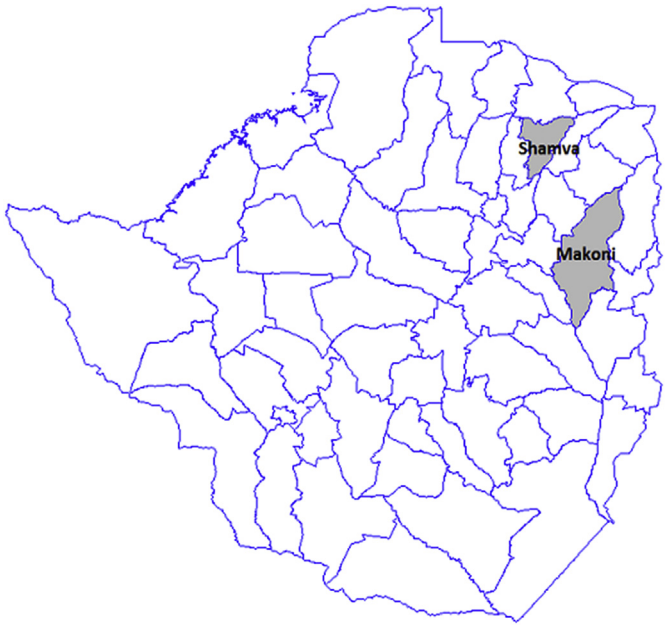

Fig. 1. Map of Zimbabwe showing the study sites where maize samples were collected.

2.2. Collection of samples

Samples of either shelled maize or maize meal were collected from 166 households in Shamva and 222 households in Makoni. During collection of maize meal, the meal was thoroughly mixed before randomly drawing a sample weighing 500 g. For collection of shelled maize grain stored in polypropylene bags or conventional granaries, grain was drawn from various points of each bag or granary using a grain sampling probe (Seedburo Equipment, Chicago, USA). The extracted grain was thoroughly mixed to compose an aggregate sample and a primary sample weighing at least one kg was collected. The collected samples were packaged in cotton bags, labelled, sealed and transported to the laboratory for analysis. Fourteen maize grain and 152 maize meal samples were collected from Shamva district whilst 61 maize grain and 161 maize meal samples were collected from Makoni District. The samples of grain were ground in a heavy duty blender (JTC OmniBlend III, China) for 5 min at maximum speed. All samples were stored in a freezer at −20 °C until required.

2.3. Reagents, solvents and other materials

The standard solution of AFB1 was obtained from Sigma Aldrich Chemicals (Steinheim, Germany). Chromatographic-grade methanol, acetonitrile and isopropanol (Merck, Darmstadt, Germany) were used. Sodium chloride (Glassworld, Gauteng, South Africa), iodine (Merck, Gauteng, South Africa) and methanol (Alpha Chemicals, India) were all of analytical grade. FB1 direct competitive enzyme linked immunosorbent assay (ELISA) kits including standard solution of FB1, were purchased from EuroProxima™ (Arnhem, Netherlands).