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Review Article

Update on mycotoxin contamination of maize and peanuts in East African Community Countries

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Abstract

The East African Community (EAC) is a regional Inter-Governmental body comprising of Uganda, Kenya, Tanzania, Rwanda, Burundi, and South Sudan. This region produces and extensively consumes maize and peanuts as staple foods. Maize and peanuts are susceptible to fungal growth and mycotoxin contamination and this is favored by high temperatures, high humidity as well as other factors such as grain damage by birds or insects, poor postharvest handling, and storage. Mycotoxins are toxic secondary metabolites of fungi that contaminate food with far-reaching consequences on human and animal health in addition to causing huge economic losses. Major mycotoxins of concern in maize and peanuts are Aflatoxins, Fumonisins, Zearalenone, and Deoxynivalenol. Among the East African Community countries aflatoxins and fumonisins are the most detected and researched mycotoxins in maize and peanuts. The highest reported aflatoxin contamination levels in maize and peanuts among the East African Community countries were 48,000μg/kg and 7,525μg/kg respectively both of which were recorded in products from Kenya while the highest fumonisin contamination in maize was 18,184 μg/kg which was reported in products from Tanzania. Human beings are exposed to mycotoxins mainly through the consumption of contaminated foods or their products. The East African Community through the East African Bureau of Standards set regulatory limits for aflatoxins and fumonisins in maize and peanuts at 5 ppb for aflatoxin B_1, 10 ppb for total aflatoxins, and 2000 ppb for fumonisins. This paper reviews the current literature on mycotoxin contamination of Maize and Peanuts in the East African Community region, current regulations, their negative consequences on health and trade as well as factors contributing to their high prevalence in the region.

Introduction

The East African Community (EAC) is a regional block comprising of 06 countries; Uganda, Kenya, Tanzania, Rwanda, Burundi, and South Sudan with an estimated population of 177.2 million people (East African Community Facts and Figures, 2019). The region extensively produces and consumes maize and peanuts as staple foods and according to statistics from the Food and Agriculture Organization of the United Nations the region produced a total of 13,755,477 tonnes of maize and 1,311,926 tonnes of peanuts in the year 2018 as shown in Table 1 [1].

Maize and peanuts are susceptible to fungal attack and mycotoxin contamination [2]. According to the East African Community Facts and Figures, 2019 the region in 2018 recorded the highest maximum rainfall of 953mm while the average minimum and maximum temperatures were 20°C and 29°C respectively. These conditions are conducive for fungal growth and mycotoxin production [3]. Mycotoxins are secondary toxic metabolites of fungi that contaminate food in many different parts of the world with far-reaching consequences on human and animal health in addition to causing enormous economic losses [4-8]. Several studies have reported high mycotoxin levels in maize and peanuts from the East African community region [9-15]. Major mycotoxins of concern in maize and peanuts are Aflatoxins (AFT), Fumonisins (FBs), Zearalenone (ZEN), and Deoxynivalenol (DON) which are mainly produced by *Aspergillus sp* and *Fusarium sp* as shown in Table 2 [2,16-19]. Fungal growth and subsequent mycotoxin production

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Table 1: Maize and Peanut Production by East African Community Countries in 2017 [1].

Country	Food Item	Production (Tonnes)
Uganda	**Maize**	2,964,017
Kenya		4,013,777
Tanzania		5,986,905
Rwanda		410,280
Burundi		290,498
South Sudan		90,000
Total		**13,755,477**
Uganda	**Peanuts**	242,243
Kenya		27,751
Tanzania		940,204
Rwanda		20,678
Burundi		12,372
South Sudan		68,678
Total		**1,311,926**

can occur when the crops are still in the field as well as after harvesting, during processing, handling, transportation, and storage [13,20,21]. Other factors such as grain damage by birds or insects and poor postharvest handling and storage also greatly contribute to high mycotoxin occurrence in food [22-27] Table 2.

Table 2: Common Mycotoxins occurring in Maize and Peanuts.

Mycotoxin	Fungi	Food
Aflatoxins (B_1, B_2, G_1, G_2, M_1)	*Aspergillus flavus* *A. parasiticus*	Maize and Peanuts
Zearalenone	*Fusarium graminearum*	Maize
Deoxynivalenol	*F. graminearum*	Maize
Fumonisins (B_1, B_2, B_3)	*F. verticillioides*	Maize

Adopted from [28] A. (Aspergillus), F. (Fusarium)

Good grain handling and storage practices such as cleaning to remove dirt and debris, sorting to remove damaged grains, proper aeration of the warehouses or stores to avoid dampness and proper grain drying to a moisture content of 12% or below before storage greatly improve grain quality and prevent or retard growth of fungi and production of mycotoxins [29]. Multiple mycotoxins can occur in one food item and this co-occurrence results in multi-toxin exposure to humans. Many health guidelines focus mainly on the toxicity of individual mycotoxins while paying less attention to the combined effects of multiple toxin interactions [6,12,30]. The problem of multiple mycotoxin occurrence in food has been attributed to the production of more than one mycotoxin by some fungal species, as well as combining raw materials contaminated with several mycotoxins during food production. It is significant to mention that DON, ZEN, and FB are all produced by the *Fusarium* species and therefore can co-occur with each other in food but may go undetected. Aflatoxins and fumonisins have been reported to co-occur in Maize and aflatoxicosis could co-occur with Fumonisin toxicity in humans who consume contaminated maize and yet go unconsidered [2]. Most of the previous studies have targeted one mycotoxin but currently, research is now targeting multiple mycotoxins because of their co-occurrence in agricultural products [5]. There is a need to evaluate the collective toxicity as a result of multiple occurrences or co-occurrence of mycotoxins in food on human health [31,32]. This paper reviews current literature on mycotoxin contamination in Maize and Peanuts in the East African community region, their negative health and economic effects as well factors contributing to their high prevalence in the region.

Occurrence and Exposure to mycotoxins in the East African Community Countries

Aflatoxins and Fumonisins are the most widely spread, detected, and researched mycotoxins occurring in maize and peanuts in the East Africa community region and Africa generally [2,3,12,23]. Aflatoxins B_1 has the highest toxicity among the aflatoxins and accounts for 75% of the total food contamination related to aflatoxins however there is Scanty information available on the prevalence of other mycotoxins like DON, and ZEN in maize and peanuts for human consumption in East Africa though some studies have been undertaken in animal feeds [2,6,18,19,33-40]. Deoxynivalenol is detected more frequently in animal feeds than in food [6,8,41]. Human beings are exposed to mycotoxins mainly through eating contaminated plant-based foods but can also be exposed to carry-over mycotoxins and their metabolites through animal-based products such as milk, meat, and eggs [4,9,23,42]. According to the Food and Agricultural Organization of the United Nations, approximately 25% of food crops all over the world are contaminated with mycotoxins [3]. Many people in East Africa are continuously exposed to high aflatoxin levels mainly through the consumption of contaminated maize and peanuts which are stapled foods in their daily diets. Many developing countries including East African Community countries export high-quality grains leaving behind low-quality ones which have increased consumption of contaminated and low-quality foods by the local population thus greatly increasing their exposure to mycotoxins [3,43,44]. It is important to note that in many instances checking for mycotoxins in food is mainly done on food products intended for the export market while the locally traded food products are not tested which exposes many East Africans to mycotoxins through their diets [45]. Babies can be exposed to aflatoxin M_1 through breast milk from their mothers who consume food contaminated with aflatoxins. A study that was undertaken in Northern Tanzania involving 143 breastfeeding mothers indicated that their breast milk contained 0.01 to 0.55ng/ml aflatoxin M_1 (AFM_1) a hydroxylated product of AFB_1 [2]. Aflatoxin M_1 occurrence in animal milk has been strongly associated with aflatoxin B_1 content in feeds given to animals [38,46]. Workers who handle and process aflatoxin-contaminated grains and feeds are also at risk of exposure to aflatoxins through inhalation of dust produced during the processing of such agricultural products [27,47]. A report from Kenya indicated that a local brew made from fermented maize was highly contaminated with aflatoxins, Fumonisin, and DON, and consumption of such a

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brew could serve as an exposure route to these mycotoxins [2]. Another report from Uganda reported that farmers use fungi-contaminated maize to make local brew which can also be a direct source of mycotoxin contamination [48].

Mycotoxin prevalence in maize and peanuts in East Africa Community Countries

Maize and peanuts are staple foods extensively produced and consumed in the East African community region and these two crops and their products are very susceptible to fungal growth and mycotoxin contamination [2,12,14,15,49,50]. In the East African region, most of the studies on mycotoxin have focused on aflatoxins in Maize and Peanuts with some studies on Fumonisin contamination in maize [2,12,23,51,52]. The region is estimated to have maize consumption of approximately 94kg to 128kg per person per annum and reports indicate that among the East African Community countries, Tanzania and Kenya have the highest maize production and highest maize consumption rates of about 355 to 400 g/person/day. Uganda recorded maize consumption rates of 177g/person/day which is lower than Kenya and Tanzania though it had the highest groundnuts consumption in the region of 93.2g/person/day [2,17,52-54].

Uganda

A study on maize samples from six high maize producing Districts in Uganda (Mayuge, Masindi, Nakasongola, Kasese, Kapchworwa, and Mbale) revealed that samples from moist mid-altitude areas registered the highest aflatoxin contamination levels of up to 32 ppb with an average of 20.54 ppb while samples from high land areas registered the lowest contamination levels of up to 15 ppb with an average of 12.35 ppb. This study reported that moist mid-altitude areas produced 75% of the total maize production in Uganda and this was a clear indication that most of the maize consumed in Uganda is contaminated with aflatoxins. Maize samples that had been stored for six months to one year also registered high aflatoxin contamination levels of up to 50 ppb with an average of 30.2 ppb [30]. A survey conducted on maize samples at the farm level and from domestic markets in Uganda reported that 11% of the samples were contaminated with aflatoxins ranging from 12.7 ppb to 123.5 ppb which is higher than the 10 ppb limit for EAC countries [55]. In [56], maize samples collected from 6 markets in Kampala (USAFI, Nakawa, St. Balikudembe, Nakasero, Kireka, and Kalerwe) revealed that 35% of the samples were contaminated with aflatoxins ranging from 0.7 ppb to 88.6 ppb. In this study, 74% of the samples taken from households were contaminated with aflatoxins with the highest recorded levels of 268 ppb and average contamination levels of 22.2 ppb which are higher than the 10 ppb limit for aflatoxins in EAC countries. Further studies involving samples from nine maize-producing Districts in Uganda (Mubende, Ibanda, Jinja, Mayuge, Buikwe, Hoima, Mpigi Masindi, and Bugiri) revealed that all the samples were contaminated with aflatoxins ranging from 2.6 ppb to 13.9 ppb. Maize samples from 3 districts of Hoima, Mayuge, and Ibanda recorded mean aflatoxin contamination levels of 11 ppb, 10.6 ppb, and 10.1 ppb respectively which are higher than the 10 ppb limit for aflatoxins in EAC countries. The rest of the districts had mean contamination levels below the 10 ppb limit and the lowest contamination of 3.8 ppb was registered in samples from Mpigi [14]. A study on the occurrence of Fumonisin contamination in maize samples from three agro-ecological zones (High attitude, mid-altitude moist, and mid-latitude dry) revealed that the high altitude areas registered the highest total Fumonisin content ranging from 0.85 ppm (850 ppb) to 10 ppm (10,000 ppb) with an average of 4.93 ppm (4930 ppb) which is higher than 2 ppm (2000 ppb) limit for fumonisins in EAC countries [51]. Peanuts provide a rich source of proteins and are widely consumed in Uganda and the East African region however they are very susceptible to mycotoxins [18,52,57]. A study conducted on peanut samples from four districts in Uganda (Mayuge, Iganga and Mubende, and Kampala) revealed that 60% of all samples collected at farm level in different villages were contaminated with aflatoxins and two villages of Kiboyo and Bugodi recorded average contamination levels of 12.4 ppb and 10.5 ppb respectively which were higher than the 10 ppb limit for aflatoxins in EAC countries. Among the market segment samples, it was observed that unsorted peanut seeds and milled peanut flour had higher aflatoxin contamination levels of 65.4 ppb and 59.4 ppb respectively compared to sorted and roasted peanut seeds which had lower contamination levels of 8.3 ppb and 12.7 ppb respectively. The study recommended that consumers should eat roasted peanut paste which had lower contamination levels compared to white milled peanut flour [53]. Another study involving peanuts, cassava, millet, sorghum flour, and eshabwe sauce samples from five districts in western Uganda (Mbarara, Ntungamo, Rukungiri, Kasese, and Kabale) revealed that peanut flour samples were contaminated with aflatoxins with average total aflatoxin contamination levels of 11.5 ppb which are higher than 10 ppb limit for aflatoxins [10]. Another study involving maize, peanuts, cassava flour, and peanut paste samples from markets in Kampala revealed that peanuts and peanut paste sold in different markets in the country were contaminated with aflatoxins and the contamination levels reached 940 ppb in peanuts and 720 ppb in peanut paste which is higher than 10 ppb limit for aflatoxins [58]. Another study conducted by Muzoora [26], on peanut samples collected from eight districts in four regions revealed that 62% of the samples were contaminated with aflatoxins and more specifically 26% of the samples tested positive for AFB_1. This study showed that 52% of the samples had aflatoxins levels higher than the 10 ppb limit for EAC countries and the total aflatoxin content in milled samples ranged from 0.31 ppb to 11,732 ppb while in seed samples the range was from 1.6 ppb to 516 ppb. It was observed in this study that milled peanut flour samples had high contamination than peanut seeds and this was suspected to be caused by traders who mill contaminated peanuts to conceal proof of spoilage. It was also observed that urban samples were more contaminated than rural samples and this was attributed to the possible long transportation and storage of peanuts from rural areas to urban areas since mycotoxin contamination has been known to occur during poor transportation and storage conditions. Another study conducted by Baluka, et al. [18] on multiple occurrences of mycotoxin contamination in peanut samples purchased from markets around Kampala revealed that the samples

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were contaminated with aflatoxins and fumonisins and that aflatoxins were the most detected mycotoxins. It was reported that 82 % of the peanut samples were contaminated with aflatoxins with contamination levels ranging from 0 to 849 ppb with an average contamination of 180.7 ppb and more than 66% of the samples had contamination levels higher than the 10 ppb limit for EAC countries. The study further revealed that 8% of the peanut samples were contaminated with Fumonisins (FB_1 and FB_2) with contamination levels ranging from 0.2 ppb to 0.6 ppb while other mycotoxins such as Zearalenone, zearalenol Ochratoxins, Deoxynivalenol, Nivalenol, Ochratoxin, and T2 toxin mycotoxins were not detected.

Kenya

In Kenya, high aflatoxin contamination was reported in maize and peanuts. In 2004 aflatoxin contamination of maize occurred in Kenya resulting in 125 deaths. It was observed that the concentration of aflatoxin B_1 in maize was as high as 4400 ppb while the total aflatoxins ranged from 1 ppb to 46,400 ppb which is far greater than the acceptable limit of 5 ppb for AFB_1 and 10 ppb total aflatoxins set by EAC countries [59,60]. A three-year study (2005, 2006, and 2007) on aflatoxin contamination in maize from Eastern Kenya revealed that maize samples collected were contaminated and that the maximum contamination levels over the three years were 48,000 ppb, 24,400 ppb, and 2,500 ppb respectively which are far greater than 10 ppb limit for aflatoxins in EAC countries [49]. Another study conducted on aflatoxin prevalence in maize flour from three ecological zones in western Kenya revealed that 49% of the samples tested positive for aflatoxins while 15% of these samples had aflatoxin levels higher than 10 ppb. The total aflatoxin contamination levels ranged from 2 ppb to 710 ppb and samples from the drought-affected areas were the most contaminated. It was also revealed that 87% of the samples from Bungoma County showed Measureable Fumonisin content and that 50% of these samples were above 1 ppm [12]. Another study involving 338 maize grain and maize flour samples collected from households in Siaya and Makueni counties revealed that all samples were contaminated with aflatoxins with contamination levels ranging from 2.14 ppb to 411 ppb. It was also revealed that 97.1% of the total aflatoxins detected was AFB_1 with contamination levels ranging from 1.69 ppb to 403 ppb with an average contamination level of 76.2 ± 63.9 ppb. The average total aflatoxins and AFB_1 contamination levels were 77.9 ± 64.3 ppb and 76.2 ± 63.9 ppb respectively which is higher than the 10 ppb and 5 ppb limits for total aflatoxins and AFB_1 in EAC countries. Both maize and maize flour samples were unfit for human consumption [13]. High aflatoxin contamination surpassing the acceptable limit of 10 ppb set by EAC Countries was reported in peanut samples in Kenya [45,61]. A study on aflatoxin contamination of peanuts in two Districts in western Kenya (Busia and Homabay) reported aflatoxin contamination levels as high as 2687.6 ppb in Busia District and 7525 ppb in Homabay District [62]. Another study conducted by [63] in Nairobi and Nyanza provinces in Kenya on aflatoxin contamination of peanuts and peanut butter revealed that peanut butter from the cottage industry had aflatoxin levels as high as 2377.1 ppb while raw peanuts had contamination levels reaching 364 ppb. The high incidence of aflatoxins in peanut butter was attributed to using defective ground nuts contaminated with aflatoxins to make peanut butter but could have also increased due to bad processing habits such as poor hygiene at the grinding mills, poor storage of roasted groundnuts before grinding as well as spreading roasted groundnuts on the floor or open-air cooling before grinding. This study also revealed 43% of the samples reported aflatoxin contamination higher than the 10 ppb limit for EAC countries and such peanut butter and raw peanuts were unfit for human consumption in East Africa and would have been rejected for export to European markets. Due to the lack of effective and efficient surveillance systems in East Africa, possibly these products were locally consumed which exposes the population to aflatoxins. Another study conducted to determine aflatoxin contamination in Peanuts in Busia and Kisii Central districts in western Kenya revealed that all peanut samples from Kisii Central District were contaminated with aflatoxins and the contamination levels ranged from 1.63 to 591.1µg/kg while 97.06% of samples from Busia were contaminated with the total aflatoxin levels ranging from 0.1 to 268µg/kg and one sample from the local red variety registered the highest aflatoxin contamination level of 268µg/kg [64].

Tanzania

Maize is also widely grown and consumed in Tanzania but is also susceptible to fungal growth and mycotoxin contamination which causes huge post-harvest losses and severe health risks to human beings and animals. ([15]. Results of a study conducted on maize samples from three villages in Babati District, northern Tanzania revealed that 19% of the samples were contaminated with aflatoxins while 35% of the samples were contaminated with fumonisins. In this study, it was reported that the average aflatoxin contamination in 19% of the samples was 2.94 ppb which was lower than the 10 ppb EAC limit for aflatoxins and therefore the samples were fit for human consumption while the average Fumonisin contamination in 35% of the samples was 5.15 mg/kg which was higher than 2 mg/kg EAC limit for Fumonisin and therefore the samples were unfit for human consumption [65]. Another study on the co-occurrence of several mycotoxins in maize samples obtained from 300 households from 3 agro-ecological zones (Kilosa, Hanang, and Rungwe) in Tanzania revealed that the maize contained multiple mycotoxins such as FB1, FB2, DON, AFB_1, HT-2 toxin, ZEN, and OTA. Kilosa recorded the highest AFB_1 levels of up to 1081 ppb with an average of 106 ppb which was higher than the 5 ppb limit for AFB_1 in EAC countries while Rungwe recorded the highest FB_1 contamination levels of up to 18,184 ppb with an average of 4722 ppb which is higher than the 2000 ppb limit for EAC countries. The study revealed that 28% of the samples had contamination for AFB_1 higher than the 5 ppb limit while 8% of the samples had contamination levels higher than the 10 ppb limit for total aflatoxins. Fumonisins were also detected in 43% of the samples and 15% of these samples had contamination levels higher than 1000 ppb. The study further revealed that 87% of the samples were contaminated with more than one mycotoxin while 45% of the samples were contaminated

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with aflatoxins and fumonisins. Co-occurrence of Fusarium toxins was also reported with 30 samples or 50% of samples having fumonisins with DON, 10 samples or 17% having DON with HT-2 toxin, 13 samples or 22% having fumonisins with HT-2 toxin, and 2 samples or 3% having DON and ZEN [66]. Another study conducted in Kilosa District, Tanzania revealed that maize had fumonisins B_1 contamination ranging from 63.26 ppb to 213.15 ppb. High Aflatoxin contamination was reported in groundnuts ranging from 72.97 ppb to 195.17 ppb which is higher than the 10 ppb limit for EAC countries [23]. Another study conducted in Tanzania involving maize samples collected from Manungu, Mlanga, and Kongwa villages in central Tanzania revealed that 30% of the samples had average aflatoxin contamination of 13µg/kg on day one and that the rate of aflatoxin contamination increased with storage time from 13.12µg/kg on the first day of storage to 19.39µg/kg after 180 days of storage with the highest detected contamination level of 70.5µg/kg. The results of this study showed that all the maize samples had aflatoxin contamination levels higher than the 10 ppb limit for EAC countries and could pose health risks to the population if consumed [15].

Rwanda

Maize and Peanuts are also staple foods in Rwanda and raw peanut consumption is approximately 21.43 g/person/day. It is not surprising that maize and peanuts from Rwanda are also very susceptible to mycotoxin contamination because of their geographic location and socio, cultural and economic similarities with other East African community countries. A study in Rwanda indicated that 40% of the maize flour samples from open markets in Kigali city were contaminated with aflatoxin B_1 and recorded the highest contamination level of 15.62 ppb which is higher than the 5 ppb limit set by EAC countries [67]. Another study conducted on maize flour, Groundnut flour, and cassava flour in Rwanda reported the presence of aflatoxins, Fumonisins, and Ochratoxins with 89% of the maize samples positive for AFB_1 while 100% of groundnut flour samples tested positive for AFB_1. The highest concentration of total aflatoxins in the maize flour samples was 16.8µg/kg which is higher than the 10ppb regulation limit for total aflatoxins in EAC countries and this was reported in maize flour samples from the Nyagatare market. The study also reported that the highest total Fumonisin concentration in maize flour samples was 48.1µg/kg which was detected in samples from the Ruhango market. Results of Peanut flour indicated that the total aflatoxin content was 126.6 µg/kg which was detected in peanut flour samples from the Kicukiro market while 16.3µg/kg of Fumonisin were detected in samples from the Huye market. This study revealed that peanut flour had more contamination levels than maize flour and both peanut and maize flours had aflatoxins levels higher than the regulation limit for EAC member countries. Fumonisin levels detected in both maize and peanut samples were below the EAC regulation limit of 2mg/kg or 2000µg /kg as well as below the European Union legislative limits of 1000µg/kg [40]. Another study carried out on maize flour for human consumption from markets in Rwanda also reported high AFB_1 contamination levels with the highest average of 24.7± 23.7µg/kg which was reported in samples from Nyarugenge in round one of assessment and 25.9± 25.9µg/kg which was reported in samples from Nyamirambo in round two. In both scenarios, the average contamination levels were above the 5 ppb limit for AFB_1 in EAC member countries [68].

Burundi

A study conducted on maize, cassava, beans, soybeans, sorghum, and groundnut samples collected from markets in Burundi and Eastern DRC revealed that all the samples were contaminated with aflatoxins. The samples from Burundi had an average total aflatoxin contamination level of 117.0µg/kg which is higher than the 10 ppb limit for EAC countries [17].

South Sudan

South Sudan is the youngest country in the world and the newest member of the East African Community having joined on 15th August 2016 and the available information on mycotoxins relates to former Sudan before it was split into Sudan and South Sudan and therefore cannot be accurately reported for South Sudan.

Regulation of mycotoxins in East African Community Countries

Regulatory limits offer a guarantee to consumers that the food will not contain toxins in concentrations that are harmful to their health [3]. The first mycotoxin regulations were set in the late 1960s and by 1981, 33 countries in the world had mycotoxin regulations. By 1987 the number of countries regulating mycotoxins had increased from 33 to 66 countries and by 2003 this number had increased to 99 countries representing approximately 87% of the world population. Out of 99 countries, only 15 countries were from Africa [69-71]. The increase in the number of countries with mycotoxin regulations demonstrates the commitment of Governments to reduce the negative effects of mycotoxins on humans health and as well as their impact on trade. It is also significant to note that the number of mycotoxins covered under the regulation limits increased from 1 mycotoxin (mainly aflatoxin) in 1981 to currently 13 [69]. The East African Community formed the East African Bureau of Standards which was mandated to harmonize standards for goods and services in the region and put in place regulatory limits for mycotoxins in food and feeds which has greatly improved the quality and safety of food products in the region. The regulation limits for mycotoxins in maize and peanuts cover aflatoxins and Fumonisins [72]. It is important to note that such harmonized regional standards mostly improve trade relations among countries but may fail to offer the desired protection to health due to differences in food consumption patterns as well as mycotoxin occurrence and exposure rates among countries [73]. There is a lot of informal trade among the EAC countries which makes it difficult to effectively enforce mycotoxin regulations within the region and this means that poor quality foods are being consumed which poses negative health effects Table 3.

Health and Economic impact of mycotoxins

Mycotoxin contamination of food has direct and indirect

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Table 3: Mycotoxin Regulations for Maize and Peanut in EU, FDA, and EAC Countries.

Mycotoxin	Food Item	EU (µg/kg)	USA (µg/kg)	CHINA (µg/kg)	EAC (µg/kg)	References
Total Aflatoxins	Maize and its products	4	20	20	10	[74-79]
	Peanuts and their products	4	20	20	10	
Aflatoxin B_1	Maize and its products	2	-	20	5	[60,74-79]
	Peanuts and their products	2	-	20	5	
Fumonisins	Maize and its products	1000	2000	-	2000	[60,74-79]
	Peanuts and their products	-	-	-	2000	
Deoxynivalenol	Maize and its products	750	1000	1000	-	[74,75,79]
	Peanuts and their products		-	-	-	
Zearalenone	Maize and its products	200	-	60	-	[74,75,79]
	Peanuts and their products	-	-	-	-	

economic consequences as well as severe health effects to humans and animals as a result of acute toxicity or chronic exposure [5,17,80]. The health consequences resulting from exposures to mycotoxins in humans range from acute to chronic effects such as aflatoxicosis, organ toxicity, neurotoxicity, Mutagenicity, Carcinogenicity, cytotoxicity, Growth retardation, diarrhea and vomiting, Immunosuppression, reproductive disorders, and death [4,17,27,35,42,43,52]. In Kenya, several cases of aflatoxicosis and death resulting from consumption of aflatoxin-contaminated maize have been reported with the most severe outbreak reported in 2004 [2,3,61,81]. Consumption of aflatoxin-contaminated food for a long time has been strongly linked to Hepatocellular carcinoma, retarded growth, and underweight in children [2,3,61]. In East Africa, several reports have indicated a correlation between aflatoxin exposure and high incidences of Hepatocellular carcinoma (HCC) in humans and it is estimated that there are 29 cases and 33.1 cases per 100,000 people in rural-Kenya and Tanzania respectively [2]. Among the East African Community countries liver cancer is the 5th ranked type of cancer occurring in men and women and in 2007 approximately 290,052 new cases of liver cancer were registered [10]. In Uganda, it is reported that the country loses $577 million per annum due to hepatocellular carcinoma treatment, and an extra 910,000 US dollars are spent on treating sicknesses and medical conditions related to aflatoxins [52]. Research by numerous scientists has shown a correlation between chronic exposure to mycotoxins (such as aflatoxins and Fumonisins) and impaired growth rate in children as was reported in a study conducted in Haydom Tanzania [82]. Growth impairment in children is reported to increase as the children grow and this is because as they grow they stop exclusive breastfeeding and start taking weaning foods (complementary foods) many of which are cereal-based (maize and peanut) which are suspected to be contaminated with aflatoxins and fumonisins [83]. Chronic exposure to fumonisins through consumption of contaminated maize has also been linked to regular occurrences of oesophageal cancer in Kenya although more studies are needed to confirm this pattern in other high maize consuming countries in East Africa [2,51]. A study conducted on the incidence of oesophageal cancer in Eastern Africa revealed that this region is a high incidence area for oesophageal cancer and that this presents a hefty burden on the health service systems in the region. It is reported that in East Africa oesophageal cancer is the second most frequently detected cancer among men with an estimated 10,500 new detected cases in 2008 which is strongly linked to consumption of maize-based diets [2]. The agricultural and economic consequences of mycotoxin contamination of food include low crop yield and livestock productivity, reduced value of contaminated products and low profits, rejection of food and feeds in international markets, high human medical and animal veterinary care costs, and death of humans and animals [17,41,54,84]. There are other high implied and indirect costs related to mycotoxin contamination of food and feeds such as the enforcement of regulation, continuous monitoring, and research on occurrence levels, toxic effects, and detoxification strategies to avert the negative effects of these mycotoxins [47,85]. The high mycotoxin limits used by the European Union hinder trade between the European Union and countries in Sub-Saharan Africa [17]. Sub-Saharan Africa which includes East African Countries loses approximately $670 million in exports every year because of high EU regulation) [80]. Uganda experiences a 43.5% reduction in agriculture exports due to aflatoxins contamination of agriculture products including maize and peanuts and the country loses approximately 38 million dollars every year as a result of export rejects related to aflatoxin contamination [52]. Acute or chronic exposure to mycotoxins causes several health problems in humans including death (Table 4).

Factors contributing to prevalence and exposure to mycotoxins in East Africa

In the East Africa Community region, several factors contribute to fungal growth and the high prevalence of mycotoxins in food. These factors are environmental (soil contamination by fungi, water stress, warm and humid conditions) political (regulations, laws, policies, enforcement), and economic as well as related to food production, handling,

Table 4: Health Effects of Common Mycotoxins.

Mycotoxin	Health Effects	References
Aflatoxins	Strong carcinogenic, immunosuppressive, hepatotoxic, growth impairment.	[3,16,17,27,35,43,86]
Zearalenone	Reproductive toxicity and teratogenic effects	[5,16,35,47,86]
Deoxynivalenol	Inhibits protein synthesis, affects the human immune system and the gastrointestinal tract; cytotoxicity, vomiting, and anorexia	[5,16,35,47,86]
Fumonisins	Cytotoxic, carcinogenic, neurotoxicity, endangering primate liver and kidney, inducing human esophageal cancer	[5,12,16,17,35,47, 51]

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and post-harvest management systems [3,18]. Many traditional practices such as drying of cereals on the bare ground are still used in post-harvest handling of food and this increases the likelihood of food contamination by mycotoxins. Storage of harvested crops in poorly ventilated and humid stores, as well as high insect and rodent damage of food in many rural households, is still a big contributing factor to the high occurrence of mycotoxins in the region. Insects and rodents cause physical damage to grains and this may start during pre-harvest stages while crops are still in the field and continue during storage which exposes the grains to fungal attack, growth, and mycotoxin production [3,10,24,87,51,52]. In East Africa, many of the farming systems are based on smallholder subsistence farming which makes it difficult to effectively enforce mycotoxins regulations in the produced and consumed foods at the household level. In Tanzania, for example, smallholder farmers contribute about 85% of the total maize production [16]. Widespread poverty, hunger, and malnutrition in East Africa make it very difficult to enforce mycotoxin regulations when there isn't enough food for people to eat. Poor people in many parts of East Africa have low purchasing power for quality foods which forces them to purchase and consume low-priced, low-quality, and often contaminated foods. [79,88-90]. There is also a problem of weak enforcement of mycotoxin regulations in some countries while in others the existing regulations cover a limited number of mycotoxins which has greatly contributed to the high prevalence of mycotoxins in the region [10,12,17,52] . Illiteracy among farmers and consumers in East Africa and limited access to information about mycotoxins have also greatly contributed to their high occurrence in food in the region [3,16,17,30]. Limited funding for mycotoxin research, limitations in terms of expertise, limited up to date mycotoxin data as well as limited research facilities have also greatly contributed to the high prevalence of mycotoxins in the region [3,17,52]. Most of the East African countries experience warm and humid weather conditions which are very favorable for fungi growth and mycotoxin production. There is an argument that climate change will make East Africa warmer and more humid which will greatly increase mycotoxins in the region [27,62]. The above factors coupled with low technological applications in food production, processing, and handling systems contribute to the high prevalence of mycotoxins in this region of Africa.

Conclusion

Mycotoxin contamination of food and feeds is not a new phenomenon all over the world and it poses a great danger to the health of humans and animals. East African Community countries greatly rely on Maize and peanuts as staple foods but unfortunately, they are very susceptible to mycotoxin contamination which greatly lowers their economic value and poses significant food safety concerns in the region. The above-reviewed literature on mycotoxin contamination in maize and peanuts in the East African Community region clearly shows that the region is grappling with a big problem of mycotoxins especially aflatoxins and fumonisins. More efforts should be directed to the prevention of fungal growth and mycotoxin production in food at pre-harvest, during harvest, during post-harvest storage, transport, and processing stages because they are difficult to eliminate from food once contamination occurs. East African Community Countries should continue to prioritize, design, and support programs aimed at mitigating health and economic threats posed by mycotoxin contamination of food. The creation of the East African Bureau of Standards has greatly improved the quality of food products in the region as well as boosted cross-border trade. The East African Bureau of Standards currently has put in place regulatory limits for aflatoxins and fumonisins in maize and peanuts but there is a need to widen the regulations to cover other potential mycotoxins such as Deoxynivalenol, Zearalenone among others. Regional governments should ensure that existing regulations are enforced to effectively control mycotoxin occurrence and contamination in food. Farmers and traders should be sensitized and trained on the dangers of mycotoxin occurrence and contamination in food, prevention, and possible control methods to fill the knowledge gap currently existing. All the different stakeholders such as Government, Academia, food manufacturers' and traders within the region should continue to work together, share expertise, experience, knowledge as well as resources and facilities to effectively detect, monitor, and control mycotoxins in susceptible foods along the whole value chain.

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References

1. FAO Statistics Division F and AO of the UN (2017) Faostat. Link: http://bit.ly/3uszanH

2. Kimanya ME (2015) The health impacts of mycotoxins in the eastern Africa region. Curr Opin Food Sci 6: 7-11. Link: https://bit.ly/3bCwY4r

3. Wagacha JM, Muthomi JW (2008) Mycotoxin problem in Africa: Current status, implications to food safety and health and possible management strategies. Int J Food Microbiol 124: 1-12. Link: https://bit.ly/3pOIeQ7

4. Islam R, Zhou T, Young JC, Goodwin PH, Pauls KP (2012) Aerobic and anaerobic de-epoxidation of mycotoxin deoxynivalenol by bacteria originating from agricultural soil. World Journal of Microbiology and Biotechnology 28: 7-13. Link: https://bit.ly/3bB7Jzk

5. Vanhoutte I, Audenaert K, De Gelder L (2016) Biodegradation of mycotoxins: Tales from known and unexplored worlds. Front. Microbiol. Link: https://bit.ly/3byluim

6. Lee HJ, Ryu D (2017) Worldwide Occurrence of Mycotoxins in Cereals and Cereal-Derived Food Products: Public Health Perspectives of Their Co-occurrence. J Agric Food Chem 65: 7034-7051. Link: https://bit.ly/3uscTXe

7. Udomkun P, Mutegi C, Wossen T, Atehnkeng J, Nabahungu NL, et al. (2018) Occurrence of aflatoxin in agricultural produce from local markets in Burundi and Eastern Democratic Republic of Congo. Food Sci Nutr 6: 2227-2238. Link: https://bit.ly/37HPxDf

8. Gao X, Mu P, Wen J, Sun Y, Chen Q, et al. (2018) Detoxification of trichothecene mycotoxins by a novel bacterium, Eggerthella sp. DII-9. Food Chem Toxicol 112: 310-319. Link: https://bit.ly/3bvOkA0

9. He J, Zhou T, Young JC, Boland GJ, Scott PM (2010) Chemical and biological transformations for detoxification of trichothecene mycotoxins in human and animal food chains: a review. Trends Food Sci Technol 21: 67-76. Link: https://bit.ly/3qOEaAV

10. Kitya D, Bbosa GS, Mulogo E (2010) Aflatoxin levels in common foods of South Western Uganda: A risk factor to hepatocellular carcinoma. Eur J Cancer Care 19: 516-521. Link: https://bit.ly/3qR42Mi

11. Anukul N, Vangnai K, Mahakarnchandkul W (2013) Significance of regulation limits in mycotoxin contamination in Asia and risk management programs at the national level. J Food Drug Anal 21: 227-241. Link: https://bit.ly/2NSrCty

12. Mutiga SK, Hoffmann V, Harvey J, Milgroom MG, Nelson R (2015) Approximately 25% of the world's food crop are affected each year by mycotoxin. Phytopathology 105. Link: https://bit.ly/2ZIVVFA

13. Nabwire WR, Ombaka J, Dick CP, Strickland C, Tang L, et al. (2019) Aflatoxin in household maize for human consumption in Kenya, East Africa. Food Additives and Contaminants: Part B Surveillance 13: 45-51. Link: https://bit.ly/37Eo2dp

14. Omara T, Nassazi W, Omute T, Awath A, Laker F, et al. (2020) Aflatoxins in Uganda: An Encyclopedic Review of the Etiology, Epidemiology, Detection, Quantification, Exposure Assessment, Reduction, and Control. Int J Microbiol 2020. Link: https://bit.ly/3dTB0Iz

15. Sasamalo M, Mugula J, Nyangi C (2018) Aflatoxins Contamination of Maize at Harvest and during Storage in Dodoma, Tanzania 7. Link: https://bit.ly/37G2YmW

16. Suleiman R, Rosentrater K (2015) Current maize production, postharvest losses and the risk of Mycotoxins contamination in Tanzania. American Society of Agricultural and Biological Engineers Annual International Meeting. Link: https://bit.ly/3dN0KWZ

17. Udomkun P, Wiredu AN, Nagle M, Müller J, Vanlauwe B, et al. (2017) Innovative technologies to manage aflatoxins in foods and feeds and the profitability of application – A review. Food Control 76: 127-128. Link: https://bit.ly/37HFUUN

18. Baluka SA, Schrunk D, Imerman P, Kateregga JN, Camana E, et al. (2017) Mycotoxin and metallic element concentrations in peanut products sold in Ugandan markets. Cogent Food & Agriculture 3. Link: https://bit.ly/3dHYrnJ

19. Manizan AL, Oplatowska-Stachowiak M, Piro-Metayer I, Campbell K, Koffi-Nevry R, et al. (2018) Multi-mycotoxin determination in rice, maize and peanut products most consumed in Côte d'Ivoire by UHPLC-MS/MS. Food Control 87: 22–30. Link: https://bit.ly/3bzjEh9

20. Reddy KRN, Salleh B, Saad B, Abbas HK, Abel CA, et al. (2010) An overview of mycotoxin contamination in foods and its implications for human health. Toxin Reviews 29: 3-26. Link: https://bit.ly/3aMCxxS

21. Samuel MS, Sivaramakrishna A, Mehta A (2014) Degradation and detoxification of aflatoxin B1 by Pseudomonas putida. Int Biodeterior Biodegradation 86: 202-209. Link: https://bit.ly/37HI07m

22. Hussaini M, Michael D, Patrick N, Timothy G, Godwin O (2012) Aflatoxin Contamination in Foods and Feeds: A Special Focus on Africa. In Trends in Vital Food and Control Engineering. Link: https://bit.ly/2ZMRKIV

23. Magembe KS, Mwatawala MW, Mamiro DP (2016) Mycotoxin contamination in stored maize and groundnuts based on storage practices and conditions in subhumid tropical Africa: The case of kilosa district, Tanzania. J Food Prot 79: 2160-2166. Link: https://bit.ly/2NAKY6z

24. Atongbiik Achaglinkame M, Opoku N, Amagloh FK (2017) Aflatoxin contamination in cereals and legumes to reconsider usage as complimentary food ingredients for Ghanaian infants: A review. J Nutr Intermed Metab 10: 1-7. Link: https://bit.ly/3qOVcyL

25. Xing F, Wang L, Liu X, Selvaraj JN, Wang Y, et al. (2017) Aflatoxin B1 inhibition in Aspergillus flavus by Aspergillus niger through down-regulating expression of major biosynthetic genes and AFB1 degradation by atoxigenic A. flavus. Int J Food Microbiol 256: 1-10. Link: https://bit.ly/3bxWasJ

26. Muzoora S (2017) Status on aflatoxin levels in groundnuts in Uganda. Pan Afr Med J 1: 11. Link: https://bit.ly/3bwJsul

27. Rushing BR, Selim MI (2019) Aflatoxin B1: A review on metabolism, toxicity, occurrence in food, occupational exposure, and detoxification methods. Food Chem Toxicol 124: 81-100. Link: https://bit.ly/3slwczt

28. Patricia Jackson (VICAM, A. W. B). (n.d.) (2020) Mycotoxins & Food Safety. Link: https://bit.ly/2ZNr1fv

29. Bullerman LB, Bianchini A (2007) Stability of mycotoxins during food processing. Int J Food Microbiol 119: 140146. Link: https://bit.ly/3urPvZP

30. Kaaya, Archileo Natigo, & Kyamuhangire, W. (2006). The effect of storage time and agroecological zone on mould incidence and aflatoxin contamination of maize from traders in Uganda. Int J Food Microbiol 110: 217-223. Link: https://bit.ly/3qL81dk

31. Smith MC, Madec S, Coton E, Hymery N (2016) Natural Co-occurrence of mycotoxins in foods and feeds and their in vitro combined toxicological effects. Toxins 8: 94. Link: https://bit.ly/3kmIMLZ

32. Loi M, Fanelli F, Liuzzi VC, Logrieco AF, Mulè G (2017) Mycotoxin biotransformation by native and commercial enzymes: Present and future perspectives. Toxins 9: 111. Link: https://bit.ly/3smiUTd

33. Guan S, Ji C, Zhou T, Li J, Ma Q, et al. (2008) Aflatoxin B 1 degradation by Stenotrophomonas maltophilia and other microbes selected using coumarin medium. Int J Mol Sci 9: 1489-1503. Link: https://bit.ly/37GVUGN

34. Guchi E (2015) Aflatoxin Contamination in Groundnut (Arachis hypogaea L.) Caused by Aspergillus Species in Ethiopia. Journal of Applied & Environmental Microbiology. Link: https://bit.ly/37JNSwL

35. Darwish WS, Ikenaka Y, Nakayama SMM, Ishizuka M (2014) An overview on mycotoxin contamination of foods in Africa. J Vet Med Sci 76: 789-797. Link: https://bit.ly/3dHDtFS

36. Raksha Rao K, Vipin AV, Hariprasad P, Anu Appaiah KA, Venkateswaran G (2017) Biological detoxification of Aflatoxin B1 by Bacillus licheniformis CFR1. Food Control 71: 234-241. Link: https://bit.ly/2Nqll8L

37. Echodu R, Edema H, Malinga GM, Hendy A, Colebunders R, et al. (2018) Is nodding syndrome in northern Uganda linked to consumption of mycotoxin contaminated food grains? BMC Res Notes 11: 678. Link: https://bit.ly/2ZLgmSE

38. Intanoo M, Kongkeitkajorn MB, Pattarajinda V, Bernard JK, Callaway TR, et al. (2018) Isolation and screening of aflatoxin-detoxifying yeast and bacteria from ruminal fluids to reduce aflatoxin B1 contamination in dairy cattle feed. J Appl Microbiol. Link: https://bit.ly/3uoz4NQ

39. Ma R, Zhang L, Liu M, Su YT, Xie WM, et al. (2018) Individual and combined occurrence of mycotoxins in feed ingredients and complete feeds in china. Toxins 10 113. Link: https://bit.ly/3dHC6ac

40. Umereweneza D, Kamizikunze T, Muhizi T (2018) Assessment of mycotoxins types in some foodstuff consumed in Rwanda. Food Control 85: 432-436. Link: https://bit.ly/2NVT61g

41. Pestka JJ, Smolinski AT (2005) Deoxynivalenol: Toxicology and potential effects on humans. J Toxicol Environ Health B Crit Rev 8: 39-69. Link: https://bit.ly/3uCzsZk

42. Alshannaq A, Yu JH (2017) Occurrence, toxicity, and analysis of major mycotoxins in food. In Int J Environ Res Public Health 14. Link: https://bit.ly/3bybrJZ

43. Wu F, Guclu H (2012) Aflatoxin Regulations in a Network of Global Maize Trade. PLoS One. Link: https://bit.ly/2ZIaF7V

Citation: Ankwasa EM, Francis I, Ahmad T (2021) Update on mycotoxin contamination of maize and peanuts in East African Community Countries. J Food Sci Nutr The 7(1): 001-010. DOI: https://dx.doi.org/10.17352/jfsnt.000026

44. Mwakinyali SE, Ding X, Ming Z, Tong W, Zhang Q, et al. (2019) Recent development of aflatoxin contamination biocontrol in agricultural products. Biological Control 128: 31-39. Link: https://bit.ly/3kpymLF

45. April 2018 EAC Policy Brief on Aflatoxin Prevention and Control | Policy Brief No. 5, 2018 Use of Biocontrol for Aflatoxin Prevention and Control in the EAC. (n.d.). Link: https://bit.ly/2ZK6MPF

46. Mahmoudi R, Norian R (2015) Aflatoxin B1 and M1 contamination in cow feeds and milk from Iran. Food and Agricultural Immunology 26: 131-137. Link: https://bit.ly/3dTClz5

47. Omotayo OP, Omotayo AO, Mwanza M, Babalola OO (2019) Prevalence of mycotoxins and their consequences on human health. Toxicol Res 35: 1-7. Link: https://bit.ly/37I6YTW

48. Bigirwa G, Kaaya AN, Sseruwu G, Adipala E, Okanya S (2007) Incidence and severity of maize ear rots and factors responsible for their occurrence in Uganda. J Appl Sci 7: 3780-3785. Link: https://bit.ly/3snvamq

49. Daniel JH, Lewis LW, Redwood YA, Kieszak S, Breiman RF, et al. (2011) Comprehensive assessment of maize aflatoxin levels in eastern Kenya, 2005-2007. Environ Health Perspect 119. Link: https://bit.ly/3aNPJ5F

50. Ngoma S, Tiisekwa B, Mwaseba D, Kimanya M (2016) To cite this article: Selestin Ngoma, Bendantukuka Tiisekwa, Dismas Mwaseba, Martin Kimanya. Awareness of Aflatoxin Health Risks Among Parents with Children Aged Between 6-23 Months in Central Tanzania. International Journal of Nutrition and Food Sciences 5: 429-436. Link: https://bit.ly/3bDxwal

51. Atukwase A, Kaaya AN, Muyanja C (2009) Factors associated with fumonisin contamination of maize in Uganda. J Sci Food Agric 89: 2393-2398. Link: https://bit.ly/3byEjSy

52. Lukwago FB, Mukisa IM, Atukwase A, Kaaya AN, Tumwebaze S (2019) Mycotoxins contamination in foods consumed in Uganda: A 12-year review (2006–18). Scientific African 3: e00054. Link: https://bit.ly/3dL91uj

53. Kaaya AN, Warren HL, Kyamanywa S, Kyamuhangire W (2005) The effect of delayed harvest on moisture content, insect damage, molds and aflatoxin contamination of maize in Mayuge district of Uganda. J Sci Food Agric 85: 2595-2599. Link: https://bit.ly/3usjxfV

54. Suleiman RA, Rosentrater KA, Chove B (2017) Understanding postharvest practices, knowledge, and actual mycotoxin levels in maize in three agro-ecological zones in Tanzania. Journal of Stored Products and Postharvest Research. Link: https://bit.ly/3kisow4 .

55. Lee S, Lee S, Sserumaga JP, Hwang N, Park S, et al. (2013) Survey for Contamination of Aflatoxin in Uganda Maize. J Korean Soc int Agric. Link: https://bit.ly/37H66Pz

56. Wacoo A, Wendiro D, Nanyonga S, Hawumba J, Sybesma W, et al. (2018) Feasibility of A Novel On-Site Detection Method for Aflatoxin in Maize Flour from Markets and Selected Households in Kampala, Uganda. Toxins 10: 1–12. Link: https://bit.ly/3pPzSYo

57. Christie ME, Kyamureku P, Kaaya A, Devenport A (2015) Farmers, peanuts, and aflatoxins in Uganda: A gendered approach. Development in Practice 25: 4-18. Link: https://bit.ly/2Nxq888

58. Osuret J, Musinguzi G, Mukama T, Halage AA, Natigo AK, et al. (2016) Aflatoxin contamination of selected staple foods sold for human consumption in Kampala markets, Uganda. Journal of Biological Sciences 16: 44-48. Link: https://bit.ly/2NVZ6r6

59. Azziz-Baumgartner E, Lindblade K, Gieseker K, Rogers HS, Kieszak S, et al. (2005) Case-control study of an acute aflatoxicosis outbreak, Kenya, 2004. Environ Health Perspect 113. Link: https://bit.ly/3utl31d

60. EAST AFRICAN STANDARD EAS 2:2011 Maize grains — Specification (2011). Link: https://bit.ly/3dIbJ3B

61. Lewis L, Onsongo M, Njapau H, Schurz-Rogers H, Luber G, et al. (2005) Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in eastern and central Kenya. Environ Health Perspect 113: 1763-1767. Link: https://bit.ly/2ZLthnC

62. Mutegi CK, Ngugi HK, Hendriks SL, Jones RB (2009) Prevalence and factors associated with aflatoxin contamination of peanuts from Western Kenya. Int J Food Microbiol 130: 27-34. Link: https://bit.ly/3uusJAD

63. Ndung'u J, Makokha A, Onyango C, Mutegi C, Wagacha J, et al. (2013) Prevalence and potential for aflatoxin contamination in groundnuts and peanut butter from farmers and traders in Nairobi and Nyanza provinces of Kenya. Journal of Applied Biosciences Link: https://bit.ly/3qQ2Usq

64. Menza C, Margaret N, Lucy MW (2015) Incidence, Types, and Levels of Aflatoxin in Different Peanuts Varieties Produced in Busia and Kisii Central Districts, Kenya. Open J Med Microbiol. Link: https://bit.ly/3dIqnlq

65. Nyangi C, Beed F, Mugula JK, Boni S, et al. (2016) Assessment of pre-harvest aflatoxin and fumonisin contamination of maize in Babati district, Tanzania. African Journal of Food, Agriculture, Nutrition and Development. Link: https://bit.ly/3buICOG

66. Kamala A, Ortiz J, Kimanya M, Haesaert G, Donoso S, et al. (2015) Multiple mycotoxin co-occurrence in maize grown in three agro-ecological zones of Tanzania. Food Control 54: 208-215. Link: https://bit.ly/3utJbkA

67. Matsiko F, Kanyange C, Ingabire G, Dusingizimana T, Vasanthakaalam H, et al. (2017) Detection and quantification of aflatoxin in cassava and maize flour sold in Kigali open markets, Rwanda. Int Food Res 24: 459-464. Link: https://bit.ly/37ZI0jl

68. Nishimwe K, Wanjuki I, Karangwa C, Darnell R, Harvey J (2017) An initial characterization of aflatoxin B1 contamination of maize sold in the principal retail markets of Kigali, Rwanda. Food Control 73: 574-580. Link: https://bit.ly/3kjlV4b

69. Van Egmond HP, Schothorst RC, Jonker MA (2007) Regulations relating to mycotoxins in food : PPPPerspectives in a global and European context. Anal Bioanal Chem 389: 147-157. Link: https://bit.ly/2NVU1Pz

70. Mazumder PM, Sasmal D (2001) Mycotoxins - limits and regulations. Anc Sci Life 20: 1-19. Link: https://bit.ly/3pIlMZ2

71. Food and Agriculture Organization of the United Nations (2004) Mycotoxin regulations in 2003 and current developments. Worldwide Regulations for Mycotoxins in Food and Feed in 2003.

72. Catalogue of East African Standards May 2015. (n.d.). Link: https://bit.ly/2NY2OjH

73. FAO/WHO 1995 (2015) GENERAL STANDARD FOR CONTAMINANTS AND TOXINS IN FOOD AND FEED (CODEX STAN 193-1995) Adopted in 1995 Revised in 1997, 2006, 2008, 2009 Amended in 2010, 2012, 2013, 2014, 2015. General Standard for Contaminants and Toxins in Food and Feed (Codex Stan 193-1995). Link: https://bit.ly/3kkvH68

74. van Egmond HP, Jonker MA (2005) Worldwide regulations for mycotoxins in food and feed in 2003: Summary of study. Food and Nutrition Paper.

75. Commission Regulation 1881/2006/EC of 19 December 2006 (2006). Link: https://bit.ly/3dL9bBV

76. Milling EAS. E. 57-1: 2000 G. (peanuts) — S. P. 1: R. groundnuts for table use and for oil. (2000). East African Standard EAS 57-1: 2000 Groundnuts (peanuts) — Specification Part 1: Raw groundnuts for table use and for oil milling. Link: https://bit.ly/3qQ7k2u

77. FDA Mycotoxin Regulatory Guidance. A Guide for Grain Elevators, Feed Manufacturers, Grain Processors and Exporters (2011) www.ngfa.org

78. East African Standard EAS 44: 2011 Milled maize (corn) products — Specification (2011) Link: https://bit.ly/2ZMUbLQ

Citation: Ankwasa EM, Francis I, Ahmad T (2021) Update on mycotoxin contamination of maize and peanuts in East African Community Countries. J Food Sci Nutr The 7(1): 001-010. DOI: https://dx.doi.org/10.17352/jfsnt.000026

79. GB 2761-2017 (2017). Link: https://bit.ly/3pNXxst

80. Wielogorska E, Mooney M, Eskola M, Ezekiel CN, Stranska M, et al. (2019) Occurrence and Human-Health Impacts of Mycotoxins in Somalia. J Agric Food Chem 67: 2052-2060. Link: https://bit.ly/3sllB6v

81. Shetty PH, Jespersen L (2006) Saccharomyces cerevisiae and lactic acid bacteria as potential mycotoxin decontaminating agents. Trends Food Sci Technol 17: 48-55. Link: https://bit.ly/37IlY4c

82. Chen C, Riley RT, Wu F (2018) Dietary Fumonisin and Growth Impairment in Children and Animals: A Review. Compr Rev Food Sci Food Saf 17:1448-1464. Link: https://bit.ly/3sqRknN

83. Cheng ML, Zhang L, Borok M, Chokunonga E, Dzamamala C, et al. (2015) The incidence of oesophageal cancer in Eastern Africa: Identification of a new geographic hot spot? Cancer Epidemiology 39: 143-149. Link: https://bit.ly/2MjoVRk

84. Milicevic D, Nesic K, Jaksic S (2015) Mycotoxin Contamination of the Food Supply Chain - Implications for One Health Programme. Procedia Food Sci 5: 187-190. Link: https://bit.ly/2PaN0ep

85. Zain ME (2011) Impact of mycotoxins on humans and animals. Journal of Saudi Chemical Society 15: 129-144. https://bit.ly/2MkIiJT

86. Zinedine A, Brera C, Elakhdari S, Catano C, Debegnach F, et al. (2006) Natural occurrence of mycotoxins in cereals and spices commercialized in Morocco. Food Control 17: 868-874. Link: https://bit.ly/3aT1JDb

87. Manjula K, Hell K, Fandohan P, Abass A, Bandyopadhyay R (2009) Aflatoxin and fumonisin contamination of cassava products and maize grain from markets in Tanzania and republic of the Congo. Toxin Reviews 28: 63-69. Link: https://bit.ly/3uv1G83

88. Sibanda L, Marovatsanga LT, Pestka JJ (1997) Review of mycotoxin work in sub-Saharan Africa. Food Control 8: 21-29. Link: https://bit.ly/2ZICjkX

89. East African Community. (n.d.). Quick Facts about EAC. Link: https://bit.ly/3pS8p8y

90. Kaaya AN, Harris C, Eigel W (2006) Peanut Aflatoxin Levels on Farms and in Markets of Uganda. Peanut Science 33: 68-75. Link: https://bit.ly/2ZLMTrC

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