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Global distribution of Fumonisin B_1 – A review

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ABSTRACT

Fumonisin B_1 (FB_1) is one of the toxins associated with several species of Fusarium. It was reported to be commonly found in maize and maize- based products. Thus, several surveys on the natural occurrence worldwide have been conducted.. Some of the reviewed results indicated 82% occurrence in the samples investigated in Oceania. Elsewhere in Africa, Latin America, North America, Europe and Asia, 77%, 85%, 63%, 53% and 52% occurrences respectively were recorded. The highest incidence was reported in maize-based feeds, ground maize products, maize kernels and maize-based foods in this order. This review notes that in the range of values reported, the lowest limits were less than the safe levels recommended for humans and animals excepting in USA. On the other hand, some of the highest limits were higher than the safe levels .It was observed that human exposure to FB_1 estimate for Switzerland and South Africa as well as animal exposure in USA, Italy and Brazil were very alarming. It is therefore hoped that this review will instigate the interests of the scientific world and others to act in a positive direction to safe guard our society from this fast occurring and spreading mycotoxins in our environments. This could be achieved through enlightenment programs on mycotoxicoses and strict adherence to agronomic practices, to ensure production of wholesome agricultural commodities.

Keywords: *Animals, Humans, Fumonisin B_1 (FB_1), maize and maize-based products, recommended levels..*

INTRODUCTION

Fusarium species are widespread in nature as saprobes in decaying vegetation and as parasites on all parts of plants. Many of their metabolites cause diseases of economically important plants especially fumonisins, trichothecenes and zearalenone. Consequently, a lot of researches have been carried out by plant pathologists, mycologists, veterinary doctors, animal scientists and other stakeholders. Almost all the researchers reported that maize and maize-based products were the only commodities that contain significant amounts of fumonisins (Hesseltine *et al.*, 1981; Bacon and Williamson, 1992; Pitt *et al.*, 1993; Bullerman and Tsai, 1994; Sanchis *et al.*, 1995; Pascale *et al.*, 1997). Essien (2000) reported that *Fusarium* species are the most widespread in pre-harvest and stored maize in Nigeria.. About fifteen different fumonisins have been identified by researchers, who grouped them into FA_1, FA_2, FA_3, FAK_1, FB_1, FB_2, FB_3, FB_4, FC_1, FC_2, FC_3 FC_4, FP_1, FP_2 and FP_3 (Musser and Plattner, 1997; Abbas and Shier, 1997). But the most occurring and distributed in nature was reported to be fumonisin B_1 (FB_1), which was isolated and chemically characterized in 1988 (Gelderblom *et al.*, 1988; Bezuidenhout *et al.*, 1988).Fumonisin B_1 was reported to be produced by isolates of *Fusarium verticillioides, F. proliferatum, F. anthophilum, F. becomiforme, F. dlamini, F. globosum, F. napiforme, F. nygamai, F. oxysporum, F. polyphialidicum, F. subglutinans* and *F. thapsinum* from maize samples in Africa, The Americas, Oceania, Asia and Europe (Gelderblom *et al.*, 1988; Ross *et al.*, 1990; Nelson *et al.*, 1991; Chelkowski and Lew, 1992; Miller *et al.*, 1993; Desjardins *et al.*, 1994; Abbas and Ocamb, 1995; Logrieco *et al.*, 1995; Leslie *et al.*, 1996; Sydenham *et al.*, 1997). However, only *F. verticillioides* and *F. proliferatum* are recently receiving attention in the scientific world, because they have been implicated in a number of mycotoxic cases, both in animals and humans. Pascale *et al.* (1997) reported that significant FB_1 accumulation in maize occurs when weather conditions favour *Fusarium* kernel rot. And the severity of ear infection was discovered to be a good indicator of FB_1 accumulation in maize ears, artificially inoculated with *F. verticillioides.* A study of FB_1 occurrence in hybrids grown across the USA maize belt indicated that hybrids grown outside their range of adaptation had higher FB_1 concentration. Similarly, samples collected from Africa, Italy and Croatia also indicated FB_1 accumulation in hybrids grown outside their area of adaptation. Meanwhile, the occurrence of FB_1 in Ontario was limited to drought-stressed fields (Shelby *et al.,* 1994; Miller *et al.*, 1995; Doko *et al.*, 1996). Also, the level of insect damage in maize and other grains influences the extent of FB_1 contamination. Avantaggio *et al.* (2002) discovered that insect damage to maize is a good predictor of *Fusarium* mycotoxin contamination and can serve as early warning of FB_1contamination. The insects transfer the *Fusarium* spores on plant surfaces into the interior of stalk or kernels during feeding (Munkvold and Hellminch, 2000). Meanwhile, Bankole *et al.* (2003) found out that FB_1 level in maize samples did not correlate with the extent of visible mouldiness in the samples. Apart from maize and maize-based products, FB_1 was reported to be detected in other food products like rice (Abbas *et al.*, 1998), asparagus (Logrieco *et al.*, 1998), beer (Torres *et al.*, 1998) and sorghum (Shetty and Bhat, 1997). But surveys on wheat, rye, barley and oats did not show the occurrence of FB_1 (Meister *et al.*, 1996).

Since maize is a staple food for man as well as feed ingredient for animals and maize being a carrier of FB_1, global occurrence becomes a major risk factor with very serious repercussions on humans and animals health. In spite of this health threat, there seems to be little or no awareness of possible occurrence and distribution of FB_1 in our environment. Thus, this present review is hoped to remind the scientific world and others, the need for strict measures required for healthy agricultural commodities. This will go a long way safe guarding our societies against the consumption of mouldy foods and feeds.

Incidence of Fumonisin B_1

Although the concept that mouldy food could lead to illness in humans and animals was long suspected, the existence of mycotoxins was not documented until 1960. Before 1900 in Italy, researchers believed that consumption of mouldy maize by children led to the development of illness (Christensen, 1975). An extensive investigation of the outbreak of “mouldy maize disease” in the southeastern United States in the early 1950’s was carried out, where hundreds of wild pigs foraging in cultivated maize fields became ill and many died. In 1900, Sheldon (1904) described fumonisins as a family of mycotoxins produced by *Fusarium* species. The effects of fumonisins were documented in the 1940’s and were associated with an outbreak of “alimentary toxic aleukia”. Presently, more reports on the effects of FB_1 have been documented and it was evidently deleterious in all the experimental animals (Gelderblom, 1992a). However, Idahor (2003) observed no effects on rabbits reproductive performance at micro doses (1.7 – 1.9ppm FB_1/kg diet).

More recently, a number of surveys on the natural occurrence of FB_1 in maize and maize-based foods and feeds were conducted worldwide. According to WHO (2000), the results showed that 60% of the 5, 211 samples analysed was discovered to be contaminated with FB_1. The highest occurrence was in Oceania (82% of 82 samples) followed by Africa (77% of 383 samples), Latin America (85% of 266 samples), North America (63% of 1,662 samples), Europe (53% of 1,918 samples) and Asia (52% of 900 samples). In Nigeria, Bankole *et al.* (2003) detected 59% of 108 maize samples analysed and recorded average of 0.39mg FB_1/kg. The levels and incidence of contamination vary considerably in relation to the commodities analysed and their sources. The highest incidence was recorded in maize-based feeds (82% of 1,112 samples) slightly followed by ground maize products (73% of 517 samples), maize kernels (52% of 2,525 samples) and maize-based foods (40% of 892 samples).Table 1 shows the occurrence of FB_1 in maize and maize-based products in some regions of the world. It could be observed that FB_1 concentration was highest in maize-based feed except in Asia where Lee *et al. (*1994) recorded as low as 1.33mg /kg. Whereas, least concentration appears to be in maize flakes, foods, flour and grits. This observation could be probably due to the extensive processing of the maize-based foods compared to maize-base feed. Also, it could be partly due to the maize cultivar and quality requirements for various destinations (WHO, 2000).

However, all the lowest limit values of maize-based foods reported in this table, were less than the safe levels of between 0.5 and 4.0mg/kg recommended for humans (Guerzoni, 2008; FDA, 2001). The same trend was observed in maize-based feeds excepting in USA, where Colvin and Harrison (1992) reported 105 mg/kg that was above 5.0 – 100.0mg/kg recommended for animals (Miller *et al.*, 1996).

Table 1: Occurrence of Fumonisin B_1 in Maize and Maize-based Products in some Regions of the World.

Continent/Product	Country	FB_1 Conc. (mg/kg)	Reference
North America			
Maize	Canada	0.08	Stack and Eppley (1992)
Maize flour	Canada	0.05	Sydenham *et al.* (1991)
Maize feed	USA	105 – 155	Colvin and Harrison (1992)
Maize grits	USA	0.11 – 2.55	Sydenham *et al.* (1991)
Maize flakes	USA	0.01	Stack and Eppley (1992)
Maize foods	USA	0.01 – 0.12	Stack and Eppley (1992)
Latin America			
Maize	Argentina	0.18 – 27.05	Visconti *et al*. (1995)
Maize flour	Peru	0.66	Sydenham *et al.* (1991)
Maize feed	Brazil	0.2 – 38.5	Sydenham *et al.* (1992)
Tortillas	Texas/Mexico	0.19	Stack (1998)
Masas	Texas/Mexico	0.26	Stack (1998)
Polenta	Uruguay	0.1 – 0.43	Pineiro *et al.* (1997)
Europe			
Maize	Austria	1.0-15.0	Lew *et al.* (1991)
Maize flour	Austria	0.05 – 1.15	Sydenham *et al.* (1993a)
Maize feed	France	0.02 – 8.82	Doko *et al*. (1994)
Maize grits	Germany	0.01	Usleber *et al.* (1994b)
Maize foods	Germany	0.007 – 4.83	Meister *et al.* (1996)
Polenta	Czech	0.01 – 1.2	Ostry and Ruprich (1998)
Africa			
Maize	Benin	0.02 – 2.63	Doko *et al.* (1995)
Maize flour	Botswana	0.18 – 0.45	Sydenham *et al.* (1993a)
Maize	Nigeria	0.06 – 1.83	Bankole *et al*. (2003)
Maize feed	South Africa	0.47 – 4.34	Viljeon *et al.* (1994)
Maize grits	South Africa	0.05 – 0.19	Sydenham *et al.* (1991)
Maize foods	South Africa	0.05 – 0.09	Sydenham *et al.* (1991)
Maize kernels	Tanzania	0.02 – 0.16	Doko *et al.* (1996)
Asia			
Maize	China	5.3 – 8.4	Ueno *et al.* (1993)
Maize flour	China	0.06 – 0.2	Ueno *et al.* (1993)
Maize feed	Korea	0.05 – 1.33	Lee *et al.* (1994)
Maize grits	Thailand	0.25 – 1.82	Wang *et al.* (1993)
Maize foods	Taiwan	0.07 – 2.39	Tseng and Liu (1997)
Maize powder	Vietnam	0.27 – 1.52	Wang *et al*. (1995)
Oceania			
Maize	Australia	0.3 – 40.6	Bryden *et al.* (1996)
Maize flour	New Zealand	NA	Sydenham *et al*. (1993a).

NA: Not Available; FB_1 Conc: Fumonisin B_1 Concentration

Source: WHO, 2000.

Recommended levels of FB_1 in Human Foods and Animal Feeds

The recommended maximum levels of fumonisins in human foods and animal feeds that US Food and Drug Administration considers achievable with the use of good agricultural commodity and manufacturing practices are shown in tables 2 and 3 below. Strict adherence to these recommendation levels though will result in huge economic losses due to rejection for international trade (Guerzoni, 2008), it will reduce human and animal exposure to FB_1.

Table 2: Recommended levels of FB_1 in Human Foods

Products	Total Fumonisins (FB_1 + FB_2 + FB_3)
Degermed dry milled maize products like flakes, grits, flour with less than 2.25% dry weight basis of fat content.	2.0 part per million
Whole or partially degermed dry milled maize products like flakes, grits, flour with greater than 2.25% dry weight basis of fat content	4.0 part per million
Dry milled maize bran	4.0 part per million
Cleaned maize intended for masa production	4.0 part per million
Cleaned maize intended for popcorn	3.0 part per million

Source: FDA, 2001.

Meanwhile, human exposure estimate of 0.017 – 0.89 µg/kg body weight per day have been made for Canada, 0.08 µg/kg for USA, 0.03 µg/kg for Switzerland, 4.0 – 220.0 µg/kg for The Netherlands and as high as 14.0 – 440.0 µg/kg for South Africa (Kuiper – Goodman *et al*., 1996; Humphreys *et al*., 1997; Zoller *et al*., 1994; De Nijs, 1998; Thiel *et al*., 1992). Gradual and continuous consumption of FB_1 at these levels will in no doubt pose health hazard to the consumers especially, in The Netherlands and South Africa where much more than the recommended levels were reportedly taken in on daily basis.

Table 3: Recommended levels of FB_1 in Animal Feeds

Maize and maize by-products intended for:	Total Fumonisins (FB_1 +FB_2+FB_3)
Equine and Rabbits	5.0 part per million (Not > 20% of diet)
Swine and Catfish	20.0 part per million (Not > 50% of diet)
Breeding Ruminants, Poultry and Mink	30.0 part per million (Not > 50% of diet)
Ruminants ≥ 3 months old meant for beef and Mink meant for pelt productions	60.0 part per million (Not > 50% of diet)
All other species or classes of livestock and pet animals	30.0 part per million (Not > 50% of diet)

Source: FDA, 2001.

But FB_1 levels in animal feed stuffs were reportedly high and reached maximum of 330.0mg/kg in USA, 70.0mg/kg in Italy, 38.0mg/kg in Brazil, 9.0mg/kg in South Africa and as low as 2.0mg/kg in Thailand (WHO, 2000). It could be observed that animal exposure to FB_1 in USA, Italy and Brazil were exceptionally higher than the recommended levels.

Conclusion

It is obvious that FB_1 has occurred in some regions of the world in which nearly all the continents were represented. Based on the outcome of this present review, it could be speculated that humans are exposed to FB_1 directly by consuming contaminated maize and maize-based foods and indirectly from consuming animal products with significant accumulation of $FB_{1.}$ .More research strategies are needed with a view to slowing down the rate of occurrence and spread or if possible eradicating the mycotoxic scourge, thereby guaranteeing wholesome foods and feeds should be developed, tested and adopted. In the long run, our societies will be rest assured of the consumption of wholesome foods and feeds.

As a guide to achieving this, there should be regular programs on the media, creating awareness of mycotoxins hazards. This will enlighten the society to always discard stale and mouldy foods as well as feeds, no matter the poverty level. Also, seminars and workshops should be organized regularly to exchange discoveries and progressive reports on mycotoxin researches.

More importantly, there should be strict adherence to the agronomic practices. Such as early weeding, application of fertilizers, adequate water supply, prompt harvesting, drying, sorting and grading, processing and use of proper preservation and storage techniques required for healthy agricultural commodities.

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