C O D E X   A L I M E N T A R I U S   C O M M I S S I O N

Food and Agriculture Organization of the United Nations

World Health Organization

Viale delle Terme di Caracalla, 00153 Rome, Italy - Tel: (+39) 06 57051 - Fax: (+39) 06 5705 4593 - E-mail: codex@fao.org - www.codexalimentarius.net

Agenda Item 9(a) **CX/CF 11/5/9**
January 2011

JOINT FAO/WHO FOOD STANDARDS PROGRAMME
CODEX COMMITTEE ON CONTAMINANTS IN FOODS
5th Session
The Hague, The Netherlands, 21 – 25 March 2011

DISCUSSION PAPER ON MYCOTOXINS IN SORGHUM

Prepared by Sudan with assistance from Belgium, Brazil, Japan and the United States of Amercia

BACKGROUND

1. The 36th Session of the Codex Committee on Food Additives and Contaminants (CCFAC) agreed in 2005 to request information on mycotoxins in sorghum, covering the mycotoxins involved, analytical methods and sampling procedures, consumer protection and potential problems in international trade. At its 37th Session, the Committee noted that only Japan had submitted information in response to the request and agreed to discontinue this work.

2. At the 2nd Session of the Codex Committee on Contaminants in Foods (CCCF), the Delegation of Sudan stated that sorghum is a main crop in African countries and requested to consider the issue of mycotoxins in sorghum at the plenary session. The Committee agreed to establish an electronic working group led by Tunisia to prepare a discussion paper with an overview of the available data on mycotoxins in sorghum with a view of possible evaluation by JECFA.

3. The Discussion Paper presented at the 3rd Session of CCCF included information on sorghum world production, use of sorghum as food and feed around the world, and conservation of sorghum to avoid deterioration. Contamination data were presented as three separate study cases, from Tunisia, Sudan and Brazil (da Silva *et al*., 2004). The JECFA Secretariat expressed the view that the Priorities Working Group should in addition to considering fumonisins in the context of maize also consider sorghum.

4. The Committee considered whether there was a need to develop a specific annex on prevention and reduction of contamination by aflatoxin in sorghum to the *Code of Practice for the Prevention and Reduction of Mycotoxin Contamination in Cereals*, but concluded that the Delegation of Tunisia would continue to collect all available data and to provide a more complete overview for discussion at the next session.

5. The Discussion Paper was not available for discussion at the 4th Session of CCCF, and the Delegation of Sudan, supported by a number of other delegations, proposed to keep this agenda item and volunteered to take the lead on collecting all available data and preparing an overview document for discussion by the Committee at the next session.

6. The Committee agreed that this new discussion paper should focus on two main areas: the mycotoxin-producing fungi that have been reported to be found in sorghum and the type of mycotoxins and their levels found in this grain.

7. This discussion paper was prepared by Sudan, with assistance from Belgium, Brazil, Japan, the USA and based on the publications listed in the reference list of this document.

INTRODUCTION

8. Any of the various plants of the genus Sorghum, family Poaceae, subfamily Panicoideae is generally referred to as sorghum. *Sorghum bicolor* (L.) Moench is the species cultivated as grain for human consumption and animal feed. Sorghum is the fifth most important cereal crop in the world, after rice, wheat, maize and barley. It constitutes the main grain food for over 750 million people who live in the semi arid tropics of Africa, Asia and Latin America.

9. Typically, sorghum is an annual crop, but some varieties are perennial. Sorghum is produced within latitudes 45° north and south in regions that are too hot or too dry for corn production. It requires a minimum average temperature of 25°C to give the maximum grain yield.

10. Moisture is the agro-climatic limiting factor for sorghum production in most areas. The morphological characteristics of the crop make it one of the most drought tolerant cereal crop currently under cultivation. It has large root to surface area ratio and during drought it rolls its leaves to reduce water loss by transpiration. If the drought continues, it goes into dormancy rather than dying. The leaves are protected by a waxy cuticle to cut the evapo-transpiration.

11. The International Water Management Institute (IWMI) warns that by the year 2025, 25% of the world population will experience severe water scarcity. Water productivity in both irrigated and rain-fed areas can be increased through the use of more water-use efficient crops, like sorghum.

12. The USA is the world largest producer of sorghum, followed by Nigeria and India (Table 1). In 2008 Argentina had the highest productivity, followed by China and USA. At regional level, Sub-Saharan Africa is the largest producer with up to more than 26 million tons produced annually, and also it is the largest consumer (Table 2)

13. The largest group of the producers in Africa is the small-scale subsistence farmers with minimal access to production inputs such as fertilizers pesticides, improved seeds (hybrids or varieties), good soil, water and improved credit facilities in addition to many socio-economic obstacles. In view of the low input systems, productivity levels are very low throughout the African countries and India, ranging from 1.5 to less than 0.6 ton per ha in Ethiopia and Sudan respectively (Table 1). In general the most significant change in sorghum productivity has been the development of hybrid sorghum. Systems yield, in average, 3 to 5 tons per ha rely on hybrid seeds.

Table 1: World leading countries in sorghum production - 2008*

Country	Production (million tons)	Area (ha)	% world production	Productivity (ton/ha)
USA	11.997	2942170	17.51	4.077
Nigeria	9.318	7617000	13.60	1.223
India	7.926	7764000	11.57	1.021
Mexico	6.641	1833130	9.69	3.622
Sudan	3.869	6619330	5.64	0.584
Australia	3.072	845000	4.48	3.635
Argentina	2.936	618625	4.24	4.746
China	2.502	580649	3.65	4.303
Ethiopia	2.316	1533537	3.38	1.510
Brazil	1.965	811662	2.86	2.421
Burkina Faso	1.875	1901776	2.74	0.986
Others	14.073	12465013	20.54	1.129

*Source: FAO Statistic Division -21 June 2010.

Table 2: Regional sorghum production, consumption and import (million tones) 2008/2009*

Region	Production	Domestic consumption	Imports
Sub-Saharan Africa	26497	26885	597
North America	19066	16919	2499
Southern Asia	7455	7349	14
South America	4625	4491	665
Oceania	2690	1805	0
East Asia	1857	3699	1719
North Africa	915	965	45
Middle East	612	724	81
EU	516	905	66
Central America	298	316	-
Caribbean	128	128	0
Southern –East Asia	60	68	-
World total	**64718**		

Source*: USA Department of Agriculture – foreign Agric. Service Grain World Market and Trade(12/8/2010)

14. The total world sorghum production in 2008/2009 was over 64 million tones. Sorghum production that enters the world trade was about 9.4% of the total global production. The USA accounted for about 59% of the world exports, followed by Australia (22%) and Argentina (15%). Mexico and Japan accounted for about 41% and 27%, respectively, of the total global imports.

15. Requirements for export and quality assurance for sorghum have been established by Codex Alimentarius (Codex standard 172-1989). The standard applied to sorghum for direct human consumption states that the grain shall not have abnormal odour or taste; must be sound, clean and free from living insects; may be white, pink, red, brown, orange, yellow or a mixture. The moisture content must not exceed 14.5 %, ash not more than 1.5%, and protein not less than 7 % on dry matter basis. The product should be in accordance with the Recommended International Code of Practice - General Principle of Food Hygiene CAP/RCP1-1969.

16. Sorghum has the potential to improve nutrition, boost food security, foster rural development and support land care. It has a protein level typically around 9 %, enabling human populations to subsist on it at times of famine. Some sorghum varieties are rich in antioxidants, and all sorghum varieties are free of gluten, an attractive alternative for wheat allergy sufferers or Celiac disease.

REPORTED MYCOTOXINS IN GRAIN SORGHUM

17. Worldwide occurrence of mycotoxins in grain sorghum was reported in twelve countries. They include: Australia, Brazil, Colombia, Ethiopia, India, Japan, Nigeria, South Africa, Sudan, Tunisia, Uganda and the USA. (Table 3). At least nine mycotoxin types were confirmed on the crop. Contamination in terms of intensity (% contaminated samples) and level (µ/kg) of each mycotoxin type, in each country are shown in Table3.

18. Aflatoxins were reported in nine countries: Australia (Ryle, 2010), Brazil (da Silva, 2004), Ethiopia (Amare Ayalew, 2006), India (Tripathi, 1973; Bhat, 2000); Nigeria (Hussaini, 2009); Sudan (CX/CF09/12.2009); Tunisia (Ghali, 2007, 2009); Uganda (Alpert,1971) and the USA (Stoloff, 1976; Shotwell, 1969). The highest intensity, 100%, was reported in India and highest level of 3282µg/kg was reported in Brazil.

19. Fumonisins were reported in four countries: Brazil (da Silva, 2004); Ethiopia (Amare Ayalew, 2006); India (Bhat, 2000) and the USA (Trucksess, 2000). Intensity, 100%, and level of 7800µg/kg were both reported in India.

20. Ochratoxins were reported in four countries: Ethiopia (Amare Ayalew, 2006); Nigeria (Hussaini, 2009); Sudan (Anon, 2010) and Tunisia (Ghali, 2007). The highest intensity (24%) and the highest level of 2106 µg/kg, were both reported in Ethiopia.

21. Zearalenone was reported in three countries: Colombia (Diaz, 1997), Ethiopia (Amare Ayalew, 2006) and Japan (Aoyama, 2009); the highest intensity (55.6%), reported in Colombia and highest level of 7260 µg/kg reported in Japan.

22. Alternariol was reported in South Africa (Sydeham, 1988) and the USA (Hagler, 1987). The highest level of 2250 µg/kg was reported in South Africa.

23. Deoxynivalenol was reported in Ethiopia only (Amare Ayalew, 2006), at 48.8% intensity and a highest level of 2340µg/kg

24. Ergosine was reported in Australia (Ryle, 2010). No intensity or level was given.

25. Altenuene was reported in India (Ansari, 1990). The highest level was 700µg/kg.

26. Nivalenol was reported in Ethiopia (Amare Ayalew, 2006), in low frequency and a high level of 380µg/kg.

27. Sorghum being a tropical and subtropical crop is usually grown in areas where the temperature and moisture are favourable for the growth of aflatoxins-producing fungi more than others.

Table 3: Worldwide reported mycotoxins, producing fungi, intensity and level of contamination on grain sorghum- September – 2010

Country	Reported mycotoxins	Producing fungi	Contamination		References
			Intensity (%)	Level µg/kg	
Argentina*	n.d**	Fusarium, Aspergillus and Penicillium spp. were isolated with no mention of the relevant mycotoxins	n.d.	n. d.	Gonzalez *el al*.,1997
Australia	Ergosine	*Claviceps*	n.d	n. d	Ryle, 2010

		africana			
	Aflatoxins	n.d.	n.d.	n.d.	Ryle, 2010
Brazil	Aflatoxins B1and B2	*A. flavus*	64.4	12 -3282.5	da Silva *et a*l., 2004.
	Fumonisin B1	*F. verticilliodes*	91.5	1.2-5.38	da Silva *et a*l., 2004.
		F.proliferatum	n.d.	low	da Silva *et a*l., 2004
Colombia	Zearalenone	n.d.	55.6	36-3659	Diaz and Cespedes 1997
Ethiopia	Aflatoxin B1	n.d.	8.8	trace-26	Amare Ayalew *et al.*, 2006
	Ochratoxin A	n.d.	22	54.1-2106	Amare Ayalew *et al.*, 2006
	Deoxynivalenol	n.d.	48.8	40-2340	Amare Ayalew *et al.*, 2006
	Nivalenol	n.d.	Low	50-380	Amare Ayalew *et al.*, 2006
	Fumonisins	n.d.	Low	2117	Amare Ayalew *et al.*, 2006
	Zearalenone	n.d.	Low	32	Amare Ayalew *et al.*, 2006
India	Fumonisin B1	*F.moniliforme*	4.5,normal.	150-510 normal.	Bhat *et al*.,2000.
		F.proliferatum	100, rain affected.	70-7800 rain affected.	
	Aflatoxin B1	*A. flavus*	2.5 normal.	trace-30 normal.	Bhat *et al*., 2000.
			100 rain affected.	2-830 rain affected.	
	Aflatoxins B1,B2,G1,G2	n.d.	n.d.	600-800	Tripathi, 1973.
	Alternariol monomethyl ether(AME)	n.d.	n.d.	600-1800	Ansari and Shrivastava, 1990
	Altenuene (ALT)	n.d.	n.d.	20-700	Ansari and Shrivastava, 1990

* : No specific mycotoxin mentioned

**: No data

Table 3: continued

Country	**Reported mycotoxins**	**Producing fungi**	**Contamination**		**References**
			Intensity (%)	**Level µg/kg..**	
Japan	Zearalenone	*F. semitectum*	52.5	60-7260	Aoyama, .*et al*.,2009
Mexico *	General information on mycotoxins in cereal crops with no specific	n.d.	n.d.	n.d.	Garcia, and Heredia,.2006

	reference to sorghum				
Nigeria	Aflatoxin B1	*A ..flavus*	54	0-1164.	Hussaini *et al*., 2009
	OchratoxinA	n.d.	20.5	0-712.	
	Zearalenone	n.d.	35.5	0-1454	
South Africa	Zearalenone	n.d.	n.d.	0.8- 1.25	Sydenham *et al.*,1988
	Alternariol monomeethyl Ether	n.d.	n.d.	1250-2250	Sydenham *et al.*,1988
Sudan	Aflatoxin B1	n.d.	17.8	1-7	CX/CF09/12. 2009
	Aflatoxin B2	n.d.	3.5	1.5	CX/CF09/12. 2009
	Ochratoxin	*A. ochraceus*	n.d	trace-6.9	Anonymous,2010
Tunisia	Ochratoxins	n.d.	n.d.	n.d.	Ghali *et al*., 2007
	Aflatxin B1	n.d.	n.d.	34-0.53	Ghali *et al*., 2009
	AflatoxinB2	n.d.	n.d.	0.11-3.7	Ghali *et al*., 2009
	AflatoxinG1	.n.d.	n.d.	0.45-0.70	Ghali *et al*.,2007
Uganda	Aflatoxins	n.d.	n.d.	n.d.	Alpert *et al*.,1971
USA	Aflatoxins	n.d.	1.3	<19	Shotwell *et al*., 1969b .
	Aflatoxins	n.d.	3	13-50	Stoloff, 1976
	Aflatoxins	n.d.	56	1-99	Shotwell *et al*.,1969a
	Alternariol monoethyl ether	n.d.	n.d	443	Hagler *et al*.,1987
	Fumonisins B1	n.d.	2.8	120	Trucksess *et al*., 2000

REPORTED MYCOTOXINS IN SORGHUM PRODUCTS

28. In many parts of the world, sorghum is used in food items such as porridge, unleavened bread, cookies, cakes, malted beverages and soft drinks. Traditional food preparation of sorghum is quite varied, with boiling being the simplest. Small grains are normally desired for this type of food product. The whole grain may be ground into flour or decorticated before grinding to produce either fine particles product or flour which is then used in various traditional foods. Away from the non-traditional use of sorghum, attempts to develop composite flour in some countries and the use of the Japanese food processors for sorghum flour in recipe development, leading to commercialization of snack food products are examples in point. It is anticipated that more white sorghum based product will debut in North America (USA Grain Council, 2009). Some of the more recent examples of the contamination of sorghum products with mycotoxins are given in the following paragraphs.

29. In the USA, Trucksess *et al*. (2000), analyzed fumonisin B1 in 35 samples of sorghum syrup collected from 15 states. One sample was found to contain FB1 at 0.12 µg/g (LOQ of 0.1µg/g).

30. In Botswana, Nkwe *et al*. (2005), isolated from 46 samples of traditional sorghum malt, wort, and beer, *F. verticillioides* and *A. flavus* in 72 and 37% of the samples respectively. No aflatoxins were detected. FumonisinB1 was detected in malt at intensity of 6.5% and level of 47-1316µg/kg. Zearalenone was detected in: malt, at 56% intensity and level of 102-2213µg/kg, wort at 48% intensity and level of 26-285µg/L and in beer at 48% intensity and level of 20 -201µg/L.

31. In Brazil, Campos *et al*. (2008) isolated, from sorghum meal, *Aspergillus* spp.(75.3%) *Alternaria* spp. (22.3%) and *Fusarium*. spp. (2.4%). Seventy seven per cent of the stains in *A. flavus* were aflatoxin producers. All samples examined were contaminated with aflatoxins, at levels of 0.1 to 23.8µg/kg.

32. In India, Bhat *et al*. (2000) working with Fumonisin B1 spiked sorghum samples found an insignificant reduction of 6.4% in the fumonisin level in flat bread baking and a reduction of 11.9% in porridge cooking.

33. Mendez-Albores *et al*. (2008) evaluated the effect of the extrusion-cooking process with the addition of different acids concentration on the stability of B-aflatoxins in sorghum (at 140µg/kg). Citric acid reduced aflatoxin by 92% as compared with 67% reduction by lactic acid.

ASSOCIATED HEALTH HAZARDS

34. The mycotoxins reported to occur in sorghum, are associated with hazards to humans and animals with different degrees of epidemiological evidence.AflatoxinB1 is hepatotoxic, mutagenic, carcinogenic and probably teratogenic in animals. Fumonisins causes syndrome of ataxia leading to death of horses and donkeys and are associated with oesophageal cancer in humans. Ochratoxins are thought to cause a chronic kidney disease and are possibly linked with human testicular cancer. Deoxynivalenol reduces feed uptake, causes vomiting, and immuno-suppresion. Zearalenone has estrogenic effects on mammals. Ergosine causes vomiting, endocrine imbalance, and convulsions and impairs mental functions.

REGULATIONS

35. Many countries have established regulatory systems for aflatoxins, ochratoxins, and a few for deoxynivalenol and zearalenone, in general, or for some specific crops such as maize and wheat. A variety of methods are available for their analyses. Widely used methods include the High Performance Liquid Chromatography method with Fluorescence Detection or Liquid Chromatography combined with Mass Spectrometry.

CONCLUSIONS

36. The major grain sorghum producing countries may be divided into four categories, in terms of production, productivity, trade and utilization:

- Countries with high production, high productivity, high export and which utilize sorghum as feed and in other industrial activities. This category includes USA, Australia and, to less extent, Argentina.
- Countries with high production, high productivity, no exports, and which utilize sorghum as feed. Only Mexico represents this category.
- Countries with high production, low productivity, little or no export, and which utilize sorghum as food and feed. This category includes Nigeria, India and, to less extent, Ethiopia.
- Countries with medium to low production, very low productivity, very little export, and often they import sorghum. They utilize sorghum as food and feed. This category includes Sudan and Burkina Faso.

37. Records and information on the occurrence of mycotoxins in grain sorghum in many countries are incomplete. In some cases, only the genus, such as *Fusarium, Penicillium* etc. of the producing fungus is mentioned with no mention even of the toxin produced. In others, a mycotoxin is mentioned with no mention of the producing fungus. In many cases the toxins were reported with no mention of the group of the mycotoxin, such as aflatoxinB1, G1. Generally the intensity and level of contamination are well expressed.

38. The main toxigenic fungi reported on grain sorghum were: *Aspergillus flavus, A. parasiticus, A. ochraceus, Alternaria alternata, Clavicep africana, Fusarium verticilliodes, F. proliferatum, F.graminearum and F. semitectum.*

39. Aflatoxins were the most researched mycotoxins in grain sorghum. They were reported in Australia, Brazil, Ethiopia, India, Nigeria, Sudan Tunisia, Uganda and the USA at levels up to 3282µg/kg. Fumonisins, ochratoxins A and zearalenone were also frequently reported in various countries. One study in Ethiopia reported the tricotecenes deoxynivalenol and nivalenol. Another, in Australia, reported ergosine

40. Toxinogenic fungi and mycotoxins have also been reported in processed sorghum, such as sorghum meal and beer.

RECOMMENDATIONS

- Development of a **code of practice** for the management of the relevant mycotoxins in grain sorghum at the pre- and post-harvest levels.
- Evaluation of the data on mycotoxins in grain sorghum, compiled in this document, by JECFA.
- Establishment of **a network** to define the eminent research areas, coordinate and execute the proposed research programmes on mycotoxins in sorghum.
- More research regarding the **occurrence** of mycotoxins on sorghum in the various parts of the world particularly where sorghum is the main cereal crop, and in the major producing and importing countries where the crop is largely used as animal feed.
- Further studies on the specific **critical stage** at which the contamination with the different mycotoxins -producing fungi in grain sorghum takes place.
- Further studies on the **physical factors** that affect fungal growth and mycotoxins formation in grain sorghum under pre –and post- harvest conditions.
- Development of **rapid and standard methods** for the identification of the toxic strains within the toxin –producing fungi and for measurements of mycotoxins levels in grain sorghum.
- Initiate studies on the effects of **the traditional processing** of grain sorghum on the initial contamination.

REFERENCES

Alpert, G. E., Hutt, G. S. R., Wogan, G. N.and Davidson, C. S. 1971. Association between aflatoxin content of food and hepatoma frequency in Uganda. Cancer. 28: 253-260.

Amare Ayalew, Hartmut Fehrmann, Johnn Lepschy, Robert Beck and Dawit Abate. 2006. Natural occurrence of mycotoxins in staple cereals from Ethiopia. Mycopathologia. 162: 57 – 63.

Anonymous, 2010. Annual Report, Sudanese Centre for Mycology. Sudanese Standard & Metrology Organization. Khatoum, Sudan.

Ansari,A.A. and Shrivastava,A.K.1990.Natural occurrence of Alternaria mycotoxins in sorghum and ragi from North Bihar,India. Food Additives andCotaminants.7:815-820.

Aoyama,K. Ishikuro,E., Nishiwaki,M.,Ichinoe,M. 2009.Zearalenone contamination and the causative fungi in sorghum. J. Food Hyg. Soc.50(2):47-51

Bandyopadhyay,R. Frederickson,D.E.,McLaren,N.W., Odvody,G. N.,Ryley,M.J.1998. Ergot: a new disease threat to sorghum in the Americas and Australia.Plant Disease. 82(4)356-367.

Bandyopadhyay, R., Kumar, M., Leslie, J. 2007. Relative severity of aflatoxin contamination of cereal crops in West Africa. *Food Additives and Contaminants* 24 (10):1109-1114.

Bhat, R.V.,Shetty,H.P.K.,andVasanthi,S. 2000 Human and animal health significance of mycotoxins in sorghum with special reference to fumonisins.Pages 107-115, in technical and institutional options for sorghum grain mold management. Proceedings of an international cosultation. 18-19 May 2000,ICRISAT Patancheru,India.

Broggi, L.E., Gonzalez, H.H.L., Resnik, S.L.R., Pacin, A. 2007. Alternaria alternate prevalence in cereal grains and soybean seeds from Entre Rios, Argentina. *Rev. Iberoam. Micol*. 24:47-51.

Campos, S.G., Cavaglieri, L.R., Fernandez Juri, A.M., Dalcero, C., Kruger, L.A.M. Keller, Magnoli, C.E., Rosa, C.A R. 2008. Mycobiota and aflatoxins in raw materials and pet food in Brazil. *J. Animal Physiology and Animal Nutrition* 92:377-383.

Davis,N.D.and Diener,U.L. 1970.Environmental factors affecting the production of aflatoxin. In:Herzberg,M., ed.Proceeding of the First US-Japan Conference on Toxic Micoorganisms.Washington,D.C US Govt. Printing Office, pp.43-47.

da Silva,J.B.,Dilkin,P.,Fonseca,H.andCorrea,B. 2004. Production of aflatoxins by *Aspergillus flavus* and of fumonisins by *Fusarium* species isolated from Brazilian sorghum.Braz.J.Micobiol.35(3):182-186.

Diaz,Gonzalo J.and Cespedes,Angel E,1997.Natural occurrence of zeralenone in feeds and feedstuffs used in poultry and pig nutrition in Colombia.Mycotoxin Resarch.13:81-87.

Garcia, S. and Heredia, N. 2006. Mycotoxins in Mexico: Epidemiology,management,and control strategies. Mycopathologia, 162: 255 – 264.

Ghali,R., Hmaissia-Khalifa,K., Ghobbel, G., Maaroufi K., and Hidili, A. 2007.Incidence of aflatoxins ochratoxin A and zearalenone in Tunisian food .J.Food Con. 19: 921-924.

Ghali,R.,Belouaer I.,Hdiri S.,Ghorbel,H.,Maaroufi K.,Hedilli A. 2009. Simultaneous HPLC determination of aflatoxin B1,B2 G1and G2 in Tunisian sorghum and pistachois. Journal of Food Composition and Analysis:751-755

Gonzalez,H.H.L. Martinez,E.J.and Resnik,S.L. 1997. Fungi associated with sorghum grain from Argentina. Mycopathologia.139:35-41.

Hagler, W.M. Jr., Bowman, D.T., Babadoost, M.; Haney, C.A., Swanson, S.P. 1987. Aflatoxin,zearalenone and deoxynivalenol in North Carolina grain sorghum. Crop Science.27:1273-1278.

Hesseltine,C.W.1976. Conditions leading to mycotoxin contamination of food and feed.In: Rodrick,J.V., ed.Mycotoxins and other related food problems, Washington ,D.C.,American Chemical Society. pp.1-22 (advances in Chemistry Series 149).

Hussaini,A.M.,Timothy,A.G.,Olufunmilayo,H.A.,Ezekiel,A.S.and Godwin,H.O. 2009.Fungi and some mycotoxins found in mouldy sorghum in Niger State, Nigeria. World Journal of Agricultural Sciences 5(1) 5-17.

Krausz, J. and Isakei , T. 1998. Sorghum ergot new disease threat to sorghum industry. Texas Agricultural Extension Service. The Texas A&M University System L 5179 6-98.

Méndez-Albores, A., Martinez-Bustos, F., Gaytan-Martinez, M., Moreno- Martinez, E. 2008. Effect of latic and citric acid on the stability of B-aflatoxins in extrusion-cooked sorghum. *Letters in Applied Microbiology* 47:1- 7.

Nelson,P.E. Desjardins,A.E.,and Platner,R,D. 1993. Fumonisins, mycotoxins produced by Fusarium species: biology, chemistry, and significance. Annu.Rev.Phytopathol.1993.31:233-52.

Nkwe, D.O., Taylor, J.E., Siame, B.A. 2005. Fungi, aflatoxinas, fumonisin B1 and zearalenone contaminating sorghum-based traditional malt, wort and beer in Botswana. *Mycopathologia* 160:177-186

Odhav B, Naicker V. Mycotoxins in South African traditionally brewed beers. *Food Addit Contam*. 2002 Jan; 19(1):55-61

Reis, T.A., Zorzete, P. Pozzi, C.R., da Silva, V.N., Ortega, E., Correa, B. 2010. Mycoflora and fumonisin contamination in Brazilian sorghum from sowing to harvest. *J. Sci Food Agric.* 90:1445-1451.

Ratnavathi, C.V., Sashidhar, R.B. 2003. Substrate suitability of different genotypes of sorghum in relation to *Aspergillus* infection and aflatoxin production. *J. Agric. Food Chem.* 51: 3482-3492.

Ryle,M. 2010 Ergot affected and mouldy sorghum.Department of employment, economic development and innovation,Australia. Primary industries and fisheries 28.

Shetty,P.H. and Bhat,R.V.1997. Natural occurrence of fumonisinsB1 and its co-occurrence with aflatoxin B1 in Indian sorghum, maize and poultry feed. Journal of Agricultural Food Chemistry.45;2170-2173.

Shotwell, O. L., Hesseltine, C. W., Burmeister, H. R., Kwolex, W. F., Shannon, G. M. and Hall, H. H. 1969a. Survey of cereal grains and soybeans for the presence of aflatoxin: II. Corn and soybeans. Cereal Chem., 46. 454-463.

Shotwell, O. L., Hesseltine, C. W., Burmeister, H. R., Kwolex, W. F., Shannon, G. M. and Hall, H. H. 1969b. Survey of cereal grains and soybeans for the presence of aflatoxin: I. Wheat, grain sorghum, and oats. Cereal

Chem. 46: 446-454.

Stoloff, L. 1976. Occurrence of mycotoxins in foods and feeds. In: Rodricks, J. V., ed. Mycotoxins and other fungal related food problems, Washington, DC, American Chemical Society.pp. 23-50 (Advances in Chemistry Series 149).

Sydenham,E.W.,Thiel,P.G.,Marasas,F.O. 1988.Occurrence and chemical determination of zearalenone and alternariol monomethylether in sorghum-based mixed feeds associated with an outbreak of suspected hyperestrogenism in swine. Journal of Agricultural Food Chemistry.36 :621-625.

Tripathy,R. K.,1973. Aflatoxins in sorghum grains infested with head moulds. Indian Exp.Biol., 11:361-362.

Trucksess,M.W.,Cho,T.and Ready,D.2000. Liquid chromatographic method for fumonisinsB1 in sorghum syrup and corn-based breakfast cereals Food additives and contaminants.17:161-166.