IJIRR

International Journal of Information Research and Review
Vol. 04, Issue, 03, pp.3828-3833, March, 2017

Research Article

ASSESSMENT OF MAIZE (*ZEA MAYS* L.) AND GROUNDNUTS (*ARACHIS HYPOGAEA* L.) SPOILAGE LOSS DUE TO MYCOTOXINS AND ITS EFFECT ON HOUSEHOLD FOOD SECURITY IN KILOSA DISTRICT, TANZANIA

***Kija Steven Magembe**

Lecturer, Institute of Adult Education, P. O. Box 20679 Dar es Salaam, Tanzania

ARTICLE INFO

Article History:

Received 17th December, 2016
Received in revised form
21st January, 2017
Accepted 13th Febuary, 2017
Published online 30th March, 2017

Keywords:

Maize,
Groundnuts,
Spoilage loss,
Mycotoxins,
Food Security,
Tanzania.

ABSTRACT

The study was conducted in Kilosa District to assess spoilage loss of stored Maize (*Zea mays* L.) and Groundnuts (*Arachis hypogaea* L.) due to mycotoxins and its effect on household food security**.** The sample of approximately 10 kg of maize and 5 kg of groundnuts were stored in a small polythene bag for 9 months. The data collected were maize grains and groundnuts kernel which were later sorted into rotten and discolored and further counted as spoiled grains expressed in percentages**.** The losses were estimated by the count and weighing method. The damaged kernels were determined and calculated as percentages using the Statistical Analysis System (SAS® Version 9.4). The average weight loss of maize and groundnuts were 20.8% and 14.5% respectively as a result of mycotoxin contamination. The estimated annual revenue loss in U$D was about 179, 116.37 (=268, 674, 555 Tshs) in maize. Further analysis indicated that 22% of farmers lost up to 10 kg of groundnuts and 31.9% of farmers lost up to more than 10 kg of groundnuts as a result of aflatoxin contamination. Maize and groundnuts spoilage in the study area was caused by poor handling and storage conditions such as insufficient drying. Some of the suggested solutions to mycotoxin threat in Kilosa District include: early harvesting, prevention of kernel damage during harvesting, adequate drying and proper storage below 13 % moisture for maize and below 7% moisture for groundnuts, and keeping storage facilities clean and dry.

INTRODUCTION

In addressing issues of food security, agricultural production has gained considerable attention from researchers and policy makers (Godfray *et al*., 2010, Tilman *et al*., 2011), but food spoilage, storage, and transport have received much less attention. Ensuring global food security represents one of the greatest challenges facing humanity in the 21st century. The pressures on food production are immediate, but by 2050 the world will need to increase agricultural production by at least 30 % in order to feed its anticipated population of 9 billion (FAO, 2012). A multitude of fungal pathogens cause diverse diseases like rusts, smuts, blasts, blotches and mildews of staple crops, which ultimately destroy enough food annually to feed 600 million people, approximately 8.5 % of the total population (Fisher *et al*., 2012). Human beings require a reliable food supply to meet metabolic requirements for maintenance, growth, and reproduction. All food spoils and some deterioration occur through the spontaneous breakdown of complex organic molecules. However, most spoilage of food meant for human consumption is caused by microorganisms, which effectively compete with humans for limited and valuable food resources. Given access to unprotected foodstuffs, bacteria and fungi rapidly colonize, increase in population, and produce toxic and distasteful chemicals such as mycotoxins (Blackburn 2006, Pitt and Hocking, 2009). Food contaminated by mycotoxins may affect the taste and food safety, and consequently reduce the price consumers are willing to pay. Mouldy grain may still be saleable, but only at a reduced price. The damaged grain or other food maybe be less appealing to consumers and therefore attract a lower price in the market. Farmers and traders may not be able to access certain high value markets if their products are damaged or contaminated, and thus they realize lower sales prices. Worldwide, approximately 25% of the world's food crops are significantly contaminated with mycotoxins (CAST, 1989; WHO, 1999). Mycotoxins contaminations in stored produce cause both quantitative and qualitative loss. Quantitative loss indicates the reduction in physical weight, and can be readily quantified and valued, example a portion of grain damage by pests or lost during transportation. A qualitative loss is contamination of grain by moulds includes loss in nutritional quality, edibility, consumer acceptability of the products and

****Corresponding author: Kija Steven Magembe,***
Lecturer, Institute of Adult Education, P. O. Box 20679 Dar es Salaam, Tanzania.

the caloric value (Zorya *et al*., 2011; Kader, 2005). Economic loss is the reduction in monetary value of the product due to a reduction in quality and or/ quantity of food (Tefera, 2012). Food quality and safety issues resulting from mycotoxin contamination are significant obstacles for improving nutrition and agricultural production while linking smallholder farmers to markets. The ingestion of such mycotoxin contaminated grains by animals and human beings has enormous public health significance, because these toxins are capable of causing diseases in man and animals (Bhat and Vasanthi 2003, TFDA, 2012). In addition, to health concerns, mycotoxins can restrict maize trade and limits income of smallholder farmers, because of food safety concern and trade restrictions (WHO, 2006). Numerous moulds may be involved in groundnut and maize spoilage, such as species of Aspergillus, Penicillium, Fusarium and of. However, other types of mycotoxins such as Zearalenone, Deoxynivalenol, Ochratoxins, and T-2 toxins, HT-2 toxins have also been reported (Mboya *et al*., 2011; Kimanya *et al*., 2014; Kamala *et al*., 2015). Mycotoxins contamination causes a reduction in grain quality, through the utilization of stock carbohydrates and proteins and producing also oxidative mellowness of the grains (Lacey and Magan, 1991). These phenomena interact with other adverse factors such as immaturity, mechanic injury, unfavorable environmental conditions, incorrect drying, storage and processing factors, all of which contribute to the deterioration of the product quality and flavor, which means a reduction of product quality and economic loss (Ahmed and Pattee, 1987).

Mycotoxins have a significant impact on economic and trade. Losses due to contamination, yield losses due to diseases, losses in animal productivity, human health costs, and cost due management and prevention (Schmale and Munkvold, 2015) plus regulatory and research costs related to mycotoxins (Hussein and Brasel, 2001). Researchers categorized economic losses into two main groups: direct and indirect economic losses. Direct economic losses are those related to reducing crop yields for growers and animal performance (morbidity and mortality) and rejection of crops by the international market (PACA, 2013). While indirect economic losses are those costs related to reduce the marketable value of the product, and costs associated with monitoring, research, loss of consumer confidence and increased processing costs (PACA, 2013). Further, the economic losses of mycotoxins have both domestic and international trade effects. In domestic, economic losses occur at all stages of the product value chain from the producers (farmers) to the final consumer (WHO, 2006). On the other hand, in the international market, products that exceed the maximum tolerance level of mycotoxins are either quarantines and confiscated at the port-of-entry, assigned a lower price or diverted to animal feeds (PACA, 2013). Therefore, the present study was carried out with the objective of assessing the spoilage losses inflicted to the stored maize and groundnuts due to mycotoxins and suggesting the possible control options of minimizing spoilage loss in the study area.

MATERIALS AND METHODS

Experimental trials were carried out in the four surveyed villages. The sample of approximately 10 kg of shelled maize grain and 5kg of groundnuts kernel were stored in a small polythene bag for 9 months from August 2010 to April 2011. The damage and losses of maize and groundnuts were evaluated using the count and weighing method. The count and weigh method developed by Adams and Schulten (1978) was used in the experiment to determine the spoiled loss due to mycotoxin contaminations. The data collected were rotten and discolored maize and groundnuts grains which were further counted as spoiled grains expressed in percentages. The damaged kernel characteristics which were determined during this study include: mouldy kernel, and off colour kernels. Here it must also be put in minds that; the visual absence of mould, however, does not mean that kernels do not contain the toxin. Intact corn kernels may contain the fungus and the toxin but show no sign of the fungal contamination. In severe cases, the corn shucks will become "glued" to the kernels in the cob. To control the initial moisture content (MC), freshly harvested maize was dried until below 14 MC as a range commonly recommended for safe storage and for groundnuts was dried until below 7 MC. Keeping grain moisture content below the level required by fungi (mold) to grow will minimize spoilage and poor quality grain is more likely to spoil, especially during the warmer months.

Procedure used in estimating % weight loss of grains

The grains were separated into undamaged and damaged categories, the latter being separated according to cause. The resultant data were substituted in the formula shown in Equation 1.

$$\%\,Weight\ loss = \frac{(Wu * Nd) - (Wd * Nu)}{Wu * (Nd + Nu)} * 100 \quad (1)$$

Where,

W_u = weight of undamaged grains
N_u = number of undamaged grains
W_d = weight of damaged grains
N_d = number of damaged grains

The estimate annual revenue loss in U$D for groundnuts was calculated using mathematical formula shown in Equation 2.

$$ARL = AVRP * AVC * \left(\frac{USD}{1500}\right) * 1000 \quad (2)$$

Where,

ARL = Annual revenue loss (in USD)
AVRP = Average annual production (in Tons)
AVC = Average contamination (%)

The export loss of maize/groundnuts at international market is given by mathematical expression shown in Equation 3 as developed by Wu (2004).

$$Export\ Loss_{ijk} = P_i \times W_{ij} \times r_{ijk} \quad (3)$$

Where;

$$r_{ijk} = 1 - \int PDF_{ijk}\ dk$$

i = Crop (maize or groundnuts),
j = Nation,
k = International mycotoxin standard (fumonisin, aflatoxin),

P_i = World price for food crop i per unit volume,

$W_{i,j}$ = Total export weight (in metric tons) of crop i from nation,

$r_{i,j,k}$ = Fraction of export volume of crop i from nation j, rejected at international mycotoxin standard k and

$^{j}PDF_{ijk}\,dk$ = Probability density function

Statistical Data Analysis

Data were analyzed using Statistical Analysis System (SAS® Version 9.4, SAS Institute Incorporation, USA).

RESULTS

Spoilage loss of maize due to fumonisin contamination across the four villages in Kilosa District, 2010/2011 season. The cumulative total loss due to mould damage in nine months of maize storage was about 20.8% of the total stored grains (Fig.1). Incremental losses were observed in December to March, the period which coincides with high rainfall in the study area. The results also showed that undamaged maize grain estimated to worth U$D 0.33 per kg (=495 Tshs/kg), and the maize grain with 10% damage estimated to worth only U$D 0.285 per kg (=427.50 Tshs/kg), and with 20% damage it worth only U$D 0.275 per kg (=412.50 Tshs/Kg (Fig.2).

The estimated annual revenue loss in U$D was about 179 116.37 (=268, 674, 555 Tshs). If this commodity has to be exported at a world market, a nation's total export loss of a particular food crop, given a particular internationally imposed mycotoxin standard, can be calculated using the Wu (2004) mathematical model described in equation 3. Specifically, in the international market, products that do not meet the aflatoxin standards are either rejected at the border, rejected in channels of distribution, assigned a reduced price, or diverted to non-human or even non-fee uses.

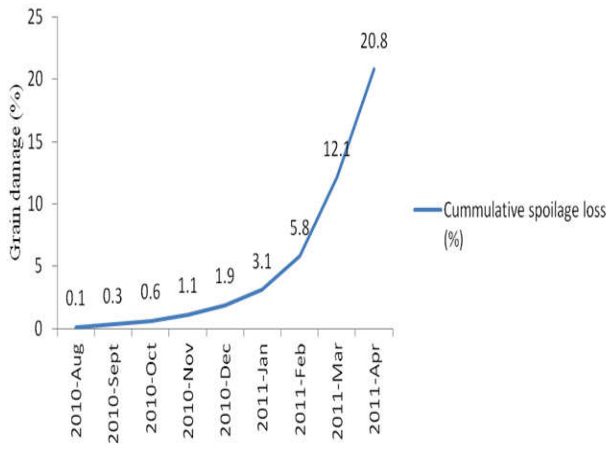

Fig. 1. Cumulative spoilage loss due to fumonisin (%) for the stored maize grain after 9 months of storage in Kilosa District, Tanzania

Contamination of food by microbes and chemicals also has economic consequences due to rejection of exports and loss of credibility as trading partners. Capacity to implement effective food safety controls is of vital importance to agricultural and food exports from developing countries.

For example, importing countries frequently require guarantees that minimum standards of hygiene have been applied in the manufacture of a food product and that food do not have excessive mycotoxins contamination. The exporting country must be able to comply with these requirements and demonstrate that compliance has been achieved. While basic scientific and technical infrastructure is clearly vital, administrative structures, management, financing and human capital are also important elements. Indeed, the experiences of many countries suggest that lack of efficient management or sustainable levels of resources can seriously compromise the effectiveness of food safety controls.

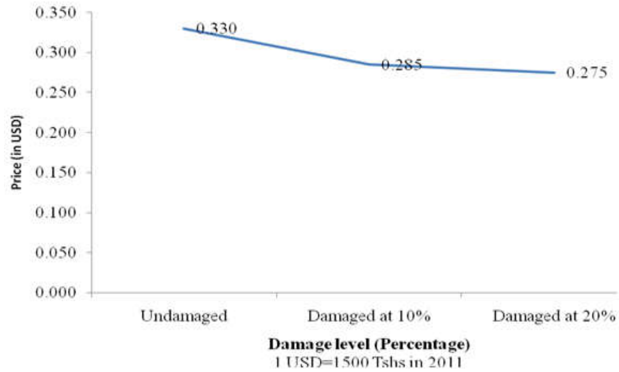

Fig. 2. Relationship between fungal spoilage in stored maize and relative price

Spoilage loss of groundnuts due to aflatoxin contamination in the four surveyed villages in Kilosa District, 2010/2011 season

The cumulative total loss due to mould damage in nine months of groundnuts storage was about 14.5% of the total stored groundnuts (Fig.3). Incremental losses were observed in December to March, the period which coincides with high rainfall in the study area. The results from this study also indicated that, in a survey of 72 farmers about 22.2% (16/72) of farmers lost more than 10 kg of groundnuts as a result of aflatoxin contamination. Farmers indicated that they were only rejecting rotten nuts, which were infested by fungus. The highest volume of rejected groundnuts was above 10 kg (31.9%) (Fig. 4).

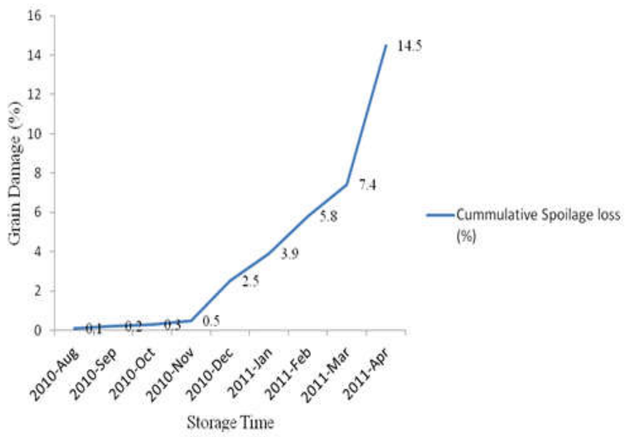

Fig.3. Cumulative spoilage loss due to aflatoxin (%) for the stored groundnuts after 9 months of storage in Kilosa District, Tanzania

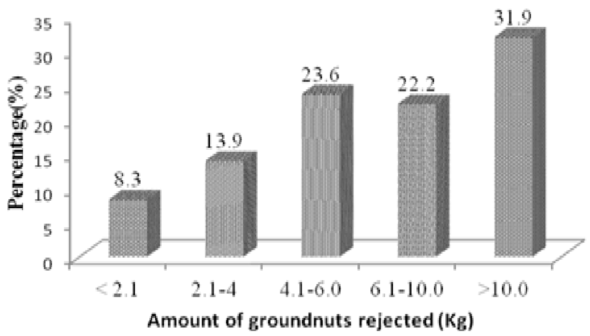

Fig.4. Amounts of rejects of groundnuts due to aflatoxins contaminations

DISCUSSION

Grain export like the maize has a significant driving force for overall economic growth, increase farmers' income and poverty reduction (Diao *et al*., 2013). However, maize in most parts of the country are contaminated with mycotoxins well above acceptable levels (TFDA, 2012) thus, posse's greater economic losses and risk to agricultural export and trade. Spoiled maize cause great concern among farmers due to the loss of maize quality and quantity. In this study, the spoilage loss due to mould infection in the stored maize amounted to 4,330.62 tons of maize per year equivalent to one-fifth of the total maize production (20,622 tons per year). This spoiled amount of maize would be enough to feed 23,730 people for the whole year (at about 0.5 kg/day/person at an estimated value of 11.1 US Dollars per 100 kg bag of maize). It has been reported by Fandohan *et al*. (2003) that storage fungi contributes to loss of more than 50 % of maize grain in tropical countries, and ranks second after insects as the major cause of deterioration and loss of maize. According to Williams and McDonald (1983), when storage moulds invade maize grain they cause rot, kernel discoloration, loss of viability, vivipary, mycotoxin contamination, and subsequent seedling blights. Kossou and Aho (1993) reported that fungi could cause about 50 to 80% of damage on farmer's maize during the storage period if conditions are favourable for their development. Africa loses an estimate of sixty seven (67) million US dollars annually from export rejects due to high levels of mycotoxins in food and agricultural produce coming from developed countries (Atanda *et al*., 2013).

In 2005, groundnuts losses in Argentina caused by biotic disease-causing agents at the postharvest level were estimated at 4.1 million tons of grains or 6–8% of total production, this represented a loss of income amounting to US Dollars 6.1 million to producers (SAGPyA, 2006). Tiongson and Gacilos (1990) observed an inverse relationship between the price of maize grits and aflatoxin content in the Philippines i.e. the lower the level of aflatoxin content the higher the price of maize grits. For example, Compton *et al*. (1998) used focus groups of grain traders in Ghana to estimate price discounts based on samples of insect damaged maize. They found a 0.60% to 0.97% price reduction for every 1% of insect-damaged maize kernels beyond a threshold of 5% to 7% damage. Jones (2012) asked grain traders in Malawi to choose between samples of maize labeled with different price levels. In the 10% to 30% damaged kernel range, they found that a 1% increase in percent of damaged kernels resulted in a price discount of 2.8% to 3.6% depending on the total damage level, but little evidence of a discount below 10% damage. Accordingly, Cardino-Bermundo *et al*. (1991) concluded that moisture content and colour of the commodity determines the price of corn grain in the Philippines. Bottema and Altemeier (1990) and Wattanutchariya *et al*. (1991) indicate that moisture content and colour are the two most important factors in grain price formation in Indonesia and Thailand. In these countries the grain trader (middleman) measures the two factors through sensory evaluation and visual observation.

Generally, local grain traders and processors do not use laboratory equipment, like moisture testers, to measure grain attributes. The trader discounts wet or discolored grain by deducting a certain percentage off the gross weight of grain. Alternatively, the trader deducts a percentage off the market price to get the price per unit weight of wet or discoloured grain. The discounts increase with the wetness of grain. As Cardino Bermundo *et al*. (1991) observed damaged grain in the Philippines; traders reduced the gross weight or the unit price of the produce by a factor ranging from 30% to 50%. These potential losses in value can make a substantial difference to a family's livelihood due to low value (carbohydrate) starch. Withdrawing contaminated crop without alternative uses may heighten economic losses and affect food security among the poor. Low or volatile prices pose significant problems for farmers and other agents in food chains who risk losing their productive investments if price falls occur while they are locked into strategies dependent on higher price levels to be viable. Farmers who have already planted their crop are the classic example. Poor smallholders who do not have access to credit may have difficulty financing the crucial inputs needed to plant again and stay in business. Many farmers in developing economies may not be operating on a sufficiently large scale to be able to carry over income from one season to another. Thus, both the welfare of the family and the viability of the farm may be threatened by excessive volatility. Uncertainty may also result in sub-optimal investment decisions in the longer term.

Conclusion

Mycotoxins contaminations attract an attention because of the significant economic losses associated with their impact on trade and the livelihoods of people. The average weight loss of maize and groundnuts were 20.8% and 14.5% respectively as a result of mycotoxin contamination. Some of the suggested solutions to maize and groundnuts spoilage threat in Kilosa District includes: good agricultural practices, early harvesting, prevention of kernel damage during harvesting, adequate drying and proper storage below 13% moisture for maize and below 7% for groundnuts, keeping storage facilities clean and dry and physical separation of damaged grains. It is very important to undertake further research that will help small-scale farmers to meet international quality standards and continue to profitably market their crops, as well as to adapt to those practices that minimize risks to mycotoxin contamination. There should also be extensive awareness programmes across all villages in the district. Awareness of mycotoxin problem and management strategies should be extended to inform farmers, traders, processors, extension officers, other agriculture research partners, private sector, government regulatory agencies and the ministry of agriculture and food security about the risk of mycotoxins contaminations would reduce tremendous grain losses and training of the smallholders is necessary in order to achieve food security and improved nutrition.

Acknowledgment

The author expresses sincere thanks to all who helped execution of the study. Also, special thanks should go to all farmers in the four villages who participated in this study.

Conflicts of Interest

The author declares no conflict of interest.

REFERENCES

Adams, J. M., and Schulten, G. G. M. 1978. Loss caused by insects, mites and microorganisms. In: Harris, K. L., Lindbland, C. L., (Eds.). Post-Harvest Grain Loss Assessment Methods. *American Association of Cereal Chemists*, USA, pp. 83-95.

Ahmed, E. M., and Pattee, H. E. 1987. Peanut quality: Its assurance and maintenance from the farm to end-product (pp. 874). University of Florida, Institute of Food and Agricultural Science.

Atanda, O., Makun, H. A., Ogara, I.M., Edema, M., Idahor, K.O., Eshiett, M. E. and Oluwabamiwo, B. F. 2013. Fungal and mycotoxin contamination of Nigerian foods and feeds Countries. In: H.A. Makun (Ed) Mycotoxin and Food Safety in Developing Countries. *InTech, Rijeka, Croatia*. pp. 3-38.

Bhat, R.V. and Vasanthi, S. 2003. Mycotoxin food safety risks in developing countries. Food Safety in Food Security and Food Trade. Vision 2020 for Food, Agriculture and Environment, Focus 10, Brief 3, pp 1–2.

Blackburn, C .W. 2006. Food Spoilage Microorganisms. Woodhead.

Bottema, T. and Altemeier, K. 1990. Market channels, quality incentives and contract harvesting: The case of maize, soybean and groundnut. *Bulletin of Indonesian Economic Studies,* 26(1): 11 – 16.

Cardino-Bermundo, A. G., Cabacungan, P. R. and Bermundo, E. A. Z. 1991. *Socio-economic Factors Affecting the Utilisation of Postharvest Technologies in the Maize Industry*. Technical Bulletin No. 11. National Postharvest Institute for Research and Extension, NAPHIRE, CLSU Compound, Munoz, Nueva Ecija, Philippines. 76pp.

CAST. 1989. Mycotoxins-Economic and health risks. Task-Force report No.116, Ames, IOWA, USA 92pp.

Chulze, S. 2005. Aflatoxinas en Man´ı. In G. J. March and A. D. Marinelli (Eds.), Enfermedades del Manı´ en Argentina (pp. 103–113). Co´ rdoba, Argentina: Biblia Impresores.

Compton, J. A. F., S. Floyd, S., Magrath, P. A., Addo, S., Gbedevi, S. R., Agbo, B., Bokor, G., Amekupe, S., Motey, Z., Penni, H and Kumi, S. 1998. Involving grain traders in determining the effect of postharvest insect damage on the price of maize in African markets. *Crop Protec*, 17(6): 483-489.

Diao, X., Kennedy, A., Mabiso, A., Pradesha, A. 2013. Economy wide impact of maize Export bans on agricultural growth and household welfare in Tanzania. A dynamic computable general equilibrium model analysis. IFPRI discussion paper 01287. Development strategy and governance division. Available at: http://www.ifpri.org /sites/default/ files/publications/ifpridp01287. pdf. Retrieved on October, 20 2016.

Fandohan, P., Hell, K., Marasas, W. F. O. and Wingfield, M. J. 2003. Infection of maize by Fusarium species and contamination with fumonisin in Africa. *African J. of Biotechnology,* 23(4): 415 – 421.

FAO. 2012. World agriculture towards 2030/2050: the 2012 revision.

Fisher, M.C., Henk, D.A., Briggs, C. J., Brownstein, J.S., Madoff, L.C., McCraw, S. L. and Gurr, S. J. 2012. Emerging fungal threats to animal, plant and ecosystem health. *Nature*, 484:186–94.

Godfray, H.C., J, Beddington, J., Crute, J. R., Haddad, I. R., Lawrence, L., Muir, D, Pretty, J. F., Robinson, J., Thomas, S, Toulmin, S. M, 2010. Food security: The challenge of feeding 9 billion people. *J. of Science*, 327: 812–818.

Hussein, H. S. and Brasel, J. M. 2001. Toxicity, metabolism, and impact of mycotoxins on humans and animals. *J. of Toxicology,* 167(2):101-134.

Jones, M. 2012. "Measuring the Value of African Smallholder Grain Protection: Two Essays on Storage Economics and Market Valuation of Maize Attributes in Malawi," Purdue University, Department of Agricultural Economics.

Kader, A. A. 2005. Increasing food availability by reducing postharvest losses of fresh produce. In V International Postharvest Symposium 682 (pp. 2169-2176). Available at: http://ucce.ucdavis.edu/files/datastore/234-528.pdf. Retrieved on August 22, 2016.

Kamala, A., Ortiz, J., Kimanya, M., Haesaert, G., Donoso, S., Tiisekwa, B., and De Meulenaer, B. 2015. Multiple mycotoxin co-occurrence in maize grown in three agro-ecological zones of Tanzania. *Food Control*, 54: 208-215.

Kimanya, M. E., Shirima, C. P., Magoha, H., Shewiyo, D. H., De Meulenaer, B., Kolsteren, P., and Gong, Y. Y. 2014. Co-exposures of aflatoxins with deoxynivalenol and fumonisins from maize based complementary foods in Rombo, Northern Tanzania. *Food Control*, 41: 76-81.

Kossou, D. K and Aho, N. 1993. *Stockage et Conservation des Grains Alimentaires Tropicaux Principies et Pratiques.* Les Editions du Flamboyant, Benin, 125pp.

Lacey, J., and Magan, N. 1991. Fungi in cereal grains: Their occurrence and water and temperature relationships. In: J. Chelkowski (Ed.), Cereal grains mycotoxins, fungi and quality in drying and storage (pp. 77–118). B.V. Amsterdam: Elsevier Science Publisher.

Mboya, R., Tongoona, P., Yobo, K. S., Derera, J., Mudhara, M. and Langyintuo, A. 2011. The quality of maize stored using roof and sack storage methods in Katumba Ward, Rungwe District, Tanzania: Implications on household food security. *J. of Stored Products and Postharvest Research,* 2(9): 189-199.

PACA (Partnership for aflatoxin control in Africa) 2013. Aflatoxin impacts and potential solutions in agriculture, trade, and health. A background paper for the PACA stragegy development-stakeholder consultation workshop.

Pitt, J. I. and Hocking, A. D. 2009. Fungi and Food Spoilage, 3rd Ed. Springer.

SAGPyA 2006. Secretar´ıa de Agricultura, Ganader´ıa, Pesca y Alimen- tacio´ n. Estimaciones Agrı´colas Cereales.

Direccio´ n de Coordinacio´ n de Delegaciones. Buenos Aires.

Schmale, D. G. and Munkvold, G. P. 2015. Mycotoxins in crops: A Threat to human and domestic animal health. Available at: http: // www. apsnet.org/ edcenter/intropp /topics/Mycotoxins/Pages/EconomicImpact.aspx. Retrieved on May 26, 2015.

Tefera, T., Mugo, S., Likhayo, P., and Beyene, Y. 2011. Resistance of three-way cross experimental maize hybrids to post-harvest insect pests, the larger grain borer (Prostephanus truncatus) and maize weevil (Sitophilus zeamais). *International J. of Tropical Insect Science,* 31(2): 3-12.

TFDA. 2012.Tanzania food and drug authority. Aflatoxin contamination and potential solutions for its control in Tanzania. Stakeholder workshop held on December 3-4, Dar-es Salaam. Available at: http://www.aflatoxinpartnership.org/uploads/Tanzania% 20Policy% 20Brief. pdf. Retrieved on May 15, 2016.

Tilman D, Balzer C, Hill J, Befort BL. 2011. Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences,* 108: 20260–20264.

Tiongson, R. L. and Gacilos, R. G. 1990. *Maize deterioration at off-farm-level of operation*. Technical Bulletin No. 8. National Postharvest Institute for Research Extension, Nueva Ecija, Philippines. 17pp.

Wattanutchariya, S., Puthikorn, B., Tugsinavisutti, S., Isvilanonda, S. and Kao Ian, S. 1991. *Maize Commodity Study: Production and Marketing Structure of Maize in Thailand.* Department of Agricultural and Resource Economics, Kasetsart University. 240pp.

WHO. 1999. Basic Food Safety for Health Workers.

WHO. 2006. Mycotoxins in African foods: Implications to food safety and health. AFRO food safety. Newsletter Issue No 2. July 2006.

Williams, R. J. and Macdonald, D. 1983. Grain molds in the tropics: Problems and importance. *Annual Reviews of Phytopathology,* 21(1): 153 – 178.

Wu, F. 2004. Mycotoxin risk assessment for the purpose of setting international regulatory standards. *Environmental Science Technology* 38(15): 4049 – 4055.

Zorya, S., Morgan, N. and Rios, L. D. 2011. Missing food: The Case of Postharvest Grain Losses in Sub-Saharan Africa. The International Bank for Reconstruction and Development /The World Bank. Report No. 60371-AFR. The World Bank, Washington, DC.

****