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Aflatoxin Update

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Introduction

Aflatoxin has been a massive food safety issue since its discovery in 1961. Natural mixtures of aflatoxin are highly toxic and potent liver carcinogens, especially aflatoxin B1. National food safety agencies and the food industry in developed countries have been successful in reducing aflatoxins to acceptable levels but at considerable effort. Billions of dollars have been spent to address their presence in grain staples, such as maize, as well as in peanuts and tree nuts. Exposure in developing countries, however, is largely unabated, which is especially worrisome because of the high prevalence of the hepatitis B virus in these countries, which is estimated to increase the risk by a factor of 30.

Recently, two new publications related to aflatoxin have appeared that should be of particular interest to the food science and technology community. The first is a World Health Organization (WHO) report, *Global Burden of Foodborne Disease* (WHO 2015), that was released late last year. For the first time, estimates of global foodborne disease incidence, mortality, and disease burden are provided in terms of *Disability Adjusted Life Years* (DALYs). The report was prepared by the WHO Foodborne Diseases Burden Epidemiology Reference Group (FERG) and includes estimates of the public health burden of 31 foodborne hazards, including 11 diarrhoeal disease agents (1 virus, 7 bacteria, 3 protozoa), 7 invasive infectious disease agents (1 virus, 5 bacteria, 1 protozoan), 10 helminths and 3 chemicals (aflatoxin, dioxins and cyanide in cassava) as well as peanut allergens. An explanation of the methods with the estimates for infectious/invasive diseases were just published (Kirk et al. 2015). Data on the chemicals considered as well as peanut allergen are also available (Gibb et al. 2015). While this important work is

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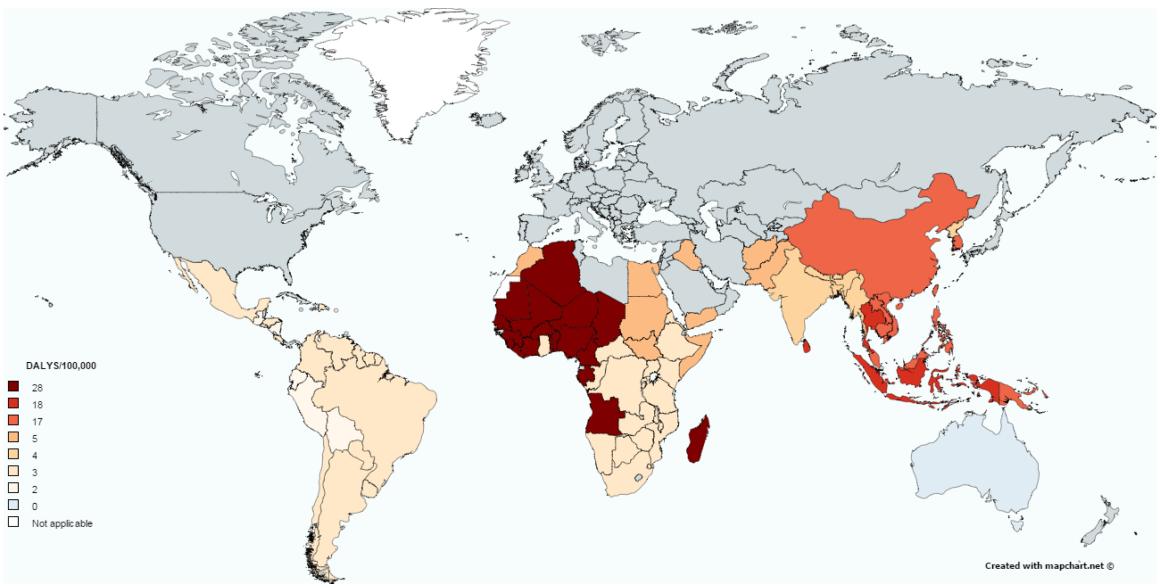
of general interest to food scientists and technologists, only aflatoxin will be discussed in this IUFoST Scientific Information Bulletin. Readers are encouraged to review the both papers as they quantify the importance of foodborne diseases from a public health perspective.

Another important publication was issued on 17 February 2016 by the International Agency for Research on Cancer (IARC) with support from the Bill and Melinda Gates Foundation. The report, *Mycotoxin Control in Low- and Middle-Income Countries* (Wild et al. 2015), focuses on the overall health impact of aflatoxin and fumonisins in developing countries. The IARC Working Group of world-leading experts concluded that these mycotoxins are not only a cause of acute poisoning and cancer but are also likely contributors to the high levels of stunting in children in exposed populations. The group also identified effective measures to reduce exposure in developing countries, including post-harvest interventions that would involve the food science and technology community. Some of these recommendations will be discussed in this IUFoST Scientific Information Bulletin.

WHO Estimates of the Global Burden of Foodborne Disease

The WHO report presents global estimates of the burden of disease for 31 bacteria, viruses, parasites, toxins, and chemicals that can contaminate food. The initiative represents a continuing effort by WHO to address the lack of data on foodborne illness and to develop a global strategy to improve food safety. The new data provide evidence that show almost 1 in 10 people fall ill every year from eating contaminated food, resulting in 420, 000 deaths. The FERG Task Forces reported their research findings in a series of 6 papers published in various journals.

In a translational research paper, Gibb et al. (2015) of the FERG Task Force on Chemicals in Food used global estimates of incidence to calculate illnesses, deaths and DALYs for dioxin, aflatoxin, cyanide present in cassava and peanut allergen. Estimates of the health burden posed by lead and methylmercury are in progress. The results to date underscore the global threat posed by chemicals in food. Taken together, the four selected chemicals were estimated to be associated with 339,000 illnesses, 20,000 deaths, and 1,012,000 DALYs in 2010. DALYs are the most common single metric used for death and disability, and are expressed as the sum of years lived with disability and years of life lost; one DALY equates to one year of healthy life lost. While dioxin was associated with the greatest number of illnesses (193,447), aflatoxin was associated with the highest global DALYs (636,869). Note that peanut allergen also resulted in a large number of DALYs, but these were confined to industrialized countries where data are available. Statistical methods were used to provide estimates for countries without data. In the case of aflatoxin, adjustments were made to account for the synergism between hepatitis B virus and aflatoxin. The public health burden due to aflatoxins occurs almost exclusively in low and medium-income countries as shown below.



Global distribution of aflatoxin health burden (DALYs per 100,000 population)[iii]

IARC's Working Group Report on Aflatoxin and Fumonisin

The International Agency for Research on Cancer (IARC) has evaluated a range of mycotoxins, including aflatoxin (first in 1971) and fumonisin, as potential carcinogenic agents. Further, in late 2012, IARC published a highly regarded comprehensive treatment of mycotoxins oriented to developing countries

[iii] Data is provided on 2010 median exposure to aflatoxin. WHO Estimates of the global burden of foodborne diseases, 2015.

(Pitt et al. 2012). The most recent IARC report focuses on other possible threats to child health and offers a health-based evaluation of a number of interventions to improve the safety of available food. It also addresses the dilemma in where starving people have no choice but to consume crops that are highly contaminated during ‘bad’ years, such as drought. While some of these interventions would require major investments and food sufficiency to implement, others would be practical and achievable through greater gender-specific knowledge mobilization.

Background

Even before the chemical structure was elucidated, aflatoxin was detected in African peanut samples known to make children and animals sick (Anon. 1962). By the mid-1960s, amidst calls for more efforts to study the risks of aflatoxin exposure to Africans (Latham 1964), WHO attempted to set a limit for aflatoxin in high protein supplements for children (Anon. 1966). Since that time, the Codex Alimentarius Commission has adopted recommended limits for aflatoxin (total) in peanuts and several tree nuts, which included detailed sampling plans because of its heterogeneous distribution. Codex also has adopted a level for aflatoxin M_1 in milk, but has not adopted a level for maize. However, many countries have national limits for aflatoxin B_1 and total aflatoxins in maize and other commodities. In this regard, regulatory limits are strictly enforced in most industrialized countries as reflected in the above WHO estimates, which showed no burden of disease due to aflatoxin exposure for these countries.

While some progress has been made, mycotoxin contamination of staple crops in developing countries, particularly in Africa, remains what IARC Director Prof. Chris Wild described as a shamefully neglected problem (Wild & Gong 2009). Despite sustained investment in research over the past 60 years, aflatoxin is an agricultural problem that has not diminished. The growth of susceptible crops, such as maize, has expanded into the geographic area affected by mycotoxins. High temperatures and both drought and too much precipitation can also increase in aflatoxin levels, especially in years with an intense El Nino effect (currently). Notably, in countries with dependency on maize for the majority of calories, aflatoxin (as well as fumonisin) exposure remains a threat to public health. These trends have been exacerbated with a reliance on a few crops as the main source of carbohydrates at the expense commodities less affected by aflatoxin. An estimated 500 million of the poorest people in sub-Saharan Africa, Latin

America, and Asia are exposed to aflatoxin and fumonisin in staple foods at levels that greatly exceed international norms. Opportunities exist to develop strategies that effectively reduce exposure to aflatoxin and fumonisin that are tailored to the particular challenges of both the urban and rural food systems.

Health risks posed by aflatoxin

Although it has been known for decades that exposure to aflatoxin was high in some populations, the advent of new methods for measuring exposure to multiple mycotoxins in urine and blood has raised unexpected and sobering questions. A high prevalence of co-exposure to both aflatoxin and fumonisin has been documented throughout Africa and parts of Latin America. Exposure to these toxins at high levels substantially increases morbidity and mortality. In addition, it is now known that aflatoxin poses serious chronic health risks other than liver cancer. Fatalities from acute exposure to high levels of aflatoxin in food have been reported in Africa and Asia. For example, a decade ago, an aflatoxicosis outbreak in eastern Kenya resulted in at least 125 child deaths. However, chronic exposure to aflatoxin may also contribute to poor growth or stunting in children. An estimated 162 million children aged less than 5 years worldwide were stunted. Poor-quality diets and high rates of infection, both in pregnancy and in the first years of life, are known to result in poor child growth. While the relative contribution of these factors to stunting are unknown, provision of all of these established nutrition-specific interventions in the most affected regions had reduced stunting by less than 20%.

The IARC report evaluated the evidence that chronic exposure to aflatoxin and co-exposure to fumonisin might explain the some of this large gap. Significant harmful effects of aflatoxin on child growth have been reported, as well as immune system modulation. These observations are consistent with impaired fetal development. Damage to the immune system and gut function in relevant three animal models has also been observed. Taken together with well-documented population-based studies, these data suggest that mycotoxin exposure contributes to stunting independently of other risk factors. The WHO assessment has considered the disability and loss of life associated with diseases that occur in later life, notably the proportion of liver cancers caused by aflatoxin. The impact of aflatoxin on child stunting and other consequences probably represents a much larger health burden. Chronic exposure to mycotoxins and associated undernutrition can lead to adverse effects on survival, health, and physical and mental development. Considering the co-exposure to aflatoxin and fumonisin, the Joint FAO/WHO Expert Committee on Food Additives and Contaminants (JECFA) concluded in 2011 that co-exposure to aflatoxin and fumonisin likely results in additive effects beyond exposures to the individual toxins (FAO/WHO 2011).

Interventions to reduce aflatoxin

Great efforts have been made to develop methods or approaches to reduce exposure to aflatoxin and fumonisin in maize and peanuts. In fully developed market economies, these efforts along with good growing conditions, abundance of food and dietary diversity have effectively managed these toxins. However, in low- and medium-income countries, attempts to control mycotoxins have yielded meager results. The IARC Working Group evaluated the evidence concerning the effectiveness of various public health interventions, including credibility, completeness and transferability at the individual, community and national levels. The highest ranking was reserved for interventions that were considered ready for implementation. Such interventions had reached a mature stage of development, resulted in significant intervention effects, and addressed the needs of important stakeholders.

The IARC Working Group considered a total of fifteen interventions which were placed into one of following categories:

(1) sufficient evidence for implementation,
(2) needs more field evaluation,
(3) needs formative research, or
(4) no evidence or ineffective.

Recommendations on further investigation and potential scale-up were also made. Four of the 15 interventions were judged to be ready for implementation. Improving dietary diversity had the strongest evidence for health improvement, but was also considered the most difficult to achieve. Other strategies deemed ready for implementation included sorting of the crop; improved storage, including a package of post-harvest measures, and optimized nixtamalization of maize[iv], the latter of which is limited to Latin America Several interventions were considered that might be used in emergency situations of extremely high exposure, e.g. protective agents that can be added to the diet to ameliorate the effects of ingested aflatoxin.

Food processing interventions

Aflatoxin and fumonisin (and the other agriculturally-important mycotoxins) are heat stable. Excepting in the case of nixtamalized maize, concentrations of these toxins in food, therefore, are only materially reduced by dilution by other ingredients. This means that the toxins must be removed prior to food preparation. In developed countries, sorting of contaminated grains and nuts is the primary tool used to reduce mycotoxin contamination and can be effective at all scales of production. For example, the removal of ergot sclerotia is performed by specific gravity seed cleaning equipment. For maize, normal grain cleaners can reduce aflatoxin and fumonisin contamination by 50–60%. Commercially, optical sorting equipment is commonly used to remove nuts containing aflatoxin.

In developing countries, hand sorting of shell peanuts is an efficient way to roughly segregate contaminated peanuts, but some shell peanuts that appeared sound contained substantial levels of aflatoxin. Removal of the shells and mild heating to remove the skins greatly improved the accuracy of identifying contaminated peanuts. A study in the Philippines found that manual sorting of shelled and blanched peanuts resulted in a 20 fold reduction in aflatoxin concentrations. Research conducted in Kenya demonstrated that manual sorting of peanuts purchased at local markets could reduce aflatoxin concentrations by about 98%. In West Africa, manual sorting was shown to be moderately effective at the village level in decreasing concentrations of aflatoxin. In South Africa, hand-sorting of contaminated maize was effective reducing fumonisin exposure.

As currently envisaged, the IARC recommendations are relevant for investment of public-, nongovernmental- and private-sector funds at the scale of the subsistence farmer, the smallholder, and

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[iv] Nixtamalization is the soaking and cooking in alkaline solution.

through to the more advanced value-chain operations. The IARC Working Group foresaw an opportunity to adapt commercial optical sorting equipment for peanuts in the African value chain for both large and small operations. They also concluded that targeted training in manual sorting for rural women would appear to be a good investment. In Africa, food security was the major barrier to implementation of sorting and safe alternative uses for rejected lots needed further research. The education of women in developing countries should be considered critical because of their roles as mothers, educators, and businesswomen managing household nutrition, farming, and the selling of smallholder crops. More research on gender and mycotoxin management is needed to properly develop education campaigns and ensure equitable access to information by both men and women.

The role of the food science and technology

In 1995 the International Union of Food Science and Technology (IUFoST) General Assembly adopted a resolution (the Budapest Declaration) that committed the global food science and technology community to eliminating hunger and reducing all forms of malnutrition. In particular, it recognized the unique role of food science and technology in ensuring food quality, safety, sustainability and security for the world's growing population. More recently in 2010, IUFoST adopted the Cape Town Declaration that identified several priorities for possible intervention, including promotion of food safety and quality; reduction of physical and nutritional losses in food; adaptation and improvement of traditional processes; more efficient and environmentally sustainable food production, processing and packaging; and education in food science and technology at all levels.

A number of public and private sector initiatives at the national and international levels have been launched to implement some the priorities identified in the Cape Town Declaration. Application of food science and technology has been recognized as a key component in addressing many of the problems related to food security, wastage, safety and sustainability. In cooperation with The World Bank, IUFoST has undertaken the development of food safety curricula at the Bachelor's and Master's levels.

In 2012, IUFoST in cooperation with the University of Georgia, USA held training courses in a manual sorting technique in various African countries. However, the peanut possessing industry has been slow to adopt this technology. As a result, the IUFoST Food Safety Committee in collaboration with young food scientists from Africa has developed a project proposal that is intended to promote the introduction of peanut sorting technology in Africa. This will be accomplished through the establishment of pilot visual/manual sorting facilities at departments of food science and technology at universities in several of African countries. These pilot facilities would provide students as well as staff of existing commercial peanut processors with the knowledge and skills to establish and manage visual/manual sorting operations. Although optical/mechanical sorting equipment used in developed countries is presently considered too expensive and difficult to maintain in under most conditions in developing countries, optical methods to augment manual sorting would be explored. Ultimately, the wide-scale adoption of sorting technology by the commercial sector would have a significant impact on aflatoxin levels that would benefit both health and trade. The projects would be administered by the IUFoST Secretariat in cooperation with the IUFoST Adhering Body and the academic institution and the peanut processing association in the country.

Initial projects to demonstrate that visual/manual sorting is a sustainable solution to the problem of aflatoxin contamination in peanuts is being planned by IUFoST and the departments of food science and technology at universities in Nigeria and Kenya. Based on these projects, a guidance manual will be prepared that can be used to facilitate the successful replication of the approach in other countries and to other commodities, such as maize. Based on the information collected, a model business plan will also be developed. It is recognized that the success of this approach will require unprecedented cooperation by all parties (regulators, food industry and consumers), but similar to the Marshall Plan after World War II, this approach offers opportunities to not only save lives, but also to develop a food industry in Africa. This will serve to improve safety, quality, sustainability and security of food, in line with the goals of IUFoST's Cape Town Declaration.

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After 16 years at Agriculture Canada working on Fusarium toxins, Dr. Miller became a Professor and Natural Sciences and Engineering Research Council of Canada (NSERC) Research Chair at Carleton University in 2000. Dr. Miller has published more than 350 papers and co-written and edited 9 books on public health aspects of fungi and fungal toxins. He participated in IARC, International Programme on Chemical Safety and Joint FAO/WHO Expert Committee on Food Additives panels that included mycotoxins. He has invested considerable time on mycotoxin issues in Asia, South America and Africa. Miller was a co-author of IARC publication "Improving public health through mycotoxin control (2013). With Professors Chris Wild and John Groopman, he helped to plan the working group leading to the report discussed in this SIB. Among other awards, he received the Ag Excellence Award from Agriculture Canada (1992), Ministry of Agriculture of China, Science and Technology Award for work on Fusarium (1994), the Toxicology Forum Scott Award for contributions to toxicology (1998) and an NSERC Synergy Award (2016). Dr. Miller is on the Board of the Toxicology Forum in Washington, DC.

ABOUT IUFoST

The International Union of Food Science and Technology (IUFoST) is the global scientific organisation representing more than 300,000 food scientists and technologists from over 75 countries. IUFoST is a full scientific member of ICSU (International Council for Science) and it represents food science and technology to international organizations such as WHO, FAO, UNDP, The World Bank, and others. IUFoST organises world food congresses, among many other activities, to stimulate the ongoing exchange of knowledge and to develop strategies in those scientific disciplines and technologies relating to the expansion, improvement, distribution and conservation of the world's food supply. IUFoST Contact: General Secretariat, IUFoST, 112 Bronte Road, Oakville, Ontario, Canada, L6L 3C1, Telephone: + 1 905 815 1926, e-mail: secretariat@iufost.org, www.iufost.org

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