Caribbean Agro-Economic Society

Farm & Business

The Journal of the Caribbean Agro-Economic Society

32nd Conference Theme:

Food & Nutrition Security: The Pathway to Sustainable Agricultural Development in the Caribbean

Vol. 9, No. 1, December 2017

Cover Design: **Kavita Butkoon**

ISSN 1019 – 035 X

From Farm to Table: Reducing Mycotoxin Contamination of Food in the Caribbean - A Review of Sustainable Strategies.

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Abstract

An important aspect of food security is food safety, i.e., ensuring that food reaching consumers is safe and that consumers perceive the food to be safe. As Caribbean countries typically have hot and humid climates, there is the possibility that its food supply can be exposed to and become infected with harmful fungi. Mycotoxins are secondary metabolites of toxigenic fungi, which, if consumed in sufficiently large amounts, can have adverse effects on human health. In addition to being a risk to public health, uncontrolled mycotoxins in food supply can also temporarily or permanently harm Caribbean export and tourism markets.

This review briefly examines the effects of mycotoxins on human health and focuses on culturally consistent, cost-effective and sustainable strategies that encourage local entrepreneurial engagement in the management of mycotoxins. These strategies may straddle the range of important mycotoxins examining mechanisms along the supply chain, recognizing the need for increased education and awareness, promoting local production and harmonizing food safety standards in the Caribbean.

***Keywords**: food safety, prevention, control, postharvest, preharvest, detoxification*

Introduction

The Caribbean[1] produces a wide range of fruits, vegetables, cereals and spices. In spite of this, the Caribbean is still a net importer of food. For example, the CARICOM's import bill is now over US$4 billion per annum (Deep Ford 2015, 7). At the CARICOM Heads of Government summit for 2017, the President of the Cooperative Republic of Guyana, David Granger, also expressed concern about the burgeoning food import bill (Ministry of the Presidency, Cooperative Republic of Guyana 2017)

Local produce and even imports can potentially become contaminated with mycotoxins caused by fungus along the production/marketing value chain. With the high net importation of

[1] The focus of this review is the CARICOM subset of countries: Antigua & Barbuda, Barbados, The Bahamas, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent & the Grenadines, Suriname and Trinidad and Tobago.

food into the Caribbean, there are concerns about the influence these have on changing dietary habits of Caribbean nationals and the concomitant health issues including obesity and other lifestyle diseases. However, as pointed out by Beckford (2012, 29) there is little attention to food safety.

Food imported to the Caribbean comes from countries all over the world. The longer the time between production and consumption and the more food is handled and stored along the marketing chain, the more likely it can become contaminated with microorganisms and their metabolites. With a population of over 16 million people in CARICOM whose health might be at risk, it is important to examine strategies that prevent the effects of food contaminants such as mycotoxins.

Since research on mycotoxins in the Caribbean is limited, it is difficult to estimate the economic cost associated with contamination. However, it is estimated that 25% of the world's food crops are affected by fungal growth (Bryden 2007, 95). Therefore, sustainable strategies must be developed to limit the presence of mycotoxins in food production and marketing chain.

Bennett and Klich (2003, 498) define mycotoxins as low-molecular-weight natural products (i.e. small molecules) produced as secondary metabolites by filamentous fungi. These metabolites constitute a toxigenically and chemically heterogeneous assemblage that is grouped together only because the members can cause disease and death in human beings and other vertebrates.

To achieve the aim of this review, the concept of food security and food safety in the Caribbean region is discussed; the likely impact of mycotoxins is outlined; an overview of the most significant mycotoxins and their likely effects on human is explained; the presence of mycotoxins in food commodities is briefly examined; a general idea of food imports to the Caribbean is outlined. The main focus is on strategies to control mycotoxins and discussions on governments' of the Caribbean policies to achieve the goal of public safety.

Food Security and Food Safety

The concept of food security is evolving ever since it focused on the provision of adequate food supply at the World Food Conference in 1974 (FAO 1974). The currently accepted definition of food safety goes beyond food supply by emphasizing the need for safe and nutritious food:

> "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life"[2]

In keeping with the above definition, there are four overarching dimensions of food security: (i) physical availability of food; (ii) economic and physical access to food; (iii) food utilisation; and (iv) stability of the other three dimensions. The availability of food encompasses the presence of food, its quality and safety. The universally accepted definition of food safety is 'Food that is free of chemical, biological and physical hazards'

The Director-General of the World Health Organization (WHO) acknowledged that safety is often overlooked in the discussions of food security and is mainly crisis driven. It was recognized that all stakeholders should work together to raise awareness, prevent and find solutions to food safety issues (Chan 2014, 910-1911). To this end, in 2015, WHO's World Health Day focused on food safety to demonstrate the importance of global and national actions to guard against chemical and microbial contamination of food (WHO 2015). The organization's mandate is to

[2] Food and Agriculture Organization of the United Nations Agriculture and Development Economics Division (2006). Policy Brief – Food Security

assist its member countries to build capacity in developing and strengthening national food safety programs.

The assistance includes (i) developing regional and national food safety policies; (ii) preparation of food legislation, food regulation and standards, and codes of hygienic practice; (iii) implementation of food inspection programs; (iv) promoting methods and technologies designed to prevent food-borne diseases; (v) developing or enhancing food analysis capability (vi) development and delivery of hygiene training and education programs; (vii) establishing healthy markets and enhancing the safety of street food; and (viii) promoting the establishment of food-borne disease surveillance activity (Ashley 2016, 136).

The Impact of Mycotoxins

Foods contaminated with mycotoxins can be potential public health risks. Farmers, wholesalers, and retailers can potentially experience loss in income due to rejection of agricultural products they produce and sell or are forced to sell at a lower price. Therefore, developing countries such as those in the Caribbean may incur direct economic loss as well as indirect loss associated with health difficulties (Shephard 2008, 146-151). Economic losses resulting from the suspension of sales or outright loss of markets can have significant impact on countries in the Caribbean. These countries can then be required to invest in facilities to meet regulatory standards and to conduct research. Economic costs related to health result in depletion of human capital stock, hospitalization and psychological costs associated with quality of life (Udomkum et al. 2017).

The presence of pathogens and their metabolites are ubiquitous in the food production and marketing chains. Therefore, there is the need for constant surveillance, monitoring, and application of preventive and treatment measures to protect consumers. Strategies employed depend on the type of possible contaminants. Lopez-Garcia et al., (1999) suggest an integrated management system approach involving preharvest and postharvest operations. These strategies showed acceptable levels of cost-effective ratios not only in terms of the economic cost but also in improvement of the quality of life (Wu and Khlangwiset 2010, 496-509).

Important Categories Mycotoxins and Some of their Effects on Humans

The broad categories of the most significant mycotoxins that affect humans include aflatoxins, ochratoxin A, fumonisins, zearalenone, trichothecenes and patulin (see, Table 1). These are produced by a range of fungi genera including *Aspergillus*, *Penicilllium*, *Alternaria*, *Fusarium* and *Claviceps.* According to van Egmond (2007, 147-157), the risk associated with mycotoxin depends on hazard and exposure. While the potential hazard is the same for all individuals, exposure varies according to the levels of contamination and dietary habits in different parts of the world.

Table 1: The Causal Agents of the Six Most Significant Mycotoxins and their Effects on Humans.

Mycotoxin	Causal agent	Effect on humans	References
Aflatoxins	*Aspergillus flavus, Aspergillus parasiticus*	Group 1 carcinogen, Liver cancer Edema, Affect testesterone in males	IARC, 2002 Klich, 2007
Ochratoxin A	*Aspergillus Penicillium*	Mitochrondrial poison Nephrotoxic Liver toxin Immune suppressant	Bennett and Klich, 2003
Fumonisin	*Fusarium moniliforme Fusarium proliferatum*	Oesophageal cancer	JECFA, 2001 Shephard et al., 1996
Zearalenone	*Fusarium graminearum, F. culmorum, F. cerealis*	- Acts like female hormone - Gynecomastia in boys - Early sexual development in females	Marin et al., 2013 Sáenz de Rodriguez et al., 1985
Trichothecenes – deoxynivalenol Nivalenol T-2	*Fusarium graminearum, F. sporotrichiodes, F. poae*	-They inhibit protein synthesis, - Alter integrity of intestinal mucosa, - immunomodulator	Sergent et al., 2006 Maresca et al., 2002 Sudakin, 2003
Patulin	*Penicillium expansum*	Immunotoxic, Neurotoxic, Genotoxic	Marin et al., 2013

Presence of Mycotoxins in Commodities

Many regularly used commodities can potentially have mycotoxins. For example, deoxynivalenol was found in wheat flour at relatively lower frequencies in Brazil than in Northern Iran (Machado et al 2017, 10; Darsanaki et al. 2015, 36). Also, aflatoxin, ochratoxin A and patulin were found in fruit juices and wine (Delage et al. 2003, 226; Fernández-Cruz et. al. 2010, 118). In cornflakes, a popular breakfast food, fumonisins were found but lower than the maximum tolerable limit, while aflatoxins exceeded the maximum tolerable limit (Castells et al. 2008, 84). Ochratoxin and Zearalenone were observed in high-fiber breakfast cereals (Ibáñez-Vea et al. 2011, 1951). Cappozo et al. (2017, 254-255) determined that ochratoxin A was present in soy-based and milk-based infant formula and also in infant cereals. Rice was found to be contaminated with multiple mycotoxins aflatoxin, ochratoxin A, zearalenone, deoxynivalenol (Almeida et al. 2012, 700). The latter mycotoxins were also found in cereal-based products made of rice, barley, wheat, and corn. Rice-based cereals had the highest concentration of deoxynivalenol (Ok et al. 2009, 156). In the Caribbean, zearalenone was found in premixes and concentrates in Jamaica and aflatoxins in groundnuts in Jamaica and St. Vincent (Resnik, et al. 1995).

Food Imports to the Caribbean

As indicated above, the Caribbean is a net importer of food. Specifically, the countries of CARICOM have an import bill of US$4 billion per annum. The top ten imports by value are: processed foods, wheat, rice, meat, maize, beverages (nonalcoholic), sugar (refined), sugar (raw), soybean oil, and palm oil (Deep Ford 2015, 10). Although, food safety regulatory authorities of the exporting countries may have mechanisms in place to monitor and control contamination, there is still the potential for these exports to be contaminated with mycotoxins en route to the consumers. While most Caribbean states have regulatory bodies which monitor food imports, they do not routinely monitor mycotoxins.

Strategies to Control Mycotoxins

As Governments in the Caribbean focus on expanding food production and reducing imports, concomitantly there should be adequate mechanisms to monitor and prevent mycotoxin contamination so as to limit spoilage and to safeguard human health. Management strategies may straddle the range of mycotoxins. Therefore, the best approach should be to prevent or manage mycotoxin contamination at each phase along the production and marketing chain.

- ***Preharvest control strategies of mycotoxins***

  Preharvest contamination can be reduced through a combination of good crop husbandry and cultural practices. Fungi will grow and proliferate when conditions are ideal and they produce mycotoxins which have adverse effects on the crop.

  Field management: Improved agronomic and cultural practices applied in land preparation and cultivation in crop production can reduce the presence of fungi and their metabolites mycotoxins. Among the mycotoxin-producing fungi, Accinelli et al. (2008, 371-379) determined that *A. flavus* produces aflatoxin in the soil. The land should be cleared to remove vegetation, stubble and debris which can be sources of fungal inoculum. Seeds and other planting material should be cleaned or treated to reduce the pathogens. Adequate irrigation and drainage are essential so that water does not stay on the land and subsequently encourage the growth of fungus. Adequate irrigation is also needed for peanut which is prone to aflatoxins under drought stress (Cole et al. 1985, 41-46; Sanders et al. 1985, 90-93). Large commercial farming operations may be equipped with heavy machinery for land preparation, however for relatively small or homestead farms, simple motorized or manual implements can be just as effective. The soil should also be tested to ensure adequate plant nutrients and pH in order to avoid plant stress. In the case of deficiency of nutrients, fertilizers should be applied (Kabak et al. 2006, 595). On the other hand, Brodal et al. (2016, 755) suggest that healthy organically-grown produce can potentially reduce mycotoxin contamination, and organic farming is also good for the environment.

  Selection of crop/variety: An important method of mycotoxin control is the selection of crop/variety. Crops cultivated in most parts of the world are based on tradition and cultural practices which may be difficult to change. For example, in West Africa, the staple food is maize but this crop is proned to mycotoxin contamination. Vismer et al. (2015, 1956) determined that the replacement of maize with pearl millet and sorghum will reduce exposure to aflatoxin and fumonisin B.

Blandino et al. (2017, 18) observed that a moderately deoxynivalenol-resistant variety of wheat along with the application of fungicide reduced deoxynivalenol in the field significantly (89%). In India, Iqbal et al. (2014; 354) found that super basmati rice produced the highest level of aflatoxins among five rice varieties studied. Therefore, if this variety is selected for planting, there should be measures to monitor the production of aflatoxin along the production and marketing chain. However, since there have been no similar studies in the Caribbean, caution should be exercised when making decisions about the crops and varieties to be cultivated.

Application of biocontrol agents: The use of biocontrol agents exploits the competitiveness of atoxigenic strains to reduce the relative numbers of aflatoxin-producing fungi infecting the crops in the field. Such treatments are designed to increase the presence of atoxigenic strains relative to the aflatoxigenic strains (Cleveland et al. 2003). In the case of the peanut, which is susceptible and usually has high concentration of aflatoxins, this can be reduced by application of a nontoxigenic strain of *A. flavus* to the soil (Dorner et al. 2003, 323; Dorner and Horn 2007, 215). Biocontrol of *Aspergillus flavus* in maize can also be achieved by the use of atoxigenic strains of the fungus with continued postharvest protection (Brown et al. 1991, 623-626; Atehnkeng et al. 2014, 62-70). A biocontrol product afla-guard® is now registered by the US environmental Protection Agency for commercial use in the maize and groundnut industry (Dorner 2009, 381-384). *Aspergillus flavus* AF36 developed by the Agricultural Research Service of USDA (USDA-ARS) can be used in the maize industry. Collaboration between the International Institute for tropical agriculture (IITA) and USDA-ARS led to development of biocontrol products as biopesticides with trade name Aflasafe. The products are adapted to be used in the different countries of Africa (Bandyopadhyay et al. 2016). Aflasafe can potentially be used in the Caribbean.

Application of Chemical agents: During the growth of the crop, it is important to protect it from insect damage and fungal infection. Insecticides should be used for infections associated with insect injury (Schmale and Munkvold 2017). Fungicides can be used alone or with biological control has reduced mycotoxin contamination in corn (NC Extension 2015).

Environmental factors: The ecological conditions of the Caribbean with near constant high temperatures and humidity are favorable for the growth of the fungi. Therefore, these conditions should be assessed in determining the appropriate time of cultivation. Jaime-Garcia and Cotty (2010, 1846) determined that of the two *Aspergillus* morphotypes, 'S' and 'L', the 'S' strain produces more aflatoxin and it is dominant during the warmer seasons of the year. In such conditions, crop rotation should be among the agronomic options. Reddy et al. (2007, 1370) reported that the *A. flavus* propagules were lower when corn was rotated with cotton, than when only corn or cotton was cultivated. Also, water activity (a_w) in the range of 0.86-0.99, with the optimal a_w at 0.98 and an optimal temperature in the range of 25-30^{o}C (Mousa et al. 2011, 1262) are favorable conditions for fungal infection in rice. This temperature range is typical of Caribbean countries. Therefore a combination of agronomic practices is needed to manage the cultivation of these crops. It was also demonstrated that high temperature and low rainfall favor the formation of aflatoxin B_1 in corn while low temperature and high rainfall resulted in low $AFLB_1$ on corn (Giorni et al. 2016, 257-258). An understanding of the crop type or variety would determine how best to take advantage of its response to weather conditions.

Good Agricultural Practice: A United States Department of Agriculture (USDA) project promoting good agricultural practices in the Caribbean in order to minimize microbial hazards, reinforced and enhanced traditional methods used in ensuring that the food is safe along the production/marketing chain. That project emphasized irrigation and washing of produce with clean water, correct manure management and the establishment of a traceability system from production to local and international marketing (USDA 1998, 9-25). It is also recognised that organic farming used in many parts of the Caribbean, especially on small farms, have the potential to provide commodities for niche markets locally and also higher-priced markets internationally.

- ***Postharvest control strategies of mycotoxins***:

The proliferation of the fungi and production of mycotoxins can potentially continue from harvest up to the point of consumption. Hodges et al. (2011, 40) estimated postharvest loss in developing countries to be between 5 and 35 per cent. At harvest and along the marketing chain, produce such as fruits and vegetables that are infected or show signs of spoilage, should be removed since there is the potential for diffusion of mycotoxin from the rotted to the sound produce (Barkai-Golan and Paster 2008, 147-159). In addition, insects and mites should be controlled since they make wounds that serve as entry points for colonization of fungi and aflatoxin production.

Since many fresh fruits and vegetables are used in the preparation of salads and juices, they must be properly disinfected before being consumed. Therefore, there is need to ensure that there is the proper washing and sorting of fruits. For big commercial operations, the system is automated for cleaning, application of fungicides, and sorting which can be also done by hand. Less sophisticated cottage-level operations should endeavor to achieve the same purpose of getting clean and healthy food to the consumers. Potable water must be used for washing the fruits and vegetables, and the working area must be sanitary (USDA 1998, 13). Fruits should be air-dried before packing for transportation and distribution.

For grains, such as rice, it is important that the moisture levels are significantly reduced to about 12% – 16% before harvesting. But even at this desired pre-harvest level, the moisture in freshly harvested paddy still encourages the growth of fungus with subsequent production of aflatoxins, deoxynivalenol, nivalenol and zearalenone (Reddy et al. 2009, 29; Ok et al. 2014, 288-290). Hence before processing into the various fractions, the paddy should be further dried. According to Sales and Yoshizawa (2005, 434), aflatoxin levels decreased as fractions are progressively prepared.

Peanuts may be sorted by taking advantage of the differences in density between contaminated and sound nuts. The former has a lower density and will float when placed in water (Dorner, 2008). This method is simple and can be effective for small operations.

Environmental conditions: Fungal growth and sporulation can occur during storage and in the production of dried foods since the fungus thrives at low water activity. Abdel-Hadi (2017, 615) observed that *Aspergillus flavus, Aspergillus ochraceus, Aspergillus carbonarius and Penicillium verrucosum* optimum for grow is in the range 0.98-0.995a_w while optimum spore production for *Aspergillus flavus, Aspergillus carbonarius, Penicillium verrucosum* occurs at 0.95-.995 and .85a_w for *A. ochraceus*. With regard to aflatoxin, the commodity should have less than 10% moisture and the presence of insects controlled since moisture content increases through condensation of moisture from respiration (Williams et. al. 2004, 1116). Hence, the storage area must be adequately aerated, the moisture levels controlled and the temperature and relative humidity regulated. *A. flavus* and *A. parasiticus* grow in the temperature range of 10-12^{o}C to 42-43^{o}C, with an optimum in the range of 32 to 33^oC, while aflatoxins are produced in temperature ranging from 12 to 42^oC (Sweeney and Dobson 1998, 148).

The interaction of a_w and temperature is important since a decrease in a_w restricts the temperature range for the growth of fungus (International Commission on Microbiological Specifications for Foods 1998, 321). Storage in bags made of natural fibers (jute bags), using pallets to avoid contact with the ground and sun-drying can potentially reduce the disease burden, caused by aflatoxin, associated with the production of groundnut crops (Turner et al. 2005, 1955). Generally, care should also be taken to ensure that contamination from external agents, such as animals (for example, rodents and birds), is minimised (Codex Alimentarius CAC/RCP 51-2003, 3).

Physical control methods: Studies examining the degradation of mycotoxins by ordinary boiling and microwaving show that they are relatively heat stable. However, some methods have proven to be effective in reducing the levels of mycotoxins. For example, oven roasting peanuts for 30 minutes at 150^oC and microwave-roasting for 85 minutes at 0.7kW was effective in reducing the aflatoxin B_1 concentration by 30% to 45% (Pluyer et al. 1987). Wet-milling of corn contaminated with T-2 toxin showed that there was a 67% reduction when treated by steep and process water (Collins and Rosen 1981, 877-879). Wheat flour heated to 250^oC for 40 minutes reduced the concentration of ochratoxin A by 76% (Scott 1984, 489-499). Lower reduction, 14 to 38%, of ochratoxin A occurs during the beer-making process (Chu et al. 1975, 313-316; Nip et al. 1975, 1048-1049).

Extrusion cooking involving high-temperature for a short time reduced mycotoxins in cereals (Castells et al. 2005, 151). Twin-screw extrusion reduced ochratoxin A in oat flakes (Lee et al. 2017, 1628-1634). Reductions ranging from 72.5% to 87.5% of Aflatoxin B_1 and ochratoxin A were observed in rice cooked in excess water, rice cooked in normal water and microwave oven cooking. Sani et al., (2014, 549) also demonstrated that there was 24.5% reduction in aflatoxins after cooking rice in a rice cooker.

Chemical control methods: There are a range of chemicals that can be used for postharvest control of mycotoxins. Fungicides including organophophorus compounds and iprodione have proven to be effective in controlling *Aspergillus* (Dutton and Anderson 1980, 381-384; Arino and Bullerman 1993, 718-721). Phosphine can be used as a fumigant to control the presence of *Aspergillus flavus* and *A. parasiticus* in warehouses with peanuts (Fernanda 1996, 407-411).

Application of chemicals potassium sorbate, potassium benzoate and sodium benzoate control or prevent the growth of fungus including *Aspergillus flavus* and *A.parasiticus* and production of aflatoxin (Bullerman 1983, 305-309; El-Gazzar and Marth 1987, 305-309; Rusul and Marth 1987, 820-825). These are currently being used in the food processing industry.

Experiments with oils extracted from natural herbs and spices show fungicidal properties against mycotoxin-producing fungi. Soliman and Badeaa (2002) tested the inhibitory activity of 12 essential oils and observed that they have different effects depending on their concentration. Oills of anise, fennel and caraway inhibitory effect was proportional to concentration. Overall oils of thyme, cinnamon, anise and spearmint had the best effect on inhibiting fungal development. Growth of *A. flavus* was also inhibited by carvacol (*Satureja montana*) and thymol (*Origanum vulgare*) while oil of ruta (*Ruta graveolens*) inhibited the synthesis of aflatoxins (Soares et al. 2016, 525-534). Kumar et al. (2016, 3725-3734) tested six essential oils for their ability to inhibit the growth stored grain fungi *Fusarium spp*. Corn mint (**Mentha arvensis** L.) had the best effect while thyme (**Thymus Vulgaris** L.) and Dill seed (**Anethum graveolens** L.) also had high inhibitory efficacy. The

Caribbean's variety of herbs and spices can therefore be used to control mycotoxins locally or be exploited for large scale production if it is commercially feasible.

Method of transportation and distribution: The method of transporting and distributing produce range from trucks to push-carts. The trays and bins should be cleaned before and after hauling produce. Equipment used in all forms of transportation must be washed and sprayed with a decontaminant. A clean lining made of natural fiber may be used to avoid direct contact with the surface of the containers where they are difficult to clean. Postharvest management practices, such as not stacking the bags of produce too high, minimizing the possibility of movement of produce during transportation and prevention of the produce falling to the ground should be practiced. A tarpaulin or any other suitable material should be used to cover produce during transportation.

Mycotoxin monitoring during processing: During the processing of foods to secondary (value-added) products, mycotoxin control should be based on the Hazard Analysis and Critical Control Point (HACCP). This involves applying strategies for prevention, control, good manufacturing practices and quality control at all stages of production from field to consumer (Lopez-Garcia et al. 1999).

Baker et al. (2014, 20181-2188) outlined the principles of HACCP to manage mycotoxins during the manufacturing process. These principles include agronomic data on specific crops to determine the potential for mycotoxin contamination. It also requires working with suppliers of raw materials to audit the effectiveness of mycotoxin control programs to prevent contaminated materials from being sent to the manufacturing facility. There is testing and inspection of the inbound loads at the manufacturing facility using industry standards and protocols. The finished product is also verified for release where the level of scrutiny and audit depends on the level of risk that is high-risk or low-risk. The manufacture of peanut butter should include the principles of HACCP to ensure a safe product (The American Peanut Council 2009).

Governments' Policies to Control and Monitor Mycotoxins in Produce

Good governance is necessary to achieve food and nutrition security (Ashley 2016, 165). Hence, the policies of governments in the Caribbean region should aim at production of high quality foods in order to ensure healthy and productive populations.

- ***Increase regional agricultural production*:**

  Agriculture's contribution to real gross domestic product (GDP) across the Caribbean region declined from 12.9% in 1990 to 7.1% in 2013. The economies of the Caribbean have traditionally been agricultural-based revolving around sugar, rice, and banana. Other crops of economic importance include coffee from Jamaica and Haiti and to a lesser extent spices such as nutmeg, mace and pimento (Deep Ford 2015, 6; CARIFORUM-EU Business forum 2015).

  Apart from the growing food import bill, the need for self-sufficiency, and a combination of factors including loss of access to preferential markets, tariff and non-tariff trade barriers, and high unemployment have forced the Caribbean countries to expand and diversify their agricultural production. For example in Guyana, apart from the wide range of locally-grown fruits and vegetables, cultivation is expanding to onions, carrots, potato, garlic and other spices in an attempt to reduce their food imports and improve their food self-sufficiency (Ministry of Agriculture Guyana 2013, 15).

  In all communities at the local level, more land should be made available to farmers, infrastructure for drainage and irrigation should be provided, and access roads to facilitate marketing and distribution of produce should become a priority. This should be accompanied by intense education about the advantages of 'eating local' and mechanisms to engage and encourage the youth to be involved in agriculture.

Community projects, such as the production of tomatoes, value-added processing into sundried tomato salad dressing in Paramakatoi, an indigenous community in Guyana, provide employment and financial independence to their members (Kaieteur News 2017). There is also an opportunity to brand the product since production is mainly organic. Such projects can be duplicated in urban areas in Guyana. Another example is the United Nations Development Programme (UNDP) and United States Agency for International Development (USAID) support to the Jamaican Government that provides training, technical knowledge and facilities aimed at encouraging youth involvement in agriculture and entrepreneurship (Ashley 2016, 72).

The Caribbean, especially bigger countries of CARICOM (Guyana, Belize, Suriname and Jamaica) have fertile and arable land capable of producing abundant food for the Region. Efforts by governments in Guyana in the food sufficiency thrust of the 1970's and 'Grow more food' campaign of the early 2000's have not yielded long-term desired results. CARICOM's initiatives aimed at increasing agricultural production in the regional economic organization by making land and other incentives available are still to be implemented.

Politically, economically, and socially, it is important to continue to strive towards achieving food security in the Region. This will slow the importation of food into the Caribbean while ensuring food sufficiency. Regionally, there can be various mechanisms to encourage farming such as provision of seeds and fertilizers, and reduction in the duties and taxes of farming equipment.

Beckford (2012, 30) suggests application of the food sovereignty approach to protect and regulate domestic agriculture and trade from being suffocated by imports. These initiatives would ensure that produce would be fresh by the time they reach the consumer since less time would elapse from farm to table and fungus and mycotoxins are less likely to contaminate the produce. Culinary institutions, agroprocessors, researchers and other stakeholders can be engaged to demonstrate innovative methods of preparing meals, adding value and improving methods of preservation of locally-grown foods. These may have health benefits since diets with antioxidants, fresh herbs and spices as suggested by Galvano et al. (2001, 120-131) can potentially confer protection from the effects of aflatoxins.

- ***Training and awareness***:

Training and awareness are vital components of any endeavor to achieve food security and reduce mycotoxin contamination in the region. Stezhko (2016, 18-22) pointed out that there is a correlation between Human Development Index (HDI) and Food security. Populations with high HDI have more qualified professionals and farmers in the agricultural industry enabling them to readily adopt new technologies and better manage their food problems. Hence the Caribbean countries should continue their endeavor to build capacity at all levels. Qualified professionals should be equipped with the technical knowledge to conduct research and provide training to all other members in the production and marketing chain. Training should include information about the types of food pathogens, the pathogens' harmful effects on humans and the methods of control.

Extension and Advisory services with trained agricultural officers are also required to provide support, so as to optimize productivity especially among farmers of limited resources. These farmers might not have the facilities to harvest, dry or store their produce in a timely manner, and this can lead to aflatoxin contamination.

Traceback, which tracks food from its source, requires training in record keeping at all levels of the production and marketing cycle. Among the benefits of traceback is identifying the source of contamination and implementing preventive and treatment measures. In Kenya, for example, training growers in Good Agricultural Practice (GAP) in preparing fresh and value-added products led to a significant increase in exports (Henson and Jaffe 2008; 564). Information can be disseminated through training sessions, face-to-face meetings, the traditional media of television and radio and the current social media such as email and Facebook. The method of dissemination should be appropriate to the target group.

For international trade, exporters will have to be trained in new guidelines required by importing countries. These guidelines in Codex Alimentarius and the Food Safety Modernization Act (FSMA) of the United States can limit export or can be beneficial to the exporting countries. The FSMA involves verification of the safety of imported foods from foreign suppliers. Thirty-seven percent (37%) of consumer-oriented goods entering the US is imported from the Caribbean. The requirements of the law include establishment of preventive controls at food-processing facilities and farms as well as certification and traceability measures (Mosquera et al. 2013, 151-176).

This means that each country must conduct its own self-examination to determine the changes needed to meet the standards. Mosquera et al. (2013, 167) suggest a value chain approach which is a systematic examination of key agents and supporting activities involved in taking a product from the initial stage to the final stage of consumption.

Adherence to the FSMA and other regulations by exporting countries can indirectly protect the local population. On the other hand, as pointed out by Cardwell (2001, 1), exporters may sell the high-quality foods overseas while leaving the low-quality food for the local consumer. Thus, leaving local consumers vulnerable to exposure by contaminants such as mycotoxins.

- ***Import replacement***

Increased crop and animal production along with related value-added processing should reduce the need for importation of food. Deep Ford (2015, 11) opined that corn and soyabean imported as protein source for the livestock industry can be replaced by rice, cassava and other root crops. Wheat flour is an important part of the diet for many countries in the Caribbean. Cassava flour can also be used as a substitute for wheat flour or used as a composite with wheat or rice flour.

Some studies of aflatoxin in cassava indicate that although the fungus *Aspergillus* is present, there was no aflatoxin B_1 present (Adjovi et al. 2014, 157). However, other studies found low concentrations of aflatoxins in cassava flour (Muzanila et al. 2000, 48; Gacheru et al. 2015, 202). Reduction of other imports, such as bottled and canned fruits and vegetable products, would prevent sickness caused by mycotoxins.

- ***Food Safety Regulatory Limit***

Regulatory controlled limits of mycotoxins in food should be established to protect the health of consumers locally and in importing countries. The mechanisms for determining the limits of various mycotoxins depend on the commodities, availability of toxicological data, the availability of data on the occurrence of mycotoxins in various commodities, the availability of methods of sampling and analysis, the inter-country trade implications, as well as the existence of sufficient food supply (Stoev 2013, 896).

The European Union and MERCOSUR (the trading block of Argentina, Brazil, Paraguay and Uruguay) have regulatory limits for their member states. However, CARICOM as a regional trading block does not have regulations for all countries even though there is the CARICOM Regional Organization for Standards and Quality (CROSQ) which is a regional body aimed at ‘promoting efficiency and competitive production of goods and services through the process of standardization and verification' with 15 country standard bodies.

Some member countries have their own regulatory limit for mycotoxins. Other countries such as Trinidad and Tobago adopted the Codex Alimentarius Commission's regulations, while Bahamas used the United States Food and Drug Administration limits (FAO 2003; Codex Alimentarius 1990; USFDA 2000) (see, Table 2). It cannot be emphasized enough that the CARICOM as a body should endeavor to have its own regulatory limits which harmonize standards as they relate to mycotoxin for regionally-produced and imported food.

It would also require that the Caribbean develops its own technical capabilities to conduct analyses for mycotoxin across the region. The laboratories can work towards having inter-laboratory standards, like the European Community, by adopting those standards formulated by established bodies such as the Association of Official Analytical Chemists (AOAC) or formulating its own standards (van Egmond 2007, 147-157).

Table 2: Mycotoxin Regulatory Limits for Selected Caribbean Countries, Codex Alimentarius and USFDA

Country/Organisation	Commodity	Mycotoxin	Limit (µg/kg)
Barbados	All foods Dairy milk Feeds – all feedstuffs	Aflatoxin B_1, B_2, G_1, G_2 Aflatoxin M_1 Aflatoxin B_1, B_2, G_1, G_2	20 0.5 50
Jamaica	Food, grains	Aflatoxin B_1, B_2, G_1, G_2	20
Suriname	Maize Groundnut, legumes Feed - Feedstuff	Aflatoxin B_1, B_2, G_1, G_2 Aflatoxin B_1 Aflatoxin B_1,B_2,G_1,G_2	30 5 30
Codex Alimentarius	All foods and grain Peanuts, raw Apple juice and apple ingredients on other beverages	Aflatoxin B_1, B_2, G_1, G_2 Aflatoxin B_1, B_2 Patulin	10 15 50
US FDA	Foods Milk Peanut and peanut products	Aflatoxin B_1, B_2, G_1, G_2 Aflatoxin M1 Aflatoxin B_1, B_2, G_1, G_2	20 0.5 20

Sources: www.fao.org/docrep/007/y5499e0c.htm
Codex Alimentarius Commission, document CL 1990/17-FAC.
www.fda.gov/food/guidanceregulation/ucm077969.htm.

Conclusion

Controlling mycotoxin in foods is rather straightforward if adequate measures are in place to manage them. Ensuring sufficiency of affordable and wholesome foods, however, is a more complex issue involving the political will, consumer awareness and sensitivity, and importantly getting buy-in from the food importers and distributors. Governments should provide incentives to encourage investments in local agricultural production. An approach involving the Caribbean governments, businesses, and producers should collaborate in putting systems in place to protect consumers.

Acknowledgement

The authors acknowledge the assistance of Dr. David Ledoux, Animal Scientist and Mycotoxin Researcher at the University of Missouri-Columbia, USA and Dr. Vernon McPherson, Animal Scientist (retired –now deceased) in reviewing the manuscript.

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