

Aflatoxins: Probing the Multifaceted Impacts and Innovative Solutions for Agri-food Security and Safety, Economic Stability, Trade and Public Health in Cameroon

Abstract

Aflatoxins (AFs), a class of mycotoxins, are well-known fungal toxins that frequently contaminate agricultural commodities especially nuts and maize, constituting a serious burden, not only to the economy and trade but results in harmful health effects following consumption of AFs-tainted foodstuffs. Preliminary reports of AF occurrences, and dietary exposures at population and individual levels revealed frequent contaminations of a variety of staple foods at occasional levels relatively higher than legislative maximum limits in foods. In contrast, no level is permissible in the body due to its carcinogenic (group 1), mutagenic, genotoxic, and immunosuppressive properties in humans. These reports collectively point to the need for national regulatory maximum limits of AFs in various foods to be prepared for human/animal consumption and or foods intended for direct consumption without any further processing. To effectively control AF dietary exposures nationally, there is a need for multi-sectorial and multi-stakeholder partnerships and institutions at all levels. The Inclusion of women at the center of every development and implementation of national AF prevention and control programs cannot be overemphasize (Figure 1).

Keywords

Aflatoxins • Agri-food safety • Biomonitoring • Dietary exposure • Economy/trade • Health • Legislation • Cameroon

Introduction

Agri-foods are frequently tainted with harmful natural contaminants such as aflatoxins (AFs), especially the B-forms (i.e., fluorescence under ultraviolet light to give

Research Article

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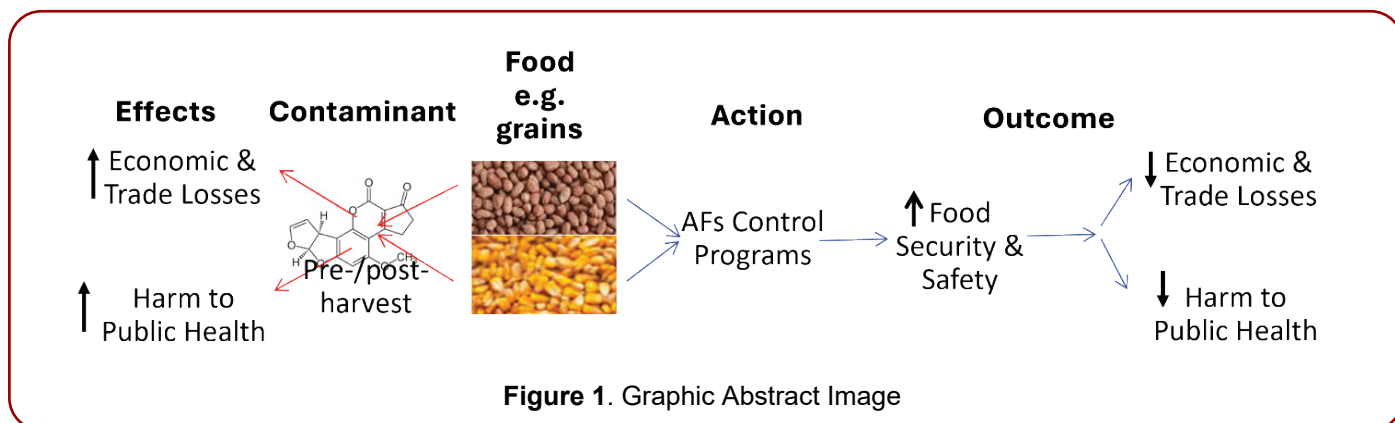
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Received: 24 June 2024; **Accepted:** 22 July 2024;

Published: 31 July 2024

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blue fluorescence) relative to the G-forms (that gives green fluorescence). Aflatoxins are naturally occurring toxins produced by toxigenic fungi as secondary metabolites intended to protect the fungi (certainly, not toxic to them), but unfortunately for humans/animals, AFs, like other mycotoxins, are harmful to man/animal. The most important AFs producers are *Aspergillus flavus* (well adapted in the above soil, thus produces only the G-form of AFs) and *A. parasiticus* (well adapted both in and above the soil, thus produces both the B- and G-forms of AFs). These toxic fungi species turn to secrete AFs only under favourable conditions including dry weather near crop maturity, high moisture during harvest, inadequate drying, storage of foods, and transportation of crops and



food products. Cameroon, like several other sub-Saharan African countries naturally located within latitudes 40 °N and 40°S is vulnerable to AF contamination. Agricultural commodities visibly contaminated by toxigenic fungi do not automatically imply contamination by AFs (or generally mycotoxins). Likewise, the absence of visible toxigenic fungi contamination does not necessarily imply the absence of AFs (or generally mycotoxins) contamination. Worthy of note is that once the fungi contaminate agricultural commodities, and establish their colony, once conditions are no longer favourable, it migrates, many times, unfortunately for man/animal as owners and dependants on the food/feed, the fungi might have already secreted its toxic secondary metabolites (AFs or in general, mycotoxins) which stays on the food invisibly.

Preliminary AFs reports revealed that AFs frequently contaminate many Cameroonian staple foods such as groundnuts, cereals, cassava, and some of their food by-products, and occur in occasionally high levels [9,10,12,16,23,18,1,5,19] as well as in feeds [2] and on the effects of processing [17]. Currently, Cameroon does not have a derived maximum limit (ML) of AFs in food/feed, thus depends on MLs set by Western bodies, particularly those with trade relationships with Cameroon such as the European Union (EU, European Commission, EC, for Europe), the Codex Alimentarius Commission (CAC)'s Food and Agriculture Organization [13], and the United States of America (USA, Food Drug Administration, FDA for the USA) [14]. Further to this, scientific evidence exists that AFs contamination of the major staple foods (groundnuts, cereals e.g., maize, and their food by-products) occurs above AFs 4 µg/Kg (4 ppb) (EC, 2023), 10 µg/Kg (10 ppb) [13], and 20 µg/Kg (20 ppb) AFs safe levels

fixed by the EU, CAC/FAO and the USA [14], respectively. Furthermore, based on the few AFs biomonitoring (or AFs biomarker) studies by [3,1,20], which mainly measure AFs levels in human urine and back-calculated short-term exposures of 1-3 days assuming a 1.5 L urine excretion per day, there seems to be a correlation between high dietary AFs levels in foods and dietary exposures. Again, dietary exposure assessment data based on the levels of the AFs B1 (AFB1) metabolite, and AFs M1 (AFM1) were unaccepted considering no amount of AF is tolerated in the body [22]. This paper provides a technical overview from the viewpoint of the IHAF/AFS1HA (Integrated Health for All Foundation/Agri-Food Safety and One Health Agency) Joint Report on food integrity (JRFI) working on the impacts of AFs in the agri-food, economy/trade, and health sectors in Cameroon, as well as proposed strategies some of which may already be implemented and others still under development.

AFs impacts on agri-food security (& safety), economy/trade and the health sectors

Potential impact on the agriculture and food security sector

Crops, especially cereals, and nuts, contamination by *Aspergillus* not only compromises the self-defences mechanism of the crop plant by the *Aspergillus* attack but also contaminates the crop seeds leading to AF production. AF contamination of the major staple foods can influence crop yields, with a direct or indirect impact on each of the four pillars of food security (namely, availability, access, utilization, and stability).

Aflatoxin contamination in staples such as groundnuts, cereals e.g., maize, and their food-based products, can directly reduce the availability of food. When considering that most local farmers sell agricultural commodities from their farms to enable them to buy foods they don't cultivate (that do not do well) in their areas, their relatively low income from selling their commodities translates into an inability to gain access or reduced access to other high-value foods. Altogether, AF contamination makes the fate of agricultural commodities as a source of income for local farmers very unstable and unpredictable. As a result, AF-contaminated food/feed in Cameroon presents a clear food security and safety threat.

Potential impact on the economy/trade sector

Globally, more than 4.5 billion people in developing countries are at risk of chronic exposure to AFs through the consumption of contaminated foods [26]. Health effects associated with dietary exposures to AFs pervade most developing nations worldwide, Cameroon inclusive. As a step towards consumers' health protection from a dietary mycotoxin perspective, many countries have instituted legislation against the major mycotoxins and AFs in particular. For example, the European Commission (EC) has fixed legislation for several mycotoxins (AFs inclusive) in various food commodities and consumer categories for the European Union. Likewise, the Food and Drug Administration (FDA) has provided regulatory limits for various mycotoxins (including AFs) in different foods destined for various consumer categories in the USA [14]. Following a world-wide study based on market samples survey, the FAO has put in place an assumed world mycotoxin (including AFs) regulatory values for various food mycotoxins vis-a-vis consumer sub-populations [13]. In Africa, about 15 countries, including Nigeria in West Africa, Kenya in East Africa, South Africa in Southern Africa, and Morocco in North Africa, have fixed specific mycotoxins regulations, especially AFs, in specific foods, mainly cereals and groundnuts. Particularly, it is only in Central Africa where not a single country still has to date no legislative value for even a single mycotoxin, not even the more dangerous AFs. It is but normal that Cameroon, known over the years for playing the food basket role, with preliminary mycotoxins (and mainly AFs) data as incentives towards some guiding values, definitely takes

the lead to fix ML of her top two mycotoxins of public health concern, AFs and fumonisins (FBs) from a mycotoxin's food safety perspective [1,3,5]. Failure to put in place national legislative limits for AFs simply implies exposing the country's economy to silent dangers including losses in market commodities (due to contamination or damage leading to insufficient market commodities, value reduction, and potential disease management cost in AFs exposed animals) and or loss of intended trade revenues that may indirectly be linked to product rejection at trade boarders, or to cost of compliance with standards in foreign markets (e.g., cost of testing), or to product under grading (from the intended human consumption to animal grade, with associated reduction in market value and price). To this vent, we have considered thorough reflections towards proposing maximum permissible limits for AFs and FBs sooner than later, in specific foods, mainly cereals and groundnuts that may hopefully serve as an incentive for the motion of national AFs prevention and control in Cameroon.

Potential impact on the health sector

AFs are well-known to exert toxic effects on humans once they consume contaminated foods. AF especially AF B1 is well recognized as a Class 1 carcinogen that induces or serves as a risk factor for human hepatocellular carcinoma (HCC) [15]. In Cameroon, preliminary studies also confirm findings elsewhere that chronic dietary exposure to even low levels of AFs in AFs-contaminated food increases the risk of liver cancer, and may lead to immune suppression [3] as well as malnutrition and stunting in children [23]. Likewise, AFs are known to induce severe health implications in animals once fed with AF-contaminated feeds either as caged animals or free-range animals. From a one-health approach, humans may become exposed to AFs by consuming animal-based food products such as eggs and meat provided the animals were already exposed to AFs in their diets. This is obvious when considering that visibly spoiled grains are generally used for animal feeds and or thrown around the compound as feed for free-range animals e.g., fowls, and we end up having the animals as protein sources, thus, we are simply recycling AFs (and mycotoxins in general) (Figure 2). Children (via direct consumption of complementary foods, AFB1), pregnant women (dietary as AFs especially AFB1, and which may

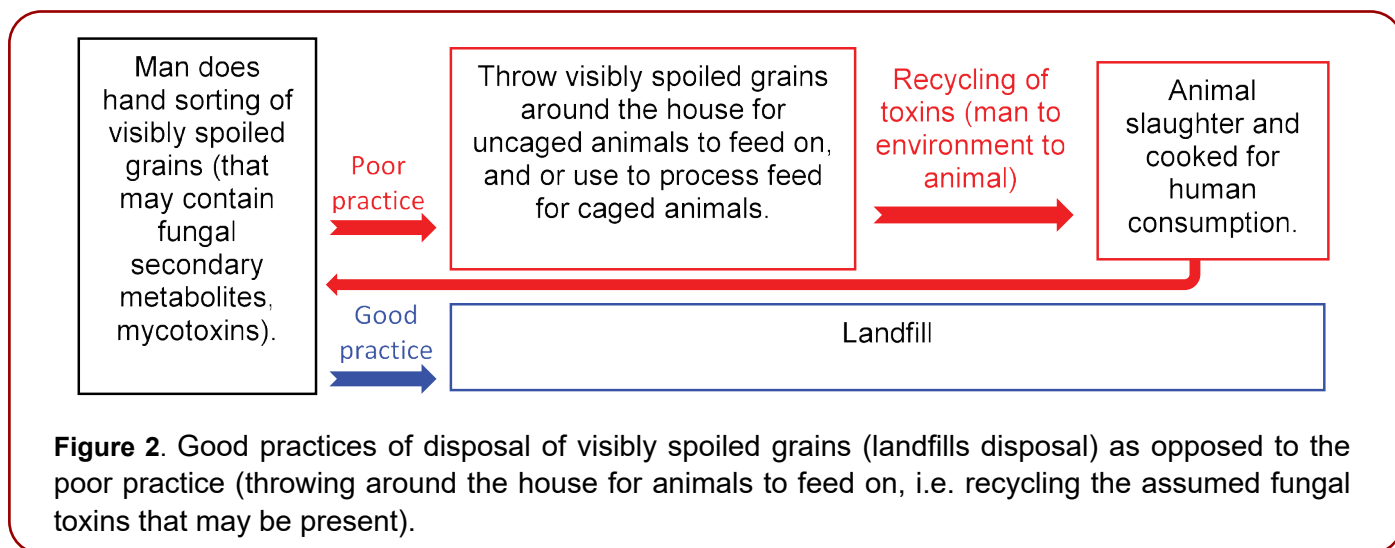


Figure 2. Good practices of disposal of visibly spoiled grains (landfills disposal) as opposed to the poor practice (throwing around the house for animals to feed on, i.e. recycling the assumed fungal toxins that may be present).

be transferred via blood meal to their unborn babies as AFM1), breastfeeding mothers (dietary as AFs especially AFB1, and which may be transferred via breast milk to their babies as AFM1), and the already immune-compromised individuals/categories (e.g., people living with HIV/AIDS) are the most susceptible to AFs exposures. Meanwhile, the potential risk derived from the additional mixture (such as stunting [21,24], as well as high incidence of liver diseases including hepatitis and cancer [6,7,8] amongst dietary AF exposed individuals remains poorly defined, dietary exposure to AFs contaminated foods presents a clear threat to food safety and public/consumers' health.

AFs prevalence and magnitude of impacts in Cameroon

The economic impact of AF contamination in Cameroon is yet to be evaluated formally. However, the AF's economic impact depends on two major factors, namely, the contribution that the liable food commodity makes to a country's consumption; and the income derived from trading the vulnerable commodities. Putting these together, it boils down to the food's share both in the nutrient requirements for the household, and as a source of income derived via national and international trades, both of which directly depend on the extent of awareness about the AFs problem within households and markets. If there is a general awareness of AFs in a country, accompanied by supporting regulations and institutions in place to enforce the legislation, then the impact of AF contamination on human health is likely to be low. Notwithstanding, it may be speculated that market impact will be high, considering

farmers or producers will have to painfully bear the burden of reduced revenues from discarded grains or costs borne for prevention and control strategies. The speculated high market impact scenario may be reduced through good agricultural practices (GAP) and good manufacturing practices (GMP). On the other hand, if awareness is low and there are no or inadequate regulations to control it, AF-contaminated foods shall be freely traded, in which case the health impacts are likely to be high. This later is the case in Cameroon. The majority of groundnuts and cereals such as maize production in Cameroon are used for a producer's consumption, implying that the human health impact will be very high as there is inadequate awareness about AFs.

In Cameroon, amongst the most vulnerable agricultural commodities are staple foods such as groundnuts and cereals such as maize. The dependence on these staples in Cameroon is relatively high across various regions of the country, symbolizing a devastating AFs-related economic/trade impact on Cameroon. Socio-economic investigations to provide data on the economic and trade impact of AFs in Cameroon are encouraged. More specifically, the women and generally the resource low-income and poor people, otherwise referred to as the masses are likely to be more economically affected by the AF's complex economic problem. For example, women constitute the majority of agricultural and market (such as "buyam-sellams") workforce, and thus remain strategic in AFs education and mitigation intervention strategies, and thus should be included at all levels of formulations and

planning, developing and implementation, monitoring, and evaluation, and decision-making processes including s, information gathering, planting, harvesting and marketing of AFs safe foods. The food insecure households are more likely to consume contaminated foods. Notwithstanding, if there is a mechanism for, and implementation of, proper information, education, and communications on AFs to the public, dietary exposure to AF may be reduced. Altogether, placing women at the center of the planning, development, implementation, monitoring, and evaluation of national AF prevention and control programs and strategies implies the inclusion of all stakeholders and sectors.

Need for united action to control AFs in Cameroon

Agricultural staple foods in Cameroon that are frequently tainted by AFs (such as groundnuts, maize, and cassava) are important for household food security and safety. Geographic imposed, and anthropogenic conditions in Cameroon, like elsewhere in Africa, turn to influence the observed chronic dietary exposure to AFs with devastating impacts on economic development and farmers and consumers health. For instance, preliminary reports all point towards occasionally higher levels of AFs whether in foods or the body, at levels generally exceeding EU, FAO, and SCF MLs. This is further complicated by the mixture of other common substances or worsening health conditions such as liver diseases and stunting which may act synergistically. Therefore, united action is necessary to control AFs in Cameroon.

Agriculture and food security and safety

Lots of efforts are being invested in the farms to produce food commodities to feed the over 26 Million people in Cameroon. Such efforts should not be compromised for anything and for whatever the reason may be. This leaves us with an undeniable fight to control the quality and guarantee the authenticity of our farm products/yields. This requires building and routinely strengthening the capacity of local farmers on GAP. Furthermore, encourage and promote capacity building amongst farmers and consumers on proper harvest and post-harvest food handling to reduce contamination levels. Such probably good yields should be protected jealously to conserve both food security and nutritional safety aspects for consumers.

Therefore, there is a need to strengthen the capacities of food businesses on GMP. Faced with the preliminary AF reports from Cameroon, it is vital to establish a cartographic map for AF contamination across different geographic locations, which may guide decision-makers on potential sources and actions on any commodity in the market.

Recently, the Ministry of Agriculture and Rural Development (MINADER) initiated the improved maize seeds. Such assumable AFs-resistant planting materials should be encouraged, while researchers keep an eye on safety issues, especially with confirmed determinants that guided the adoption of a given variety, e.g. the case of the Cameroon Maize Series (CMS) 8704 [11]. Furthermore, proven successful AFs bio-control agricultural development programs such as the Partnership for Aflatoxins Control Africa (PACA)'s AflaSafe (to reduce aflatoxin-producing fungi in soil) which is the most effective so far [25] should be highly encouraged and expanded (African Union (AU) Aflatoxin Mitigation Efforts Extended to 12 More Countries, <https://au.int/es/node/43213>). Furthermore, there is a need for more emphasis on the importance of sorting and discarding visibly damaged foods, especially grains (e.g., visible fungi or damaged shells).

Economy and Trade

Given the potential losses to trade of Cameroonian AF vulnerable agricultural commodities at local and international markets, there is a need to encourage and promote awareness and sensitization campaigns to increase demand for AF-safe food/feed-related products. There is a need to provide incentives to facilitate the adoption and application of AF control strategies along the value chain for various foods. Additionally, there is a need to build and continuously strengthen capacities in dealers of agri-chemicals to promote the commercialization and subsidization, distribution, and retailing of AFs-reducing inputs including bio-controls, drought- and disease-resistant seeds such as those from MINADER to farmers at all levels and localities. Building and or strengthening the capacity of agrochemical dealers, distributors, retailers, farmers, and consumers for united actions for safe foods from an AF perspective is important. Capacity improvement areas may include agro-chemical handling and or usage, food safety, and compliance with food safety legislation.

Outcomes may include safe handling and or usage of agro-chemicals as per prescription for the optimum function to guarantee nutritious and adequately safe foods as well as a healthy environment. Likewise, providing safe foods to consumers does not only contribute to improved health of consumers' it also promotes the brand. Furthermore, the consequences of putting unsafe foods on the shelf (both for consumers' health and for the business's brand) either due to negligence, non-compliance, or deliberate motives is a crime.

Furthermore, it's vital to encourage and promote routine training e.g., via workshops, seminars, and conferences for traders, processors, manufacturers, and livestock producers in Cameroon. Where possible, there is a need to appraise solutions applied to resolving the AF problem in similar geographic areas and tailor-make them as deemed suitable for Cameroon. Such tailor-made solutions can then be pre-implemented, monitored, and evaluated. Where proving effective, large-scale implementation either as tailor-made or with any calculated improvements vis-à-vis agro-ecological zones should be encouraged. A good example is the need to collaborate (where possible) with the existing Partnership for Aflatoxins Control in Africa's agriculture and development project aimed at promoting safe production through AflaSafe; MINADER's improved seeds (resistant crops) program, amongst others within Cameroon and the sub-Saharan region.

Potential AFs-related areas for food safety control systems

Recently in December 2019, Cameroon put in place her first food safety framework law, a well-deserved and much-appreciated tool for improving food safety and consumers' health. This tool potentially stimulates the need for plenty of complementing initiatives to enable it to gain full function. Considering the complex AF problem, which particularly affects children – the future of our nation, there is an absolute need for AF regulations in foods/feeds in Cameroon. This requires adjusting official and private food safety standards and control systems where possible to reflect GAP, GMP, and the Hazard Analysis Critical Control Point (HACCP) approaches –extensively discussed by [5] for food contaminants including tropane alkaloids and AFs in general. These adjustments should consider consumption ranges for

different commodities (e.g., Average Daily Intake, ADI), consumer sub-populations, and tolerance levels within the diversified ethnic groups. For animals, there is a need to fix standards for animal feed to initially be at higher levels than for commodities destined for human consumption, as a worst-case scenario.

Furthermore, there is a need to establish national MLs for AF food/feed contamination in Cameroon. These legislative values should consider the consumption patterns building on Codex Alimentarius and be consistent with the World Trade Organization Sanitary and Phytosanitary Agreement (the "SPS Agreement") [27]. Once such regulations are in place, it will be vital to ensure that the regulations are enforced and that necessary incentives towards the production of AFs control technologies and marketing of AFs-safe foods/feeds be made available as forms of grants to cutting-edge research initiatives.

Furthermore, to ensure maximum compliance, there should be wide dissemination of specifications for acceptable AFs maximum limits –a probabilistic value is on the way to be proposed by our team. The capacities of associated field inspection teams irrespective of the national or private enforcement agencies for food safety should be routinely built. The attainment of all the above is not without the enhancement of laboratory capacity and facilities such as rapid test kits, trained users, documentation of results, and withdrawal of contaminated products to enable greater separation of contaminated crops in markets, assembly points, export points, and before processing. This could include carrying out more regular testing of AF contamination levels in major foods and establishing reference laboratories for mycotoxins studies in general.

Health

Undoubtedly dietary exposure to AFs is a menace to public health but it can be controlled. It is very difficult to change old habits such as abstinence or moderation in the consumption of AF-vulnerable staple foods such as groundnuts- and cereals-based diets. Therefore, it may be vital to begin any dietary shift from infants, so they grow up with the modified taste, food culture, and practices for a more food-secured and nutritionally safe future. As such, dietary diversification (targeting a balanced diet) and food safety promotion initiatives (such as washing, hand

sorting, etc) to minimize dietary AF exposure should be encouraged.

When considering that infants and adults all eat from the same pot, it is vital to understand that infants/children may be relatively more susceptible to dietary AF exposures than adults. Therefore, a major target should be protecting infants by routinely testing levels of AFs in mothers and breast milk. Likewise, in emergencies, to reduce further harm particularly associated with blood transfusion to the patient, encouraging routine blood screening for AF contamination before acceptance of blood into blood banks and or blood transfusion is recommended. Furthermore, when considering the nexus between environmental, animal, and human health, AFs-contaminated foods/grains should be destroyed either by burning or buried in landfills rather than destined for animal consumption -fungal toxin recycling mechanism (Figure 2). Therefore, it is important to promote and protect animal health from an AF perspective e.g., using AFs-safe ingredients, and feed, while promoting further research on AF detoxification. These actions necessitate effective communication and information dissemination through awareness-raising initiatives, sensitization, and advocacy campaigns among all major stakeholders for a united coordinated action.

Dietary exposure assessments generally reveal populations' exposure to AFs. To properly understand the AF exposure situation at the individual level, there is a need to conduct more biomonitoring studies using urinary AF biomarkers and bio-measures to add to the few existing studies by [3,20]. This will lead to a meaningful pool of datasets on which major conclusions can be drawn.

Altogether, the proposed actions (presented in sections 4.1-3) towards mitigating the complex AF problem in Cameroon should ensure that information and resources on AF control target areas that result in high impact whether in agriculture, food security/safety, trade, and or health.

Such interventions should take into consideration that AF contamination may disproportionately impact those in the city (may largely depend on market foods) differently from those in rural (eat subsistent farming foods) areas, as well as the rich from the poor communities. Likewise, access to control systems and or facilities, or afford commercially available agricultural inputs known to directly or indirectly reduce AFs levels (e.g., improved maize breed) may not be even across cities and rural farmers, as well as between rich and poor farmers. Generally, AF mitigation is key to food safety and nutrition, and the protection of the health of consumers from adverse health effects associated with AF exposures, with credits to the trade and economy of every nation. Furthermore, the undeniable role of women at all levels including AF prevention and control cannot be undermined. Thus, all AF prevention and control strategies should be designed to keep women's managerial role in pre- and post-harvest production, and household food preparation central. Finally, no single intervention option is sufficient to combat the complex AF problem in Cameroon. Therefore, a united action at all levels and all regions in a collective and complementing manner including all sectors and stakeholders remains the way forward.

Conclusion

To control the complex problems put in place by AF contamination of food/feed in Cameroon, multi-sectoral and multi-stakeholder approaches are unavoidable to reduce AF prevalence and exposure in Cameroon. Congregative efforts shall undoubtedly lead to improved agri-food security and safety; income and livelihoods of local farmers, as well as trade relationships; and also, improve nutritional and health status of consumer sub-populations in Cameroon. While comprehensive AF prevention and control programs may include a range of very complementary efforts, the time is now for united action to reduce AF dietary exposures and associated health implications.

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Citation: Abia, Wilfred Angie, "Aflatoxins: Probing the Multifaceted Impacts and Innovative Solutions for Agri-food Security and Safety, Economic Stability, Trade and Public Health in Cameroon." *J Environ Toxicol Res* (2024): 108. DOI:[10.59462/JETR.1.2.109](https://doi.org/10.59462/JETR.1.2.109)