Journal of Food and Nutrition Sciences
2024, Vol. 12, No. 5, pp. 222-233
https://doi.org/10.11648/j.jfns.20241205.13

Review Article

Aflatoxins in Cameroon: Occurrence, Potential Health Risks and the Way Forward in Implementing the Partnership for Aflatoxin Control in Africa (PACA) Country-Led Model

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Abstract

Aflatoxin hazard is present among the main food dangers in Cameroon. This paper gives insight on how affected crops and commodities such as maize and groundnuts are likely to be contaminated with aflatoxin. Possible negative effects of aflatoxin include hepatic injury, cancer risk, kwashiorkor, and marasmus kwashiorkor is also discussed. Therefore, this report recommends using the Partnership for Aflatoxin Control in Africa (PACA) method for Cameroon. This policy also targets aflatoxin control to be a country-led, multi-sectoral approach. The aims of the study propose useful strategies for guiding the PACA approach; these include raising awareness of the health risks of aflatoxins, enhancing the laws on food safety, supporting adequate agricultural practices, and improving proper disposal and utilization procedures of post-harvest storage and processing systems. Government authorities and research institutes must collaborate to successfully execute aflatoxin control measures. The report emphasizes the need of capacity building, resource allocation, and monitoring systems in ensuring the efficacy of these initiatives. Thus, Cameroon can apply the PACA concept and the mentioned measures to decrease the level of aflatoxin contamination. Therefore, enhance the conditions for food safety and decrease the level of health risks. Consequently, this research provides useful information and suggestions to policymakers, researchers, and any party interested in Cameroon's aflatoxin-related programs. This paper emphasizes the need for capacity enhancement, resource mobilization, and the proper monitoring and implementation of the strategies. Through the application of the PACA approach and the above-outlined strategies, Cameroon can reduce the

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Received: 6 August 2024; **Accepted:** 2 September 2024; **Published:** 20 September 2024

incidence of aflatoxin contamination and its disturbing impacts on consumer health and food security. In conclusion, the findings and recommendations of this paper are highly informative to policymakers, researchers, and other interested stakeholders in Cameroon's aflatoxin management processes.

Keywords

Aflatoxin, Food Safety, Health Risks, Paca Approach, Aflatoxin Control Strategies

1. Introduction

These are molds that are toxic and are found in virtually all commodities; being secondary metabolites they can withstand heat. Mycotoxin is produced by fungi, especially the saprophytic molds found on food, grain, plants, and animal feeds. Over three hundred mycotoxins are known, with aflatoxins and fumonisins being the most common mycotoxins in tropical countries [1, 2].

Aflatoxins are toxic metabolites produced by fungi, belonging to the species *Aspergillus flavus*, *Aspergillus parasiticus*, and other related species [3]. These poisons are regularly present in basic African foods like maize, groundnuts, rice, and cassava. It is strongly believed that dry weather during planting, high wetness during harvest, and lack of proper crop drying and storing [3, 4]. Aflatoxin-contaminated food may contain one or more of the four major types of aflatoxins: which are collectively referred to as AFB1, AFB2, AFG1, or AFG2. Likewise, milk shall be contaminated with the hydroxylated metabolites of AFB1 and AFB2, which include AFL1-contaminated milk and AFM2-contaminated milk. Being the predominant toxin among the four major classes of aflatoxins in the natural environment, AFB1 has been linked with cancer in animal studies, if its potency is above the prescribed maximum [5, 6].

As a result, the World Health Organization (WHO) has identified aflatoxins as a global food safety risk. Peasants and farmers in rural areas of developing countries are thought to be more vulnerable to aflatoxin exposure [6]. *Aspergillus* species produce aflatoxins in several foods and feeds, particularly maize, sorghum, millet, oil seeds, spices, groundnuts, tree nuts, and dried fruits. These toxins often exceed safe levels in many African countries [7]. Contamination occurs at every stage of the food supply chain, from pre-production to post-harvest, marketing, and distribution. Post-harvest aflatoxin accumulation poses a particular challenge for Africa [8]. When commodities are polluted at any stage of the value chain, they remain tainted throughout.

In humans and other animals. Aflatoxins induce cancer, mutation, and immunosuppression [3]. As with other environmental chemicals, neurotoxic species are toxic to mammals, birds, and fish at high doses and may be lethal. Concerning the toxicity of aflatoxins in the worldwide market, their toxicity has been an area of considerable discussion, while concerning the economic aspects of trade partners' development, their economy has also been an area of debate.

It was established that over 48% of the Cameroonian population consumes principally maize-based meals; therefore, most of the people of Cameroon are probably subjected to mycotoxins consumption through food. The country's unique climatic conditions also encourage the growth of toxic molds in food [2]. In this regard, it becomes important to know the extent of the exposure or proportion of Cameroonians who take plant-based diets affected with aflatoxin contamination. This study was carried out with the intention of establishing the mycotoxin contamination levels in food commodities available in Cameroon and estimating the population's mycotoxin dietary intake based on scanty literature available. It also examines the possibility of using a country-owned initiative to tackle the mycotoxin issue in Cameroon by adopting PACA and possible modifications.

2. Agro-ecological Characteristics of Cameroon

Cameroon is located at the heart of West and Central Africa, with a surface area of 475,440 km². It is bordered by Chad to the northeast, the Republic of Congo, Gabon, and Equatorial Guinea to the south, Nigeria on its west side, and the Central African Republic to its east. Bight of Biafra, an arm of the Atlantic Ocean with the Gulf of Guinea provides grounds for Cameroon's coastal location [9]. As we can see from Table 1, the five agro-ecological zones are marked by distinct climatic elements, including rainfall patterns, humidity levels, and temperature in different areas. To begin with, Cameroon is located in West-Central Africa at an intersection of latitudinal and longitudinal lines. Between Chad and Nigeria on one hand and Gabon/Congo/Equatorial Guinea on another that shares its borders with Chad/Nigeria. It is found along the coastlines of an arm (Bight) of the Atlantic Ocean named the Gulf of Guinea; it is also part of Africa (Sub-Saharan). This country's nickname among geographers, "Africa in miniature," sums up its high biodiversity. It lies in a bio-climatic zone where five natural regions form agro-ecological zones.

The agro-ecological characteristics of Cameroon (Table 1) show that maize, cassava, and legumes susceptible to aflatoxin contamination are grown all over the country as well as birds' rearing, pig farming, fisheries, and small ruminants. For example, all the agro-ecological zones in Cameroon have a mean annual temperature of between 18 to 36 ◦C and a mean annual rainfall range between 500 to 11000 mm (Table 1). Consequently, Benkerroum [10] argued that countries with mean annual temperatures ranging from 22 to 29 ◦C and mean annual precipitation generally exceeding 700 km are most prevalent for aflatoxin contamination. In this environmental condition, aflatoxins are produced by high-level aflatoxigenic molds. Especially when the water activity (aw) of the commodity is within the range of 0.90–0.99 [9]. In Cameroon, most grains are harvested during the rainy season, when the climate is damp, which promotes fungal infection and mycotoxin development. This is indicated in Table 1 by several rainy months experienced in terms of higher humidity levels.

Table 1. *Agro-Ecological Zones of Cameroon: characteristics, geographical features, rainfall patterns, major crops cultivated, and animal species reared [9].*

Agro-Ecological Zones	Regions	Altitude (m) above sea level	Rainy days/ year	Rainy months/ year	Rainfall (mm)	Mean annual temperature, ℃ (range)	Main crop and animal production
Sudano-Sahelian	North and Far North	250 - 500	90–120	3-5	500-900	28 (7.7)	Maize, millet-sorghum, rice, cowpea, soybean, onion, sesame, fruits, cotton, cattle and small ruminants
Sudano-Guinean (High Guinea Savanna)	Adamawa	500-1500	110–150	7	1500 -1800	23 (6.4)	Maize, yam, cassava, sweet potatoes, rice, cotton, cattle, pig, small ruminants, poultry birds
Western Highlands	West and North West	1500-2500	175–220	7-9	1800 -2400	21 (2.2)	Maize, beans, potatoes, rice, sweet potatoes, vegetables, coffee, pig, poultry, cattle, small ruminants, fisheries
Humid Forest (monomodal rainfall)	Littoral, South West, and maritime parts of the South	0-800	180-240	9-12	2000-11 000	26 (2.8)	Bananas, plantain, cassava, cocoyam, sweet potatoes, maize, vegetables, cocoa, coffee, oil palm, rubber, fruits, poultry, pig, poultry birds, small ruminants, fisheries
Humid Forest (bimodal rainfall)	Centre, East, and South	400-1000	125-175	7-9	1500 -2000	25 (2.4)	Plantain, cassava, banana, maize, cocoyam, sweet potatoes, cocoa, oil palm, rubber, coffee, maize, cocoa, oil palm, fruits, poultry, pig, fisheries, small ruminants

3. Occurrence of Aflatoxin in Cameroon

Aflatoxin contamination is ubiquitous, especially in maize, other grains, groundnuts, and peanuts. The impact of aflatoxin contamination on exports is difficult to estimate due to the multiple factors impacting global trade and the infrequency with which regulatory requirements vary. However, studies exposing the harmful consequences of aflatoxins on health, food security, and trade have heightened awareness across Africa. Despite being produced in small quantities, the ease with which these highly potent, carcinogenic metabolites permeate African farmers' fields is a call for concern.

Most African commodities prone to aflatoxin contamination fail to meet globally recognized standards, including the Codex Alimentarius limits (<10 μg/kg for foods and 0.5 μg/kg for milk), the regulations set by the United States Food and Drug Administration (FDA), and the European Union (EU) standards {aflatoxin contamination level <20 parts per billion (ppb)}. Products contaminated with aflatoxins are routinely rejected by major purchasers, processors, merchants, and international regulatory authorities before entering vital export markets [3].

Cameroon, known as a "breadbasket," ships some of its crops and foodstuffs to neighboring countries such as the Central African Republic, Chad, Congo, Equatorial Guinea, Gabon, and Nigeria. These countries have lax phytosanitary inspections and pay little attention to aflatoxin contamination levels. This has not led to major rejections of crops and foodstuffs. Even if products are rejected due to physical signs of contamination, they end up being sold to animal feed producers, with maize constituting over 60% of poultry feed, thus posing a risk factor to animal health [11]. However, surveys conducted on maize in 1996 and 1997 in two Agro-Ecological Zones (AEZ) in Cameroon by researchers and academia indicated low rates of contamination with *A. flavus* and aflatoxin contamination (0–5.7%) across years and regions [12].

A multiyear investigation (2009-2011) spanning several AEZ found that all the maize-based products, peanut meal, and soybean samples were contaminated with aflatoxins [2, 13, 14, 16]. Levels of aflatoxin B1 (AFB1) were highest (6–645 ppb) during both samplings in the Humid Forest Zone and were more prevalent in 2010/2011 than in 2009 (mean: 81 and 35 ppb, respectively). More recently, higher occurrence and higher mean aflatoxin levels were reported in maize samples from Yaoundé (50%; 3.5 ppb) than in samples from Bamenda (6%; <0.13 ppb) [14]. However, a few other non-listed studies indicate aflatoxin contamination of sorghum, cassava flour, and soybean [13, 14]. Considering the impact of aflatoxins on exports and food security in Cameroon, Table 2 offers a concise summary of aflatoxin contamination levels in households and markets across Cameroon, comparing them with international regulatory standards for aflatoxins.

Table 2. *Aflatoxin contamination in household and market samples from Cameroon.*

Food commodity	No. of samples	Aflatoxin-positive occurrence (%)	Mean (Range) concentration (µg/kg) of aflatoxins (AFB1/AFM1)	References
Maize	40	55	1.5 (0.1–15)	Njobeh *et al.* [15]
	NS	09	1 (≤ 2–42)	Kana *et al.* [16]
	NS	74	(6–645)	Njumbe *et al.* [13]
	16	46	(11.3-11.7)	Ingenbleek *et al.* [17]
	11	30	4(<LOQ-12)	Abia *et al.* [14]
Maize kernels	165	22	(6−645)	Njumbe *et al.* [13]
Kutukutu (fermented maize-based dough)	29	100	(≤2.8)	Tchikoua *et al.* [18]
Maize-based dishes	22	100	8(0-.20)	Nguegwouo *et al.* [2]
Maize-fufu	50	24	0.9 (n.d-1.8)	Abia *et al.* [19]
Maize-beer	5	36	1.8 (0.7-3)	Abia *et al.* [14]
Peanuts (Groundnuts)	16	75	6.5 (0.1–13)	Njobeh et al. [15]
	90	29	(0.3−12)	
	NS	62	(6–125)	Njumbe *et al.* [13]
	10	46	(56.4 -56.7)	
	35	97	47(<LOQ-210)	Abia *et al.* [14]
Peanuts meal	41	100	161.4 (39–950)	Kana *et al.* [16]
Peanuts oil	02	46	(60.2-60.4)	Ingenbleek *et al.* [17]
Groundnuts soup	11	73	15 (<LOQ -37)	Abia *et al.* [14]
Beans	15	33	2.4 (0.2–6.2)	Njobeh *et al.* [15]
	16	46	(1.2 - 1.6)	Ingenbleek *et al.* [17]
Soybeans	05	40	2.1 (0.2–3.9)	Njobeh *et al.* [15]
	10	100	2.6 (1-3)	Abia *et al.* [14]
Sorghum	NS	75	(0-230)	Djoulde [20]
	NS	45	(0-145)	

Food commodity	No. of samples	Aflatoxin-positive occurrence (%)	Mean (Range) concentration (μg/kg) of aflatoxins (AFB1/AFM1)	References
	10	46	(0.9-13)	Ingenbleek *et al.* [17]
Cassava	NS	24	(6–194)	Njumbe *et al.* [13]
Stored Cassava chips	72	33	(5.2 - 15)	Essono *et al.* [21]
Cassava products (flakes+chips)	165	25	(6−194)	Njumbe *et al.* [13]
Rice, pumpkin seeds "egusi", fermented cassava flakes "gari", fermented cassava flour “nkum-nkum"	06	17	0.3	Njobeh *et al.* [15]
Smoked fish	06	46	(0.8-1.1)	Ingenbleek *et al.* [17]
Other dried food commodities		51	2.6	Njobeh *et al.* [15]
Eggs	62	45	0.82 ±1.7	Tchana *et al.* [22]
		NS	7.86	Speijers & Speijers, [23]
Cow milk	63	16	0.006-0.53	Tchana *et al.* [22]
Breast milk	42	38	7.4 (0.9-37)	Chuisseu *et al.* [24]
Poultry feed mixtures (broiler)	NS	93.3	11.1 (2–52)	Kana *et al.* [16]
Poultry feed mixtures (layer feed)	NS	83	6.6 (2–23)	
Poultry feed	19	95	38.1(1.2-200)	Abia *et al.* [11]
Breast milk	NS	4.8	0.005-0.652	Tchana *et al.* [22]

*NS=Not specified, LOQ =Limits of quantification

Research in Cameroon (Table 2) has revealed high aflatoxin levels in peanuts, with average concentrations ranging from 0.1-13 μg/kg to 56.4-56.7 μg/kg and positive rates from 29-75% [13, 15]. These values are higher than the Codex Alimentarius dietary limits. This poses a serious health concern to consumers, demanding comprehensive contamination control methods throughout the peanut supply chain. These findings highlight the importance of guaranteeing the safety of peanut byproducts in Cameroon and tackling aflatoxin contamination in peanuts [14].

Aflatoxin has been reported in a variety of sources like eggs (45%), milk (16%) and breast milk (38%). Kana et al. [16] found that 93.3% of broiler feed and 83% of layer feed had aflatoxins, ranging from 2-52 μg/kg mean values for 2-23 μg/kg, respectively. The findings emphasized the potential danger of exposure to aflatoxins in Cameroon.

These differences in sampling methods, agricultural activities, storage facilities, and analytical techniques may be due to the different results obtained throughout the various studies. It is worth mentioning that human health risks are associated with aflatoxin contamination because liver damage and an increased risk of liver cancer can result from the consumption of contaminated maize. It is therefore important to employ best practices during agriculture, correct procedures at post-harvesting phase, proper keeping places as well as quality control mechanisms to reduce its contamination in maize. This would be achieved through constant monitoring and public awareness programs, especially on aflatoxin exposure to food safety in Cameroon.

4. Aflatoxin Health Risk in Cameroon

The high consumption of aflatoxin-susceptible commodities in Africa is exacerbated by the fact that rejected items that do not meet international standards enter African food and feed supply chains. This raises the chance of exposure to these poisons. These findings afford strong evidence that chronic aflatoxin exposure in Cameroon elevates the status of a variety /wide range/ of peremptory infectious and non-infectious diseases. Its long-term effects or fluctuations in the levels present have been associated with immunodeficiency and suppression of the immune system, stunted growth and kwashiorkor malnutrition, and abnormalities in the metabolism of micronutrients in children. In addition, the consumption of this food item has been linked to liver cancer, especially among hepatitis B or C and or liver disease patients (Table 3) [3, 17, 22].

A study was reported by Njumbe et al [25] in Cameroon on the concentration of aflatoxin in children 1 to 5 years of age. Table 3 highlights the content of aflatoxin within these youngsters was between 0. 00006 and 0. 048 μg/L. The present work reaffirms the earlier finding of this study that young infants in Cameroon are highly exposed to aflatoxin pointing towards a possible health risk associated with aflatoxin contamination.

Table 3. *Potential Health Risks from Aflatoxin Consumption in Cameroon.*

Exposure	Subject	Frequency of aflatoxin-positive samples (%) (Male/Female)	Aflatoxin contamination rate/concentration (AFM1) (μg/L)	References
Human	Adults (83% HIV-positive)	83	Detected	Abia *et al.* [26]
	Kwashiorkor (35.5%)	44/43	0.109-2.84	Tchana *et al.* [22]
	Marasmic Kwashiorkor (45.5%)	60/33	0.109-0.864	
	Control (11.1%)	15/6.3	0.007-0.15	
	Liver cancer (63.9%)	19/43	0.450-1.560	
	Children (age 1-5 years)	NS	0.00006-0.048	Njumbe *et al.*[25]

*NS=Not specified

In terms of productivity, the presence of aflatoxins in livestock is anticipated to have an impact on the availability of nutritious animal-based food, thereby affecting food security [27]. Although milk contamination poses the greatest concern for public health, other animal-derived products can also contain aflatoxins if the animals consume contaminated feed. The livers and kidneys of animals are particularly prone to containing high levels of aflatoxins (Table 3). In Cameroon, aflatoxins were detected in 25-52% of eggs, with the highest levels of 7.2 ppb and a mean of 0.8 ppb [22].

5. The Way Forward for Cameroon

Aflatoxins are considered a significant food safety threat in Africa, with contamination starting in the field and continuing during postharvest, worsened by humid climatic conditions and poor agricultural practices. As a result, aflatoxin contamination can happen at any stage of the food supply chain, affecting the health, trade, and agriculture sectors. This complexity makes controlling aflatoxins challenging, as there is no simple solution or single approach to effectively address the problem. However, a collaborative effort among the public and private sectors including government departments of agriculture and rural development, livestock and fisheries, scientific research and innovation, trade, public health, etc., research institutions, various stakeholders like the private sector, youth and development partners is crucial to effectively mitigate aflatoxin occurrence and safeguard public health in Africa. The Partnership for Aflatoxin Control in Africa (PACA) takes the lead in a collaborative endeavor to safeguard crops, livestock, and individuals from the harmful impacts of aflatoxins. PACA strives to combat these toxins, thereby making significant contributions to enhancing food security, promoting better health, and fostering trade throughout Africa. This ensures that agricultural resources are protected, public health is improved, and economic opportunities are boosted across the continent [27].

5.1. Partnership for Aflatoxin Control in Africa and Its Role

The Partnership for Aflatoxin Control in Africa (PACA) was founded in October 2012 as part of the African Union Commission (AUC). It was approved by the African Union Executive Council under Decision No. EX.CL/768 (XXII) [28, 29]. The primary purpose of PACA is to coordinate and assist with aflatoxin mitigation and control throughout Africa's health, agriculture, and trade sectors. PACA functions on the continental, regional, and national levels. On a continental level, PACA has developed a comprehensive program for aflatoxin control, encompassing various solutions and practical actions. At the regional level, PACA collaborates with Regional Economic Communities (RECs) to create Regional Aflatoxin Control Action Plans, which promote effective aflatoxin control along agricultural value chains, advocate for supportive policies, and harmonize aflatoxin standards. As Africa enters the Africa Continental Free Trade Area (AfCFTA), regional blocks will require robust and effective trade measures to aid countries in integrating into African markets and accessing profitable international markets. At the country level, PACA primarily provides direct support to African governments in their aflatoxin control efforts [27-29].

PACA plays a crucial role in Africa's aflatoxin control endeavors by assuming leadership and coordination responsibilities. Its primary functions include acting as a catalyst, facilitator, partnership and knowledge intermediary, project developer, and information hub. PACA also advocates for the creation of supportive policies and institutions, enhanced investment, and the mobilization of resources. Additionally, PACA aims to serve as a grant-maker to support priority activities related to aflatoxin control. PACA identified the following strategic thematic areas for collaboration [28]:

1) Advancing research and technology to prevent and control aflatoxins;
2) Developing policies, legislation, and standards for effective aflatoxin management;
3) Promoting commerce and trade while safeguarding human health from aflatoxins;
4) Strengthening capacity for efficient aflatoxin prevention and control;
5) Increasing public awareness, advocacy, and communication regarding aflatoxin-related issues.

The six countries began implementing the PACA country-led model in collaboration with AUC 4-5 years ago, while the three RECs started collaborating with PACA even earlier. They aimed to test and establish countrywide strategies for aflatoxin management as well as to readily assimilate measures to manage aflatoxin in the six mentioned countries. This has been achieved by PACA, which has developed and implemented country-led aflatoxin control plans [30].

Such a country-led and holistic model with practical and sustainable strategies has proved to reduce aflatoxins in African countries. It has been synthesized into a Strategic Framework for Scaling Up a Comprehensive Country-Sustained Model for Combating Aflatoxin in Africa and the same was approved by the 36th Meeting of the Ordinary Session of the Executive Council in February 2020. The decision (EX. CL/Dec. 1074(XXXVI)) called for the establishment of aflatoxin control strategies within the National Agriculture Investment Plans (NAIPs) and other national processes for long-term countrywide implementation throughout 55 AU Member States [29].

5.2. PACA Country-Led Model

The country-led model follows a 5-stage approach, where a unified government-led country plan is developed. This plan serves as a bridge between necessary interventions, resource allocation, and coordinated efforts for aflatoxin control. It ensures cohesion and provides a framework for effective implementation of aflatoxin control measures. PACA concentrated on implementing stages 1–3 during 2021–2022, while also increasing the capacity to implement the plan and monitor progress. The strategic framework for scaling a comprehensive country-led approach to aflatoxin control in Africa, as outlined by PACA [30], consists of five stages:

Stage one involves the collection of evidence to gather relevant information and data that will inform the development of an effective plan for aflatoxin control. This stage aims to have a solid foundation of scientific knowledge and understanding of the problem.

Stage two focuses on developing, validating, and finalizing the country plan. It includes engaging stakeholders, such as government officials, researchers, and farmers, to ensure their feedback and expertise are incorporated into the plan. This stage strives to create a well-designed, practical plan that meets each country's distinct concerns.

Stage three highlights the importance of integrating the plan into national strategies. This stage assures responsibility and sustainability by integrating the aflatoxin control plan into national agendas and policies. It understands that the plan's successful implementation will require concerted effort and cooperation from all sectors and stakeholders.

Stage four emphasizes the significance of building government capacity to effectively implement the plan. This stage focuses on giving government agencies and officials the training, resources, and support they need to implement their strategy effectively. Strengthening government capability is critical for long-term success and the execution of effective aflatoxin control strategies.

Stage five involves monitoring progress and advocating for the success of the plan. Regular monitoring and evaluation can help to identify gaps or areas for improvement, allowing for timely changes and improvements. Advocacy initiatives seek to create awareness, get political support, and mobilize resources to ensure the plan's success.

5.3. Achievement of the Country-Led Approach

The country-led approach has achieved significant milestones within the 6 AU Member States, including [30]:

1) Government commitment: Governments have prioritized aflatoxin control efforts.
2) Sustainability: National strategies, school curricula, and agricultural extension programs now incorporate national aflatoxin control plans.
3) Financing: Implementation has been supported through financing from various sources, such as the Global Agriculture and Food Security Program (GAFSP), African Development Bank (AfDB), government funds, and external partners like GIZ.
4) Coordination: Ministries have collaborated through joint planning and work, facilitated by National Steering Committees and Aflatoxin Technical Working Groups in most pilot countries.
5) Progress tracking: Baseline surveys, monitoring, and evaluation training, as well as annual progress reports, help track and measure the impact of aflatoxin control efforts.

5.4. Challenges of the Country-Led Approach

The country-led model faces various challenges, including [29]:

Challenges in mobilizing resources: It is difficult to secure predictable and sufficient financing for implementing the model [31]. Beltran & Bandyopadhyay, [31] confirmed that securing predictable and sufficient financing for implementing the aflatoxin biocontrol model is difficult due to the complexity of the implementation process, which includes multiple stages such as registration, acceptance, and market linkages that require significant time and resources. Furthermore, the lack of incentives for farmers and governments to adopt aflatoxin control technologies, as well as poor policy enforcement and implementation, make it difficult to collect the funds required for model implementation.

Weak data collection and sharing capacity: African countries have numerous problems in collecting and sharing data on aflatoxin contamination. One major issue is the lack of reliable data collection mechanisms and capacity within many African countries [32]. This limited capacity results in a significant imbalance in data availability, with most data coming from only three countries: Egypt, Kenya, and Nigeria [32]. Furthermore, Meijer et al. [32] highlighted that a comprehensive approach considering multiple contaminants is often absent, further limiting the quality and breadth of data. To successfully combat aflatoxin contamination, capacity and coordination limitations in data collecting and sharing must be addressed, as they are critical for guiding African policies and initiatives [32, 33].

Limited national capacity for conducting situational analyses: Many African countries struggle to conduct complete situational studies on aflatoxin contamination. Some countries lack the necessary expertise and resources for conducting comprehensive situational analyses. Many countries in the ECOWAS region face limitations in terms of human and infrastructure capacity for aflatoxin analysis [34]. Similarly, a situational study conducted in Ghana indicated gaps in teaching and research capacities, as well as insufficient awareness, attitudes, and behaviors among value chain actors about aflatoxins and their management [35]. This is a common challenge across sub-Saharan African countries, including Cameroon. In Tanzania, the monitoring systems for aflatoxins were found to be inadequate in gathering the necessary information for guiding policy decisions and interventions [35]. These capacity constraints, such as the lack of appropriate facilities, equipment, and trained personnel, hinder the ability of African countries to conduct comprehensive situational analyses on the extent and impact of aflatoxin contamination. This information is crucial for developing effective control strategies and policies.

Delays in public systems: Implementation of the model is hindered by delays, particularly within public systems. Issues related to corruption and governance can have a negative impact on the level of interest and dedication towards implementing policies, resulting in inefficiencies and delays within public systems [36]. Furthermore, the improper use of resources and a lack of coordination between different agencies can cause delays in response and communication within public systems. These obstacles can hinder the timely execution of projects and initiatives, ultimately affecting the effectiveness of public systems in implementing various models and policies.

The high turnover rate of civil servants, especially in laboratories: The frequent turnover of civil servants in laboratories necessitates repeated training to maintain the required level of expertise. The expenses associated with replacing laboratory personnel are substantial, making it difficult to maintain a stable workforce. Moreover, dissatisfaction with salaries, reductions in real-term pay, and limited opportunities for career advancement contribute to the high turnover rates within the civil service, negatively affecting morale and institutional knowledge. The frequent movement of staff within the civil service, driven by the desire for promotion and salary increases, worsens the turnover issues, impeding the development of expertise in specific subject areas and impacting the efficiency of public systems [37].

Difficulties in fund disbursement: Although countries allocate funds for the model in their national budgets, challenges are encountered in effectively disbursing these funds. The improper use of resources, dissatisfaction with salary, and slow career advancement among government employees can lead to high rates of employee turnover, which can negatively affect the stability and effectiveness of mechanisms for distributing funds, particularly in developing countries [37]. Inadequate governance structures and accountability mechanisms in institutional financing can create opportunities for corruption and misuse of funds, further complicating the process of distributing funds [38]. These challenges highlight the need to address concerns related to standardization, human errors, turnover rates, governance, and accountability to ensure that the process of distributing funds is efficient and effective.

5.5. Implementing the Country-Led Model to an Additional Twelve (12) Countries

Building on the success of the six AU Member States, PACA has expanded the country-led approach to include an additional 12 countries. These nations are Angola, Benin, Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Mali, Rwanda, Togo, and Zambia [30]. The attention has now been widened to include food safety issues other than aflatoxins. PACA's current activities in these countries involve various initiatives. These include generating evidence on food safety, enhancing coordination among relevant ministries, developing comprehensive and costed food safety master plans, prioritizing evidence-based policies and interventions to elevate food safety standards, and providing support for plan implementation. Key tools utilized in these processes include country profiles and food control assessment templates.

In the twelve (12) new PACA-led countries, several processes are undertaken to establish and strengthen aflatoxin control efforts [30]:

1) First, PACA works with the country's government and stakeholders to prioritize aflatoxin control and establish a focal institution to oversee implementation.
2) Roundtable sessions bring together key stakeholders

from government agencies, academic institutions, industry, and civil society. These sessions facilitate debate, information sharing, and consensus building regarding aflatoxin control techniques.

3) To analyze the current state and identify gaps, the World Health Organization (WHO) and Food and Agriculture Organization (FAO) country profiles and Food Control Assessment tools are introduced. These tools provide a systematic approach to evaluating the status of aflatoxin control measures, food safety regulations, and laboratory capacity.
4) Member states are then trained on how to effectively utilize these tools. This training equips them with the necessary skills and knowledge to conduct assessments and identify areas that require improvement.
5) PACA provides support to countries in developing their country profiles and conducting assessments using the tools. This ensures that each country has a comprehensive understanding of its specific aflatoxin control challenges and can prioritize interventions accordingly.
6) Based on the findings of the assessments, costed Food Safety Master Plans are developed. These plans outline a roadmap for implementing aflatoxin control measures, including specific actions, timelines, and resource requirements. The costed plans help guide countries in allocating resources effectively and ensure a systematic approach to aflatoxin control.
7) Overall, these processes in the new PACA-led countries aim to build strong foundations for aflatoxin control, foster collaboration among stakeholders, and develop evidence-based strategies to mitigate aflatoxin contamination and ensure food safety.

PACA's approach in the 12 new countries is expected to yield several outcomes that are crucial for effective aflatoxin control and improved food safety [30]:

1) Firstly, the completion of country profiles provides a comprehensive understanding of the specific aflatoxin control challenges and the existing food safety situation in each country. These profiles serve as a baseline for designing targeted interventions and measuring progress over time.
2) Secondly, the assessments conducted using the WHO/FAO country profile and Food Control Assessment tools help identify gaps in aflatoxin control measures and food safety systems. This identification of gaps is crucial for developing tailored strategies and interventions to address the specific challenges faced by each country.
3) Thirdly, the outcomes also include the development of National Costed Food Safety Master Plans. These plans outline a strategy for implementing aflatoxin control methods and increasing overall food safety. These plans, which outline precise activities, timetables, and resource requirements, assist governments in successfully prioritizing and allocating resources to reduce aflatoxin contamination and improve food safety.

Overall, PACA's approach in the 12 new nations is expected to result in a complete understanding of aflatoxin control difficulties, gap identification, and the formulation of strategic plans to guide actions and resource allocation. These outcomes are critical for fostering evidence-based decision-making, increasing stakeholder collaboration, and eventually improving food safety in these nations.

5.6. Conceptual Framework and Econometric Models for Economic Impact Assessment of Aflatoxins and Methodology of Situation Analysis

Estimating the economic impact of aflatoxin contamination involves a systematic approach that includes several steps [30]:

Step 1: Identification

The first step in calculating the economic impact of aflatoxin contamination is determining the source and extent of contamination. This entails gathering information on the prevalence of aflatoxin contamination in various food (crop) and feed commodities, as well as the locations and nations impacted. This can be accomplished by monitoring systems, testing programs, and literature studies. This helps you comprehend the problem's breadth and magnitude.

Step 2: Dose-response and exposure assessment

Once the sources of contamination have been established, the next step is to investigate the link between aflatoxin exposure and health effects. This includes investigating the dose-response relationship, or how different amounts of aflatoxin exposure affect human and animal health. This can be accomplished by laboratory studies, epidemiological research, and animal feeding experiments. Exposure evaluation is calculating the amount of aflatoxin that people or populations are exposed to through their diet, which can be accomplished using dietary surveys and biomarker analysis.

Step 3: Risk characterization

This step compares anticipated exposure levels to established toxicological thresholds or guidelines to determine the level of danger provided by aflatoxin contamination. This includes determining the likelihood and severity of health impacts linked with specific exposure levels. Risk characterisation assists in identifying the most vulnerable populations or groups, as well as informing risk management techniques.

Step 4: Value of the impact

After determining the health concerns associated with aflatoxin contamination, the next step is to determine the economic effect. This involves calculating the direct expenses of healthcare, treatment, and productivity losses owing to aflatoxin-related illnesses. In addition, indirect costs such as poorer crop yields, reduced trade prospects, and higher regulatory and monitoring expenditures should be addressed.

Step 5: Economic impact

The third step is to assess the overall economic impact of aflatoxin contamination. This can be accomplished through cost-benefit analysis or by developing economic models that evaluate the influence on various sectors such as agriculture, trade, and public health. Economic impact assessments assist stakeholders, governments, and policymakers in understanding the implications and prioritizing efforts to reduce the economic burden of aflatoxin contamination.

By taking this technique, policymakers and researchers can gain a thorough grasp of the economic impact of aflatoxin contamination. This data is critical for making educated decisions, prioritizing treatments, and pushing for investments in aflatoxin control methods that will lower the economic effect and preserve public health.

6. Conclusion

The possibility of having food contaminated with aflatoxin is a major challenge to the food safety and health of people in Cameroon. Aflatoxin interferes with different types of crops and commodities which poses health effects on the population's health as well as has an economic impact. This exposure is aired most through bad practices in agriculture, lack of proper storage facilities and lack of information. To this effect, the Partnership for Aflatoxin Control in Africa (PACA) assists Cameroon in undertaking risk assessments, as well as the formulation of country-specific classifications, and Food Safety Master Plans with component costs. Solutions relevant to the problem include encouraging GAP, proper handling and storage of produce, strengthening institutions and organizations, and increasing awareness of all the stakeholders. It means that cooperative relations and investments in the laboratories are essential to guarantee the implementation of food safety standards. By so doing and applying multiple sectoral strategies, Cameroon could easily minimize aflatoxin contamination, thus improving food safety and achieving the much-needed health sector reforms. As a result of these PACA activities in collaboration with all stakeholders, the above-laid objectives will be met and the food supply in Cameroon will progressively be safer and healthier.

Abbreviations

PACA	Partnership for Aflatoxin Control in Africa
AFB1	Aflatoxin B1
AFB2	Aflatoxin B2
AFG1	Aflatoxin G1
AFG2	Aflatoxin G2
AFM1	Aflatoxin M1
AFM2	Aflatoxin M2
AFL1	Aflatoxin L1
WHO	World Health Organisation
EU	European Union
AUC	African Union Commission
RECs	Regional Economic Communities
AfCFTA	Africa Continental Free Trade Area
AU	Africa Union
GAFSP	Global Agriculture and Food Security Program
FAO	Food and Agriculture Organisation
AfDB	African Development Bank
ECOWAS	Economic Community of West African States
NAIPs	National Agriculture Investment Plans
GAP	Good Agricultural Practice

Acknowledgments

The authors express their gratitude to the African Union Commission (AUC) through the Partnership for Aflatoxin Control in Africa (PACA) for their continuous invitation of the first author to essential workshops and training sessions on aflatoxin in Africa, as well as for providing us essential materials on aflatoxins in Africa for this review.

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Funding

No funding was received for this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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