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A method to prioritize the surveillance of chemicals in food commodities to access international market and its application to four countries in Sub-Saharan Africa

E. Armaroli[c,1], C. Bechaux[d,1], R. Delagrave[c,1], L. Ingenbleek[a,b,1], J.Ch. Leblanc[e,*,1], P. Verger[c,1]

[a] Centre Pasteur du Cameroon (CPC), Yaounde, Cameroon
[b] LABERCA Oniris, Nantes, France
[c] World Health Organization, Regional Centre for Environmental Health (WHO/EMR/CEHA), Amman, Jordan
[d] Agence Nationale pour la Sécurité de l'Alimentation, de l'Environnement et du Travail (ANSES), Maisons Alfort, France
[e] Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

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ABSTRACT

The purpose of this study was to propose an approach to predict the distribution of chemicals in food in developing countries to assess consumer risk and access to the international market with a limited number of laboratory analyses. The first step consists of identifying the GEMS/Food Contaminants database and the chemical/food combination relevant for a particular country. The identification of critical chemical/food combination should be used to prioritize the analysis to be performed in a total diet study (TDS). The second step consists of modelling a distribution model based on the mean concentration generated from TDS associated with the variability observed in a larger dataset consisting of individual food contamination data from the GEMS food database. The simulated distributions may provide information regarding how to establish food safety standards and to assess the potential for accessing international market in the context of a value chain. This method is illustrated by case studies from the recent Regional TDS (RTDS) conducted in Sub Saharan Africa.

We concluded that further work is needed to gain experience and to fully validate this approach. However, organized data sharing and developing harmonized methods for data analysis are key roles for international organizations, such as FAO, WHO, and WTO. Finally, it is important to remember that such a data-driven approach still requires significant investments in terms of human resources and analytical capacity.

1. Introduction

The implementation of a risk-based approach to assess food safety allows for better consumer protection and safe food commodities for international trade. Market access is central to fostering the growth of developing and transition economies. The benefits for successful exporting countries are as follows: (1) acquiring higher amounts of currencies; (2) decreasing trade deficits or increasing trade surplus; and (3) contributing to the generation of jobs, welfare, and stability.

In order to be able to export locally grown food commodities to foreign markets, countries should comply with food safety standards of the importer(s). According to the World Trade Organization (WTO) SPS Agreement (WTO, 1994; Chen, 2004), these standards shall refer to internationally accepted risk assessment procedures supported by scientific evidence. WTO member countries (164 countries) are encouraged to implement the international standards proposed by the Codex Alimentarius Commission for a multitude of chemicals, e.g. pesticide and veterinary drug residues, environmental contaminants, and mycotoxins. Conformity assessment of exported food commodities involves comparing the concentrations of food chemicals with maximum regulatory limits (MRLs). Considering the cost of laboratory analysis, a strategic issue for exporters is to identify the chemicals that represent a compliance check priority in food commodities.

Among the tasks of the World Health Organization (WHO), the GEMS/Food Programme is dedicated to the compilation of food chemical monitoring data collected by more than 60 WHO Collaborating Institutions worldwide. Since its implementation, this program has collected approximately 7 million analytical results for various chemicals in 530 food items classified in 24 food categories. The data are incorporated into the GEMS/Food Contaminants Database. From this

* Corresponding author.
E-mail addresses: Jeancharles.leblanc@fao.org, food-quality@fao.org (J.C. Leblanc).
[1] All authors contributed equally to the paper.

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database available online[2], it is possible to extract the distribution of chemicals in food and to identify critical levels compared with existing MRLs.

Total diet study (TDS) is a concept that emerged in the late 50 s in the United States of America (Egan, 2013), and since then it has been regularly used in many countries as a tool to estimate the average dietary exposure to food chemicals, including nutrients, and to identify foods that contribute the most to that exposure (Pennington, 1983; Egan et al., 2007; EFSA, 2011; WHO, 2009).

Assuming that the results from a TDS provide the true mean of the chemical concentrations in food, it is possible to simulate the full distribution of these chemicals by selecting an appropriate coefficient of variability (CV) from other available data, e.g. GEMS/Food data.

This paper proposes an approach for developing countries to estimate the distribution of chemicals in food by using a mean concentration generated from appropriate TDS food sampling associated with the variability observed in a larger dataset consisting of individual food contamination data from the GEMS food database. The simulated distributions may provide intelligence to highlight the countries that may need to establish food safety standards and to assess the potential for international market access in the context of a value chain.

Another output of this study is transferring the TDS methodology to propose an analogy and a complementary approach that we denoted as total export study (TES). TDS focuses on contamination in a representative sampling of the diet, and the TES methodology is applied to concentration in the food to be exported to the global market. Finally, we also aimed to identify the mitigation measures required before foods can be exported by comparing the concentration distribution to cut-off using regulatory standards, such as the Codex maximum level (ML).

We illustrated this methodological work by case studies conducted with relevant examples of chemical/food combinations in the African region. These examples focus on some of the most commonly exported food commodities and on contaminants other than those intentionally added to the food chain (e.g. pesticide residues or veterinary drugs) but known to be widespread and naturally occurring in the environment, such as heavy metals or mycotoxins.

2. Materials and methods

2.1. TDS in Sub-Saharan Africa

Between 2014 and 2017, we implemented a multi-centre TDS in Sub-Saharan Africa (FAO, 2014) with the objective of characterizing the risks resulting from exposure to food chemicals encountered by populations in Benin, Cameroon, Mali, and Nigeria. TDS (FAO/EFSA/WHO, 2011) is complementary to traditional monitoring and surveillance programs, and provides a solid basis for calculating a populations' dietary exposure to food chemicals and for assessing the potential impacts on public health. Because the primary goal of a TDS is to estimate the dietary exposure of population groups, we set up a TDS list of foods for each country, covering at least 90% of the diet (Ingenbleek et al., 2017). In order to generate a common food list among the four countries, we established a mapping system between the national food items. The two harmonized levels of classification across countries are: (1) 84 food subgroups, considered as the most aggregated level for sampling, and (2) 13 food groups. We selected and analysed the core foods from the list of 84 food subgroups.

2.2. Selection of the most exported food commodities

In order to select foods of international trade interest, we analysed food export statistics from the International Trade Centre (ITC) (ITC, 2016). ITC's market analysis tools are freely accessible online[3]. ITC data allows identifying export and import data for each of the four countries considered in this study. Ultimately, ITC tools support companies, trade promoting institutions, and policymakers in the monitoring of national trade performance for the preparation of trade negotiations. We extracted the values in US dollars (USD) over five years of each food commodity exported from Benin, Cameroon, Mali, and Nigeria and calculated the mean of the five annual values for each country. We set up the export food list by ranking the mean values of exported food commodities.

2.3. Matching food classifications

ITC food classification is very similar to the structure designed for the Sub-Saharan Africa TDS and consists of three strata, which include 18 food groups, 159 food subgroups, and 1018 food items, respectively. For each of the four countries, the food subgroups (second stratum of the ITC classification) were ranked in descending order from the highest mean export value above an arbitrary threshold of 10 M $. This ranking method is similar to the TDS approach but applies to TES of foods.

We mapped TDS and ITC food classifications to identify the correspondence of food commodities in both systems.

2.4. Sampling

In a TDS, if the sampling consists of pooled samples collected across food categories, the most common approach is based on the analysis of pooled samples created from a number of individual samples of the same food commodity (WHO, 2009; FAO/EFSA/WHO, 2011). For each of the food commodities identified as consumed or exported, we formed a pooled sample for each country from twelve individual samples of equal weight.

For chemicals widely distributed in food, the precision of the estimate of the mean concentration of chemical substances under investigation depends both on the number of individual samples and on the standard deviation of concentration of chemicals in foods on the market. The statistical basis for appropriate number of individual samples to reach a given precision of the mean estimate based on the pooled sample and assuming a certain standard deviation was investigated by a scientific project under the 7th Framework Program of research of the European Union (FP7) named as 'TDS exposure' (European Commission, 2016). The authors proposed to use the following formula for sample sizes with n = < 30 to calculate confidence intervals:

$$CI = mean \pm t_{1-alpha/2} * \frac{\sigma}{\sqrt{n-1}}$$

where $t_{1-alpha}$ is the percentile of student t-distribution corresponding to the selected significance level, e.g. $alpha$ = 5%; σ is the standard deviation; and n is the number of samples.

In this study, the authors investigated the impact of the number of individual samples on the confidence interval for a given substance in a food commodity. The width of half of the 95% confidence intervals for estimates of mean ($\bar{x}$) concentrations obtained by the TDS approach was calculated based on the given number of individual samples pooled (n) and given ratio of true standard deviations (σ) and true mean (μ) (low variability, σ:μ = 1:3 and high variability σ:μ = 1:1)

From Fig. 1, it can be observed that for both low and high variability, there was relatively little gain in precision when the number of individual samples was increased from 12 to 15.

The adequate selection of representative individual samples to form pooled samples is a major consideration in the sampling plan design

[2] GEMS/Food database: https://extranet.who.int/gemsfood/.

[3] http://www.trademap.org/tradestat/.

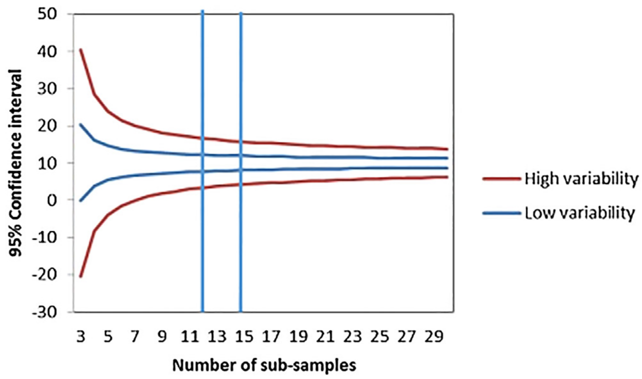


Fig. 1. 95% confidence interval around a sample mean ($\bar{x}$ = 10) with high and low variability.

(Tsukakoshi, 2011). In TDSs implemented in developed countries, it is common that the allocation of individual samples is proportional to market shares, which often refers to trademarks owned by known operators and are clearly identifiable on supermarket shelves (Sirot et al., 2009). In developing countries, this principle remains but needs to be adapted to the local food supply and distribution context. For example, most of the foods sold at the retail level in Africa, particularly locally produced commodities, do not bear any distinctive sign, brand, batch number, expiry date, or even a label. Food distribution mostly takes place at daily or weekly markets, involving a large number of ever-changing suppliers (Ingenbleek et al., 2017).

In case of commodities included in the TES food list but not in the TDS food list, we identified the main exporters and used exported volumes as the sampling criteria. In other words, we used this information to define, for each applicable criterion, the breakdown of the twelve individual samples of equal size needed to obtain a weighted pooled sample.

Some of the foods were common to both the TDS and TES food lists. These foods were prepared as consumed according to the TDS methodology as this approach is more cost-effective than sampling these foods twice. By contrast, we collected and analysed additional samples of the foods that were included in the TES food list but not in the TDS food list (in other words, commodities primarily produced for export but not for local consumption) as raw food commodities. Pooled samples were subjected to various multianalyte screenings (Ingenbleek et al., 2017).

2.5. Selection of analytes

The breakdown of monitoring data submitted to GEMS/Food includes 24 food categories and 530 food items, which we matched with the list of most exported food commodities from Benin, Cameroon, Mali, and Nigeria (Table 1).

Next, we screened the GEMS/Food database to identify the chemicals reported in these commodities. The objective of this analysis was to determine, based on GEMS/Food data, the monitoring of chemicals pertinent in each commodity of interest. As the GEMS/Food data are heterogeneous, the following criteria were applied regardless of the dataset submission date:

(1) Individual data were selected (aggregated data and data from TDSs were excluded)
(2) Raw food commodities were selected (processed foods were excluded)
(3) Producer countries were selected (e.g. for cocoa beans)
(4) Outliers were excluded based on the boxplot method: a point beyond the upper outer fence was considered an extreme outlier and excluded. The upper outer fence was estimated as the 75th percentile +3* interquartile range. It was chosen to exclude outliers based on the final dataset (i.e. composite dataset) because most of the time, the size of the country/year datasets were too small to be regarded as a distribution. Only few outliers were excluded through our method, and all of them seemed very extreme and discordant with the chosen lognormal representation.
(5) Results below the limit of quantification were substituted by half of this value. It is noted that this approach would deflate variance; however, as the datasets were chosen because of their low censorship, it was expected to be a small underestimation. It is recognized that a more complex statistical approach, such as those proposed in the NADA package for R, would have been more accurate. However, the size of the datasets does not allow analysis of such an approach systematically. This explains the reason why we selected a rather simple approach that can be reused easily on most of the datasets.

Table 1
List of the most exported food commodities from Benin, Cameroon, Mali, and Nigeria (13 items) in correspondence to GEMS/Food (25 items).

Regional TDS (RTDS) Food subgroup	GEMS Food items
Banana	Banana
Beef	Cattle meat/Cattle, kidney/Cattle liver
Cashew nut	Cashew nut
Chocolate	Cocoa beans/Cocoa beverage/Cocoa butter/Cocoa mass/Cocoa powder
Coffee	Coffee (beverage)/Coffee beans/Coffee beans (roasted)
Fresh/fermented milk	Cattle milk/Fermented milk products
Mango	Mango
Mutton/Goat	Sheep kidney/Sheep liver/Sheep meat
Other miscellaneous	Ginger, root
Other nuts/seeds	Sesame seed/Sesame seed oil, edible
Poultry	Poultry meat/Poultry offal
Rice	Rice

In practice, we applied this screening step to select the chemical/food combination that met the above-mentioned criteria to the whole GEMS/Food database with the R software (R Development Core Team, 2008).

2.6. Predicting and building distribution of concentrations

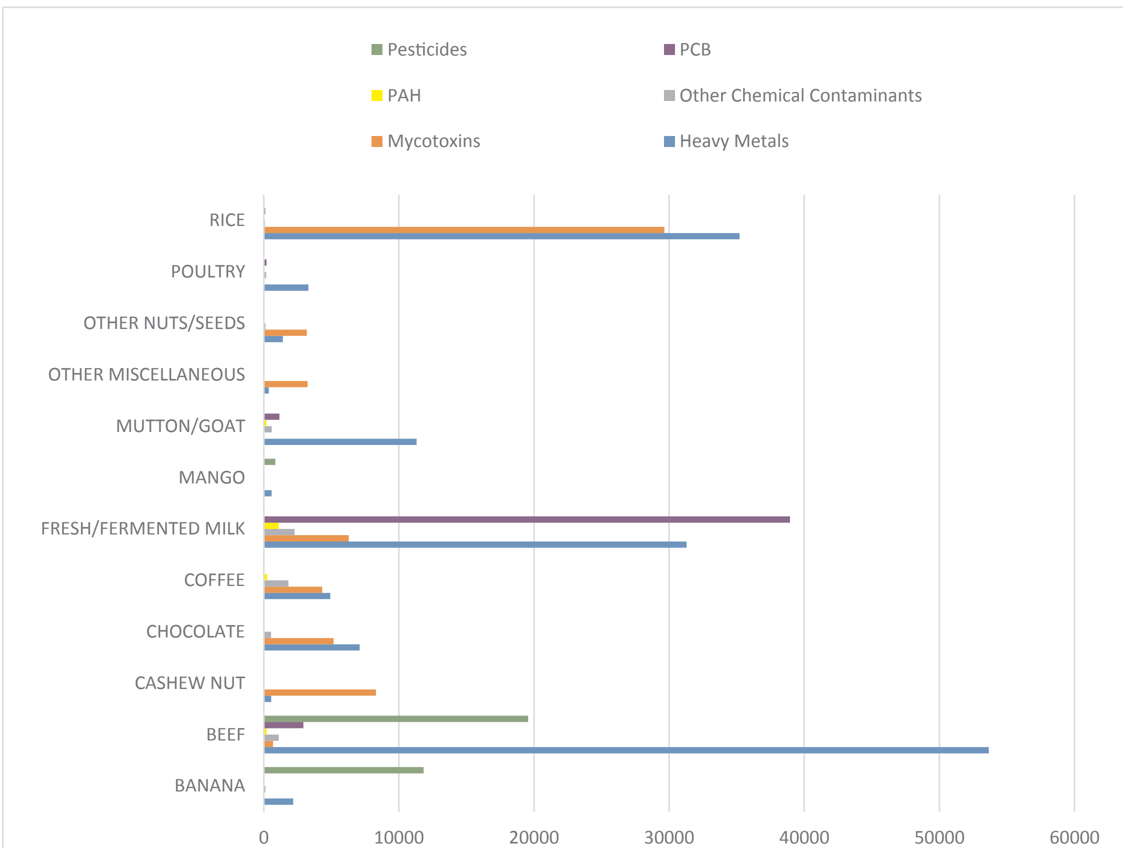
From the list of most exported food per country, we generated a distribution curve for each hazard of interest by applying a CV to the mean concentration. In a situation where the true CV was unknown, i.e. when adequate data are missing, we tested hypotheses based on a statistical analysis. In order to build the most realistic distribution, we derived this CV from different datasets from the GEMS/Food database. The accuracy of the results was dependent on the quality of the available datasets.

We considered that the most suitable data source to extract a CV are national monitoring data from the same country for the same food/chemical dyad (scenario 1). When such data were not available, we used data from the same geographical area either for the same commodity (e.g. African data for cadmium in cocoa) or another commodity likely to be contaminated by the same chemical (African data for aflatoxins in sorghum) (scenario 2). Finally, in the absence of reliable data, considering that 12 individual samples of equal weight had been pooled, we assumed similar ratios as above between true standard deviations and true mean (paragraph 2.4; Fig. 1) leading to theoretical variability of 30% (low variability) and 100% (high variability) (scenario 3).

We generated a log-normal distribution using the R software using mean food chemical concentration from TES or TDS data and variability derived from either scenario 1 and 2 (Table 2). For each distribution,

Table 2
Description of individual contamination data per region and per food of interest reported in GEMS/Food contaminants.

Food/chemical combination	Cocoa/cadmium			Poultry/lead			Peanuts/aflatoxins			Sorghum/aflatoxins		
Country/Region	Number of samples	Mean (mg/kg)	CV (%)	Number of samples	Mean (mg/kg)	CV (%)	Number of samples	Mean (mg/kg)	CV (%)	Number of samples	Mean (mg/kg)	CV (%)
Africa	501	0.11	120							1080	4.5	280
Burkina Faso										366	5.6	280
Cameroon	42	0.13	50									
Ethiopia										380	3.3	260
Mali										334	4.6	250
Nigeria	87	0.11	36									
South East Asia	75	0.44	60				19,281	8.5	200			
Western Pacific				28	0.16	210	135	4.8	470			
Americas	474	0.58	120	389	0.002	170	1819	25	350			
Europe				25	0.007	60	3684	1.8	640			



*Other Nuts: Sesame seeds + Sesame oil
**Other Miscellaneous: Ginger root

Fig. 2. Number of analytical results reported for each group of chemicals for each RTDS food sub-category in individual samples.

we added a cut-off line corresponding to the applicable Codex food standard, which represents the potential percentage of the food production volume that would be rejected from the international market. Theoretically, the lognormal is infinite and, therefore, a percentage expressed as null is strictly impossible. In practice, a simulation method was used; therefore, the observed percentage described in some figures for some food categories (e.g. Fig. 3 for cocoa bean and Fig. 4 for poultry meat) was quoted as 0 or close to 0, which as a part of an application exercise for risk assessment seemed to be an acceptable representation. We discussed the distributions thereby generated from the perspective of the safety of food supply compared to that of available international food standards. We also compared these distributions among producing countries with the perspective of potential market access.

3. Results

3.1. Export list

In total, we identified 13 foods as major contributors to the total value of exported foods in the four countries:

- three food groups for Benin, i.e. rice, cashew nuts, and poultry meat (61% of exports);
- three food groups for Cameroon, i.e. banana, coffee, and cocoa (89% of exports);
- four food groups for Mali, i.e. mango, sesame seed, bovine and ovine meat, and offal (87% of exports);
- five food groups for Nigeria, i.e. cashew nuts, sesame seed, milk,

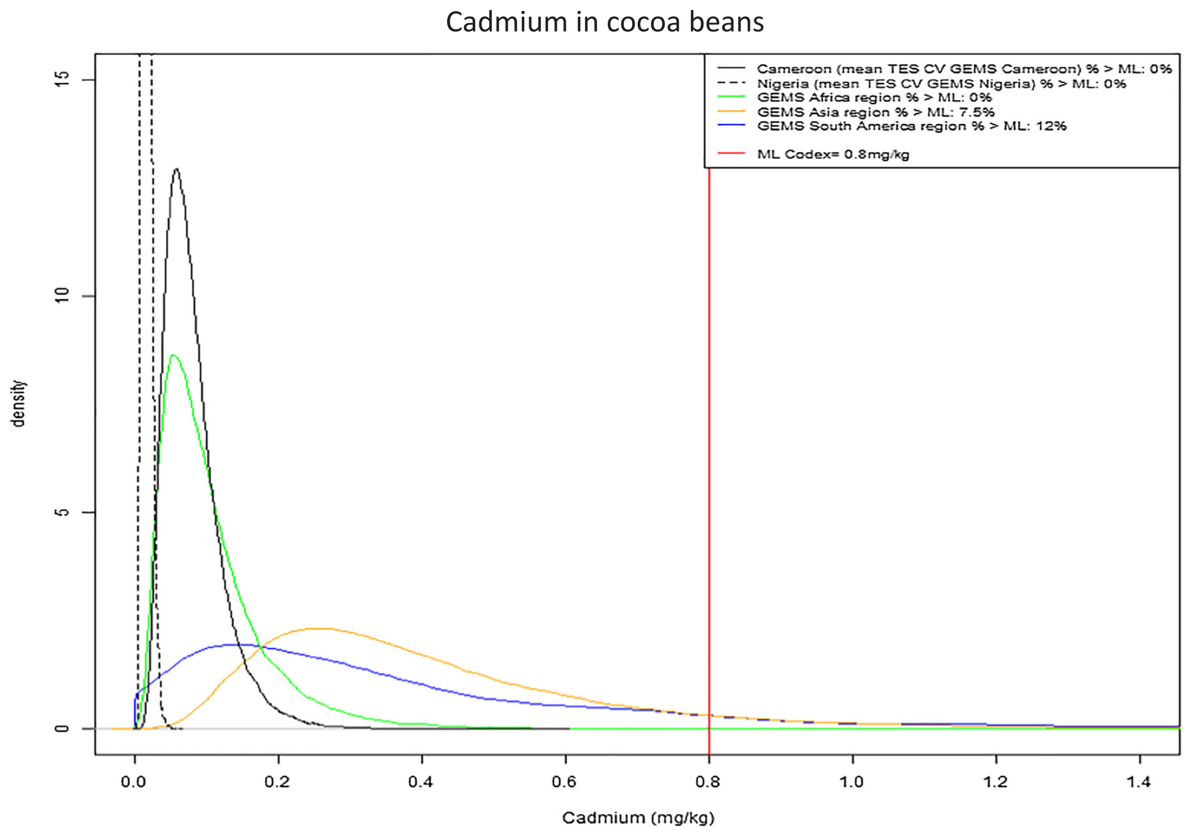


Fig. 3. Simulated distribution of cadmium in cocoa beans in Cameroon and Nigeria compared to other GEMS/FOOD regional data and the Codex standard for cadmium.

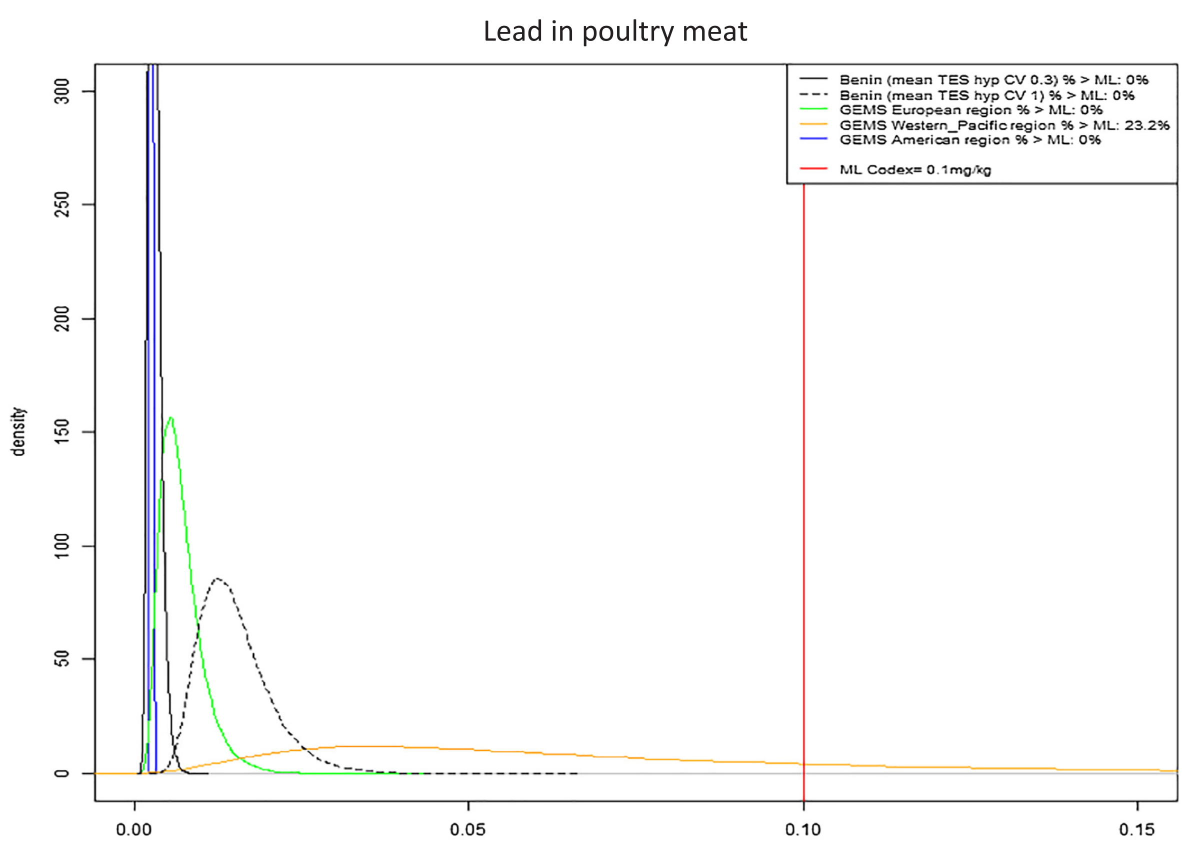


Fig. 4. Simulated distributions of lead in poultry meat in Benin compared to other GEMS/Food regional data and the Codex standard for lead.

ginger root, and cocoa (80% of exports).

Table 1 shows the correspondence between the most exported commodities and the data in GEMS/Food database.

3.2. List of chemicals

We extracted analytical results corresponding to the list of the most exported food commodities from the GEMS/Food database and grouped the identified chemicals by category. The highest number of reported analytical results were heavy metals, mycotoxins, polychlorinated biphenyls (PCBs), and agricultural and veterinary chemicals. However, we noted that detection and quantification rates of mycotoxins (27%) and heavy metals (53%) observed in the database tended to be lower than those of agricultural chemicals (79%) and PCBs (66%) (Fig. 2).

The methodology presented above was applied to estimate CVs for each selected chemical/food combination. Table 2 describes the number of individual data available from GEMS/Food, estimated mean, and CV based on the substitution of non-detected results by half of the reported limit of quantification for each available region for each chemical/food combination.

Regarding heavy metals, the results showed that when looking at a single country (scenario 1), the CVs were within the theoretical range of variability (30% < CV < 100%). For example, CVs for cadmium in chocolate were 36% and 50% for Cameroon and Nigeria, respectively. However, when evaluating data for a region, the CVs were often higher. CVs for cadmium in chocolate was 120% for both Africa and South America. Similarly, for lead in poultry, CVs were 210% and 170% for Western Pacific and Americas regions, respectively. This can be explained by the heterogeneity of geographical area (factors such as climate, mode of production, and agricultural practices). In conclusion, when these CVs were used, there was a risk to overestimate the variability.

Regarding aflatoxins, the CVs were systematically 2–3-times higher than the highest theoretical CV of 100% even for individual countries (Table 2). Such results are expected as contamination by mycotoxins varies highly with climate conditions, resulting in a skewed distribution with high variability and high percentage of censored data (WHO, 2011, 2017). This result suggested that in this case, the use of a theoretical CV of 100% was insufficiently conservative for mycotoxins and that other appropriate CV should be chosen to better characterise the geographical/chemical situation as described in Table 2.

3.3. Simulated distribution of chemical concentrations in food commodities

As mentioned previously, we have shown only two examples to illustrate the use of scenario 1 (CV extracted from GEMS/Food data from the same country, cadmium in chocolate in Cameroon and Nigeria) and scenario 3 (CV ranging from 30% to 100%, lead in poultry meat in Benin). In both cases, the simulated distributions were compared with the corresponding distributions from GEMS/Food.

We also presented a simulated distribution for aflatoxin contamination in ready-to-eat (RTE) peanuts from the four African countries. Despite the fact that these countries do not significantly export peanuts, the populations extensively consume this commodity (Ingenbleek et al., 2017). This example provides a typical illustration of how the TES approach helps in understanding and addressing the market access issue.

3.3.1. Cadmium in cocoa

The estimated CV for cadmium in cocoa from the GEMS database for Cameroon and Nigeria were 50% and 36%, respectively. We used these CVs to generate the simulated distribution of cadmium in cocoa beans from these two countries (scenario 1).

Fig. 3 compares the simulated distribution of cadmium concentrations in cocoa bean derivatives from Cameroon and Nigeria to the distribution of the GEMS data for Africa and other regions, such as Asia and South America, (Table 2) in the light of the Codex standard for cadmium of 0.8 mg/kg in cocoa products (FAO/WHO, 2018).

The result showed that the simulated distribution thereby of cadmium contamination in cocoa beans produced in individual African countries and the particular region had a lower mean and a narrower distribution than those reported from other regions (Fig. 3). The percentage of the samples that exceeded the Codex ML for cadmium of 0.8 mg/kg in cocoa products was 0 for Cameroon, Nigeria, and Africa in general, whereas it was 7.5% for the samples from Asia and 12% for South American samples.

3.3.2. Lead in poultry meat

Owing to the lack of national data from African countries in the GEMS/Food database and because lead occurs widely across food commodities, we assumed theoretical CVs ranging from low variability (CV = 30%) to high variability (CV = 100%) (scenario 3). We combined the CVs together with the mean lead concentration quantified in the TES poultry pooled sample of Benin to simulate the distribution of lead concentration in poultry meat from Benin. Fig. 4 shows the simulated distribution of lead concentration in poultry from Benin compared to other GEMS/Food data from other regions of the world (Table 2) in the light of the Codex standard for lead in meat of 0.1 mg/kg (FAO/WHO, 2018).

The result showed that lead contamination level in poultry from Benin that we simulated was lower compared to the levels recorded by the GEMS database in other parts of the world. We noted that the percentage of the samples that exceeded the Codex ML for lead of 0.1 mg/kg in poultry meat was null for Benin as well as for Americas and Europe, whereas it was 23% for the Western Pacific region.

3.3.3. Aflatoxin in ready-to-eat (RTE) peanuts

The four aforementioned African countries produce and consume, but do not significantly export peanuts. In order to illustrate the issue of market access, we applied modelling of the contamination to the mean occurrence of aflatoxin B1 (AFB1) in RTE peanuts obtained from the four African countries.

We observed that the mean AFB1 concentrations in RTE peanut TDS pooled samples from Cameroon, Mali, Nigeria, and Benin were 38, 59, 41, and 90 μg/kg, respectively (Ingenbleek et al., 2019).

Owing to the lack of national data from African countries in the GEMS/Food database concerning AFB1 in RTE peanuts, and considering that the CVs for mycotoxins are higher and more heterogeneous in comparison to the maximum theoretical CV of 100%, as mentioned previously, we used a CV of 280% corresponding to the CV of the aflatoxin dataset on sorghum in various African countries (Table 2) (Ssepuuya et al., 2018). With this scenario, the theoretical percentage of samples that would exceed the ML for RTE peanut was approximately 47% for Cameroon, 58% for Mali, 49% for Nigeria, and 71% for Benin (Fig. 5). Fig. 5 describes the distribution of AFB1 in RTE peanuts consumed in Benin, Cameroon, Mali, and Nigeria in the light of the Codex standard for total aflatoxins in RTE peanuts of 15 μg/kg (FAO/WHO, 2018). We observed that AFB1 typically represents 76% of total aflatoxins (Ingenbleek et al., 2019).

The result showed that the simulated contamination of AFB1 in RTE peanuts from the four African countries had a proportion that exceeded the current Codex standard. We noted that the theoretical percentage of samples that would exceed the ML for peanut was higher than 45% in the four countries. This result highlighted the urgent need for countries to take appropriate mitigation measures to reduce aflatoxin content in peanuts. Moreover, this study showed that the current aflatoxin levels in RTE peanuts of the four countries were too high to allow access to the global market.

In Fig. 6, the distribution of aflatoxin B1 in RTE peanuts in other regions from the GEMS/Food database has been displayed. We observed that the percentage of exceedance of the current Codex standard

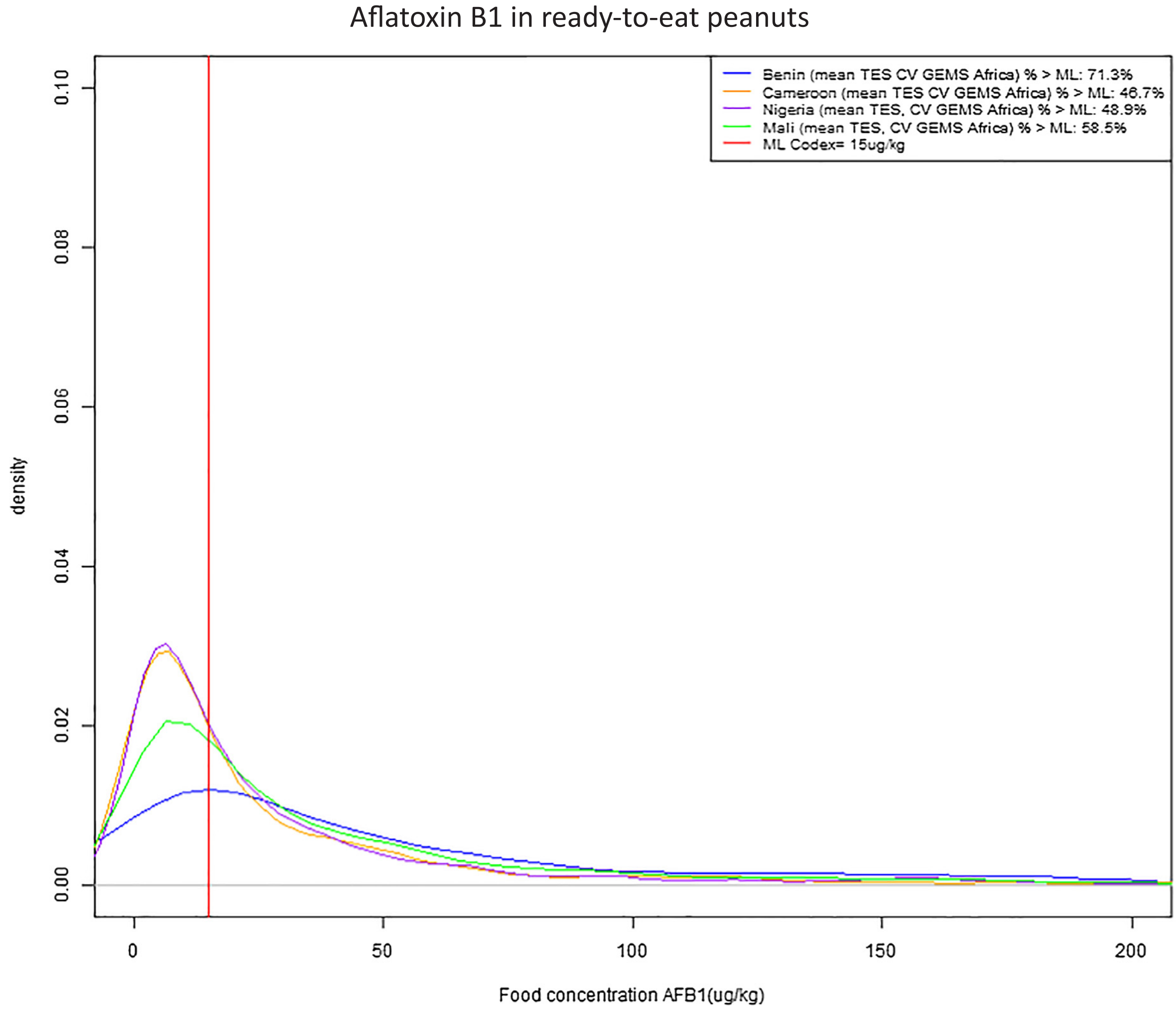


Fig. 5. Simulated distribution of AFB1 in ready-to-eat peanuts in the four African countries (using a CV of 280%) compared to the Codex standard for total aflatoxin in ready-to-eat peanuts.

for Americas, South East Asia, Western Pacific, and Europe was 58%, 14%, 5%, and 2%, respectively.

4. Discussion and conclusions

This study showed that worldwide data collected and compiled in the GEMS/Food database may be useful for developing countries to identify the chemicals that are more likely to occur in a certain food and to obtain a statistical description of their distribution. This information can either help to prioritize monitoring programmes to protect public health or serve to assess a particular food value chain with the intention to gain access into the international market.

Moreover, the GEMS/Food data can be used to estimate the variability (CV) of contamination. Combining this CV with a robust mean concentration generated by TDS or TES approach represents an interesting tool to predict the distribution of chemicals at the country level. It seemed that to select a relevant CV, the considered dataset should have been obtained from a single country and a single chemical. Our results showed that when a CV could not be derived from the data in the GEMS/Food database for the same hazard and from the same country, it seemed preferable to use a range of theoretical CVs to simulate distribution. Further work is needed to support CVs of 30% and 100% to represent low and the high variability, respectively, around a mean value. However, we have already shown that these CVs are not adequate to describe the variability of aflatoxins. Higher CVs should be used to simulate the distribution of this contaminant.

It is critical to emphasize that designing a statistically meaningful sampling plan to obtain a mean concentration estimate within a reasonably narrow confidence interval around the true mean concentration is a pre-requisite to use the results of a TDS or TES. When the censorship rate of the data is too high, the CV observed from the proposed method (middle bound) can be underestimated. In this case, depending on the size of the data available, a more appropriate statistical method, such as distribution fitting, should be considered. Under these conditions, a TDS or TES approach combined with CVs is a powerful tool to simulate the distribution of chemical contamination in food commodities.

Finally, we observed that for cadmium in cocoa and lead in poultry, the simulated distribution of contamination were lower for Africa than those for Asia and Americas. These results are unexpected and inconsistent with the overall dietary exposure and burden of foodborne disease estimated recently by WHO (Gibb et al., 2015). Our hypothesis is that exported commodities may be less contaminated than food produced only for local consumption. To support this assumption, we also showed that the mean and simulated distribution of aflatoxin B1 in RTE peanuts from Africa was much higher than that in other regions and were above the Codex ML. Hence, we can again argue that this higher contamination may be due to bad climatic conditions or bad agricultural practices. This is where simulated distribution can be used to identify a need for mitigation and/or monitoring via further surveys. However, for cashew nuts, we observed that all results of whole distribution for aflatoxin concentration are below the level of detection of

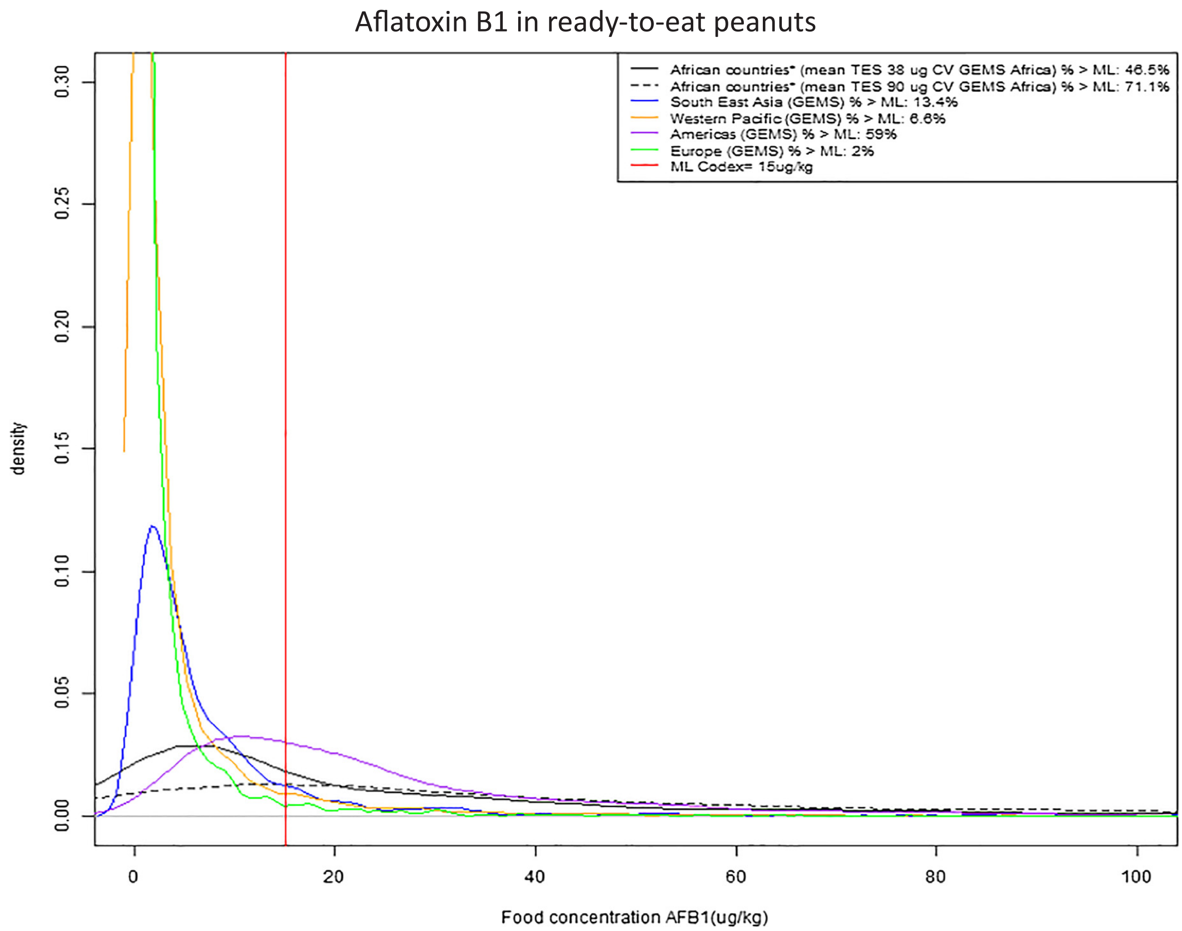


Fig. 6. Simulated distribution of AFB1 in ready-to-eat peanuts in Africa (using a CV of 280%) compared to other GEMS/FOOD regional data and the Codex standard for total aflatoxin in ready-to-eat peanuts.

0.1 µg/kg from the TDS of Sub-Saharan Africa (Ingenbleek et al., 2019). As mentioned above, cashew nuts are largely produced to be exported, whereas peanuts are primarily consumed locally. Further work is needed to confirm a possible positive effect of accessing international market as an incentive to implement good agricultural practices.

By developing, improving, and promoting the use of global tools like the TDS, TES, and GEMS/Food database, FAO and WHO are supporting the implementation of a risk-based approach for food safety. The methodology requires significant investments in terms of human resources and analytical capability to obtain the data needed for our tool. This is in relation to both obtaining the data required for TDS and for other countries submitting their data to the GEMS/Food database.

5. Disclaimer

The views expressed in this information product are those of the authors and do not necessarily reflect the views or policies of FAO and WHO.

Authors in alphabetical order contributed equally to the paper.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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