Consumption Risk Assessment of Pesticides Residues in Yam

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ABSTRACT

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Chemical pesticides have contributed significantly to agriculture production throughout the world. However, human exposure to pesticides remains a critical concern. One important source of human exposure to pesticides is through food consumption. The potential negative effects of pesticides have resulted in stringent regulation in the production and use of the products, especially in the developed countries. To limit the potential negatives effects of pesticides, risk assessments are usually conducted by scientific experts to establish the risk levels and to offer risk management strategies. Yam is a food commodity widely consumed by Africans both home and by the diaspora. Yam farmers have been using pesticides in yam production over years. The public is concerned about the health impacts that may result from exposure to residues. This study was designed to assess the risk of dietary intake of 12 pesticides, including five insecticides (cadusafos, fenitrothion, imidacloprid, profenofos and propoxur), four fungicides (carbendazim, fenpropimorph, metalaxyl, propiconazole) and three herbicides (bentazone, glyphosate and pendimethalin) in yam cropped by farmers in the Nanumba traditional area of Ghana. Residue and consumption data were collected and combined to derive Estimated Daily Intake (EDI). Three approaches were adopted in the calculation of EDI (deterministic, simple distribution and probabilistic) and the EDI values were compared with Acceptable Daily Intake (ADI) values. The study revealed that farmers' EDI to the twelve pesticides, according to the deterministic and the simple distribution approaches were lower than their respective ADI set by the EU Commission. However, the EDI of about 10% of the farmers to fenpropimorph and fenitrothion were higher than their ADI.

Keywords: Consumption, deterministic, pesticide risk assessment, probabilistic, yam

Agriculture represents an important economic sector in Ghana, accounting for about 40% of the country's gross domestic product and offering employing to over 50% of the economically active population of the country (FAO 2018; MoFA 2010). With an annual average growth rate of 2.5%, the population is estimated at 25 million. Like in many other countries throughout the world, the need to increase

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food production to meet the demands of the burgeoning population has led to the adoption of chemical pesticides. The use of pesticides does not only boost crop production, but also serves as an insurance policy against devastating crop losses due to diseases and pests attacks (Bempah 2012). As a result, there has been increasing use of pesticides in the country over the last decade (FAOSTAT 2018). When pesticides are used correctly, they clearly produce tangible benefits and increase crop yields. However, their misuse can possibly lead to the presence of residues in the environment and in food products which could trigger negative effects on human health (de Gavelle et al. 2016; Illyassou et al. 2018; Nougadère et al. 2012). Chronic exposure to certain categories of pesticides have been linked to diseases such as Parkinson's, cancers and Alzheimer's (Chourasiya et al. 2015; Darko and Akoto 2008; Gorell et al. 1998; Ouédraogo et al. 2014). Many reports showed pesticide residues in vegetables, fruits, cereals and yam in Ghana (Bempah et al. 2011; Fosu et al. 2017; Samuel et al. 2012; Wumbei et al. 2018).

To ensure food safety for the public, consumption risk assessment is often carried out to determine the risk levels and to take appropriate risk management decisions. As part of consumption risk assessment, exposure assessment to pesticides residues is done by combining the amount of food consumed and the amount of pesticides residues present in the food. The obtained exposure values are compared with Acceptable Daily Intake (ADI) for chronic risk assessment and with the Acute Reference Dose (ARfD) for acute risk assessment in order to make a decision regarding food safety (Mekonen et al. 2015).

When a certain fraction of the population (e.g. median or 95th percentile) is exposed to higher levels of the concerned chemical than the ADI or ARfD, they have a potential risk of illness (Hamilton et al. 2004). The risk index (RI) for human exposure can be calculated using the following formula:

$$\mathrm{RI} = \frac{\mathrm{Exposure}}{\mathrm{ADI\ or\ ARfD}},$$

where: RI = Risk Index, ARfD = Acute Reference Dose and ADI = Acceptable Daily Intake.

Exposure assessment is defined as "the qualitative and/or quantitative evaluation of the likely intake of biological, chemical or physical agents via food as well as exposure from other sources". It involves the estimation of how likely an individual or a population will be exposed to a chemical of concern and how much of that chemical is taken up in the body through consumption of food, drinking water and others (Lammerding and Fazil 2000).

It requires many data sources, such as: supervised field residue trials, national pesticides monitoring programs and food consumption surveys. Exposure assessment can be calculated for both chronic (long term) and acute (short term) scenarios. When samples residues are below Limit of Detection (LOD) or Limit of Quantification (LOQ), different scenarios can be adopted: lower bound (replacing non-detects by 0), medium bound (replacing non-detects by ½ of LOD/LOQ) and upper bound (replacing non-detects by the LOD/LOQ). The adoption of the lower bound is sometimes called the 'optimistic scenario' and the adoption of the upper bound is called the 'pessimistic scenario' (Kettler et al. 2015).

The two well-known dietary exposure assessment methods are the deterministic and probabilistic methods. The deterministic exposure model can be used as a simple exposure modeling tool on fixed values (point estimates) derived from residue concentrations and consumption data. The deterministic calculation is done by multiplying a fixed value of the food consumed and residue concentration, usually the mean or 97.5 percentile values (worst case scenario) (FAO/WHO 1997; Kroes et al. 2002). Deterministic exposure models are used as a low tier approach to determine whether there is an indication of concern for the given exposure. They form part of the regulatory decision making guidelines because of their simplicity, rapidity and inexpensive character (EFSA 2012; Hamilton et al. 2004). The deterministic model does not include information about variability in potential exposure of the population.

Probabilistic dietary exposure models are the most preferred exposure models, because they take into account the distribution of one or more parameters to represent variation and uncertainty and generate more realistic exposure estimates. Most of these distributional models are based on Monte Carlo simulations and are referred to as Monte Carlo models (EFSA 2012; Hamilton et al. 2004). The simulation is repeated for a certain number of iteration (e.g. 10,000) using statistical software such as @Risk or Monte Carlo Risk Assessment and results in intake curve of the concerned population (Kettler et al. 2015).

Yam (*Dioscorea* spp.), as one of the important staples and cash crops in Ghana, is consumed by many people, especially, people in the Nanumba traditional area. There is public concern regarding pesticides residues and their possible health risks. This study was initiated based on residues analysis in Wumbei et al. (2018) and Wumbei et al. (2019), to estimate farmers risk of dietary intake of 12 pesticides (bentazone, carbendazim, cadusafos, fenitrothion fenpropimorph, glyphosate, imidacloprid, metalaxyl, pendimethalin, profenofos, propiconazole and propoxur) in yam, using deterministic, simple distribution and probabilistic methods and to determine the risk associated with such exposures.

MATERIALS AND METHODS

Consumption survey.

To be able to estimate intake of pesticides, consumption data were collected from 100 farmers from randomly selected households in eight communities in the Nanumba traditional area (Nanumba South and North districts) during the yam planting season of March, 2016. During the survey, socio-demographic data including weight of the farmers were collected. The consumption data were collected in a repeated 24 hours recall interview in accordance with standard practice (Illyassou et al., 2018). The interviews were done in two non-consecutive days separated by 15 days. The interviews were done face-to-face by trained interviewers using a structured questionnaire. The type of yam dish eaten and the amount of yam consumed was estimated using pictures of various portion sizes. The average of the two recall interviews was taken and used to calculate yam consumption on a daily basis. The average daily consumption (kg/kg bodyweight (BW)/day) of yam for each person was calculated.

Yam sampling and sample preparation for residues analysis.

A total of 328 yam samples were collected. Out of this number, 150 samples were collected from Ghanaian markets, 100 samples were collected from households in Ghana, 48 samples were collected from a field trial in Ghana and 30 samples were collected from shops in Ghent, Belgium. The yam samples collected from Ghent were imported from Ghana. Sample preparation, extraction and analysis for pesticides residues were done in Wumbei et al. (2018) and Wumbei et al. 2019.

Exposure analysis.

Pesticides residue data of Wumbei et al. (2018) and Wumbei et al. (2019) were pooled for the consumer exposure assessment. This was done by calculating the EDI *i.e.* chronic exposure. The residues of each pesticide were mostly below the LOD. Therefore, in the dietary exposure assessment, the upper bound scenario, also known as the pessimistic was adopted. The exposure was compared with the toxicological limits *i.e.* ADI of the pesticides. Three approaches were adopted for the exposure assessment, *i.e.* the deterministic, the simple distribution and the probabilistic, as prescribed by the European Food Safety Authority (EFSA 2012). Fenitrothion and fenpropimorph were assessed deterministically and probabilistically and the rest were assessed by simple distribution. An independent t-test was conducted to compare the estimated dietary exposure of the farmers to the two pesticides derived from the probabilistic and deterministic approaches.

Dietary exposure to fenitrothion and fenpropimorph was calculated based on the daily yam consumption data and the pesticide residues in yam, using the deterministic approach. This is a method that makes use of point estimations. In this study, the dietary exposure was estimated by multiplying a single value of consumption and a single value of concentration and dividing by the body weight as in the equation below:

$$\mathrm{EDI}\left({}^{\mathrm{mg}}\!\big/_{\mathrm{kg\ bodyweight}}\big/_{\mathrm{day}}\right) = \frac{\mathrm{Residue}\ \left(({}^{\mathrm{mg}}/_{\mathrm{kg}})\ \mathrm{x\ Consumption}\ \left({}^{\mathrm{kg}}/_{\mathrm{day}}\right)\ \mathrm{x\ E}\right)}{\mathrm{Bodyweight\ (kg)}}$$

where: E = correction factor for the edible portion.

However, since the yam samples were peeled before being analyzed Wumbei et al. (2018) and Wumbei et al. (2019), there was no need to correct for the edible part, hence E was taken as 1. Statistical means and percentiles (P 50, P 75, P 90, P 95, P 97.5 and P 99) were calculated for the consumption and concentration data, and combined to generate the corresponding exposures.

Probabilistic dietary exposure assessment was done using @Risk® 5.7 software, version 6.0, a Microsoft Excel add in program from Palisade Corporation, USA. In contrast to the deterministic approach, here both the consumption and concentration data were fitted to distributions after which the consumption and concentration distributions were combined to obtain an exposure distribution. Subsequent to the generation of the exposure distribution, first-order Monte-Carlo simulation was performed with 10,000 iterations. From the simulated results the means and relevant percentiles (P 50, P 75, P 90, P 95 P 97.5 and P 99) of the estimated exposure to the two pesticides were determined. In the process of the probabilistic risk assessment, the residue data of fenitrothion and fenpropimorph could not be fitted directly to a distribution. Hence, the data were grouped into high values (above the LOQ), medium values (LOQ) and low values (LOD). The high values were fitted to a distribution, after which the IF function in @Risk® was used to generate a random distribution for the residue data (lower bound values and upper bound values).

The IF function for the lower bound distribution was: IF(RAND() < fraction of LOD;0;IF(RAND() < fraction of LOQ; LOD;distribution of fraction above LOQ)).

The IF function for the upper bound distribution was: IF(RAND() < fraction of LOQ; LOD;IF(RAND() <

fraction above LOQ ; LOQ; distribution of fraction above LOQ)).

The consumption data on the other hand, had only one zero and therefore, it was possible to fit it directly to a distribution. Subsequent to the generation of the random distributions (lower bound and upper bound) for both pesticides, exposure was calculated by adding output in @Risk® and multiplying the random distributions by the consumption distribution.

With the simple distribution approach, a single residue value is combined with a distribution of consumption to obtain an exposure estimate. The 10 pesticides detected with concentrations below their LOD/LOQ, were converted to the LOD/LOQ. These single values were combined with the distribution of the yam consumption data to obtain exposure estimates for the pesticides. Like in the case of the probabilistic approach, the exposure estimates were subjected to Monte-Carlo simulation with 10,000 iterations and from the simulated results the means and the relevant percentiles (P 50, P 75, P 90, P 95, P 97.5 and P 99) of the estimated exposure were determined.

RESULTS

Socio-demographic data.

The majority (99%) of the farmers interviewed were adult men with their ages ranging between 21 and 65 years. The weight of the famers ranged between 55 and 99 kg with an average of 69 kg. The farmers consume yam a maximum of three times and a minimum of one time per day with the individual consumption ranging between 0.12 kg and 0.85 kg/day, with an average of 0.4 kg/day.

Pesticides residue concentration and consumption data.

Residues data of twelve pesticides and consumption data of 100 people were used for the dietary intake assessment. Out of the twelve pesticides, there were 314 residues detects for fenpropimorph, 288 for cadusafos and 257 for fenitrothion, out of 328 samples. The rest of the pesticides had more non-detects (zeros) than detects. Among them, there were 58 residue detects for metalxyl, 41 for propiconazole, 19 for propoxur, 14 for glyphosate, 6 for bentazone and 2 for carbendazim. The rest (imidacloprid, pendimethalin and profenofos) had only one residue detect each.

Exposure assessment.

The deterministic and probabilistic methods of dietary exposure assessment were used to evaluate farmers EDI towards fenitrothion and fenpropimorph while simple distribution was used to evaluate farmers EDI to the rest of detected pesticides. The levels of exposure to the pesticides between the two methods (deterministic and probabilistic) were compared.

Dietary exposure assessment by the deterministic method was carried out based on single point estimation. The concentration data of the pesticides, the yam consumption data and the resultant EDI are presented in Table 1. The mean and 99th percentile concentrations of fenitrothion were 0.0029 and 0.014 mg/kg respectively, while those of fenpropimorph were 0.0003 and 0.003 respectively. The mean and 99th percentile yam consumption were 0.006 and 0.013 kg/kgBW/day respectively.

Table 1. Estimated daily intake of fenpropimorph and fenitrothion through deterministic exposure assessment and corresponding ADIs

Exposure	Residues (mg/kg)	
	Fenitrothion	**Fenpropimorph**
Mean	0.0043	0.0003
Median	0.0023	0.0002
P75	0.0069	0.0002
P90	0.0069	0.0006
P95	0.0079	0.0007
P97.5	0.0097	0.0013
P99	0.0144	0.0031

Yam consumption (kg/kgBW/day)

Mean	Median	P75	P90	P95	P97.5	P99
0.006	0.006	0.008	0.009	0.01	0.011	0.013

Exposure	EDI (mg/kgBW/day)	
	Fenitrothion	**Fenpropimorph**
Mean	0.000026	0.000002
Median	0.000014	0.000001
P75	0.000055	0.000002
P90	0.000062	0.000006
P95	0.000082	0.000007
P97.5	0.000110	0.000014
P99	0.000187	0.000040
ADI (mg/kgBW/day)	**0.005**	**0.003**

Simple distribution method of dietary exposure assessment.

The intake results for the 10 pesticides, whose EDI were assessed through the simple distribution method, and their respective ADIs are presented in Table 2.

Table 2. Estimated daily intake of used pesticides through simple distribution and corresponding ADIs

	Residues (mg/kg)				
	Cadusafos	**Carbendazim**	**Glyphosate**	**Imidacloprid**	**Metalaxyl**
	0.0005	0.0007	0.12	0.0007	0.0009
Statistical dist. of yam consumption (kg/kgBW/day) = Log logistic(-0,017192;0,02288;14,635)					
Exposure	**EDI (mg/kgBW/day)**				
	Cadusafos	**Carbendazim**	**Glyphosate**	**Imidacloprid**	**Metalaxyl**
Mean	0.0000029	0.0000041	0.00070	0.0000041	0.0000053
Median	0.0000028	0.0000039	0.00068	0.0000039	0.0000051
P75	0.0000037	0.0000052	0.00089	0.0000052	0.0000067
P90	0.0000047	0.0000066	0.00113	0.0000066	0.0000084
P95	0.0000054	0.0000075	0.00129	0.0000075	0.0000097
P97.5	0.0000061	0.0000085	0.00146	0.0000085	0.000011
P99	0.0000071	0.00001	0.00169	0.00001	0.000013
ADI (mg/kgBW/day)	**0.0004**	**0.02**	**0.5**	**0.06**	**0.08**
	Residues (mg/kg)				
	Pendimethalin	**Profenofos**	**Propiconazole**	**Propoxur**	**Bentazone**
	0.0003	0.0004	0.0002	0.0004	0.0007
Exposure	**EDI (mg/kgBW/day)**				
	Pendimethalin	**Profenofos**	**Propiconazole**	**Propoxur**	**Bentazone**
Mean	0.0000018	0.0000023	0.0000012	0.0000023	0.0000041
Median	0.0000017	0.0000022	0.0000011	0.0000022	0.0000039
P75	0.0000022	0.0000029	0.0000015	0.0000029	0.0000052
P90	0.0000028	0.0000037	0.0000019	0.0000037	0.0000066
P95	0.0000032	0.0000043	0.0000021	0.0000043	0.0000075
P97.5	0.0000036	0.0000049	0.0000024	0.0000049	0.0000085
P99	0.0000042	0.0000056	0.0000028	0.0000056	0.00001
ADI (mg/kgBW/day)	**0.125**	**0.03**	**0.04**	**0.02**	

With the probabilistic method of dietary exposure assessment, the yam consumption data and the concentration data of fenpropimorph and fenitrothion were fitted to distributions in @Risk®, the palisade Microsoft excel add in program. In the case of the concentration data, where the data were grouped, the best fitting distribution was chosen for the high values (>LOQ) prior to the use of the help function to find a random distribution. The best fitting distribution was also chosen for the yam consumption data, considering the χ^2 value, the shape of the graphs (PP and QQ plots) and the closeness of the distribution data to the input data. The fit comparison curves and the PP and QQ plots are presented in Figs. 1, 2, respectively.

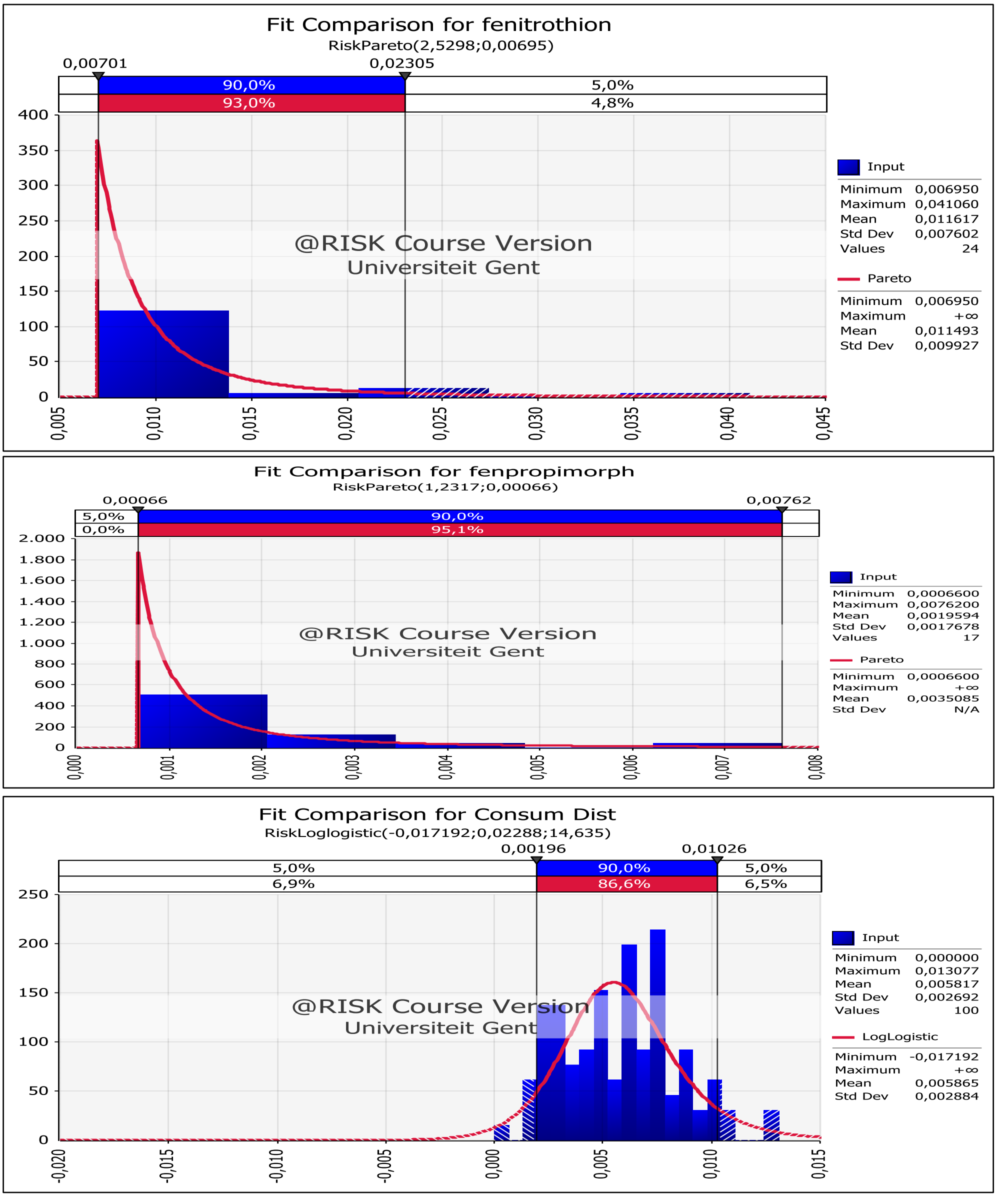

Fig. 1. Fit comparison curves for probabilistic risk assessment.

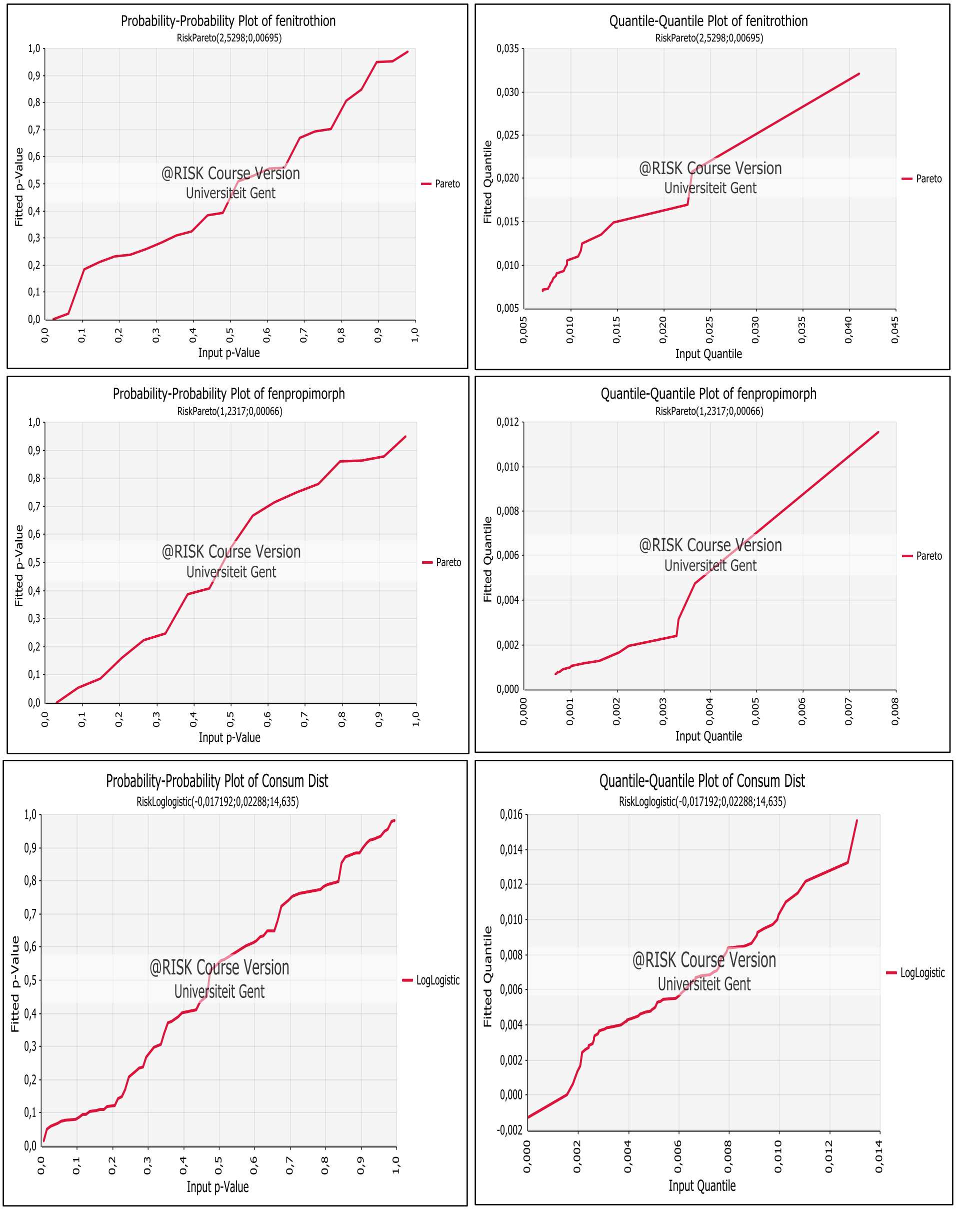

Fig. 2. PP and QQ Plots for probabilistic risk assessment.

The distribution for the concentration data and that of the consumption were multiplied by each other to obtain the intake or exposure distribution. The distribution for the consumption data, the distribution for the concentration data of the pesticides and the estimated daily intake from the probabilistic method are presented in Table 3.

Table 3. Estimated daily intake of fenpropimorph and fenitrothion through probabilistic exposure assessment

Statistical Distributions of Residue and Consumption Data				
Fenpropimorph (mg/kg)	**Fenitrothion (mg/kg)**		**Yam consumption (kg/kgBW/day)**	
LB (0), UB (0.0035)	LB (0) UB (0.0115)		Loglogistic(-0,017192;0,02288;14,635)	
	EDI (mg/kgBW/Day)			
Percentile	**Fenpropimorph**		**Fenitrothion**	
	Lower Bound	**Upper Bound**	**Lower Bound**	**Upper Bound**
Mean	0.000008	0.00058	0.000024	0.0012
Median	0.000000	0.00001	0.000000	0.0001
P75	0.000000	0.00002	0.000043	0.0022
P90	0.000006	0.0023	0.000076	0.0042
P95	0.000011	0.0051	0.0001	0.0052
P97.5	0.000019	0.0066	0.00013	0.0060
P99	0.000044	0.0082	0.0002	0.0071
ADI(mg/kgBW/Day)	**0.003**	**0.003**	**0.005**	**0.005**

LB = Lower bound, UB = Upper bound.

DISCUSSION

From the yam consumption survey, it was found that majority (99%) of the farmers interviewed were adult men having ages ranging between 21 and 65 years. The weight of the famers ranged between 55 and 99 kg with an average of 69 kg. Similar to the per capita yam consumption in Ghana as reported by the FAO (FAOSTAT, 2019), the farmers consume yam on the average 0.4 kg/day.

From the deterministic exposure assessment, it was found that, fenitrothion and fenpropimorph did not exceed their ADI. For those pesticides whose EDI were determined through the simple distribution approach, it was found that none of them had its EDI exceeding its respective ADI.

From the probabilistic dietary exposure assessment, it was found that the estimated daily intake for fenitrothion and fenpropimorph, for the lower bound scenario, was lower than their respective ADI, implying that there was no dietary intake risk. However, with the upper bound scenario, about 10% of the farmers had their EDI to the two pesticides above their respective ADI. The EDI of the 10% farmers exceeded the ADI of fenitrothion by about 4% and exceeded the ADI of fenpropimorph by about 70%. This means that those farmers had dietary intake risk to fenpropimorph and fenitrothion. The 99th percentile EDI for fenitrothion was 0.0002 mg/kgBW/day for the lower bound scenario and 0.0071 mg/kgBW/day for the upper bound scenario. This implies that 1% of the farmers had their EDI exceeding the ADI of fenitrothion by about 42% under the upper bound scenario. The 99th percentile EDI for fenpropimorph was 0.000044 mg/kgBW/day for the lower bound scenario and 0.0082 mg/kgBW/day for the upper bound scenario. This implies that 1% of the farmers had their EDI exceeding the ADI of fenpropimorph by about 173%. The results imply that, the 10% farmers with dietary intake risk to fenitrothion and fenpropimorph, are more at risk to fenpropimorph than to fenitrothion. This could be attributed to the low ADI of fenpropimorph (0.003 mg/kgBW/day) compared to the high ADI of fenitrothion (0.005 mg/kgBW/day).

Generally, the exposure assessment showed that the farmers have minimal exposure to the twelve pesticides with only about 10% having intake risk under the upper bound scenario. These minimal exposures to the pesticides could be attributed to the very low concentrations of the pesticides detected in the yam samples (Wumbei et al. 2018 and Wumbei et al. 2019), which in turn could be attributed to the fact that the yam samples were peeled before being analyzed, as peeling is found to reduce pesticide residues in yam and other root vegetables by about 40% (Clostre et al. 2014).

The farmers' exposure to the pesticides could even go further lower considering the fact that yam is not eaten raw, but rather boiled, fried or roasted, each of which can contribute to reducing the residues of pesticides in food. In a study of Kumari (2008) to monitor the levels of organochlorines, organophosphates, synthetic pyrethroids and carbamates in processed and unprocessed vegetables, it was found that boiling reduced residues by 32-100%. Household processing such as boiling is found to reduce pesticides residues in food by 20 to 100% (Kumari, 2008). In a study of Bonnechère et al. (2012), to measure the effect of household and industrial processing on pesticides, it was found that washing vegetables with tap water could reduce pesticides in the vegetables by 10-50%. In another study by Bonnechère et al. (2012) to assess the effect of processing on pesticide residues in carrots, it was found that washing and peeling each decreased the concentration of the pesticides in the carrots by 90%. In other studies (Keikotlhaile 2010; Soliman 2001) it was found that frying combined with washing could reduce pesticides residues in food crops up to 50%.

A comparison between the results of the deterministic and probabilistic methods (Fig. 3) showed that there is a significant difference ($P < 0.05$) between the two methods. The exposure values were consistently higher under the probabilistic approach than under the deterministic approach. This confirms the assertion that the deterministic dietary exposure assessment method has the tendency to either underestimate or overestimate exposure while the probabilistic method gives more accurate estimates of exposure (Finley and Paustenbach 1994; Kirchsteiger 1999; Rivera-Velasquez et al. 2013).

Human exposure to pesticides through the consumption of food is as important as any of the other routes of exposure. As a result there has been research in Ghana to determine human exposure to pesticides via the consumption of fruits and vegetables, maize, cowpea and Bambara beans (Akomea-Frempong et al. 2017; Akoto et al. 2013; Bempah et al. 2016; Donkor et al. 2015). The results as observed in this study, conform with some of the studies done in Ghana and in the UK (Akomea-Frempong et al. 2017; Bempah et al. 2016; Donkor et al. 2015) on fruits and vegetables, including yam, in which the produce were contaminated with pesticides, but no risk of dietary intake was observed. The results were different from other studies in Ghana (Akoto et al. 2015;) in which risk of intake to organochlorine and organophosphate pesticides was observed. These studies considered children and also cumulative risk of the various pesticides when one eats all the vegetables concerned. The results, as far as glyphosate is concerned also conform with the studies of EFSA (2016).

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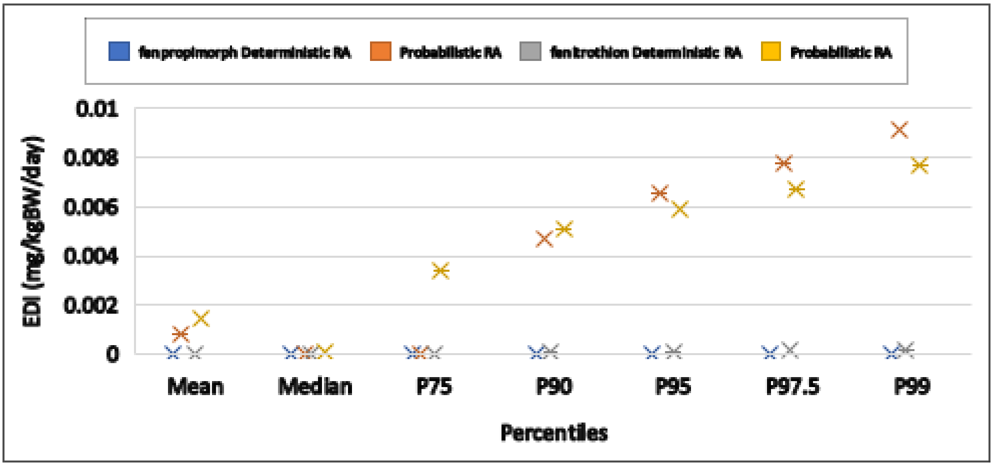

Fig. 3. Comparison of EDI of farmers to fenpropimorph and fenitrothion between the deterministic and the probabilistic methods.

RESUME

Wumbei A., Issahaku A., Abubakari A., Lopez E. et Spanoghe, P. 2019. Evaluation des risques de consommation des résidus de pesticides dans l'igname. Tunisian Journal of Plant Protection 14 (2): 49-64.

Les pesticides chimiques ont largement contribué à la production agricole à travers le monde. Cependant, l'exposition humaine aux pesticides reste une préoccupation majeure. La consommation alimentaire est une source importante d'exposition humaine aux pesticides. Les effets négatifs potentiels des pesticides ont entraîné une réglementation stricte de la production et de l'utilisation des produits, en particulier dans les pays développés. Pour faire face aux effets négatifs potentiels des pesticides, les évaluations des risques sont généralement effectuées par des experts scientifiques afin d'établir les niveaux des risques et de proposer des stratégies de gestion des risques. L'igname est un produit alimentaire largement consommé par les africains à la maison et par la diaspora. Les producteurs d'igname utilisent des pesticides pour la production de cette culture au fil des années. Le public est préoccupé par les effets sur la santé de l'exposition aux résidus. Cette étude visait à évaluer le risque d'ingestion de 12 pesticides par le régime alimentaire, dont cinq insecticides (cadusafos, fénitrothion, imidaclopride, profénofos et propoxur), quatre fongicides (carbendazime, fénpropimorphe, métalaxyl, propiconazole) et trois herbicides (bentazone, glyphosate et pendhalin) dans l'igname cultivé par des agriculteurs de la zone traditionnelle du Nanumba au Ghana. Les données de résidus et les données de consommation ont été collectées et combinées pour obtenir l'absorption journalière estimée (EDI). Trois approches (déterministe, distribution simple et probabiliste) ont été adoptées dans le calcul de l'EDI et les valeurs de l'EDI ont été comparées à la dose journalière admissible (ADI) des différents pesticides afin de déterminer s'il existait un risque d'ingestion. L'étude a révélé que l'EDI des agriculteurs utilisant les douze pesticides visés par l'approche déterministe et la distribution simple, était inférieur à leur ADI fixé par la Commission de l'UE. Cependant, l'EDI d'environ 10% des producteurs de fenpropimorphe et de fénitrothion était supérieur à leur ADI.

Mots clés: Consommation, déterminisme, évaluation des risques liés aux pesticide, probabiliste, l'igname

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ملخص

ويمباي، أبوكاري وعبد الرحمان إسحاق وعبد الله أبوبكر وإيديليبيس لوبيز وبيتر سبانوغ. 2019. تقييم مخاطر استهلاك بقايا المبيدات في زراعة اليام. Tunisian Journal of Plant Protection14 (2): 49-64.

ساهمت المبيدات الكيميائية بشكل كبير في الإنتاج الزراعي في جميع أنحاء العالم. ومع ذلك، لا يزال التعرض البشري للمبيدات مصدر قلق بالغ. أحد المصادر المهمة للتعرض البشري للمبيدات هو استهلاك الغذاء. أدت الآثار السلبية المحتملة للمبيدات إلى تنظيم صارم في إنتاج واستخدام المنتجات، وخاصة في العالم المتقدم. لمعالجة الآثار السلبية المحتملة للمبيدات، عادة ما يتم إجراء تقييمات للمخاطر من قبل خبراء علميين لتحديد مستويات المخاطر وتقديم استراتيجيات لإدارة هذه المخاطر. يام هي سلعة غذائية يستهلكها الأفارقة على نطاق واسع في الوطن وفي الشتات على حد سواء. يستخدم مزارعو اليام (نوع من البطاطا الحلوة) المبيدات في إنتاج هذه الزراعة على مر السنين. يشعر عموم الناس بالقلق إزاء الآثار الصحية التي قد تنجم عند التعرض إلى بقايا المبيدات. صُممت هذه الدراسة لتقييم مخاطر ابتلاع 12 من مبيدات الآفات، بما في ذلك خمسة مبيدات حشرية (كادوسافوس وفينيتروثيون وإيميداكلوبريد وروفينوفوس وبروبوكسور) وأربعة مبيدات فطرية (كاربيندازيم وفينوبربيمورف وميتالاكسيل وبروبايونازيل) وثلاثة مبيدات عشبية (بانتازون وغلايفوزات وبنذالين) في زراعة اليام في منطقة نانومبا التقليدية في غانا. تم جمع بيانات البقايا وبيانات الاستهلاك ودمجها لاستخراج الامتصاص اليومي المقدر (EDI). تم اعتماد ثلاثة مناحي (حتمي، توزيع بسيط، احتمالي) في احتساب الامتصاص اليومي المقدر وتمت مقارنة قيم هذا الامتصاص اليومي المقدر مع الجرعة اليومية المقبولة (ADI) لمختلف المبيدات وذلك لتحديد ما إذا كان هناك مخاطر مع الابتلاع. وكشفت الدراسة أن الامتصاص اليومي المقدر عند المزارعين للمبيدات الاثنتي عشر المستهدفة بالمنحى الحتمي وبمنحى التوزيع البسيط، كان أقل من الامتصاص اليومي المقبول الذي ضبطته مفوضية الاتحاد الأوروبي. ومع ذلك، كان الامتصاص اليومي المقدر لدى حوالي 10% من المزارعين للمبيديْن فينوبربيمورف و فينيتروثيون أعلى من الجرعة اليومية المقبولة عندهم.

كلمات مفاتيح: الاستهلاك، الحتمية، الاحتمالية، تقييم مخاطر المبيدات، اليام

LITERATURE CITED

Affum, A.O., Acquaah, S.O., Osae, S.D., and Kwaansa-Ansah, E.E. 2018. Distribution and risk assessment of banned and other current-use pesticides in surface and groundwaters consumed in an agricultural catchment dominated by cocoa crops in the Ankobra Basin, Ghana. Science of The Total Environment 633: 630-640.

Akomea-Frempong, S., Ofosu, I.W., Owusu-Ansah, E. de-G.J., and Darko, G. 2017. Health risks due to consumption of pesticides in ready-to-eat vegetables (salads) in Kumasi, Ghana. International Journal of Food Contamination 4 (1): 13.

Akoto, O., Andoh, H., Darko, G., Eshun, K., and Osei-Fosu, P. 2013. Health risk assessment of pesticides residue in maize and cowpea from Ejura, Ghana. Chemosphere 92 (1): 67-73.

Akoto, O., Gavor, S., Appah, M.K., and Apau, J. 2015. Estimation of human health risk associated with the consumption of pesticide-contaminated vegetables from Kumasi, Ghana. Environmental Monitoring and Assessment 187 (5): 244

Akoto, O., Oppong-Otoo, J., and Osei-Fosu, P. 2015. Carcinogenic and non-carcinogenic risk of organochlorine pesticide residues in processed cereal-based complementary foods for infants and young children in Ghana. Chemosphere 132: 193-199.

Bempa, C.K. 2012. Market Basket Survey for Some Pesticides Residues in Fruits. Microbiology, Biotechnology and Food Sciences 2 (3): 850-871.

Bempah, C.K., Agyekum, A.A., Akuamoa, F., Frimpong, S., and Buah-Kwofie, A. 2016. Dietary exposure to chlorinated pesticide residues in fruits and vegetables from Ghanaian markets. Journal of Food Composition and Analysis 46: 103-113.

Bempah, C. K., Buah-kwofie, A., Denutsui, D., Asomaning, J., and Tutu, A. O. 2011. Monitoring of Pesticide Residues in Fruits and Vegetables and Related Health Risk Assessment in Kumasi Metropolis, Ghana. Research Journal of Environmental and Earth Sciences 3 (6): 761-771.

Cha, E.S., Hwang, S., and Lee, W.J. 2014. Childhood leukemia mortality and farming exposure in South Korea: A national population-based birth cohort study. Cancer Epidemiology 38 (4): 401-407.

Chourasiya, S., Khillare, P. S., and Jyethi, D. S. 2015. Health risk assessment of organochlorine pesticide exposure through dietary intake of vegetables grown in the periurban sites of Delhi, India. Environmental Science and Pollution Research 22 (8): 5793-5806.

Claeys, W.L., Schmit, J.-F., Bragard, C., Maghuin-Rogister, G., Pussemier, L., and Schiffers, B. 2011. Exposure of several Belgian consumer groups to pesticide residues through fresh fruit and vegetable consumption. Food Control 22 (3-4): 508-516.

Corsini, E., Liesivuori, J., Vergieva, T., Van Loveren, H., and Colosio, C. 2008. Effects of pesticide exposure on the human immune system. Human & Experimental Toxicology 27 (9): 671-680.

Darko, G., and Akoto, O. 2008. Dietary intake of organophosphorus pesticide residues through vegetables from Kumasi, Ghana. Food and Chemical Toxicology 46 (12): 3703-3706.

de Cock, J., Westveer, K., Heederik, D., te Velde, E., and van Kooij, R. 1994. Time to pregnancy and occupational exposure to pesticides in fruit growers in The Netherlands. Occupational and Environmental Medicine 51 (10): 693-699.

de Gavelle, E., de Lauzon-Guillain, B., Charles, M.-A., Chevrier, C., Hulin, M., Sirot, V., and Nougadère, A. 2016. Chronic dietary exposure to pesticide residues and associated risk in the French ELFE cohort of pregnant women. Environment International 92-93: 533-542.

Donkor, A., Fosu, P.O., Nyarko, S., Kingsford-adaboh, R., Yaa, J., and Okyere, A. 2015. Health Risk Assessment of Pesticide Residues via Dietary Intake of Cowpea and Bambara beans Among Adults in Accra Metropolis, Ghana. Research Journal of Chemical and Environmental Sciences 3 (1): 10-18.

EFSA. 2012. Guidance on the Use of Probabilistic Methodology for Modelling Dietary Exposure to Pesticide Residues. EFSA Journal, 10 (10): 1-5.

EFSA. 2016. EFSA explains risk assessment of glyphosate. EFSA Journal 14 (9): 2839-2879

Essumang D. K., T. G. K. and C. L. 2009. Pesticides Residues in Water and Fish (Lagoon Fish) Samples from Lagoons in Ghana. Bulletin of the Chemical Society of Etiopia. 23 (1): 19-27.

FAO/WHO. 1997. Food consumption and exposure assessment of chemicals: Report of a FAO/WHO consultation, Geneva, Switzerland, 10-14 February 1997. Geneva. Retrieved from http://apps.who.int/iris/handle/10665/63988

FAO and WHO. 2018. Pesticide Details | Codex Alimentarius Database. Retrieved June 20, 2018, from http://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/pesticide-detail/en/?p_id=188

FAOSTAT. 2018. Pesticides Use Data. Retrieved June 14, 2018, from http://www.fao.org/faostat/en/#data/RP

Finley, B., and Paustenbach, D. 1994. The Benefits of Probabilistic Exposure Assessment: Three Case Studies Involving Contaminated Air, Water, and Soil1. Risk Analysis 14 (1): 53-73.

Food and Agriculture Organization. 2018. Global Trends in GDP, Agriculture Value Added, and Food-Processing Value Added (1970-2016). Retrieved February 24, 2019, from http://www.fao.org/economic/ess/ess-conomic/gdpagriculture/en/

Food Safety Authority. 2017. The 2015 European Union report on pesticide residues in food. EFSA Journal 15(4): 4791

Fosu, P. O., Donkor, A., Ziwu, C., Dubey, B., Kingsford-Adaboh, R., Asante, I., and Nazzah, N. 2017. Surveillance of pesticide residues in fruits and vegetables from Accra Metropolis markets, Ghana, 2010-2012: a case study in Sub-Saharan Africa. Environmental Science and Pollution Research International 24 (20): 17187-17205.

Gorell, J. M., Johnson, C. C., Rybicki, B. A., Peterson, E. L., and Richardson, R. J. 1998. The risk of Parkinson’s disease with exposure to pesticides, farming, well water, and rural living. Neurology 50 (5): 1346-1350.

Hamilton, D., Ambrus, Á., Dieterle, R., Felsot, A., Harris, C., and Petersen, B. 2004. Pesticide residues in food-acute dietary exposure. Pest Management Science 60 (4): 311-339.

Illyassou, K.M., Adamou, R., and Schiffers, B. 2018. First diet survey in Niger River valley and acute risk assessment for consumers exposed to pesticide residues in vegetables. Tunisian Journal of Plant Protection 13 (2): 243-262.

Jacobson, D.L., Gange, S.J., Rose, N.R., and Graham, N.M. 1997. Epidemiology and estimated population burden of selected autoimmune diseases in the United States.

Clinical Immunology and Immunopathology 84 (3): 223-243.
Kettler, S., Kennedy, M., McNamara, C., Oberdörfer, R., O'Mahony, C., Schnabel, J., and Tennant, D. 2015. Assessing and reporting uncertainties in dietary exposure analysis: Mapping of uncertainties in a tiered approach. Food and Chemical Toxicology 82: 79-95.
Kirchsteiger, C. 1999. On the use of probabilistic and deterministic methods in risk analysis. Journal of Loss Prevention in the Process Industries 12 (5): 399-419.
Kroes, R., Müller, D., Lambe, J., Löwik, M.R. ., van Klaveren, J., Kleiner, J., and Visconti, A. 2002. Assessment of intake from the diet. Food and Chemical Toxicology 40 (2-3): 327-385.
Lammerding, A. M., and Fazil, A. 2000. Hazard identification and exposure assessment for microbial food safety risk assessment. International Journal of Food Microbiology 58 (3): 147-157.
Larsen, S. B., Giwercman, A., Spanò, M., and Bonde, J. P. 1998. A longitudinal study of semen quality in pesticide spraying Danish farmers. The ASCLEPIOS Study Group. Reproductive Toxicology 12 (6): 581-589.
McKinlay, R., Plant, J.A., Bell, J.N.B., and Voulvoulis, N. 2008. Calculating human exposure to endocrine disrupting pesticides via agricultural and non-agricultural exposure routes. Science of Total Environment 398 (13): 1-12.
Medeiros Vinci, R., Jacxsens, L., Loco, J. Van, Matsiko, E., Lachat, C., De Schaetzen, T., and De Meulenaer, B. 2012. Assessment of human exposure to benzene through foods from the Belgian market. Chemosphere 88(8):1001-1007.
Mekonen, S., Ambelu, A., and Spanoghe, P. 2014. Pesticide residue evaluation in major staple food items of Ethiopia using the QuEChERS method: A case study from the jimma zone. Environmental Toxicology and Chemistry 33 (6): 1294-1302.
Mekonen, S., Lachat, C., Ambelu, A., Steurbaut, W., Kolsteren, P., Jacxsens, L., and Spanoghe, P. 2015. Risk of DDT residue in maize consumed by infants as complementary diet in southwest Ethiopia. Science of Total Environment 511: 454-460.
Ministry of food and agriculture (MoFA). 2010. Agriculture in Ghana: Facts and Figures. Accra. https://doi.org/10.1126/science.35.911.927-a
Nougadère, A., Sirot, V., Kadar, A., Fastier, A., Truchot, E., Vergnet, C., and Leblanc, J.-C. 2012. Total diet study on pesticide residues in France: Levels in food as consumed and chronic dietary risk to consumers. Environment International 45: 135-150.
Ntow, W. J. 2001. Organochlorine Pesticides in Water, Sediment, Crops, and Human Fluids in a Farming Community in Ghana. Archives of Environmental Contamination and Toxicology 40 (4): 557-563.
Ntow, William J, Tagoe, L.M., Drechsel, P., Kelderman, P., Nyarko, E., and Gijzen, H. J. 2009. Occupational exposure to pesticides: blood cholinesterase activity in a farming community in Ghana. Archives of Environmental Contamination and Toxicology 56 (3): 623-630.
Ntow, W. J. 2005. Pesticide residues in Volta Lake, Ghana. Lakes and Reservoirs: Research and Management 10 (4): 243-248.
Ouédraogo R., Toé A.M., Ilboudo S., and Guissou P.I. 2014. Risk of workers exposure to pesticides during mixing / loading and supervision of the application in sugarcane cultivation in Burkina Faso. International Journal of Environmental Science and Toxicology Research 2 (7): 143–151.
Quansah, R., Bend, J.R., Abdul-Rahaman, A., Armah, F.A., Luginaah, I., Essumang, D.K., and Afful, S. 2016. Associations between pesticide use and respiratory symptoms: A cross-sectional study in Southern Ghana. Environmental Research 150: 245-254.
Richendrfer, H., and Creton, R. 2015. Chlorpyrifos and malathion have opposite effects on behaviors and brain size that are not correlated to changes in AChE activity. NeuroToxicology 49: 50-58.
Rivera-Velasquez, M. F., Fallico, C., Guerra, I., and Straface, S. 2013. A Comparison of deterministic and probabilistic approaches for assessing risks from contaminated aquifers: an Italian case study. Waste Manag Res. 31 (12): 1245-54.
Samuel Kofi Frimpong, Philip O. Yeboah b, John J. Fletcher, J. and Dickson P. 2012. Multi-residue levels of Organophosphorus pesticides in cocoa beans from Ghana. Elixir Food Science. 47: 8721-8725.
Senyo, K.S., Komla, A.G., and Oduro, O.E. 2016. Drawdown Farming and Pesticide Residue Levels of the Afram River in Ghana. International Journal of Environmental Monitoring and Analysis 4 (3): 102-109.
Sobel, E.S., Gianini, J., Butfiloski, E.J., Croker, B.P., Schiffenbauer, J., and Roberts, S. M. 2005. Acceleration of autoimmunity by organochlorine pesticides in mice. Environmental Health Perspectives 113 (3): 323-328.
Wumbei, A., Senaeve, D., Houbraken, M., and Spanoghe, P. 2018. Pesticides residue analysis in yam from selected markets across Ghana and Belgium: An evaluation of the quechers metho

Wumbei, A. 2013. Risk assessment of applicator exposure to pesticides on cotton farms in Ghana. Journal of Environment and Earth Science 3 (1): 156-172.

Wumbei, A. Goeteyn, L., Lopez, E., Houbraken, M., and Spanoghe, P. 2019. Glyphosate in yam from Ghana. Food Additives and Contaminants: Part B Surveillance 12 (4): 231-235.

Wumbei, A. Senaeve, D., Houbraken, M., and Spanoghe, P. 2018. Pesticides residue analysis in yam from selected markets across Ghana and Belgium: an evaluation of the QUECHERS method. International Journal of Food Contamination 5 (1): 4.
