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Determination of pesticide residue levels in some common food crops: The suitability for human consumption

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Indiscriminate use of pesticides to boost agricultural produce and in public health to control pests has raised the emphasis on pesticide residue levels in foods. This study analyzed the pesticides residue levels in some common food crops consumed in Nigeria, and ascertained their suitability for human consumption. The samples were analyzed for the presence of 15 organochlorine and 10 carbamate pesticide residues using gas chromatography-mass spectrometry (GC-MS). The residual pesticides levels and hazard index in the different food crops were compared with WHO established maximum residual levels (MRL) for the pesticides. The results showed no detectable levels of pesticides in the yam samples. Beans samples, contained hexachlorobenzene and its median level (0.025 mg/kg) was greater than the MRL (0.01 mg/kg). A total of 14 (56%) different pesticides were detected in each of red and green apples, 10 (40%) in pepper and 3 (12%) in rice. The most occurring pesticides in the crops were propachlor, endosulfan-1 and hexachlorobenzene. The median pesticides contents in pepper were greater than their respective MRLs. Organochlorine pesticides are still being used in cultivation of crops, or in storage of food crops and also in some imported plant foods. Crop contents of pesticides found were below the estimated life time exposure (mg/kg/day) of 65 kg man as well as the hazard index of 1. This may pose no immediate risks to human health, but long term effects should be considered.

Key word: Pesticide residues, food crops, maximum residual limit (MRL), harzard index (HI), gas chromatography-mass spectrometry (GC-MS).

INTRODUCTION

The World Health Organization (WHO) estimates that at global level three million severe pesticide poisoning episodes occur annually and, of these, a minimum of 300.000 die with 99% of the cases being from low and middle income countries (WHO, 2002; Gunnell and Eddleston, 2003). Currently there are no precise

estimates of the health impacts resulting from longer-term exposure to pesticides. The need to ensure local agricultural production and food security in low and middle income countries and simultaneously protect the population against the health impacts following exposure to pesticides have emerged as a major global public health challenge. Although the benefits of pesticides cannot be overstated, their use raises a number of health concerns such as potential toxicity to humans and other animals that are exposed to them and these health effects may be acute or chronic (Sanborn et al., 2007; Damalas, 2009). Pesticide exposure can cause a variety of adverse health effects ranging from simple irritation of the skin and eyes to more severe effects such as affecting the nervous system, mimicking hormones causing reproductive problems and cancer (Ikpeme et al., 2016; EPA, 1999). Also a 2007 systematic review found that "most studies on non-Hodgkin lymphoma and leukaemia showed positive associations with pesticide exposure" and thus concluded that cosmetic (non commercial) use of pesticides should be decreased (Bassil et al., 2007). Strong evidence also exists for other negative outcomes from pesticide exposure including neurological, birth defects, foetal death (Sanborn et al., 2007), and neuro-developmental disorder (Jurewicz and Hanke, 2008). Also pesticide use raises a number of environmental concerns and thus a potent source of exogenous molecules such as chemical associated molecular pattern (CAMP). These exogenous molecules have been associated with immune complex formation, which is a potent source of chronic inflammation especially when it persists (Ezeani et al., 2017). Over 98% of sprayed insecticides and 95% herbicides reach a destination other than their target species, including non-target species, air, water and soil (Lovanh et al., 2012; Miller, 2004). Pesticides are one of the causes of water pollution; some are persistent organic pollutant and contribute to soil contamination (Miller and Spoolmal, 2012). Pesticides are toxic in nature and do not differentiate between targeted and non-targeted species (Lama, 2008; Bolognesi and Merlo, 2011). Some farmers may lack this knowledge and their ignorance may hamper the need for essential subjection of the pesticides to safe and judicious use (Enserink et al., 2013; Recena and Caldas, 2008). Due to injudicious and indiscriminate use of pesticides, many accidents have occurred in different parts of the world and presence of pesticides in foods, fruits, vegetables and even in mother's milk is a matter of grave concern (WHO, 2002). In addition, pesticide use reduces biodiversity, reduces nitrogen fixation, contributes to pollinator decline, destroys habitat (especially for birds), and threatens endangered species

(Walter, 2009).

Pesticide residue refers to the pesticides that may remain on or in food after they are applied to food crops(Wolde and Abirdew, 2019). The levels of these residues in foods are often stipulated by regulatory bodies in many countries such as WHO, NAFDAC, Codex Alimentarius commission, etc. Exposure of the general population to these residues most commonly occurs through consumption of treated food sources, or being in close contact to areas treated with pesticides such as farms or lawns around houses (Damalas and Eleftherohorinos, 2011). Many of these chemical residues, especially derivatives of chlorinated pesticides, exhibit bioaccumulation which could build up to harmful levels in the body as well as in the environment (Walter, 2009). Persistent chemicals can be magnified through the food chain, and have been detected in products ranging from meat, poultry, and fish, to vegetable oils, nuts, and various fruits and vegetables (Grewal, 2017).

Heavy environmental contamination by petroleum, its by-products and pesticides due to indiscriminate use by some farmers in developing countries with little or no knowledge about these chemicals, in their quest for large farm produce, have opened a wide door for pesticides threat to human health. Some of these farmers have ignorantly but successfully controlled these insects and weeds by spraying pesticides directly on crops to kill the parasites that compete with their crops pre-and post-cultivation. Though these pesticides have been in use in our locality but there is paucity of data on the types of pesticides used, their dietary intake studies and their risk assessment process in our local food crops; hence, the need for this study, which importance should not be over emphasized (Awofadeji, 2008). Based on these, it becomes pertinent that these farm produce: Apple {red and green}, Rice {foreign and local}, Beans {white and brown}, Pepper {dry and fresh}, Yam {local and imported from north} are subjected to continuous check to ascertain their suitability for human and animal consumption.

The aim of this work is to determine the pesticide residues levels in some common food crops so as to evaluate their suitability for human consumption.

MATERIALS AND METHODS

Sampling site

Food crops including Apple {red and green}, Rice {foreign and local}, Beans {white and brown}, Pepper {dry and fresh}, and Yam {local and imported from north} were collected from five different major markets in Nigeria for pesticide residue analysis. The food

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crops were purchased from their sellers in the open air market the same way as the local buyers get the food crops for consumption.

Sample selection

A total of 50 samples of five (5) groups of food crops were selected randomly from five different markets for this study (namely: Ose, Ochanja, Relief, head bridge and main market) in Onitsha, Anambra State, Nigeria. The different types of food crops were sub grouped as follows: apple (green and red types); yam (local yam - cultivated within Onitsha area, and yam supplied from the Northern part of Nigeria); beans (white and brown species); rice (local rice - cultivated in Nigeria, and foreign rice - imported from outside Nigeria, mainly Thailand); and pepper (fresh and dried types). These food crops are among the most commonly consumed crops in Africa including Nigeria. Each sub group is made up of 5 samples, each from the five (5) different markets, thus, total of 10 samples were collected for each group. Following the description of Thai Agricultural Standard (2008), the weight/kg of the samples are as follows: Apple (green type,1.4 kg and red type, 1.2 kg); Yam (local yam cultivated within Onitsha, 1.7 kg and yam from northern part of Nigeria, 1.6 kg); Beans (white specie, 1.4 kg and brown species, 1.4 kg); Rice (local rice, 1.8 kg and foreign rice, 1.8 kg) and Pepper (fresh type, 1.4 kg and dried type, 1.6 kg) (TAST, 2008).

Sample handling

The fresh food samples (red and green apples, and fresh pepper) were wrapped separately in a foil to prevent contamination, while the yam was pealed before wrapping and sent to the laboratory the same day. The dried food samples (rice, beans, dried pepper) were wrapped in black nylon bag. All the wrapped fresh food samples were stored at 4°C before processing (Wallace et al., 2003).

Pesticide analysis

Twenty five pesticides from two groups of pesticides were analyzed in the food samples using Gas chromatography-mass spectrometry (GC-MS) (Perkin Elmer Clarus 500 GC-MS) (Lehotay and Mastovska, 2011). These include: Carbamates: eptam, sutan, vernam, ordram, propachlor, ro-neet, treflan, balan, tilliam, and simazine; Organochlorine: tetrachloro-m-xylene, α-benzenehexachlorides, β-benzenehexachlorides, γ-benzenehexachlorides, δ-benzenehexachlorides heptachlor, aldrin, endosulfan-1, δ-chlordane, α-chlordane, dibromochloropropane, hexachlorobenzene, cis-dillate, 2,4,5,6-tetrachloro-m-xylene, and hexachloropentadiene.

Sample processing

The laboratory blender was decontaminated with acetone and then rinsed with water (EPA,1994). Later the compositing and homogenization (Mixing) of the samples were carried out using the clean laboratory blender. The homogenized samples were put in amber coloured bottles after sieving and extracted with 10 ml of methanol. The extracted samples were taken to K-D apparatus and concentrated. 2 μl of the concentrate was collected with gas tithe syringe into the GC-MS for pesticides analysis.

The following specifications of the GC-MS protocol were met for each of the classes of analytes. For the carbamates, the column used was elite 35. The initial oven temperature was 120°C which was held for 1 min for the sample to vaporize and pass through the

columns. The rate at which the temperature increased was 8.5°C min^{-1}, and then when the temperature reached 285°C, the runs end. For the organochlorine pesticides, the column used was elite CL pesticides. The initial oven temperature was 80°C which was held for 1 min for sample to vaporize and pass through the columns. The temperature increased at the rate of 10°C min^{-1} till it reached 300°C. The temperature was held for 15 min for it to cool down to initial temperature, then the analysis ends. The results were read through the computer connected to the GC-MS.

Determination of life time exposure (mg/kg/day)

The estimated life time exposure (ELTE) was derived by multiplying residual pesticides level obtained by analysis in each food material by the food consumption rate (kg/day) and dividing by the average adult body weight as stated in the formula that follows (Akoto et al., 2015; Wang et al., 2011). The average adult body weight of 65 kg was used for the study. This was the average body weight of adult Nigerians residing in Calabar, South South Nigeria, as reported by (Igiri et al., 2009).

The per capita food consumption rates (mg/day) of the following food crops: yam 89.5, beans 0.1, pepper 5.4, apple 0.3, and rice 103.4 (WHO/FAO, 2010a) were used for the derivation of the life time exposure.

ELTE = Pesticide residue level (mg/kg) × Food consumption rate (kg/day) / Body weight (kg)

Determination of the hazard index

In adults, it was estimated as ratios between pesticide exposure doses and the reference doses which are considered to be safe levels of exposure over the life time (Reffstrup et al., 2010).

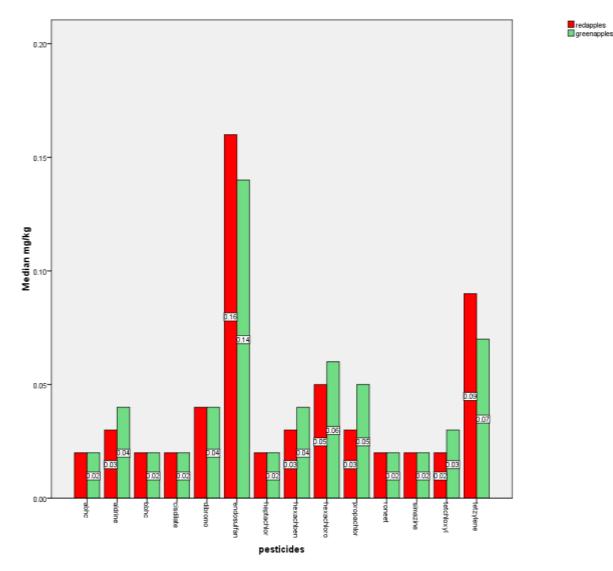Hazard Index = Estimated pesticide exposure doses / MRL (as determined by WHO/FAO)

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 20.0. Descriptive statistics was done with the use of bar charts and line graphs of the median values of the variables, while inferential statistics was done by using the unpaired t-test. The level of significance was chosen as 0.05.

RESULTS

Red and green apples

Out of the twenty five pesticides from two classes of pesticides (Organochlorines and Carbamates) tested for in subgroups of different food crops, 14 (56%) were detected in each of red and green apples (Table 1). There were no significant differences (p > 0.05) between the median levels of the pesticides detected in the red and green apples. Of these 14 pesticides detected in the apples, only propachlor was found at a level lower (0.038 mg/kg) than its maximum residue level (MRL) (0.05 mg/kg), whereas the other 13 pesticides where found at levels above their respective MRLs (Figure 1).

Figure 1. Median pesticide residue levels detected in red and green apples. Tetzylene = Tetrachloro-m-xylene; tetchloxyl = 2,4,5,6-tetrachloro-m-xylene; hexachloro = hexachloropentadiene; hexachben = hexachlorobenzene; dibromo = dibromochloropropane; bbhc = β-benzenehexachloride; abhc = α-benzenehexachloride

Local and foreign rice samples

There were only 3 (12%) pesticides detected in the rice samples (Table 1). No significant differences (p > 0.05) between the median levels of the pesticides within the local and foreign rice types. Only tetrachloro-m-xylene level (0.02 mg/kg) was found to be above the WHO MRL (0.01 mg/kg) in the rice samples, whereas endosulfan and propachlor were found at levels below their MRL (Figure 2).

Fresh and dried pepper samples

The pepper samples contained 10 (40%) of the pesticides tested (Table 2). There were significant difference (p <

0.05) between the median pesticide levels of propachlor, eptam and dibromochloropropane within the fresh and dried pepper samples. Only the level of propachlor in pepper (0.047 mg/kg) was found at a level lower than its MRL (0.05 mg/kg), whereas the rest occurred at levels higher than their MRLs (Figure 3).

Brown and white beans samples

In the beans samples, only hexachlorobenzene was detected (Table 1), and the difference in median levels of pesticide was statistically not significant (p > 0.05) in the brown and white beans types. However, the pesticide was found at a higher level (0.025 mg/kg) than its MRL (0.01 mg/kg) (Figure 4).

Table 1. Different groups/subgroups of food crops and the number/types of pesticides detected in each subgroup.

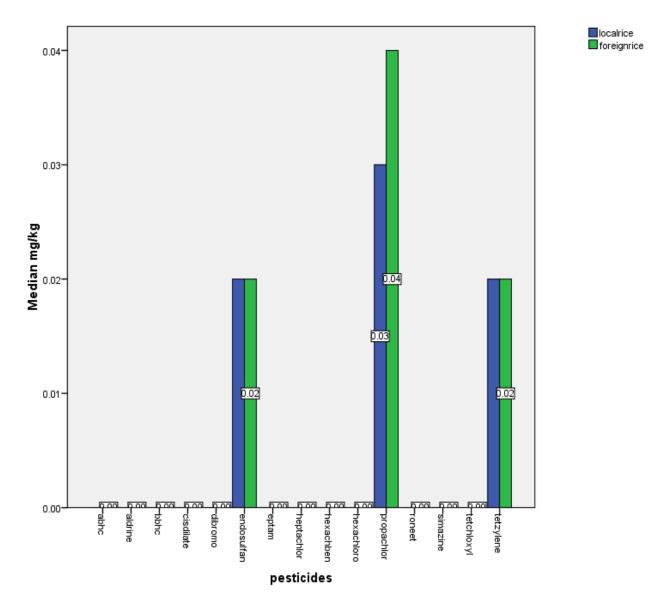| S/N	Crops	No. of pesticide/crop	Pesticide residues found
1	Red apple (No. 5)	14	α-BHC, aldrin, β-BHC, cisdillate,dibromochloropropane, endosulfan, heptachlor, hexachlorobenzene, hexachlorocyclopentadiene, propachlor, ro-neet, simazine , 2,4,5,6-tetrachloro-m-xylene and , tetrachloro-m-xylene,
2	Green apple (No. 5)	14	α-BHC, aldrin, β-BHC, cisdillate, dibromochloropropane, endosulfan, heptachlor, hexachlorobenzene, hexachlorocyclopentadiene, propachlor, ro-neet, simazine , 2,4,5,6-tetrachloro-m-xylene and , tetrachloro-m-xylene.
3	Foreign rice (No. 5)	3	Endosulfan, propachlor and tetrachloro-m-xylene.
4	Local rice (No. 5)	3	Endosulfan, propachlor and tetrachloro-m-xylene.
5	Fresh pepper (No. 5)	10	α-BHC, β-BHC, cisdillate, dibromochloropropane, endosulfan, eptam, heptachlor, hexachlorobenzene, hexachlorocyclopentadiene and propachlor.
6	Dry pepper (No. 5)	10	α-BHC, β-BHC, cisdillate, dibromochloropropane, endosulfan, eptam, heptachlor, hexachlorobenzene, hexachlorocyclopentadiene and propachlor.
7	Brown beans (No. 5)	1	Hexachlorobenzene
8	White beans (No. 5)	1	Hexachlorobenzene
9	Local yam (No. 5)	Nil	-
10	Northern yam (No .5)	Nil	-

DISCUSSION

This study analyzed pesticide residues of some food crops in Nigeria. Some of these raw food crops are imported from various parts of the world including China and the USA. Pesticide residues are implicated in many disease conditions such as food poisoning, cancer and deaths (Awofadeji, 2008; Etonihu et al., 2011). Based on this, the need arises for regular analysis of our food samples for pesticide residues, with a view to determining how safe they are for consumption and what cautions need to be taken during food storage and preparation. This is because these pesticides have been considered useful to farmers who use these pesticides as herbicides, pesticides during cultivation and preservation of the foods. Besides, some of the users of these pesticides are not well tutored in the application and thus abuse the recommended usage.

The numerous number of pesticides found in red and green apples, could be as a result of protecting the fruit using multi-active ingredient formulations at two stages – farming and storage (Matthews et al., 2003). Despite the fuss about the ban of the use of organochlorines, this work has revealed that the abuse of organochlorine pesticides is still a global problem considering that apples and the foreign rice contain many banned organochlorine

pesticides. This report also represents the pesticides combination pattern in the food materials in this locality. Just as applied to the green and red apples, the staple foodstuffs may have been protected using multi-active ingredient formulations during farming and storage as reported by (Matthews et al., 2003). The high concentrations observed may be linked to high concentrations and repeated dose applications. This is an indication that there is inappropriate use of these pesticides by the famers or as a result of environmental pollution.

Multiple treatments of crops with pesticides characterize multi-residues in individual samples. Majority of the pesticides detected at their high concentrations, such as simazine, tetrachloro-m-xylene, α-bhc, β-bhc, heptachlor, aldrin, endosulfan-1, dibromochloropropane, hexachlocyclopentadiene,   2456-tetrachloro-m-xylene, hexachlorobenzene, cisdiallate in apple; α-bhc, β-bhc, heptachlor,   endosulfan,   dibromochloropropane, hexachlorocyclopentadiene,   hexachlorobenzene, cisdiallate, eptam in pepper, tetrachloro-m-xylene in rice and hexachlorobenzene in beans, all were above the MRLs and this reflects inappropriate use of pesticides.

This suggests poor knowledge and practice of the usage of pesticides and agricultural practices by the farmers. However, the intensive use of pesticides may be

Figure 2. Median Pesticide Residue Levels in Local And Foreign Rice Samples. Tetzylene = Tetrachloro-m-xylene; tetchloxyl = 2,4,5,6-tetrachloro-m-xylene; hexachloro = hexachloropentadiene; hexachben = hexachlorobenzene; dibromo = dibromochloropropane; βbhc = β-benzenehexachloride; αbhc = α –benzenehexachloride.

low on farms, but the protection of by-products, in contrast, may be high. Therefore, there is every need to train our farmers appropriately. There could also be possibilities of extraneous residues as another source of contamination because lindane and to a lesser extent endosulfan are known to be persistent in the environment and thus, capable of routinely contaminating crops and food (WHO/FAO, 2010; Shem, 2001).

There are three potential sources of pesticide residues in food grains: application of pesticides to protect the growing crop, contamination of the environment by highly stable pesticides previously applied for other purposes, and application of insecticides to protect the harvested

crop during storage and handling (Obida et al., 2011). It is stressed that good storage practice combined with a high standard of hygiene are essential for effective application of grain protectant insecticides. Similarly, emphasis should be placed on the requirement to apply insecticides in accordance with good agricultural practice. Also, precaution has to be taken that no seeds dressed with pesticides are redistributed for consumption, as this can lead to serious poisoning.

The concentrations of these pesticide residues found in the samples analyzed were below the estimated life time exposure (ELTE) as well as hazard index of one (1). This work has shown that organochlorine pesticides persist in

Table 2. Median pesticide residues level (mg/kg), maximum residue levels (mg/kg) and hazard indices in the different food crops analyzed.

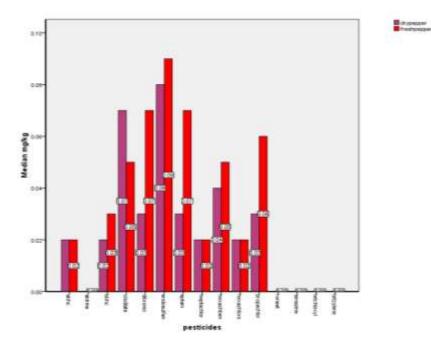| Pesticide	Apple (mg/kg)	Rice (mg/kg)	Yam (mg/kg)	Beans (mg/kg)	Pepper (mg/kg)	MRL (mg/kg)	HI (mg/kg)
Propachlor	0.038	-	-	-	-	0.05	3.5×10^{-6}
Propachlor	-	-	-	0.047	-	0.05	7.8×10^{-5}
Propachlor	-	0.028	-	-	-	0.05	8.9×10^{-4}
Ro-neet	0.019	-	-	-	-	0.01	8.5×10^{-6}
Simazine	0.02	-	-	-	-	0.01	9.0×10^{-6}
Tetchlozylene	0.076	-	-	-	-	0.01	172.5×10^{-6}
Tetchlozylene	-	0.02	-	-	-	0.01	9.5×10^{-4}
α -BHC	-	-	-	0.021	-	0.01	1.7×10^{-4}
α -BHC	0.02	-	-	-	-	0.01	9.0×10^{-6}
β-BHC	-	-	-	-	0.022	0.01	1.7×10^{-4}
β-BHC	0.02	-	-	-	-	0.01	9.0×10^{-6}
Heptachlor	-	-	-	-	0.022	0.01	1.7×10^{-4}
Heptachlor	0.02	-	-	-	-	0.01	9.0×10^{-6}
Aldrin	0.038	-	-	-	-	0.01	1.7×10^{-5}
Endosulfan 1	-	-	-	-	0.062	0.05	10.8×10^{-5}
Endosulfan 1	0.14	-	-	-	-	0.05	12.5×10^{-6}
Endosulfan 1	-	0.048	-	-	-	0.05	52.3×10^{-5}
Dibromochl	-	-	-	-	0.05	0.01	8.8×10^{-5}
Dibromochl	0.033	-	-	-	-	0.01	3.4×10^{-6}
Hexachlocy	-	-	-	-	0.02	0.01	1.7×10^{-4}
Hexachlocy	0.051	-	-	-	-	0.01	2.0×10^{-7}
2,4,5,6-tetra	0.025	-	-	-	-	0.01	12.5×10^{-6}
Hexachlo	-	-	-	-	0.04	0.01	16.5×10^{-5}
Hexachlo	0.04	-	-	-	-	0.01	9.8×10^{-6}
Hexachlo	-	-	-	0.025	-	0.01	3.5×10^{-6}
Cis-dillate	-	-	-	-	0.055	0.01	5.0×10^{-4}
Cis-dillate	0.02	-	-	-	-	0.01	9.0×10^{-6}
Eptam	-	-	-	-	0.052	0.01	4.3×10^{-4}

Tetchlozylene = Tetrachloro-m-xylene; Dibromochl = dibromochloropropane; Hexachlocy = hexachlorocyclopentadiene; 2,4,5,6-tetra = 2,4,5,6-tetrachloro-m-xylene; Hexachlo = hexachlorobenzene;   α-BHC = α -benzenehexachloride; β-BHC = β-benzenehexachloride.

some food crops in Nigeria, giving the indication that they remain in use in agriculture despite their ban in most developed countries. This work revealed that our major food stuffs contain more of the organochlorine than the cabamate pesticides which are now preferred in the developed countries to organochlorines. There were no pesticides detected in the yam samples. Perhaps the knowledge of safe storage such as curing among yam farmers and traders may have been applied in the storage other than using pesticides. Curing is one of the most effective and simple means of reducing post-harvest water and pathological loses of several root crops. Nigeria alone produces three-quarter of the world total output of yam. Yam is a very prominent crop in Nigeria WHO/FAO (2010a). Only hexachlorobenzene was found in both brown beans and white beans (*Phaseolus vulgaris*). The work of (Obida et al., 2011) earlier repor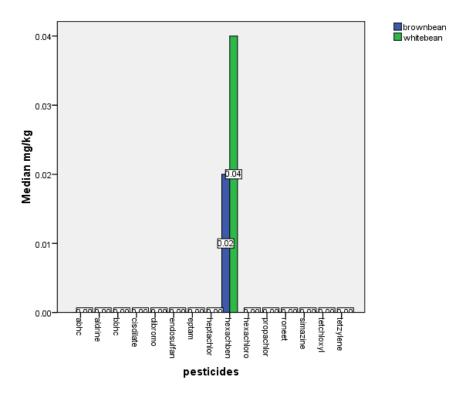ted that analysis of samples of cooked beans and the uncooked beans contained outrageously high levels of lindane (a gamma isomer of benzene hexachloride), an organochlorinated pesticide that was banned under the 1989 Rotterdam convention (Obida et al., 2011). However, Etonihu et al. (2011) showed the presence of dibromochloropropane (DBCP) in beans.

The most frequently occurring pesticides from this study were hexachlorobenzene, propachlor, and endosulfan-1. These pesticides occurred in four of the 5 different types of crops (apple, rice, beans and pepper), with endosulfan-1 at the highest concentration in most of the foods where it was detected. The increased frequency of occurrence of these pesticides may be attributed to their wide and frequent use by the farmers. It is also possible that these pesticides persist in the environment via other sources.

This work also determined the content of some pesticide residues in the samples of some marketed

Figure 3. Median pesticide residue levels in fresh and dried pepper samples. Tetzylene = Tetrachloro-m-xylene; tetchloxyl = 2,4,5,6-tetrachloro-m-xylene; hexachloro = hexachloropentadiene; hexachben = hexachlorobenzene; dibromo = dibromochloropropane; βbhc = β-benzenehexachloride; αbhc = α – benzenehexachloride.

Figure 4. Median Pesticide Residue Levels in Brown and White Beans Samples. Tetzylene = Tetrachloro-m-xylene   tetchloxyl = 2,4,5,6-tetrachloro-m-xylene; hexachloro = hexachloropentadiene; hexachben = hexachlorobenzene; dibromo = dibromochloropropane; βbhc = β-benzenehexachloride; αbhc = α – benzenehexachloride.

edible grains in other to assess their potential health risks. Worthy of note, is the fact that the concentration of these pesticide residues found in these samples are below in the estimated life time exposure (mg/kg/day) of 65 kg man as well as below the hazard index. Therefore, they are considered in this study to pose no immediate threat to man or animals that eat or forage on them. Though Onojoh et al. (2013) did not equally estimate the life time exposure of an adult man as well as the hazard index of the pesticides as obtainable in this study, they reported similar findings in their analysis of pesticides in husked rice grain and rice plant leaves collected from Omala area of Kogi State, Nigeria. These are important factors before conclusion is drawn for safety in consummation. There is every possibility that these pesticide residues may bioaccumulate in the body system of the animals and man who eventually eat them and may initiate chronic pathophysiological problems. Reports have shown that organochlorine residues may concentrate in the adipose tissues and in the blood serum of animals leading to environmental persistence, bioconcentration and biomagnifications, through the food chain pesticide concentration of chicken and meat, resulting from continuously feeding on a diet containing low concentration of pesticides (Aulakh et al., 2006).

A number of factors such as non-availability to farmers and/or non application of these insecticides during the period of cultivation or harvest, and also application of low concentration levels below the limits of quantitation may be responsible of the non-detection of some of the pesticides analyzed. These may be possible in trends of sultan, vernam, ordram, treflan, balan, γ-chlordan, and α-chlordane which are not detected in these food materials, but the higher accumulation of endosulfan-1 in apple and other food materials may be due to the volume of applications and also its solubility than others (Obida et al., 2011).

It is stressed that good storage practice combined with a high standard of hygiene are essential for effective application of grain protectant insecticides. Similarly, emphasis is placed on the requirement to apply insecticides in accordance with good agricultural practice. This means that staff using insecticides must be: well trained; able to read and understand the information on labels, especially the hazard and first aid messages; understand the specific requirements for applying individual insecticides; and understand the 'withholding period' concept. Also, precaution has to be taken that no seeds dressed with pesticides are redistributed for consumption, which can lead to serious poisoning. When pesticides are used, the quality of the product has to be monitored continuously. This is usually done by the respective national authorities. It is important to ensure that formulations and labels are accurate and in accordance with international standards. Particularly in hot climates, certain active ingredients can degrade very rapidly if they are stored improperly. There might also be incorrect labelling of the concentration of active ingredient or even indication of the wrong active ingredient.

Conclusion

The most common pesticide residues found in the food crops analyzed were propachlor, endosulfan-1 and hexachlorobenzene. Endosulfan-1 had the highest concentration in most of the foods where it was detected. This shows that contamination by organochlorine pesticides is common in food crops. The high number of residues detected with concentrations above the MRLs is a source of concern. There is therefore need for education of farmers and traders, and regular screening of food crops in Nigeria and the world at large to monitor the levels of their poisonous chemicals and thus protect the consumers, and also in case of international trade.

CONFLICT OF INTERESTS

There is no conflicting of interest.

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