Journal of Agricultural Sciences (Belgrade)
Vol. 67, No. 2, 2022
Pages 105-125

https://doi.org/10.2298/JAS2202105O
UDC: 632.95(669)"1958/2018"
Review paper

STRATEGIES TO REDUCE PESTICIDE RESIDUES IN FOOD: REMARKS ON PESTICIDE FOOD POISONING SCENARIOS IN NIGERIA (1958–2018)

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Abstract: Food insecurity across the globe, particularly in developing countries such as Nigeria, portends deleterious health challenges owing to various environmental contaminants, including the incursion of pesticides into the biosphere and the consequential retention of pesticide residues in food composition. This study provides a depth of insights into a comprehensive analysis on how the indiscriminate applications of pesticides have distorted both the terrestrial and aquatic ecosystems, altered the food chain and occasioned the appalling incidence of food poisoning. Available data from 1958 to 2018 on pesticide food poisoning scenarios in Nigeria were collected, collated and critically evaluated. The findings of this analytical study, which is navigated through a thorough content and discourse analysis of reliable information, unveiled the various channels through which pesticide residues had penetrated into the food chain and its hazardous implications on the plants, animals and humans being at the receiving ebb of the food chain. In addressing this dilemma, the authors suggested a seam of inter-connected critical and strategic tactical approaches to reduce pesticide poisoning, which, if adopted by the Nigerian government and that of other developing countries, will effectively combat the pervasiveness of this threat to food security.

Key words: action plans, environmental sustainability, Nigeria, pesticide residues, urban foods.

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Introduction

The ubiquity of pesticides is not contentious as pesticides are used everywhere, in plant protection, food storage facilities, animal and public health (residential buildings, hospitals, schools, parks), etc. The use of pesticides dates back to the era of ancient Sumerians about 4500 years ago, when the use of elemental sulfur was relied upon to control insects and mites attacking fruits and vegetables (Unsworth, 2010). Since this era, scientists have been particularly concerned about the risks linked with the use and abuse of pesticides in the environment generally. Broadly speaking, pesticides are substances that are used to protect humans against the insect vectors of disease-causing pathogens, to protect crop plants from competition from abundant but unwanted plants (i.e., 'weeds'), and to protect crop plants and livestock from diseases and depredations by fungi, insects, mites, and rodents (Rosenfeld and Feng, 2011). Synthetic pesticides, formulated to control various types of organisms, include insecticides, acaricides, rodenticides, molluscicides, nematicides, fungicides, herbicides and others. They may exist as liquids, gels, pastes, chalks, powders, granules, pellets, gases etc., with the active ingredient present at varying concentrations.

In Nigeria, synthetic pesticides were introduced in the 1950s, and their usage has been on the increase ever since their application in cocoa production (Adeyeye and Osinbajo, 1999; Adesuyi et al., 2018). It is estimated that about 125,000–130,000 metric tons of preparations of over 135 synthetic pesticides are imported and applied every year in Nigeria (Asogwa and Dongo, 2009; Erhunmwunse et al., 2012). Also, Nigerian farmers and householders have been relying heavily on pesticides for the control of various weeds, insects, and pathogens, leading to the high importation of these products (Adesuyi et al., 2018). The classes of pesticides usually employed for agricultural uses are insecticides (dichlorvos), fungicides (e.g. azoxystrobin, chloranil, thiabendazole etc.), herbicides (glyphosate, atrazine, etc.). Insecticides generally act as respiratory inhibitors, and insect growth regulators. Popular insecticide families include organochlorines, organophosphates, and carbamates. These chemicals are highly toxic, used extensively in both domestic and industrial settings and valued because of their fast action. However, some locally adulterated, uncertified, and expired chemical pesticides such as *Otapiapia* are locally manufactured and hawked by low-income dwellers in the streets of cities of Nigeria (Maduako, 2009; Musa et al., 2010a).

However, it is very important to point out that the primary essence of pesticide application is to control weeds, insects, mites and other harmful animals and plant pathogens at the time of crop cultivation and food storage (USEPA, 2017). The problem of poor transportation network remains one of the major setbacks in Nigeria and many other developing countries, and as such, farmers continue to face the difficulty of transporting their agricultural produce from the farm to the markets

in urban settlements where they are sold. Hence, they resort to applying pesticides on the farm produces in order to preserve them while it takes them days to transport them to their desired destinations.

Therefore, the common practice of applying Gamalin 20 to cocoa beans to prevent molds and maggot development is a usual practice in cocoa-trading zones in Nigeria. Many low-income households in Nigeria still depend on 'Sniper' to get rid of mosquitoes, cockroaches and other insects, even reptiles at home. Similarly, the prevalence of weevils on stored beans in various parts of Nigeria has led many bean traders to use 'Sniper', a toxic pesticide containing 2,2-dichlorovinyl dimethyl phosphate (DDVP), to control weevil infestation (Karigidi, 2018). Nigeria being a populous country and a net-importer of food has a reasonable number of people in the food business, many of whom utilize pesticides in their daily operation even to the extent of mixing together different pesticide formulations to eradicate pests without putting into consideration their harmful effects on the environment. It is the fact that over 98% of insecticides and 95% of herbicides applied in the environment reach a destination other than their target species due to pollution pathways such as air, water and soil (Miller, 2004 as cited in Babarinsa et al., 2018). Organochlorines are the most common pesticides applied to food crops on the field and during storage (Ogah et al., 2011).

Despite efforts to address indiscriminate usage, several factors are responsible for the continual use of pesticides. The most prominent factor driving pesticide use, as articulated by Xu et al. (2008), is the need to control a wide range of harmful organisms, including insects, plant pathogens, weeds, rodents etc., as well as to guard against the loss of crops and minimize the threats to human and livestock health. According to Xu et al. (2008), two main factors motivating the continual and excessive use of pesticides in our society include pesticide resistance and the simplifications in the agro-ecosystem (monocropping), causing imbalances in the agricultural ecosystems with a reduction in the density of natural enemies' populations and more intensive pest infestation, even the emergence of new pests. Furthermore, the poor awareness among farmers about the benefits and hazards associated with agricultural pesticides was reported in a study conducted in Bayelsa State, the southern part of Nigeria (Kainga et al., 2016). Low education levels of the rural populace, poor pesticide education or lack of information and training on pesticide safety measures, poor application technology, and inadequate protections leading to extensive misuse have also been identified as a major problem (Hurtig et al., 2003; Atreya, 2008; Ojo, 2016).

There are numerous ways pesticides can enter the food chain, during the pesticide production, their application during cultivation, the storage and distribution of agricultural produce, unintended contamination during household usage, the accidental discharge and surface run-offs of pesticides. When these chemicals are used injudiciously or when there is an accidental discharge or

spillage, pesticides may contaminate the soil, nearby groundwater and surface water (Erhunmwunse et al., 2012), thus contaminating potable water and even possibly endangering the aquatic organisms (e.g. fishes, crabs, and periwinkles). Children and pregnant women are most vulnerable to the hazard of pesticide exposure, perhaps because of their high metabolic rates. Exposure scenarios of children to pesticides are prevalent. Most of the times, children exposure to pesticides is because of pesticide usage to prevent mosquitoes, cockroaches and rodents, or due to storage within reach of children. Considering the behavior of children (e.g. crawling and hand-to-mouth activities) and the use of pesticides in schools and playgrounds (playing fields and parks), the exposure of children to pesticides is possible and could be lethal.

According to PAN International (2007), there is a global surge in the incidence of pesticide poisoning, with an estimate of 1–41 million people suffering health problems from exposure to pesticides annually. It is estimated that a minimum of 300,000 deaths is due to pesticide poisoning annually, with most of them (99%) from low- and middle-income countries (WHO, 2009). Pesticide residues in food have been responsible for several food poisoning and death cases in Nigeria (Shaibu, 2008), which is due to the injudicious use of chemicals on food products. A plethora of literature has emphasized the toxicity and persistence characteristics of pesticides in the environment, with limited studies on the extent of pesticide contamination and the safety measures needed to reduce pesticide residues in food.

Hence, this study attempts to address the following research questions:

i. To what extent are Nigerian local foods contaminated with pesticide residues?

ii. What safety measures are needed to minimize pesticide residues in food?

Thus, the questions above are critically explored through the analysis of the methodology, results and discussions, and conclusion on findings.

Material and Methods

This study relied on a review of relevant information about the subject matter using a wide range of appropriate key words (such as monitoring + pesticide residues + food + Nigeria) to search or filter peer-reviewed journals, books on "pesticide residues in Nigerian food markets" on scholarly search engines such as EBSCO Discovery Service (EDS), Google Scholar, Google Books, Microsoft Academic, ResearchGate, WorldWideScience, personal blogs, online newspapers and internet reports and others. Content analysis–a method of inquiry for the subjective interpretation of the content of the data of a text by the systematic process was utilized to capture and observe trends of pesticide poisoning cases and the possible measures that can be taken to reduce pesticide residues. Discourse

analysis was also utilized for studying text linguistics, i.e., tone, phonology, syntax, style and organization in academic research papers. Through the deconstruction of texts, implicit or hidden contents in academic research papers were made more obvious through reasoning and analytical thinking, thereby helping to sieve out reliable information on research objectives. Searches related to the first objective were limited to studies conducted in (or for) Nigeria, but the second objective utilized a broad range of works of literature without any geographical restrictions. Fifty (50) references were obtained for this study, but after careful selection and sieving, twenty-five (25) references were considered suitable for this purpose. In order to measure the extent of pesticide contamination, we gathered data on pesticide residue levels in Nigerian foods covering most states as well as pesticide poisoning cases in the country from 1958 to 2018 and examined the type of pesticide residues found, especially if they are on the list of persistent pesticides or banned.

Results and Discussion

The extent of pesticide contamination in Nigerian local foods

a. Pesticide residue levels in Nigerian foods

Tables 1 and 2 illustrate information on levels of pesticide residues in Nigerian foods as well as pesticide poisoning incidents in the country from 1958 to 2018. The presence of pesticide residues in foods and the events of food poisoning by pesticides is an indication that farmers or food dealers at one point or the other have used pesticides to preserve food loss or damage by the pest.

b. Pesticide poisoning incidences in Nigeria (1958–2019)

Pesticides are among the leading causes of death by self-poisoning, particularly in low- and middle-income countries (WHO, 2018). The worldwide deaths and chronic diseases due to pesticide poisoning amount to about 1 million per year (Environews Forum, 1999). Table 2 shows that pesticide poisoning in Nigeria dates back to decades and will occur again if adequate and legislative measures are not taken.

Table 1. Data on pesticide residue levels monitored in foods consumed by Nigerians across the States.

Musa et al. (2010b)	Smoked fish species, *Clarias* sp., *Gymnarchus niloticus* and *Tilapia* sp. were contaminated with DDT, dichlorvos and lindane.	Smoked fish	Northeast Nigeria
Aikpokpodion et al. (2012).	Forty percent (40%) of cocoa beans obtained from Ondo State had diazinon (organophosphate) residues while there was no detectable diazinon in cocoa beans from Cross River and Ogun States.	Cocoa beans	Ondo, Cross River and Ogun
Akinloye et al. (2011)	Paraquat residues weredetected in some crops, fruits and vegetables though these residues were within the PQ tolerance or maximum pesticide limits.	Radish, maize, plaintain, yam, tomato, pawpaw, waterleaf and other vegetables	Ogun
Gwary et al. (2012)	Dichlorvos, endrin and DDT were detected in both field samples (pre-storage), and stored samples (post-harvest). Dichlorvos was applied to prevent stored beans from insect attack.	Beans	Borno
Ogah and Coker (2012)	Maize sampled in the study contained residues of one or more organophosphate or carbamate pesticides. There is a high incidence of pesticide residues in maize sold in Lagos markets.	Maize	Various markets in Lagos State
Ogah et al. (2012)	Residues of DDT, endrin, endosulfan (except dieldrin) were detected in beans exceeded WHO MRLs. The estimated total diet intakes for aldrin and dieldrin exceeded their maximum permissible intakes by 100% and 17%, respectively.	Beans	
Gushit et al. (2013)	Residues of atrazine and other priority pollutants were detected in food samples.	Groundnut, potato, cucumber, rice straw, yam tuber, cassava, acha straw	Northern part of Nigeria
Akan et al. (2013)	Residues of organophosphorus pesticide residues (dichlorvos, diazinon, chlorpyrifos, and fenitrothion) were present in vegetables at alarming rates (exceeded WHO MRLs).	Vegetables (spinach, lettuce, cabbage, tomato and onion)	Borno State
Okoya et al. (2013)	Residues of organochlorine pesticides (cis-chlordane, α- endosulfan DDE and dieldrin and dieldrin) were detected in rivers in Ondo state. OCP levels were significantly ($P < 0.05$) higher in the dry season than in the wet season among the rivers studied.	Rivers	Ondo
Anzene et al. (2014)	Organochlorine pesticide (OCPs) residues were detected in post-harvest grains. Lindane and aldrin residues were above the maximum residue limits (MRLs) set by WHO/FAO.	Millet, guinea corn and maize grains	Nasarawa
Olufade et al. (2014)	Higher residues of aldrin and heptachlor were detected in cowpea and dried yam chips, which were generally above the EU-MRLs.	Cowpea, dried yam chips	Osun (Ile-Ife markets)
Akan et al. (2014)	Fish samples contained residues of OCP but within allowable limits.	Fish	Borno
Ogbeide et al. (2015)	High concentrations of organochlorine pesticides, specifically benzenehexachloride (α-BHC, γ-BHC, and β-BHC) were detected in water, sediment, and fish with a potential cancer risk for the local residents with lifetime consumption of pesticide-contaminated fish.	Water, fish	Edo State

Continued Table 1. Data on pesticide residue levels monitored in foods consumed by Nigerians across the States.

Shinggu et al. (2015)	OCPs were detected in water, sediments and two species of fish in Lake Geriyo, but higher levels of OCPs were found in the fish samples, higher in most cases, than the recommended WHO maximum residue levels (MRLs) of 0.05 mg/kg in food items.	Fish	Adamawa
Ogbeide et al. (2016)	Residues of organochlorine (hexachlorocyclohexane) were detected in surface water, sediment, and fish (Tilapia zilli and Clarias gariepinus). The study shows that there is a potential risk to humans exposed to contaminated water, sediment, and fish through ingestion, inhalation, and dermal routes of exposures.	Surface water, sediment, and fish	Edo
Njoku et al. (2017)	Residues of alachlor, atrazine and many other pesticides were detected in common vegetables with values greater than WHO MRLs.	Vegetables (spinach, lettuce)	Lagos
Olutona and Livingstone (2018)	Eleven OCP residues were detected in some brands of malt drinks at varying concentrations with endosulfan II above EU-MRLs.	Malt drinks	Osun
Omoyajowo et al. (2018)	Residues of different kinds of pesticides were detected in common fruits consumed, but watermelon exceptionally had residues of atrazine, clothianidin, omethoate and oxamyloxime above WHO/FAO MRLs.	Apple, watermelon and sweet orange	Lagos

Possible measures and action plans for reducing pesticide residues in foods

Reducing pesticide residues in food commodities requires conscious and concerted efforts on the part of the public and the government, given the presence of these residues may affect human health. The following approaches will go a long way in stemming the incidences of pesticide poisoning and other health-related crises associated with the ingestion of food contaminated with pesticides:

a. Thorough washing or rinsing

A plethora of studies have demonstrated that thorough washing or rinsing of food with different solvents may help reduce pesticide residues (Bhagirathi et al., 2001; Yuan et al., 2009). Washing fruits and vegetables with a salt solution is an appropriate way to remove pesticide residues from food surfaces. For instance, washing Chinese cabbage with a 1% saline solution for 10 minutes is effective in removing chlorothalonil residues (Lee and Chou, 1995). Ong et al. (1996) reported that chlorinated and ozonated water could help remove residues of azinphos-methyl, captan and formethanate-HCl on apple. Another study reported that washing potatoes with tap water or aqueous solutions of acetic acid effectively removes organochlorine and organophosphate residues (Zohair, 2001). Similarly, a study suggested that washing with sodium base (1%) or sodium hydrogen carbonate solution (1.5%) could reduce the level of chlorpyrifos-methyl insecticide and fenarimol fungicide in cherries (Hadjikinova et al., 2006). The treatment of

food with ozone water is effective in removing organochlorine residues (Kim et al., 2000; Wu et al., 2007; Vijayasree et al., 2013). Another study reported that soaking cowpea fruit in water for 15 minutes and later soaking in 0.1% edible vinegar for 15 minutes, followed by treatment with running tap water for 2 minutes, will effectively remove residues of chlorantranilipole on cowpea. Several studies have also suggested that a combination of washing, peeling, blanching, frying and cooking can remove pesticide residues effectively (Krol et al., 2000; Kang and Lee, 2005; Duhan et al., 2010; Huan et al., 2015; Keikotlhaile et al., 2010; Aondona et al., 2019). The aforementioned studies suggest that thorough washing or rinsing of food commodities will remove pesticide residues to a great extent and will reduce associated risks.

Table 2. Human poisoning incidences in Nigeria from 1958 to 2018.

State/location and year	Description of catastrophe	Citation(s)
Okebode, Southwest Nigeria:1958	All members of the family of a local chief, a prominent cocoa farmer at Okebode in southwestern Nigeria, were hospitalized after eating leaf vegetable undergrowth from a cocoa farm that had been earlier sprayed with lindane.	Ikpesu and Ariyo (2013)
Oyo State:1960	Many cases of human poisoning by Gammalin 20 (lindane) were reported at University College Hospital, Ibadan.	Igbedioh (1991)
Ondo State:1982	Twenty public health field workers were poisoned by malathion.	Igbedioh (1991)
Southwestern Nigeria:1986	Local people complained of nausea when they used water suspected to be contaminated with organophosphorous insecticide for making their local food (cassava meal).	Sridhar et al. cited in Sridhar and Ogbalu (1986)
Imo State:1988	A family of five (5) died after they had eaten the meals contaminated with pesticides.	Igbedioh (1991)
State not-specified: 2004	Carbofuran pesticide residues found on several batches of noodles manufactured in Nigeria may have resulted in 23 reported cases of vomiting and one death.	Olurominiyi and Emily (2011)
Cross River: 2008	112 people were hospitalized, and 2 people died after eating moin-moin and beans contaminated with an outrageously high level of organophosphate carbamates, fenitrothion and chlorpyrifos.	Shaibu (2008)
Gombe: 2008	Over 120 students at a public school were hospitalized after eating the meal contaminated with a high dose of lindane.	Shaibu (2008)
Gombe, Adamawa: 2011	Six family members died after eating moin-moin prepared from suspected poisoned beans.	Ikpesu and Ariyo (2013)
Cross River: 2011	Many citizens of Bekwarra Local Government Area of Cross River State were hospitalized after eating moin-moin and beans.	Ikpesu and Ariyo (2013)
Adamawa: 2018	A family of 4 died, shortly after they had eaten meals contaminated with pesticides during Ramadan fast.	Okon (2018)
Ilorin: 2018	A family of 4 died, 4 others were hospitalized after they had eaten meals contaminated with pesticides.	Okon (2018)
Bayelsa: 2018	Three family members, including a pregnant woman, died after eating a dinner contaminated with pesticides.	Okon (2018)
Yassharu village, Kafur LGA, Katsina	Some people suffered from pesticide poisoning after eating maize preserved with pesticides.	Ikpesu and Ariyo (2013)
Isua-Akoko Area of Ondo State	Four out of a 9-member family died after eating yam flour treated with pesticides.	Olulakin et al. (2015)

b. The regulation, adoption and implementation of harmonized guidelines for the registration of pesticides

As earlier reported by Ojo (2016), poor legislation and lack of enforcement of available legislation on pesticide use and distribution are a major cause of pesticide poisoning in Nigeria and even transcend beyond Nigeria. Hazards arising during the application of pesticides are mainly due to lack of information, knowledge and awareness, poor legislation or enforcement of legislation, and sales in the open market of pesticides (WHO, 1990). Governments of developing countries are beleaguered with pesticide mismanagement and handling by unlicensed retailers and smuggling across porous land borders (Keri, 2009). The regulations governing the use of chemicals are encapsulated in the ECOWAS Regulations on Pesticides which exhaustively entail monitoring, authorization, marketing, distribution and use of pesticides in the West Africa sub-region, while NAFDAC (National Food and Drug Administration Agency) is also saddled with the responsibility of monitoring compliance with safety and authorization of the use and distribution of these pesticides at the national level.

For instance, NAFDAC issues permits for specific brands of pesticide formulations used in Nigeria. Hence, the government or agency should regulate the marketing, storage, use, and disposal of pesticides and ensure that only pesticides that have been registered enter the market while those already in the country should be removed and disposed of correctly. The evaluation of the data submitted in the registration dossier should follow internationally accepted and agreed evaluation standards and procedures in as much as these are available. The harmonized protocol for bio-efficacy studies and the harmonized residue study protocol will help to inform appropriate policy and guidelines for the registration of pesticides and licensed trade of pesticides (Keri, 2009; WHO, 2010).

c. Proper pesticide labeling

Each pesticide allowed in the market should clearly show directions for use in the local language, the use for which it is intended, how and when it should be used, and the quantity should be specified. The label should contain conspicuous warnings regarding the consequences or dangers of its misuse to humans, plants, and the environment and should include statements about the route of entry and specific actions that must be taken to avoid exposure (Adesuyi et al., 2018). For instance, a pesticide label might read: “Poisonous if swallowed, inhaled, or absorbed through the skin” or “Avoid contact with eyes, quickly contact your doctor in case of any eventualities”. Thus, farmers and pesticide applicators should be encouraged to purchase protective clothing or kits at subsidized rates. The commission should be empowered to provide directives on the advertisement of all registered pesticides (Ojo, 2016; Adesuyi et al., 2018).

d. Education

Public sensitization and capacity building programs for farmers, agricultural extension workers, food wholesalers/retailers on good agricultural practices (GAPs) are critical for agricultural resilience and a safe environment. As echoed by Sridhar and Ogbalu (1986), there is an urgent need for the government to collect systematically and disseminate all the information available on pesticide production, importation, handling and usage, residues, occupational hazards and poisoning and pest resistance. Moreover, all should encourage GAPs and the integration of integrated pest management (IPM). GAPs refer to the basic environmental and operational conditions necessary for the production of safe, wholesome fruits and vegetables (NCSE, 2018) or "the proper use of pesticides to obtain maximum protection from pests" (Alexander and Anderson, 1984). The guiding principle of IPM is that pesticides should be used judiciously in conjunction with nonchemical means of pest control. Examples of GAPs include pesticide dose adjustment for tree-fruit spraying, worker hygiene and health, manure use and water quality throughout the production and harvesting process, proper storage and disposal of pesticides, understanding the characteristics of the application site (soil texture, slope, organic matter) before applying the pesticide. The food regulatory agencies in the country should ensure that pesticide applicators, especially those in agricultural activities, are trained and educated on the proper use of pesticides and the concept of integrated pest management (Adesuyi et al., 2018). The Nigerian government should also promote aggressive enlightenment campaigns through the efforts of both public and private sectors to create a high level of awareness amongst the citizenry about the available alternatives to synthetic pesticides. Training and sensitization programs on the judicious use of pesticides must be done at the village or community level to ensure grass-root participation while the cost of training and demonstrations may be shouldered by the manufacturer of these pesticides. The public should be enlightened on how to carefully dispose of empty pesticide containers and how important good personal hygiene is, such as washing their hands with soap after the use of pesticides (Ojo, 2016; Adesuyi et al., 2018).

e. The inspection of registered pesticides and monitoring of pesticide residues in locally-consumed products:

The effective post-marketing surveillance of registered pesticides will help to monitor the safety of pesticides after they have been released to the market. Prior to the use of any pesticides, the marketing authorization holder must submit a risk assessment plan to the regulator, which does not excise plans for post-authorization studies. The post-marketing surveillance of registered pesticides is critical in ensuring that newly marketed pesticides achieve the highest safety standards. All industrialized countries have food monitoring programs that measure pesticide

residues. Levels exceeding the maximum established limits have been reported occasionally in monitored food (Njoku et al., 2017; Omoyajowo et al., 2018). It has been reported that many foods consumed locally do not pass through monitoring and evaluation, unlike the cash crops or foods meant for export which must be passed through safety-check in agencies such as NAFDAC. Unfortunately, many Nigerian crops (such as cowpea, tubers, etc.) are rejected on account of a high level of residual pesticides. Sadly, there is no way an individual consumer can determine whether or not the food he/she consumes is laced with pesticides or not (Auwal-Ahmad and Awoyale, 2008; Ojo, 2016). Therefore, the consistent and stringent monitoring and evaluation of registered pesticides and of pesticide residues in locally-consumed products should be done and sustained, while tested protocols for safe disposal of expired, obsolete or otherwise unwanted pesticides should be put in place and well-publicized (Njoku et al., 2017; Omoyajowo et al., 2018; Adesuyi et al., 2018).

f. Alternatives to the use of synthetic pesticides

There are various alternative ways to control pests, which include cultivation methods, biological methods, pheromones and hormones, genetic controls, quarantine and irradiation (Raven and Berg, 2004).

Some of these methods are non-toxic methods that can be used in controlling insects in the home and gardens.

✓ Cultivation method: One way to reduce damage by crop pests is by interplanting (having alternating rows of different plants). The proper timing of planting, fertilizing and irrigating promotes healthy, vigorous plants that are more able to resist pests because they are not stressed by other environmental factors. Also, the rotation of crops can also help to control pests. When maize is not planted in the same field for 2 years in a row, the maize rootworm is effectively controlled (Raven and Berg, 2004).

✓ Botanical (or green) pesticides: This involves using plant extracts to control pests. In recent times, attention has been paid towards the exploitation of higher plant products as novel chemotherapeutics in plant protection (Dubey et al., 2008). Higher plants contain a wide spectrum of secondary metabolites such as phenols, flavonoids, quinones, tannins, essential oils, alkaloids, saponins and sterols. They are usually eco-friendly, safer for users and very effective when used correctly (Isman, 2000). For instance, essential oils possess anti-microbial and anti-fungal properties, and there is an urgent need to bio-prospect the pesticidal property of different essential oils and more efforts should be made scientifically to document the pesticidal plants and to investigate their bio-control efficacy.

The following are instances where plant products have been used to control pests: using distillates of a cocktail of herbs such as lemongrass, lime peels, and hyssop achieves 100% adult weevil and egg mortality within one hour of exposure

to infested beans, using neem oil and rotenone (Karigidi, 2019). Neem oil is extracted from the nut of the neem tree (*Azadirachta indica*), which contains the chemical *azadirachtin*. Rotenone is a natural insecticide extracted from the roots of certain tropical plants (Raven and Berg, 2004; DeAngelis, 2017).

✓ Pheromones: Pheromones are natural substances produced by animals to stimulate a response in other members of the same species. They are species-specific signals which enable communication between life-forms of the same species, i.e. intraspecific communication (Abd El-Ghany, 2019). Pheromones trigger a reaction in the recipient that causes changes in its behavior (Cork 2004). Since each insect species produces its own specific pheromones, once the chemical structure is known, it is possible to make use of pheromones to control individual pest species. Pheromones have been successfully used to lure insects, such as Japanese beetles, to traps, where they are killed.

According to Abd El-Ghany (2019), pheromones have been classified into eight types: aggregation pheromones (attract individuals of both sexes at food sites and reproductive habitats), alarm pheromones (alert members of the same species to the presence of a menace), oviposition-deterrent pheromones (discourage females from laying eggs in the same resource of another female), home recognition pheromones, sex pheromones (mediate the interaction between sexes of the same species and are mainly produced by females to attract males), trail pheromones (guide social insects to distant food sources), recruitment pheromones (induce nestmates to leave the nest and migrate to a work site or vice versa), royal pheromones (enables workers to recognize patronage like kings and queens, thereby maintaining the strain reproductive division).

✓ Genetic controls: Genetic engineering offers great promise in breeding pest-resistant plants more quickly, e.g. a gene from *Bacillus thuringiensis* has been introduced into several plants such as cotton. This has been effective against caterpillars that eat cotton leaves. Further work has been done to greatly increase the potential of Bt toxin as a natural pesticide by modifying the gene coding for the toxin, so that it affects a wider range of insect pests while studying resistance management strategies to curb pest resistance to GM crops.

✓ Quarantine: Governments attempt to prevent the importation of foreign pests and diseases by practicing quarantine or to restrict the importation of exotic plant and animal materials that might harbor pests. If a foreign pest is accidentally introduced, the quarantine of the area where it is detected helps prevent its spread. If a foreign pest is detected on a farm, the farmer may be required to destroy the entire crop.

✓ Integrated pest management (IPM): IPM coordinates practices that reduce the quantity of pesticide use and exposure to chemicals. Since it is impractical to ban a large number of pesticides right now, implementing programs to reduce pesticide use is critical and IPM represents the most effective way to control and

manage pests because it uses cultural, mechanical, and biological pest controls where possible (Raven and Berg, 2004). The general goals of IPM are to: reduce pesticide levels in the environment; lessen hazards to people and the environment; increase the use of natural pest controls; develop a greater understanding of effective pest control methods and establish programs that will encourage voluntary participation. IPM is an important part of sustainable agriculture that optimizes natural controls by using agricultural techniques that discourage pests. In order to be effective, IPM requires a thorough knowledge of the life cycles, feeding habits, migration and nesting habits of the pests as well as all of their interactions with their hosts and other organisms. The complex, sophisticated knowledge needed to use IPM as stated above accounts for why it is not widespread.

The legal framework for the reduction of pesticide residues in local foods in Nigeria

The steady increase in the incursion of pesticide residues in the food chain right from 1958 to 2018 in Nigeria vividly unveils a symmetrical dilemma in the regulatory efficiency of administrative institutions empowered by the law to monitor the influx of pesticides into the market, and indeed the efficiency of legal enforcement agencies to prosecute erring individuals and companies that consistently endanger the lives of food consumers.

Section 135(1) of the FCCPA compels manufacturers and distributors of goods to notify the public of goods that can endanger their health and then withdraw such goods completely from the market. Sub-section (2) of the above section imposes strict penal consequences for the sale of contaminated foodstuffs on the marketer and sellers. However, it is saddening that despite the existence of these penal and punitive legal sanctions against food contamination that can result from the indiscriminate application of pesticides on foods, no individual or body corporate has been brought to book. Thus, this prosecutorial dereliction on the part of enforcement agencies continues to portend a setback on the effectiveness of the law in reducing the indiscriminate use of pesticides.

Hence, the role of pesticide producers in economic growth cannot be undermined, especially in countries such as Nigeria, where there are poor transport and storage facilities for agricultural produce, and as such, the law cannot stop the production of pesticides as a measure to curb the indiscriminate pesticide application on food. However, the law put in place regulatory measures on the importation, production, registration and even advertisement of all kinds of pesticides in Nigeria by establishing statutory corporations such as the National Agency for Food and Drugs Administration and Control (NAFDAC), the Federal Competition and Consumer Protection Commission (FCCPC) and the National

Environmental Standard and Regulation Enforcement Agency (NESREA), to regulate which kinds of pesticides can be imported or produced.

The NAFDAC Act and its subsidiary legislations empower NAFDAC to control the production, importation, registration of drugs such as pesticides and even prescribe standard specifications and guidelines for their products so that the kinds of pesticides that are imported or produced are not injurious to consumers' health. Hence, no pesticide can be put to sale in the market except they are registered, and they cannot be registered until NAFDAC has certified that they pose no injurious consequences on consumers' health.

It is further worthy to note that the National Environmental Standard and Regulation Enforcement Agency has the responsibility, under section 7(f) of the NESREA Act, to enforce the safe use of pesticides, especially at the stage of its application on farm crops and during food storage. Therefore, it is safe to aver that Nigeria has sufficient laws and agencies on pesticide regulations, but the enforcement of those laws and efficiency of those agencies are lacking (Ojo, 2016; Njoku et al., 2017). Thus, there is an urgent need for effective collaboration among NAFDAC, NESREA, and FCCPC, to prosecute erring persons and regulate the sale and usage of pesticides.

Therefore, it is submitted that there is a need for a state of emergency to be declared on food security through the inauguration of a task force on pesticide residues in foods. The task force will consist of governmental agencies of strategic importance and traders' associations for surveillance. The customs and immigration services must strictly stiffen and tighten up the Nigerian borders in order to curb the illegal smuggling of pesticides in the country. It is nevertheless admitted that this clean-up plan can only thrive in a corrupt-free environment. Hence, no meaningful result will be made if the border guards are the smugglers to be waded off. However, there is no doubt that an honest, committed and painstaking scrutiny at the borders will substantially reduce the presence of sub-standardized pesticide products in the market.

It is further submitted that the federal, state and local governments can build massive pest and disease resistant silos in every local government area, where agricultural produce can be stored in large quantities and also sold to traders. If this initiative is well implemented, it will save the traders the need to fumigate their stored food with pesticides, and by implication, there will be a significant reduction in pesticide residues in foods.

Conclusion

The pervasiveness of the indiscriminate use of pesticides for agricultural, preservative and domestic purposes remains unabated. Its grave consequences on human health continue to raise serious concerns bearing the urgency of effective

strategies for reducing pesticide residues in food. While the eradication of pesticides seems not to be feasible due to socio-economic reasons, the panaceas for pesticide food poisoning scenarios in Nigeria lie in the regulation and monitoring of pesticide production, importation, marketing and usage as well as the adoption of alternatives to synthetic pesticides.

In the light of the foregoing, this study concludes with the following recommendations:

i. Future studies should not only examine the potential risks of pesticide exposure but also establish a wide range of pesticide exposure patterns that appear to exist within Nigeria's populations.

ii. The Government and private sectors should sponsor public sensitization programs on the best handling of pesticides and the danger associated with the abuse and misuse of pesticides in Nigeria.

iii. The Government should prioritize and incentivize a zero-pesticide food production and distribution from the farmers down to the food wholesalers to consumer chain in order to support food security, economic goals and community benefits.

iv. The Government should encourage the public to patronize safe alternatives to chemical pesticides and to have an inclusive national pesticide policy that will guide against misappropriation, mishandling, and smuggling of uncertified pesticides.

v. NAFDAC should develop a comprehensive regulatory system that seeks to make possible the beneficial use of pesticides while minimizing their hazards to public health and the environment.

vi. NAFDAC and other regulatory agencies should be empowered to conduct periodic monitoring of food samples for pesticide residues; they should incorporate standard reporting procedures and establish a computerized database to collect data on pesticide residues of food samples in the market, and the residue testing program should include all toxic forms of pesticides, e.g. their metabolites and degradation products.

vii. Customs and immigration services should be tasked to monitor the smuggling of contraband pesticides through the porous borders.

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Received: April 29, 2021
Accepted: February 9, 2022

STRATEGIJE ZA SMANJENJE OSTATAKA PESTICIDA U HRANI: NAPOMENE O SCENARIJU TROVANJA PESTICIDIMA U HRANI U NIGERIJI (1958–2018)

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R e z i m e

Prehrambena nesigurnost širom sveta, posebno u zemljama u razvoju kao što je Nigerija, predstavlja zdravstvene izazove zbog različitih zagađivača životne sredine, uključujući prodor pesticida u biosferu i posledično zadržavanje ostataka pesticida u sastavu hrane. Ovo istraživanje pruža uvid u sveobuhvatnu analizu o tome kako je neselektivna primena pesticida ugrozila i kopneni i vodeni ekosistem, promenila lanac ishrane i izazvala užasnu učestalost trovanja hranom. Dostupni podaci od 1958. do 2018. o scenarijima trovanja pesticidima prisutnih u hrani u Nigeriji su prikupljeni, upoređeni i kritički procenjeni. Nalazi ove analitičke studije, koja se kreće kroz detaljnu analizu sadržaja i diskursa pouzdanih informacija, razotkrili su različite kanale kroz koje su ostaci pesticida prodrli u lanac ishrane i njihove opasne implikacije na biljke, životinje i ljude koji su pri kraju lanca ishrane. U rešavanju ove dileme, autori su predložili niz međusobno povezanih kritičnih, strateških i taktičkih pristupa za smanjenje trovanja pesticidima, koji će se, ako ih usvoje nigerijska vlada i vlade drugih zemalja u razvoju, efikasno boriti protiv rasprostranjenosti ove pretnje prehrambenoj sigurnosti.

Ključne reči: akcioni planovi, ekološka održivost, Nigerija, ostaci pesticida, urbana hrana.

Primljeno: 29. aprila 2021.
Odobreno: 9. februara 2022.

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