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Article

Searching for What You Can't See - Evaluation of Pesticide Residues in Grain Sold at Selected Markets of Southwest Nigeria

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Abstract: Studies on the use of pesticides in southwest Nigeria have revealed a substantial rise in a variety of pesticide-related illnesses, including mental impairment and reproductive problems. Those who work in agriculture and are regularly exposed to pesticides are the most impacted. The World Health Organization (WHO) predicts that three million severe pesticide poisoning episodes occur globally each year, with at least 300.000 deaths and 99% of cases occurring in low- and middle-income nations. The effects of longer-term exposure to pesticides on health are not yet precisely estimated. **Objectives:** To this end, the objective of this study is to assess the knowledge of pesticide residues and common pesticides in grain-based food (brown and white beans, yellow and white maize, brown millet and rice) about pesticide use in selected markets of Southwest Nigeria. **Methods:** A total of 240 respondents were selected from four states (Ado-Ekiti, Ibadan, Osun and Ondo) with the aid of structured questionnaire and interview guide using purposive sampling technique. The markets were Oja-titun (market) Ile-Ife, Osun; Alesinloye Market Ibadan, Oyo; Oja Oba, Ado-Ekiti, Ekiti; and Oja Oba, Akure Ondo State. The identification and quantification of pesticide residues was done using a Varian 3800/4000 gas chromatograph mass spectrometer while 60 structured questionnaires were administered to respondents including food merchants, buyers/consumers as well as food vendors. Data were analysed using descriptive statistics. **Results:** The experiment was conducted from November 2020 to November 2021. Up to 50.4% never read instructions on pesticide application while a shared 24.8% read them always and occasionally. The number of respondents who never read the instructions were particularly high in Ekiti and Ondo, up to 52.5% of the respondents in Ekiti do not know whether or not they are exposed to pesticides during application. Also, majority of the respondents never attended any professional training on pesticide application, this amounted to 79.3%. Most people were not aware that unsafe pesticide application is harmful to human health. Similarly, a wide variety of symptoms were reported by respondents following pesticide application or consumption of grains, these included headaches and dizziness, itching and redness of the eyes, skin allergy, diarrhea, and stomach disorder, vomiting and loss of appetite, weakness of the body, asthma, permanent skin patches, shortness of breath, excessive sweating. Millet recorded the highest number of OCP residues while maize had the lowest. On the contrary, maize had the highest number of OPP and carbamate residues while millet had the lowest number of OPP residues. Meanwhile, maize, rice and beans had only one carbamate pesticide residue. **Conclusions:** According to the study's conclusions, farmers who can only get information from agricultural extension officials should receive urgent and immediate attention for raising awareness. Additionally, extensive IPM training programs must be created with the intention of disseminating precautions for protecting human health and a healthy agro-ecosystem. In order to find more effective pest management methods that utilize less pesticides, it

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is crucial to reevaluate the pesticide residues and common pesticides found in grains in the targeted markets. To reduce farmers' exposure to pesticides, it is also required to establish personal protective measures, special educational initiatives, and legislation promoting the use of safer pesticides. **Significance and novelty:** This study gives policymakers a comprehensive understanding of the ways that may be utilized to close the significant knowledge gap on pesticide residues in grains and provides an insight into the knowledge of pesticide residues and common pesticides in grains.

Keywords: Nigerian Market, Pesticide Applications, Knowledge, Practice, Pesticides Exposure, Public Health, Food Production

1. Introduction

Pesticides are utilized worldwide in agriculture and other industries in two million tons per year. In contrast to non-chemical-based pest management methods, economic and agricultural policies in many African countries encourage the use of pesticides. It will be extremely difficult for humankind to meet future food demands without further compromising the integrity of the Earth's environmental systems in the next decades [1–7]. Although agricultural systems presently play a significant role in the destruction of the environment, population expansion and rising consumption are predicted to roughly treble that demand by 2050 [8–14]. In response to these demands, "sustainable intensification" is receiving more attention as a way to boost yields on underutilized landscapes while at the same time lowering the environmental impacts of agricultural systems [15–20]. The persistence of pesticides in the environment as a result of their accidental or deliberate usage has had an impact on ecosystems and organisms that are not intended targets. Acute and chronic pesticide poisoning typically happens as a result of eating contaminated food, having a chemical mishap at work, or being exposed to pesticides while working in agriculture [21–30]. Nigeria imports 135 pesticide compounds totaling roughly 15,000 metric tons of pesticides per year [31]. The Environmental Protection Agency (EPA) estimates that agricultural output accounts for 76% of all pesticide use in the country, with the remaining 24% going to the urban, industrial, forestry, and public sectors [32]. With less work, agricultural production has risen owing to these chemicals. However, issues related to incorrect pesticide use had resulted in human disease, wildlife extinctions, and deterioration of water quality [21-30, 32]. Research on pesticides are seen to be crucial for lowering pesticide risk and enhancing public health regulations [33–38]. In Nigeria, it has been calculated that between 125,000 and 130,000 metric tons of insecticides are used annually [39]. Nonetheless, the use of pesticides has also given rise to worries about their impact on the environment and the possibility of harmful or cancer-causing residues persisting in the food chain [1-3]. Investigations revealed that the usage of some deadly chemicals during the production of the yam flour may be blame for cases of food poisoning that affected three households in Kano [40]. Another case of food poisoning in five families in Ilorin, central Nigeria, was linked to the intake of yam flour [41]. The usage and abuse of agrochemicals and pesticides on cereals and other agricultural goods in Nigeria has been connected to the rise in incidents of food poisoning. According to the research, these pesticides were misused and used incorrectly in order to avoid pests. Twenty thousand fatalities and over three million episodes of acute food poisoning are caused by exposure to food pesticides each year. A sudden development of gastrointestinal problems among attendees and diners at a funeral service led to 60 cases of food poisoning and three fatalities [42]. Food is still necessary since it contains nutrients that support life even at the cellular level. Regardless of social status, origin, gender, or age, everyone in human society is affected by the critical

socioeconomic and scientific issue of food security [21–30, 43]. According to the definition of food security given by the UN Committee on World Food Security, food security is achieved when everyone has access to enough, safe, nutrient-rich, and preferred choices of all food at all times, enabling them to meet their dietary needs and lead active, healthy lives [44, 45]. This is typically not the case, however, as food is typically seen from the perspective of sufficiency, with less emphasis being placed on its nutritional content and safety [30, 46]. Grains constitute a significant component of the world's staple diet and include pulses like cowpea and soybean as well as cereal crops like rice, maize, and millet [47]. In Nigeria, millet and maize are significant crops that are consumed in a variety of ways. A variety of regional foods, including akamu and tuwo, are derived from maize, as well as complementary baby food [48, 49]. Millet provides a significant source of calories and important elements in a similar way [50]. The majority of the time, it is prepared as a whole grain or transformed into auxiliary dishes like tuwo and fura [51]. It is advised for people with diabetes and celiac disease due to the absence of gluten and the slow-releasing carbs it contains [52]. Cowpeas, on the other hand, can be dehulled and turned into a paste that is cooked as moi-moi or fried to produce akara. Cowpeas are typically prepared and eaten straight away. In Nigeria, particularly in urban areas, rice is gradually becoming a staple food with no close substitute. Insufficient local production and import of rice lead to the scarcity of these grains, contributing significantly to food inflation and general inflation [53]. However, Nigeria's 2.08% increase in rice production to 5.35 million metric tonnes in 2022 did not reduce the gap between the higher demand and lower supply of the product nor the price of its 5 common brands. Thus, millions of Nigerians consume one rice variant every day, ranging from local rice, imported rice, ofada rice, long grain rice, basmati rice, and so on.

Our food systems, which include how we grow, process, and store food, are responsible for the nutritional value, quality, and safety of the food we eat [11, 54]. The need for food is expanding along with the growth of the global population. Up to 40% of food grain losses in sub-Saharan Africa occur in storage as a result of pests [55]. Food merchants should use insecticides to combat pests as their first line of defense to reduce losses [56]. Typically, this is done to limit harm and protect company revenues. Pesticides are becoming a necessary component of food storage as a result [57]. Even though pesticides are "essential" and have long been crucial to food security, their sustainable usage has generated controversy [58]. 584 tonnes of the approximately 147,446 tonnes of pesticides imported into Nigeria for agricultural usage in 2018 were reportedly dangerous [59]. Pesticides are not adequately regulated, and their presence in food has raised concerns across the globe [60]. Any organism that tampers with stored goods is referred to as a pest in the context of food storage [61]. They consist of rodents, bacteria, and insects. Insecticides, antimicrobials (fungicides and antibacterial), and rodenticides are thus some of the pesticides used on stored goods [62–64]. Pesticides can come from either natural or artificial sources. For instance, botanicals or pesticides produced from plants are typically benign, synthetic pesticides used to eradicate insect pests have been mostly to blame for the presence of toxins in food [65]. Synthetic pesticides can be divided into four categories based on their chemical structures: organochlorine (OCPs), organophosphate (OPPs), carbamates, and pyrethroids [66]. In contrast to OCPs and OPPs, which have severe toxicity, pyrethroids can also be synthesized from the flowers of plants in the genus Chrysanthemum [67–69]. OCPs are classified as persistent organic compounds because they are stable despite the rapid degradation of OPPs and carbamates [70]. For instance, Dichlorodiphenyl-Trichloroethane (DDT), a form of OCP, may take up to 30 years to degrade [71]. Therefore, research has indicated that pesticides constitute a significant global cause of death. Pesticide residues in food have been associated with a number of illnesses, including cancer, allergies, irritability, self-poisoning, and problems with reproduction and birth [72]. In Nigeria, there have been reports of low compliance with pesticide restrictions, ignorance of the risks associated with pesticide exposure,

inadequately enforced laws, and a lack of efficient monitoring programs for locally produced and consumed food [49, 73]. In order to identify and track potential health risks linked with pesticide usage and its effects on health, it is crucial to research pesticide residues in food. Additionally, it would offer crucial data or proof that decision-makers in governmental and non-governmental groups would need to take action. This study's goal is to evaluate consumer awareness of pesticide use and common pesticide residues in grain-based foods (brown and white beans, yellow and white maize, brown millet, and rice) in a few Southwest Nigerian markets.

2. Material and Methods

2.1. Study Area

The study area is selected markets across four states (Ekiti, Oyo, Osun and Ondo States) in Southwestern, Nigeria. The markets were: Oja-titun (market) Ile-Ife (16˚ 18′ N 23˚ 33′ E), Osun; Alesinloye Market Ibadan, Oyo (7˚ 26′ N 3˚ 55′ E; Oja Oba, Ado-Ekiti, Ekiti (7˚ 37′ N 5˚ 13′ E); and Oja Oba, Akure Ondo State (7˚ 15′ N 5˚ 12′ E) (see Figure 1 below). Hereinafter, the market will be referred to as Ekiti, Oyo, Osun and Ondo, for clarity.

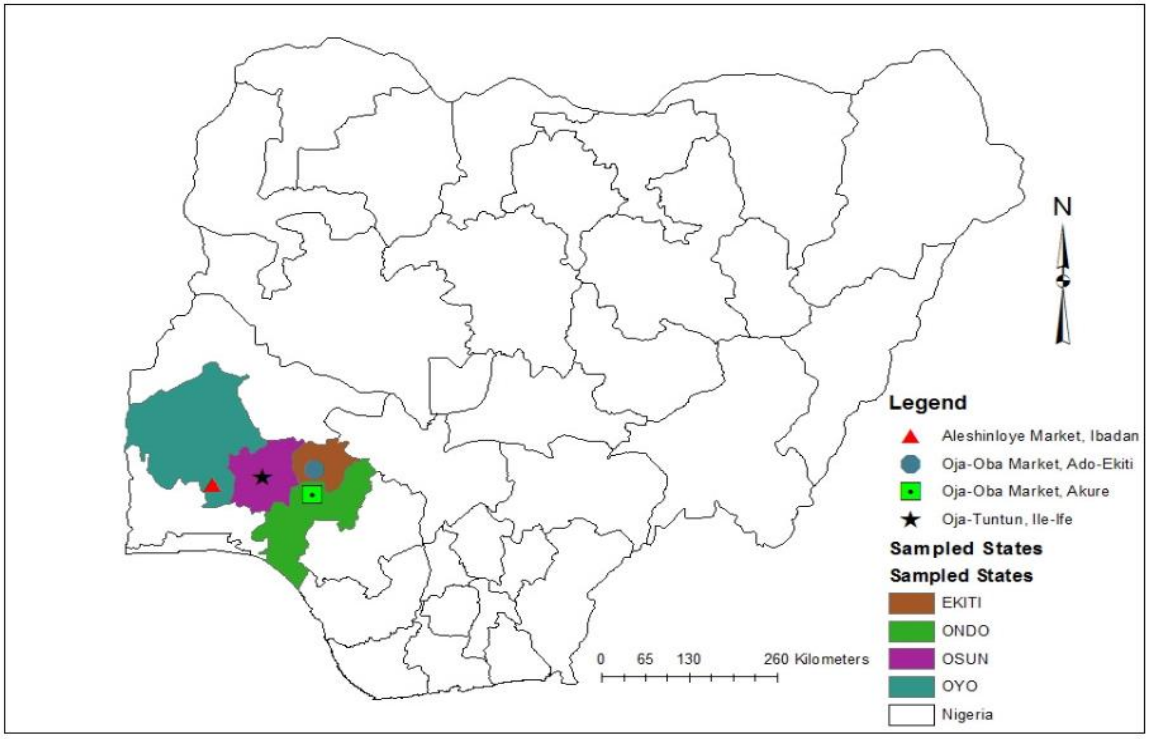

Figure 1. Map showing the study area

2.2. Sample collection and preparation

Samples of dry beans, maize, millet, and rice (local and foreign) were purchased from the four markets. Six samples of brown and white beans, white and yellow maize, brown millet, and rice were collected from all four markets except for Ondo (Oja-Oba market, Akure) where yellow maize was not available. The grain samples were bought in the dried state such that there was no need for the samples to undergo additional drying. We patronized grain merchant and purchased each of the six grains sample. Each grain sample was bought in three separate portions of 200 – 250g and put in black-coloured polyethylene plastic bags, labelled and transported to the laboratory. On arrival, the

samples were sorted to remove impurities including stones and shafts. Thereafter, the samples were thoroughly ground using mortar and pestle, and thereafter a hand-grinding machine was used to pulverize into fine powder. Finally, each of the powdered grain sample was stored in labelled Ziploc bag and kept at 4°C in a refrigerator.

2.3. Research Design

According to Abdulraheem *et al.*, [74] and Funmilayo *et al.*, [75] Research Design refers to how a piece of research is planned and carried out. The study adopted the Descriptive Survey Research Design to meet its purpose. According to Abdulraheem *et al.*, [74] and Funmilayo *et al.*, [75] surveys describe current conditions or attitudes as well as explain the reason for certain existing situations. The survey method has the advantage of effectiveness in obtaining information about personal perceptions, beliefs, feelings, motivations, anticipations and future plans as well as past behaviours. Abdulraheem *et al.*, [74], Funmilayo *et al.*, [75] put it succinctly when they stated that the survey interprets, synthesizes and integrates useful data for sound conclusions. The survey design provided a quantitative or numeric description of patterns or trends, attitudes, or opinions of market grain sellers [74]. This allowed for generalization from the sample about the population so that inferences could be made about the knowledge of pesticide residues and common pesticides in grain-based food (brown and white beans, yellow and white maize, brown millet and rice) about pesticide use in selected markets of Southwest Nigeria. The survey design was chosen because it was easy to produce economically and made data collection easy [75]. The study design was cross-sectional using structured questionnaire as the tool for collection of primary data, hence the quantitative nature of the study.

2.4. Research Population

Population refers to the entire subjects that the researcher will get information from. My population is a finite population which are, the number of market grain sellers in Southwest Nigeria [75]. Research population is generally a large collection of individuals or objects that is the main focus of a scientific query. It is for the benefit of the population that researches are done. Abdulraheem *et al.*, [74], Funmilayo *et al.*, [75] says population of study signifies the entire class of people, object, events or elements to which generalizations are to be inferred. A research population is also known as a well-defined collection of individuals that have similar characteristics. Thus, the population of this study comprised of two hundred and fourty (240) consisting of grain-based food sellers in selected markets of Southwest Nigeria namely.

Table 1. Sample distribution of selected market

S/N	Market	Sample Size
1.	Oja-titun (market) Ile-Ife, Osun State	60
2.	Alesinloye Market Ibadan, Oyo State	60
3.	Oja Oba, Ado-Ekiti, Ekiti State	60
4.	Oja Oba, Akure Ondo State	60
	Total	**240**

Source: *Researchers computation (2022)*

2.5. Population of the Study

The source populations of the study were selected market in southwest Nigeria. The study populations were respondents in selected major markets who sell grains at whole sales for at least six (6) months.

2.6. Sample Size Determination

The sample size of this study was determined using Taro Yamane formula given as:

$$n = \frac{N}{1 + N(e)^2}$$

Where, N = 240, e =0.05.

$$n = \frac{240}{1 + 240(0.05)^2} = \frac{240}{1 + 0.6} = \frac{240}{1.6} = 150.$$

Hence, sample size of 150 grain-based food sellers in selected markets of Southwest Nigeria was estimated. The sample size was calculated as follows:

Oja-titun (market) Ile-Ife, Osun State = $\frac{60}{240} \times 150 = 37.5$

Alesinloye Market Ibadan, Oyo State = $\frac{60}{240} \times 150 = 37.5$

Oja Oba, Ado-Ekiti, Ekiti State = $\frac{60}{240} \times 150 = 37.5$

Oja Oba, Akure Ondo State = $\frac{60}{240} \times 150 = 37.5$

2.7. Instrumentation and Measurement

Instrumentation is the method used to administer instrument to the respondents. The instrumentation for this study was questionnaire designed after an extensive literature review. The researcher took cognisance of the research question in a manner that enables the researcher gather as much information as possible from the respondents. Structurally, the questionnaire was divided into four sections A, B, C, and D. The section A, was the demographic data which consist of personal information or attributes of the respondent such as sex, age, etc, and the section B, C, and D was the core questions that strictly relate to the purpose of the study, by putting your conceptual framework into consideration.

2.8. Validity of Instrument

To determine the validity of the research instrument, the original copy of the research instrument (questionnaire) was validated by the research supervisor for review whether they are suitable for the purpose of the study, research questions, and the language that is used to develop the item. The supervisor make correction where necessary and modify the instrument before it was administered to the selected respondents.

2.9. Administration of Instrument

As earlier stated a questionnaire was administered by the researcher to the respondents directly or was given to the administrative heads or managers of the various markets which in turn will hand over the instrument (questionnaire) to the grain-based food sellers for coordination purpose.

2.10. Data Analysis Technique

Data were analysed both descriptively and inferentially. The results were presented pictorially using charts while data analysis was facilitated using the Statistical Package for Social Sciences (SPSS version 20.0).

2.11. Constraints/Limitations of the study

There are a number of limitations that need to be highlighted. The first limitation pertains to the questionnaire. Questionnaire was self-report measure and thus it provides

no potential for assessing whether respondents were faking good or faking bad or neither. It also relied on their self-knowledge and subjective experience of situations and this may impact the accuracy of the results. Some respondents were not willing to tell the right response especially in socio-demographic questions, which finally affect the findings of study. Another limitation of the study is the small sample size of the study. Also, the educational level and language barrier of some of our respondents made it difficult to fill the questionnaire. Additionally, because of the sensitivity nature of the research and the volatility nature of the study area, the researcher in company with the various market mobilizers were used to distribute the questionnaires to the sample population.

3. Results

3.1. Response Rate/ Completeness of Data

The response rate was 100%, however, out of the 150 questionnaires administered and retrieved, 29 were not useful due to improper and incomplete filling and only 121 were used, leading to incomplete data. The 121 questionnaires were finally used to analyse the demographic variable (information) and research questions.

3.2. Demographics of the Respondents

Figures 2 through 18 below show a descriptive summary of all the questions that were analyzed. Of the entire respondents, up to 50.4% never read instructions on pesticide application while a shared 24.8% read them always and occasionally (Figure 9). The number of respondents who never read the instructions were particularly high in Ekiti and Ondo while in Osun up to 97% of the respondents reads them occasionally or always.

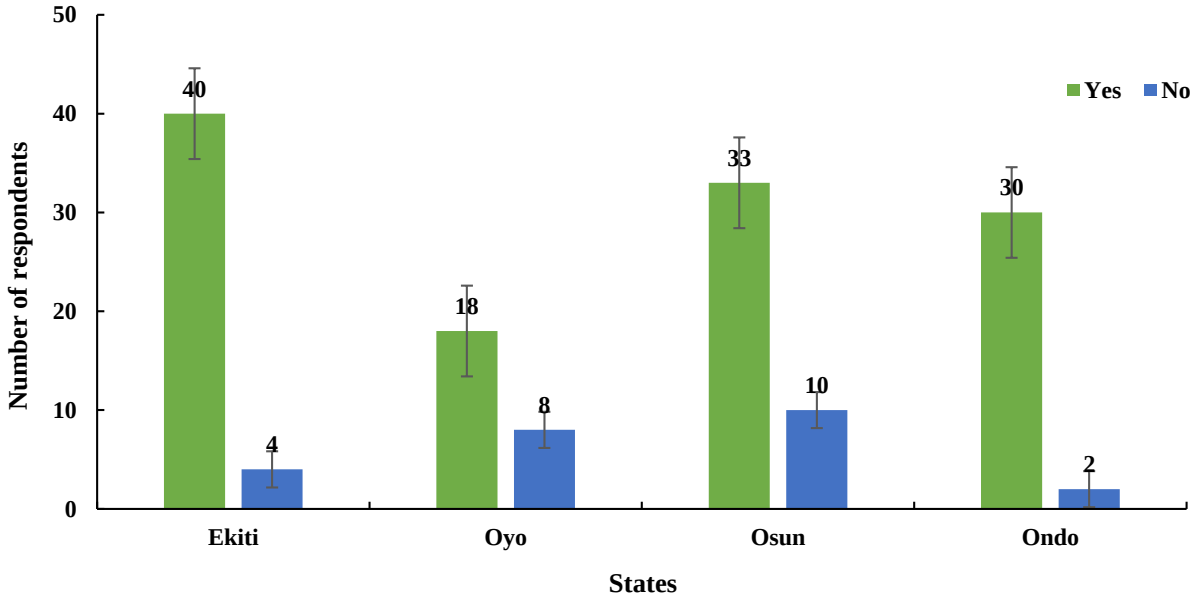

Figure 2. Responses of respondents to the question, do you spray your grains with pesticides to preserve it?

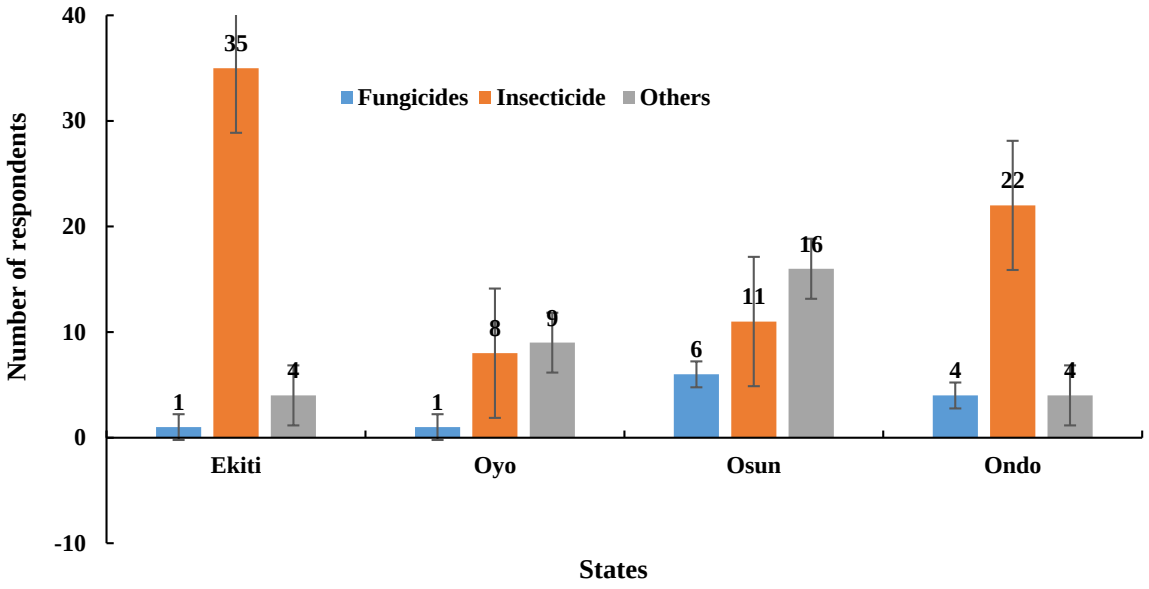

Figure 3. Responses of respondents to the question, which type of pesticide do you use?

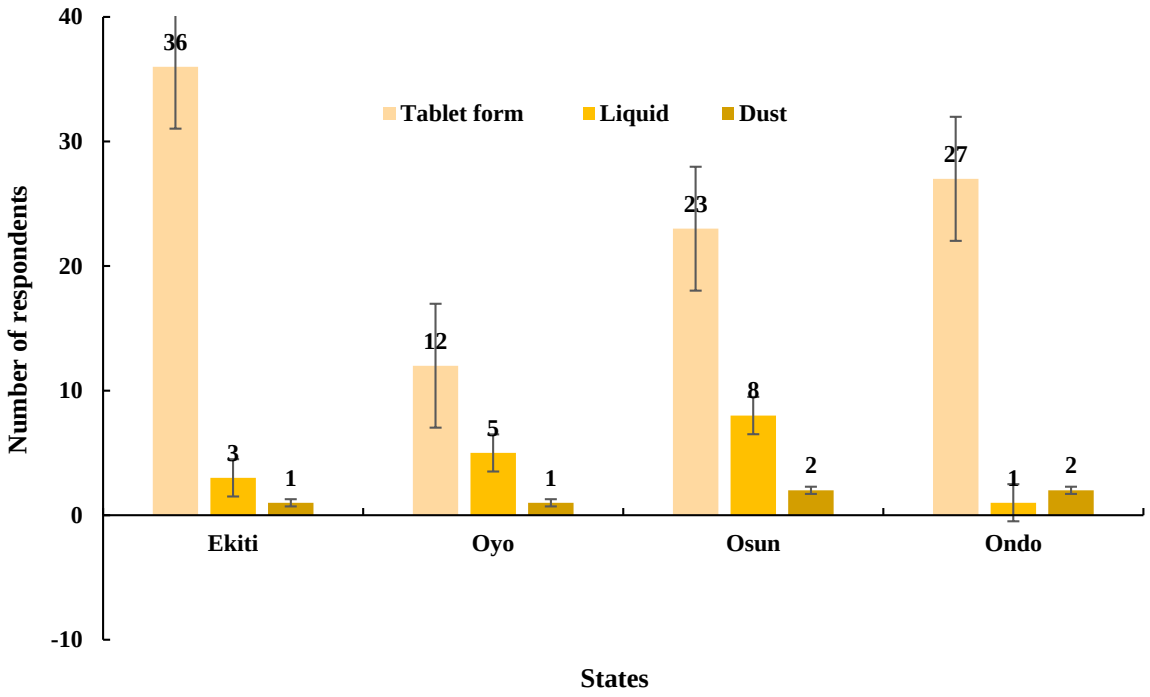

Figure 4. Responses of respondents to the question, which of these forms of pesticides do you use in preserving grains?

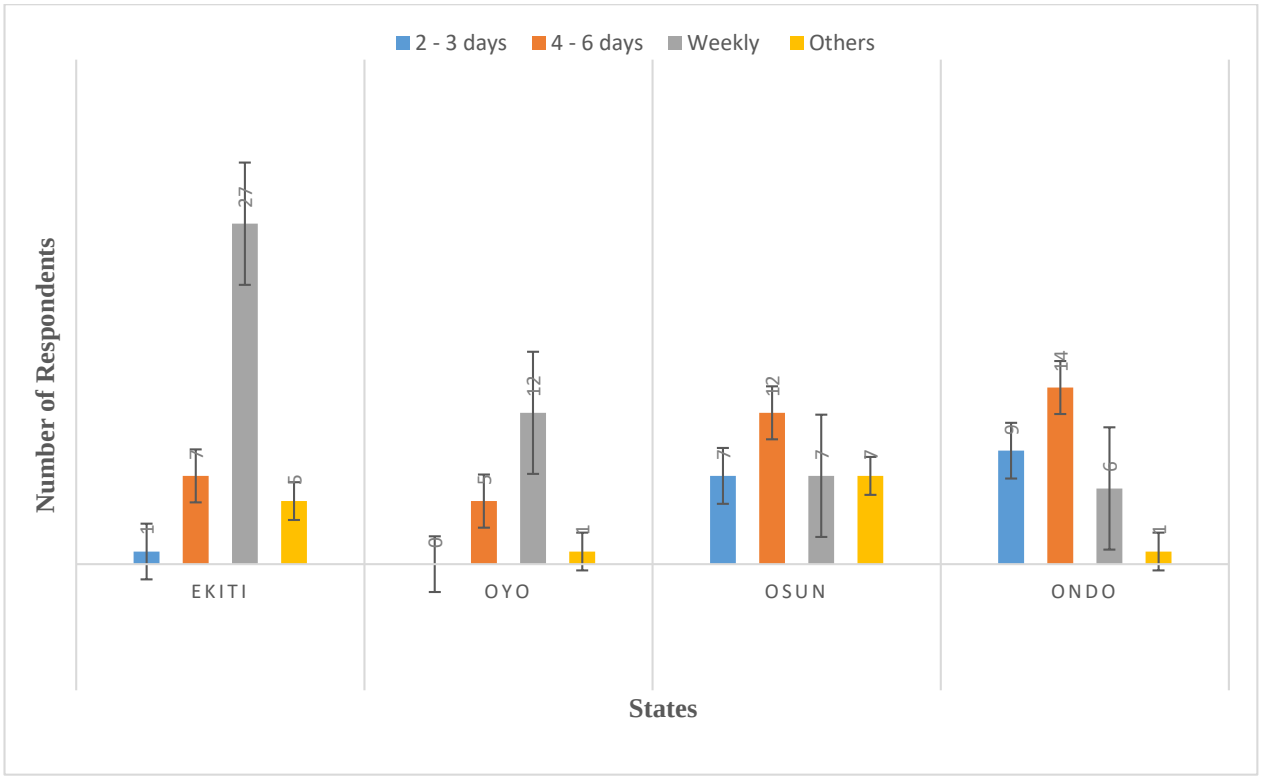

Figure 5. Responses of respondents to the question, at what time interval do you spray grains?

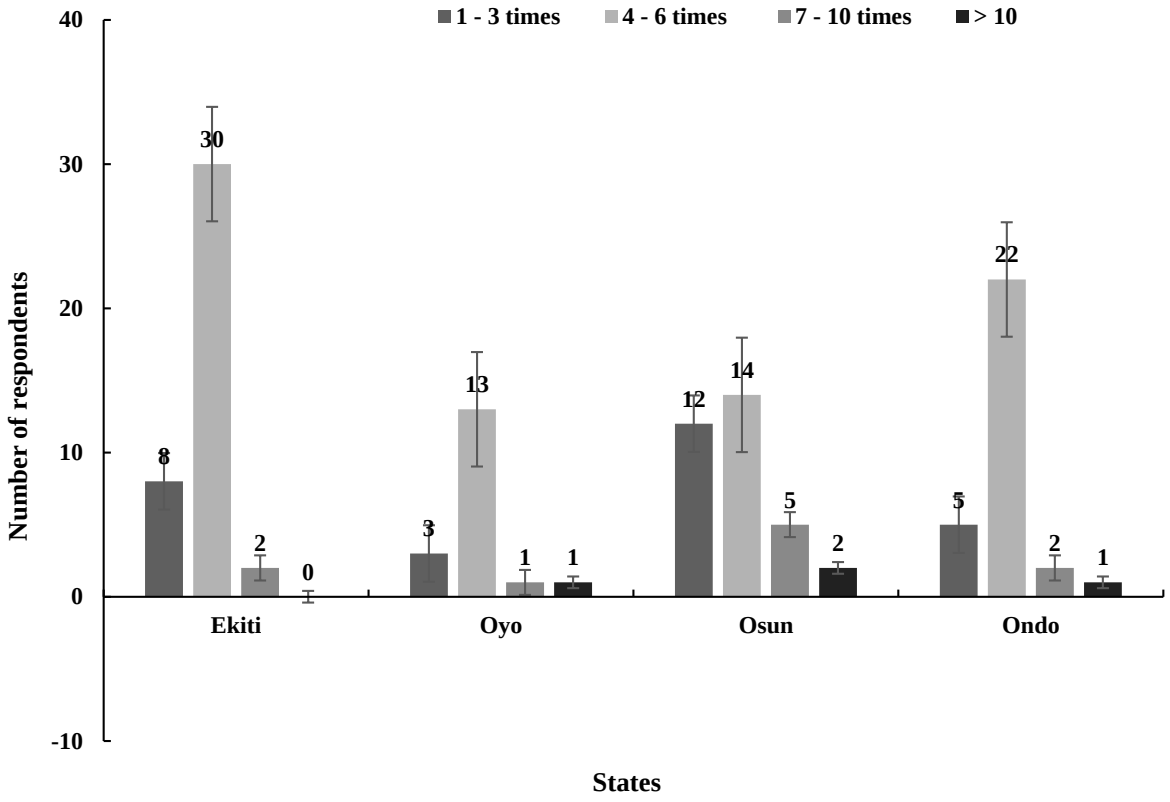

Figure 6. How many times do you spray grains each time?

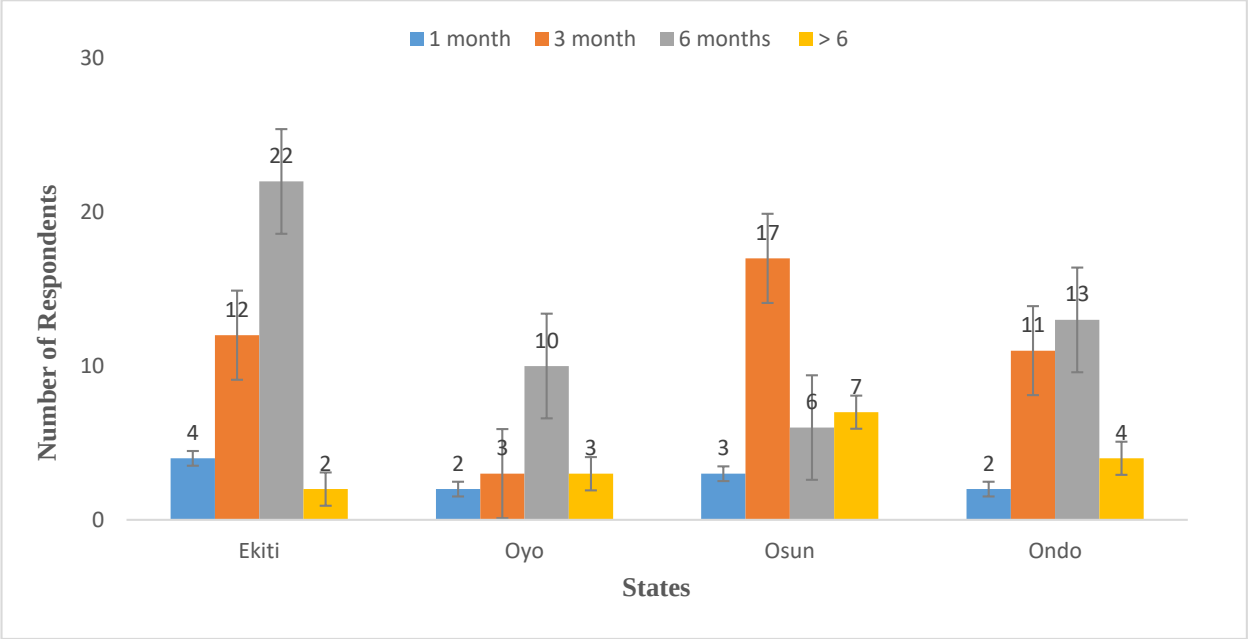

Figure 7. For, how long do you store your grains before selling?

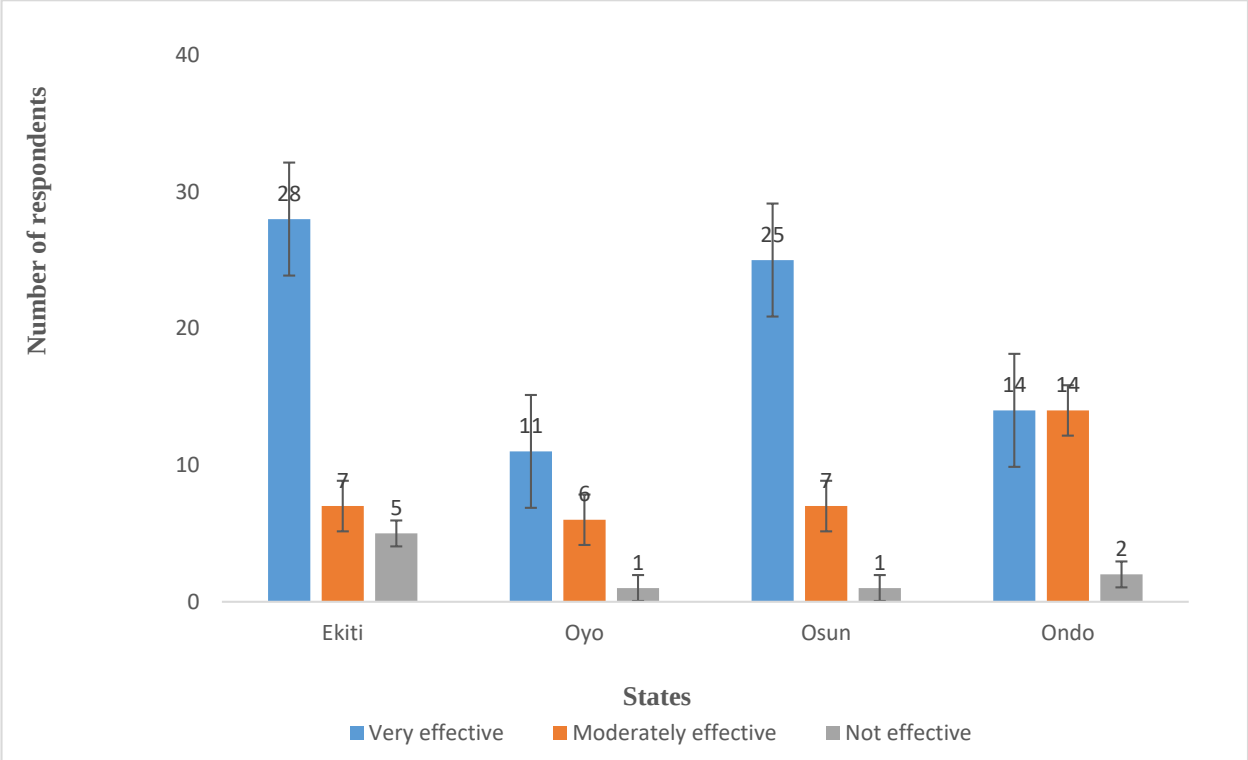

Figure 8. How effective are the most commonly used pesticide?

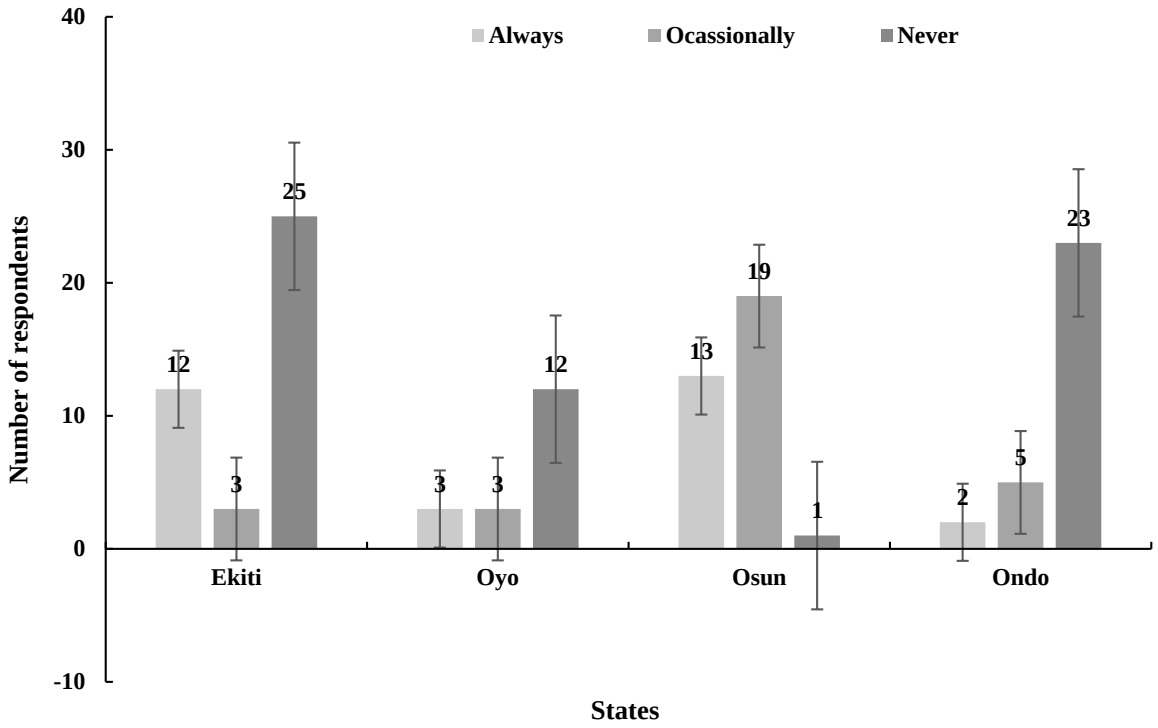

Figure 9. Do you read agrochemical instructions on pesticides before application?

Most respondents use PPE across all markets (Figure 10). These were largely facemasks in Ondo, Oyo and Osun while coveralls were also widely used in Osun (Figure 11). In Osun, Oyo and Ondo, most respondents do not get exposed to pesticides during application (Figure 12). On the other hand, up to 52.5% of the respondents in Ekiti do not know whether or not they are exposed to pesticides during application. Across the four markets, majority of the respondents never attended any professional training on pesticide application (Figure 13). This amounted to 79.3%, yet most of the respondents in each market think they can effectively handle pesticides (Figure 14). Except in Ondo where 50% of the respondents were aware that unsafe pesticide application is harmful to human health, most people were not (Figure 15). For symptoms associated with pesticide application, a wide variety of symptoms were reported by respondents following pesticide application or consumption of grains. These included Headaches and dizziness, itching and redness of the eyes, skin allergy, diarrhea and stomach disorder, vomiting and loss of appetite, weakness of the body, asthma, permanent skin patches, shortness of breath, excessive sweating (Figure 16). Headache and dizziness were the most common symptoms and thereafter itching and redness of the eyes and weakness of the body. Asthma, diarrhea and stomach disorder were the least common.

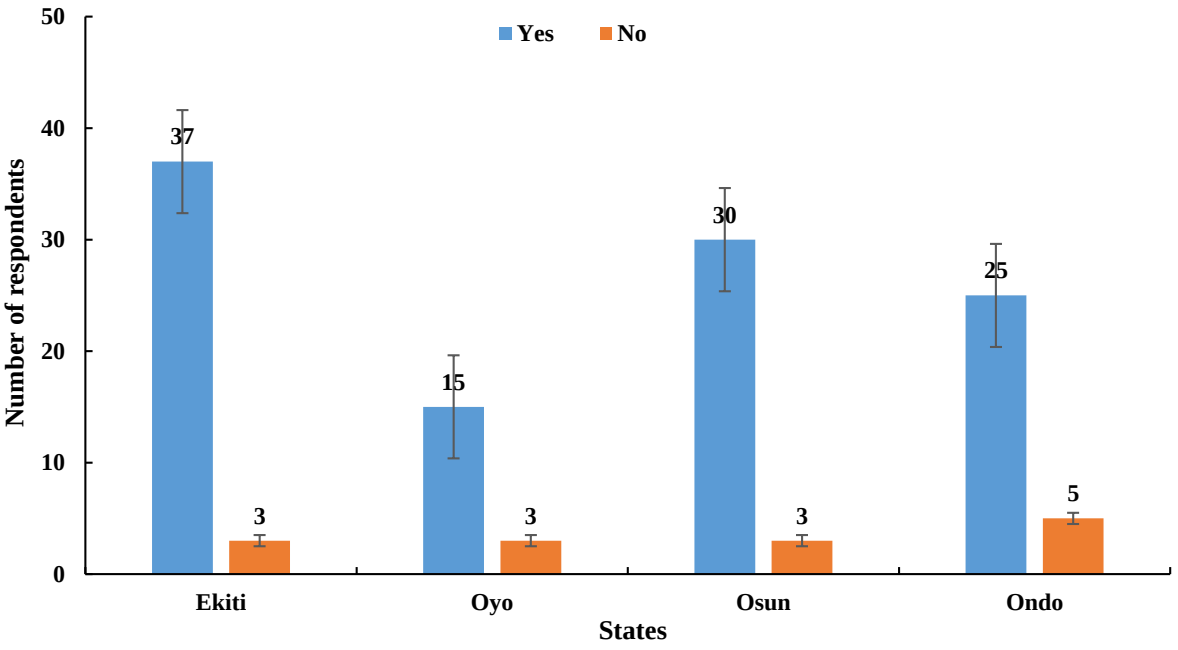

Figure 10. Do you use personal protective equipment when applying pesticides?

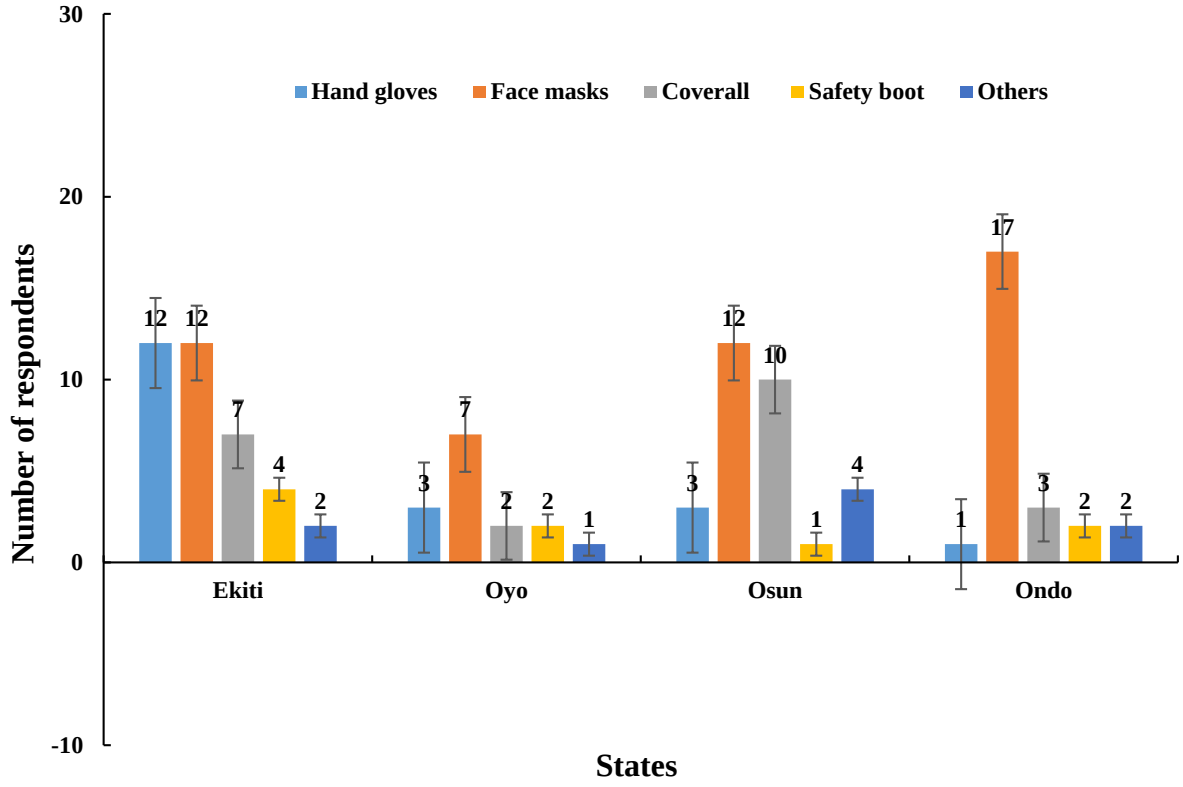

Figure 11. If yes, which personal protective equipment?

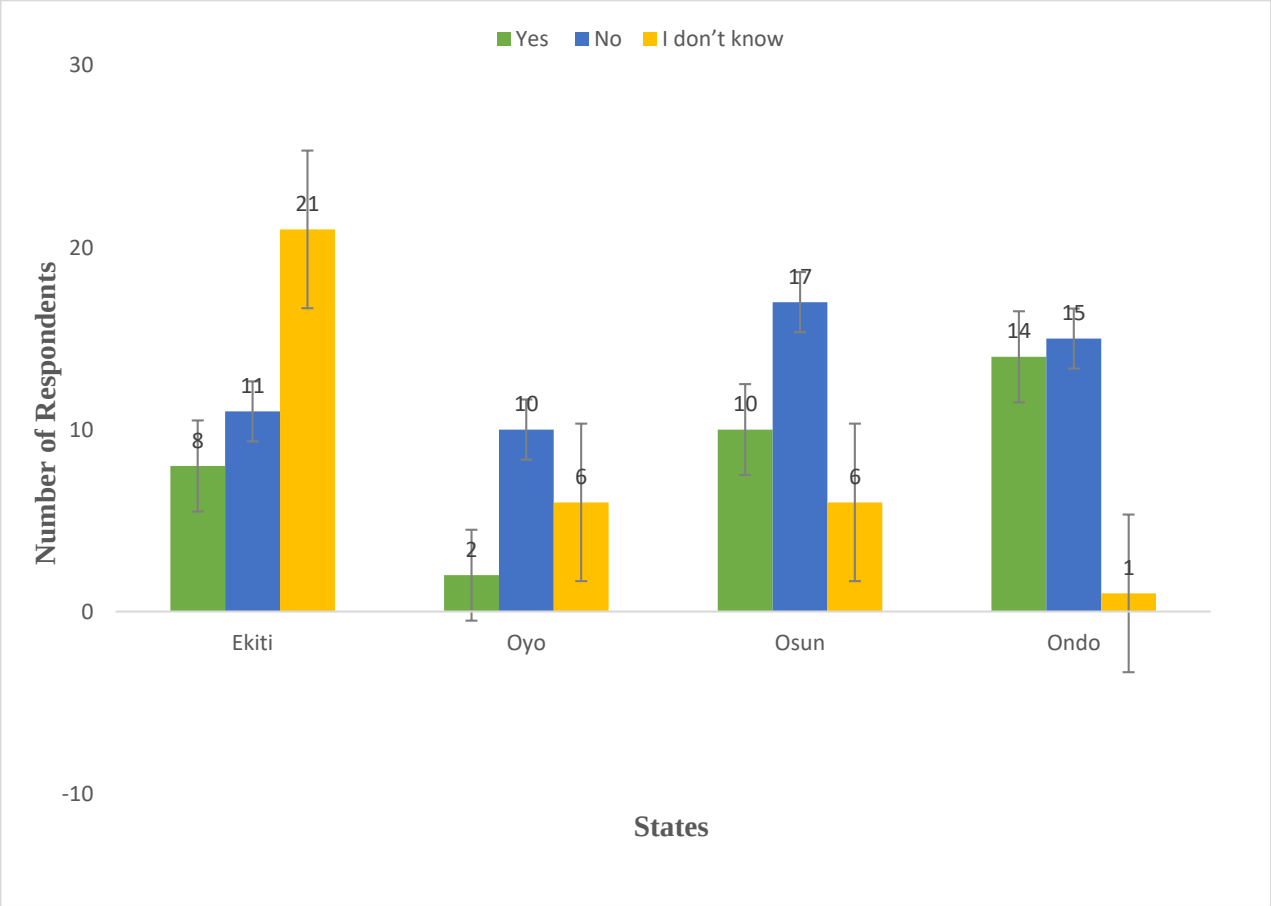

Figure 12. Do you accidently get exposed to pesticide during application?

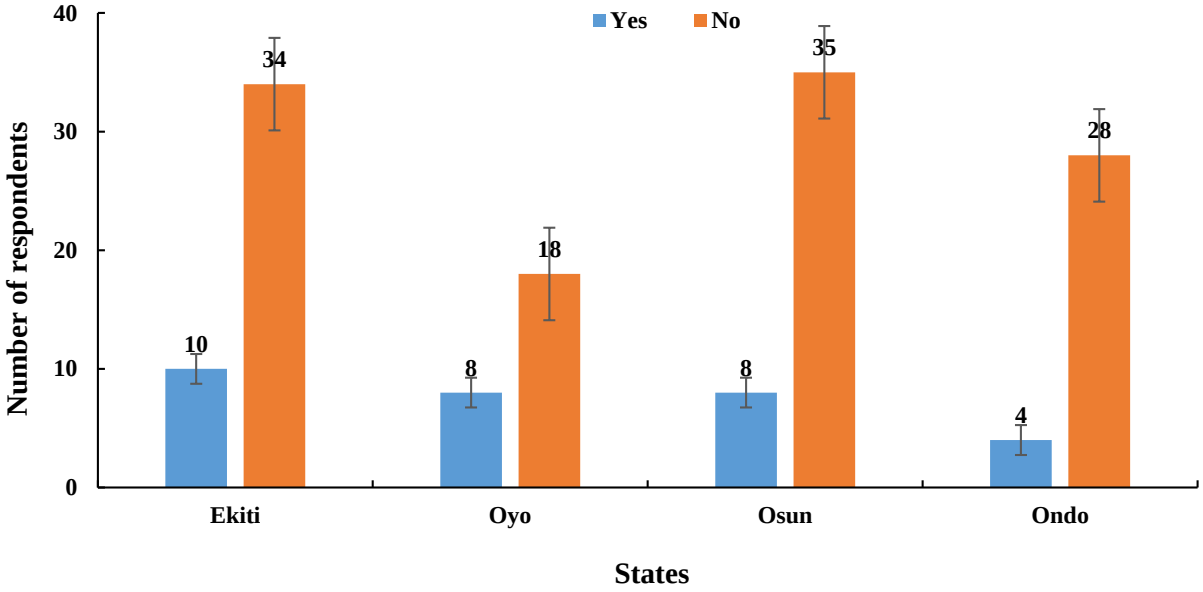

Figure 13. Do you attend any Professional training on pesticide application?

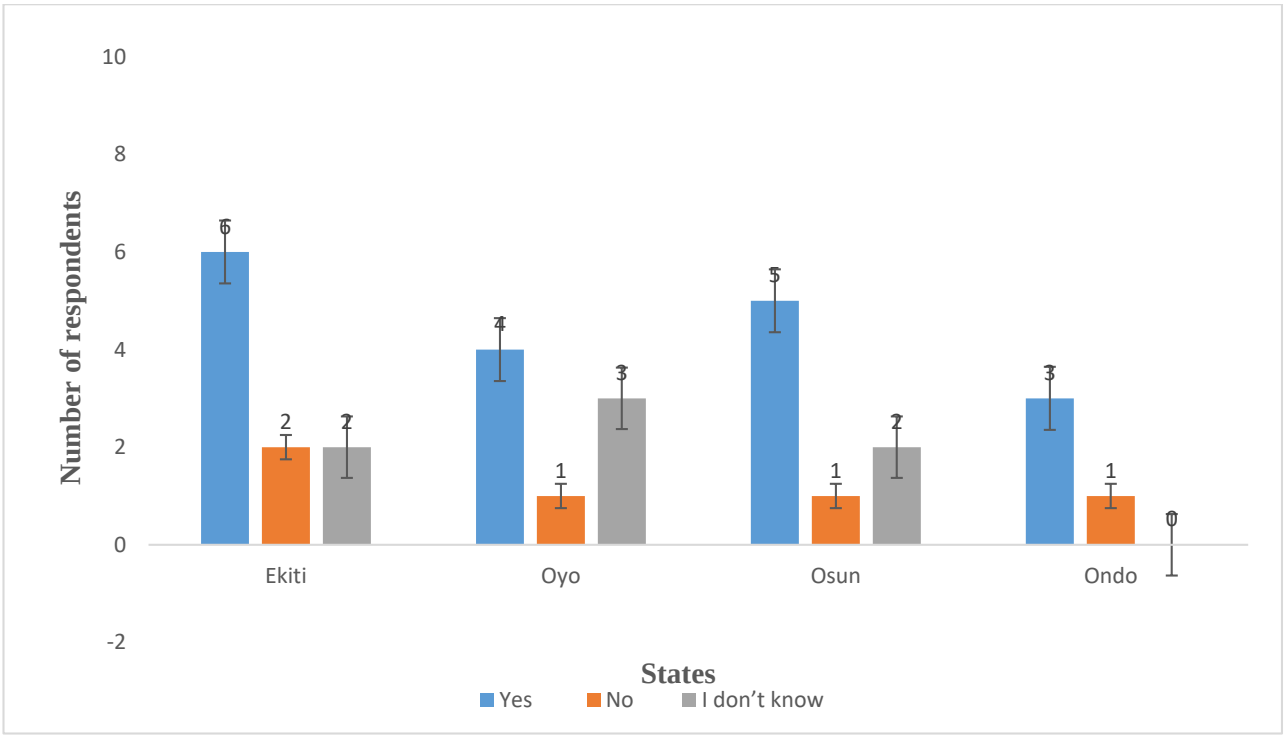

Figure 14. If yes, can you effectively handle pesticides?

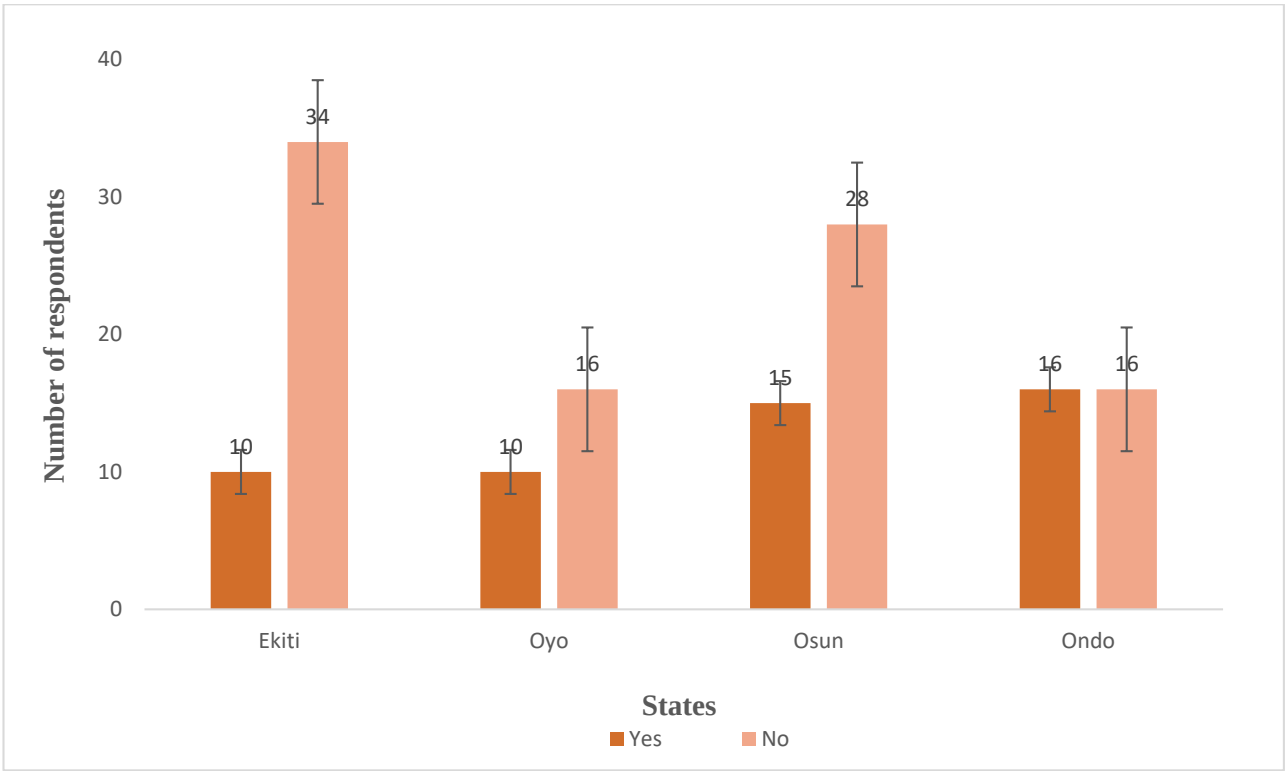

Figure 15. Are you aware that pesticide application of unsafe pesticide concentration is harmful to health?

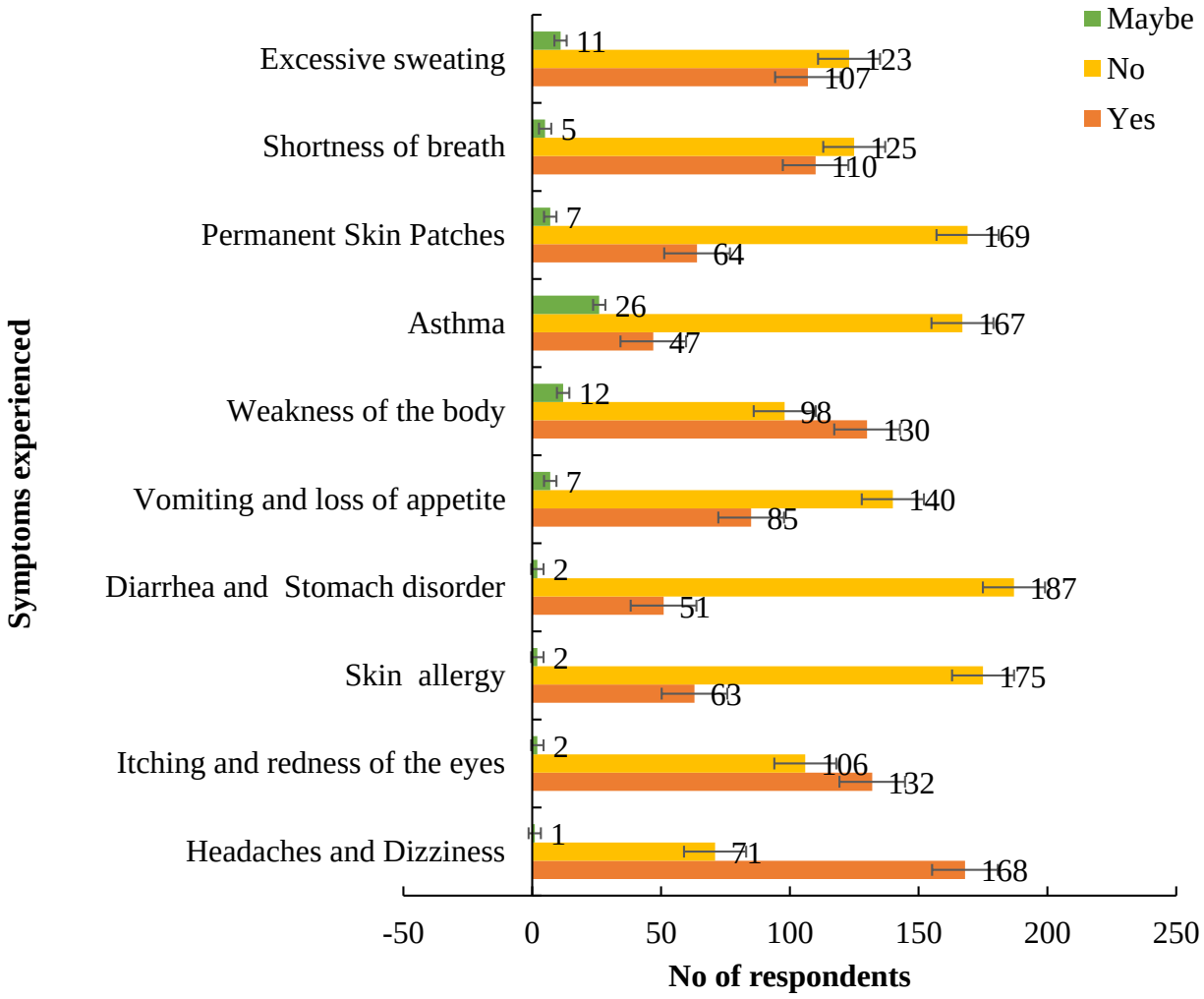

Figure 16. Which of these Health risks do you experience after pesticide application of unsafe pesticide concentration or after consumed grains treated with pesticides?

For common pesticides in grain, a total of 27 pesticide residues were identified in the grain samples. These were OCPs (δ-Lindane, α-Lindane, β-Hexachlorocyclohexane, p,p'-DDT, Dieldrin, p,p'-DDE, Aldrin, Endosulfan, Heptachlor and Chlordan); OPPs (Phenthoate, Chlorthiophos, Ethion, Prothiofos, Iodofenphos, Amitraz, Flumioxazin, Malathion, Dichlorvos, Pirimiphos methyl, Diazinon, Chlorpyrifos); Pyrethroids: (Cypermethrin I, Amitraz, Flumioxazin); and Carbamates (Carbaryl, Carbofuran). The percentage frequency of each pesticide group was in the order OPPs > OCPs > Pyrethroids > Carbamates (Figure 17). Each grain crop had a total number of 16 pesticide residues. However, there were variations in the total number of individual pesticides that made up the four groups of pesticides observed in the grains (Figure 18). Millet recorded the highest number of OCP residues while maize had the lowest. On the contrary, maize had the highest number of OPP and carbamate residues while millet had the lowest number of OPP residues. Meanwhile, maize, rice and beans had only one carbamate pesticide residue. The highest number of pyrethroid pesticide residues was jointly shared by beans and rice grains while millet had the lowest.

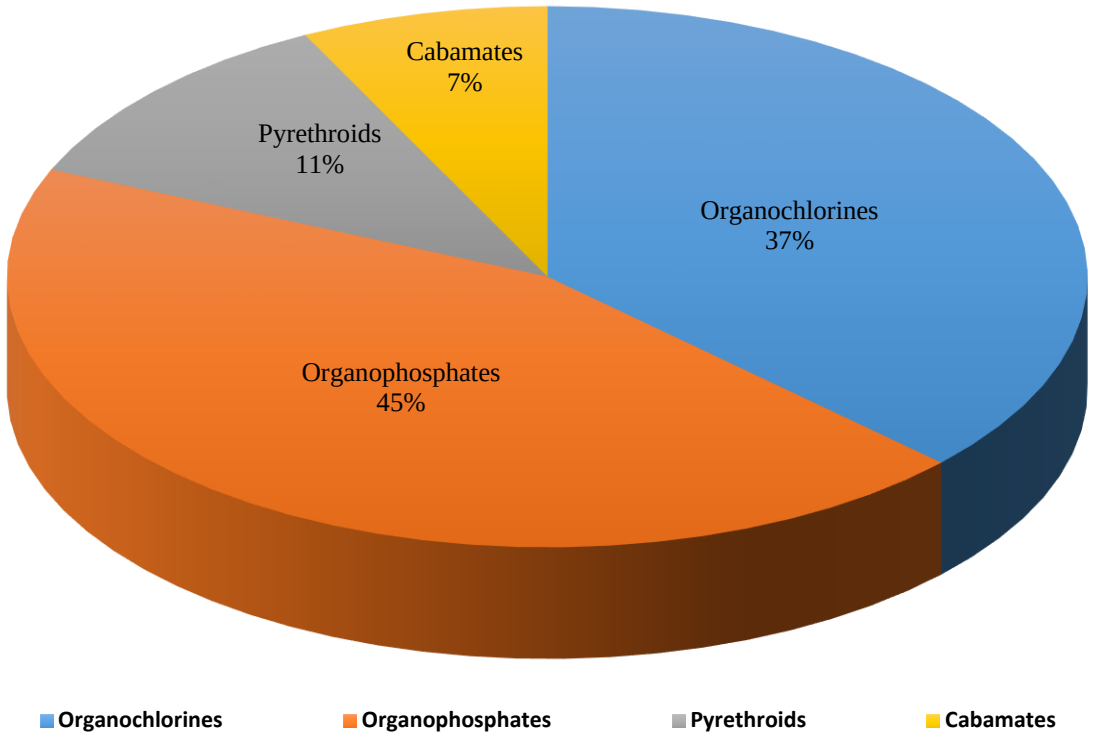

Figure 17. Percentage composition of total pesticide residues (27) identified in grains collected from selected markets in Southwest Nigeria

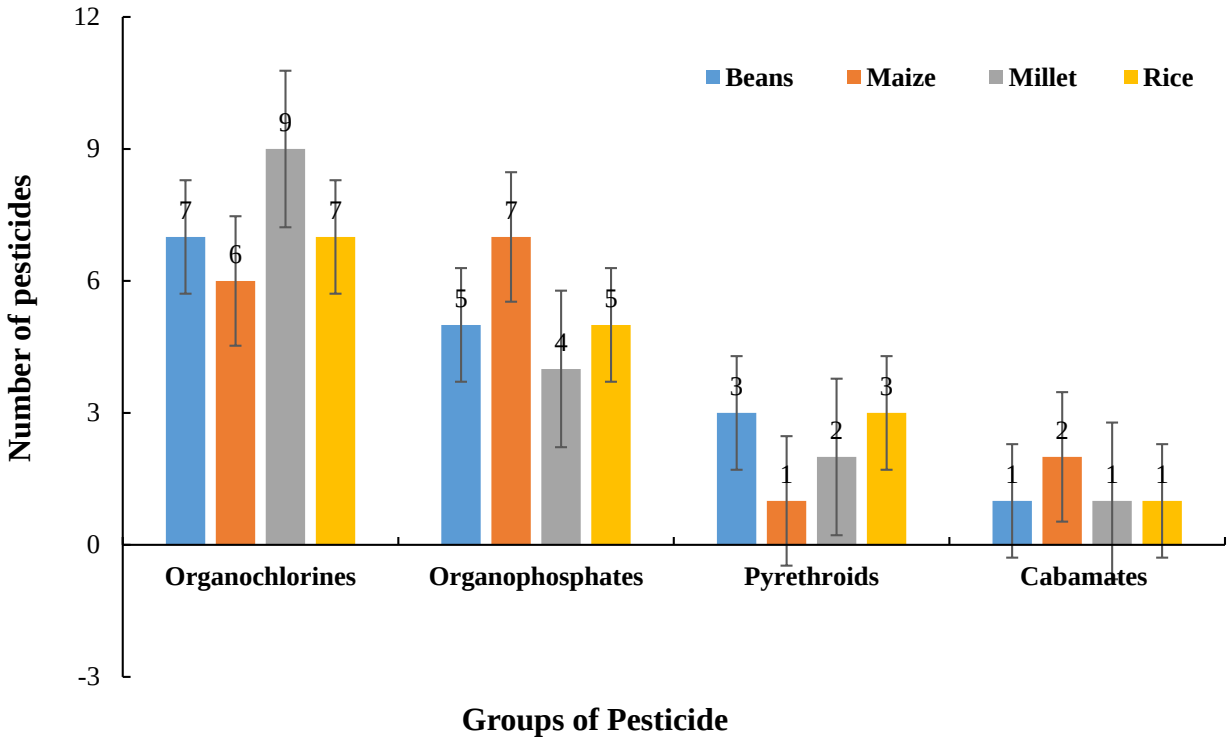

Figure 18. Distribution of pesticide residues in grain samples collected from selected markets in Southwest Nigeria

4. Discussion

4.1. Knowledge of grain sellers on the Occurrence of pesticide residue in grains

The concentration of pesticides in grain sample is largely determined by the merchant, the type, quantity, and frequency of pesticide applied to grain during storage. The factors are directly related to the attitude and knowledge of the merchants towards grain preservation [76]. This study agrees with the study of Yusuf *et al*., [77] who state that one hundred and thirty-seven (36.5%) of the respondents that use pesticides indicated that they used phostoxin only, which is dichlorvos (an organophosphate pesticide) on their grains for storage, 88 (23.5%) indicated that they use DDForce (dichlorvos) only, 103 (27.5%) use either DDForce or phostoxin tablet (both are dichlorvos), only 11 (2.9%) use DDForce and phostoxin together, while 36 (9.6%) use "others" (i.e. Jule, Rambo, Opaayan) on maize grains. In our survey, over 80% of merchants use pesticides, mainly insecticides. This agrees with previous report that the pesticides are usually applied to food crops as the first line of action in controlling pests of stored product. The high concentration of many pesticide residues may be attributed to the many rounds of application (up to 6 times) per time. Also, the pesticides are mainly applied on a weekly basis or less across the markets. Over the storage period of 3 – 6 months observed in this study, substantial amount of pesticide residues must have accumulated. The believe that pesticides are very effective as observed in this study agrees with the findings of Alex *et al*. [78]. Overall, this suggests poor knowledge and practice of the usage of pesticides and agricultural practices by the farmers. As Mekonnen and Agonafir [79] and Tariq *et al.* [80] showed that 70% of farmers in developing countries encounter difficulties in reading instruction manuals, leading to the misuse of highly toxic pesticides. In Pakistan, the chances of pesticide misuse are relatively high for several reasons. Among farmers, there is low awareness regarding the safe use of pesticides. Furthermore, Pakistan records a low literacy rate where more than 70% of farming communities do not read or understand the national language (Urdu). To compound the problem, the awareness brochures of pesticides are printed in English and in Urdu [81, 82]. Thus, if a farmer is relatively less educated, his/her ability to absorb professional knowledge is weaker. Furthermore, his/her capability to recognize pest diseases is also weaker. Hence, the less-educated farmer tends to lack awareness of both pesticide residues and the importance of applying pesticide in standardized ways. Consequently, with less education, there is a higher chance that the farmer will apply prohibited pesticide excessively, leading to highly concentrated pesticide residues Food and Agricultural Immunology [83, 84]. In India, Agarwal and Pandey [85], Abhilash and Singh [86] found that, due to the lack of adequate knowledge regarding pesticides, farmers tend to apply the same pesticide excessively rather than mixing different kinds of pesticides rationally. In Chengdu, Li *et al.* [87] found that, due to the lack of pesticide knowledge, most farmers solely focus on the outcome of pesticide use when purchasing pesticides. They rarely pay attention to the toxic side effects of pesticides on human health. Similarly, Dongmei [88] found that the education and training provided by agricultural technology personnel affect farmers' awareness of pesticide residues. Zhongze and Qingjiang [89] believed that a randomized security check of pesticide residues will increase the motivation of farmers to purchase low-toxicity pesticides with fewer residues or to apply pesticides in standardized ways. Furthermore, to a certain degree, the agricultural service environment and sale routes directly affect the amount of pesticides being applied, and indirectly affect farmers' awareness of pesticide residues [90-92]. However, the intensive use of pesticides may be 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 [93, 94]. Perhaps if farmers knew better maybe food merchants would

apply pesticides differently. The fact that about 50% of these merchants in our survey do not read instructions on pesticide cover explains to a large extent, the misuse of these pesticides. Although a significant proportion of merchants use PPEs, the lack of professional training and assumption by merchants that they can effectively apply pesticides makes the misuse of pesticides more likely. Similar reports of poor knowledge of pesticide application abounds [95, 96]. Our current results confirm previous works by Hussain *et al.*, [26], Hussain *et al.*, [27], Isah *et al.*, [24]. Isah *et al.*, [25], Morufu [29], Olalekan *et al.*, [30], Raimi *et al.*, [22] and MacFarlane's study [97] reporting pesticide knowledge, instruction level and personal protection and Aminu and Edun [98] who reported that pesticide dose used ($p<0.05$), reading and adherence to instructions on pesticide labels ($p<0.01$).

4.2. Common Pesticides in Grain

Agrochemicals, being toxic substances, need a correct application, because, otherwise, excessive use and incorrect selection of pesticides cause a high number of residues in the food being consumed. Residues of these substances can remain in plant tissues (e.g., fruits) and, in the long run, cause problems to human health such as cancer, depression and infertility. This control is done by the regulatory agencies of each country (e.g., NAFDAC, EPA, EFSA), and is based on the Maximum Residue Limit (MRL), varying according to the active principle and the intended culture [99]. However, the current outlook is that the world population will continue to increase, further expanding the demand for food [100]. Therefore, pesticide use in urban areas is a major concern for the aquatic environment as well as for human health and ecosystems [101]. The influence of water contamination resulting from urban pesticide runoff is greater on an aquatic environment than on human health, and food contamination is due to agricultural applications of pesticides. From this study, a total of 27 pesticide residues were identified in the grain samples. These were OCPs (δ-Lindane, α-Lindane, β-Hexachlorocyclohexane, p,p'-DDT, Dieldrin, p,p'-DDE, Aldrin, Endosulfan, Heptachlor and Chlordan); OPPs (Phenthoate, Chlorthiophos, Ethion, Prothiofos, Iodofenphos, Amitraz, Flumioxazin, Malathion, Dichlorvos, Pirimiphos methyl, Diazinon, Chlorpyrifos); Pyrethroids: (Cypermethrin I, Amitraz, Flumioxazin); and Carbamates (Carbaryl, Carbofuran) this is in tandem with the result of Alex *et al.*, [78] who in his findings identified thirty (30) pesticides residues in grains, the thirty pesticide contains 90% of chemicals identified in this work. Also the study of Yusuf *et al.*, [77] who state that one hundred and thirty-seven (36.5%) of the respondents that use pesticides indicated that they used phostoxin only, which is dichlorvos (an organophosphate pesticide) on their grains for storage, 88 (23.5%) indicated that they use DDForce (dichlorvos) only, 103 (27.5%) use either DDForce or phostoxin tablet (both are dichlorvos), only 11 (2.9%) use DDForce and phostoxin together, while 36 (9.6%) use "others" (i.e. jule, Rambo, opaayan) on maize grains. However, the study of Oguntade *et al.*, [102] is contrary stating that grain samples collected from all the three main markets from did not contain synthetic pesticide residue as envisaged, however many bioactive substances which have pesticide activity were detected in the grain samples from various market with n-Hexadecanoic acid, Hexadecanoic acid, methyl ester and 9,12-Octadecadienoic acid (Z, Z)-, methyl ester found in all the samples.

5. Conclusion

Pesticides are a large and expanding part of the contemporary technology that is widely used in Africa. While worries regarding the harmful effects of pesticides on human health and the environment in developing countries have been voiced for more than ten years. The evidence provided describes a situation whose intricacy is challenging to address using the conventional methods. A crucial first step in bringing about major change in preventative health is realizing the intricacy of the processes that underlie these people' susceptibility to pesticide exposure. The acceptance of preventive

recommendations and the likelihood of their implementation will be aided by adopting a thorough viewpoint of the issue's various elements. This study offers an intriguing update of earlier research on substantial pesticide residues. Because they are unaware of the dangers posed by pesticide residues, the recommended dosage levels, or the uniformed standards governing pesticide application, farmers frequently apply pesticides excessively and unreasonably. Problems with pesticide residue originate from this. For instance, many farmers keep upping the amount of pesticides they use despite not fully comprehending the leaking issues with sprayers. Because local health officials rarely diagnose symptoms in relation to exposure and are not trained to recognize the negative effects of pesticides, the expenses of health problems caused by pesticides, particularly medical costs, are typically not accounted for. Pesticides must be used correctly at this time to safeguard our environment and any potential health risks linked to them. These findings from the study show that farmers who only have access to information from agricultural extension officers should receive substantial and immediate attention in order to raise their level of awareness. Additionally, extensive IPM training programs must be created with the intention of disseminating precautions for protecting human health and a healthy agro-ecosystem. In order to find more effective pest management methods that utilize less pesticides, it is crucial to reevaluate the pesticide residues and common pesticides found in grains in the targeted markets. In order to lessen the harmful effects of pesticides on our environment, community development and various extension initiatives that might inform and encourage farmers to embrace the cutting-edge IPM tactics are crucial. Further research should concentrate on farmer behaviors in connection to pesticide use, an investigation of the variables that affect farmers' awareness of pesticide residues, and regulation of pesticide availability. Research and development (R&D) should be strengthened further and the use of pesticide residue detecting technology should be encouraged in the South-West region. An alternative would be to introduce pertinent, cutting-edge foreign technologies related to pesticide residues. Pesticide residues in South-West agricultural goods can be further monitored using cutting-edge detection equipment. At the same time, it is possible to encourage farmers and the general public to form fact-based opinions about the risks posed by pesticide residues.

Recommendations

The following are hereby recommended:

1. Training in pesticide application and sensitization to the negative health effects of pesticide misuse are necessary for farmers, grain traders, and other participants in the grain value chain. This will aid in guiding their selection of pesticide, as well as the amount and timing of sprays.
2. It is important to promote, encourage, and reward the use of natural pesticides such dried lime (Citrus aurantifolia), dried neem leaves (Azadirachta indica), and dry chilli pepper (Capsicum annum). This will lessen reliance on and use of synthetic insecticides.
3. More research funding should be made available and used to investigate plants with insecticidal qualities in order to create natural insecticides. It is necessary to separate more potent chemicals from plants and turn them into simple-to-use biological or organic pesticides.
4. Organizations that work in the food industry, like NAFDAC, need to improve their laboratory ability to monitor pesticide levels in grains, especially those that are unbranded. This will enable the tracking of dangerous grain sources.
5. The new and current restrictions on the application of pesticides should be implemented clearly and correctly. There should also be regular audits and

sanctions for retailers who violate the law. Punishments for criminals will prevent others from breaking the law.

6. The general people has to be made aware of the risks of pesticide exposure and counseled against purchasing unbranded and uncertified grains from marketplaces. This will protect them from the risks associated with pesticide use.

Declaration of competing interest

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

Ethics approval

This study entitled: "Evaluation of Pesticide Residues in Grain Sold at Selected Markets of Southwest Nigeria", which was submitted for ethical approval on August 15, 2020 to the Research Ethics Committee of Kwara State University. For the development of this study, the fundamental ethical principles for research involving human beings, described and established by the Resolution 466/2012 and its complementary ones, was considered and approval was granted by the Kwara State University research ethics committee.

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Consent to participate

During the course of this research work, the participants were accorded the due respect so as to ensure co-operation and information collected were treated with utmost confidentiality. The cultures of the community were also respected during the course of the research work. Informed consent was obtained from all of the participants.

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Authorship contribution statement

Modupe Abeke Oshatunberu: Conceptualization, Investigation, Writing - original draft, Writing - review & editing. Modupe Abeke Oshatunberu and Adebayo Oladimeji: Investigation, Writing - original draft, Writing - review & editing. Adebayo Oladimeji and Sawyerr Olawale Henry: Resources, supervising, review & editing. Modupe Abeke Oshatunberu, Morufu Olalekan Raimi: Methodology, Project administration, Writing - original draft, Writing - review & editing. Morufu Olalekan Raimi: Data curation, Formal analysis, Writing - original draft, Writing - review & editing. Modupe Abeke Oshatunberu, Adebayo Oladimeji, Sawyerr Olawale Henry: Conceptualization, Data curation, Funding acquisition, Project administration, Writing - original draft, Writing - review & editing.

Appendix

Questionnaire on Analytical and Experimental Analysis of Pesticide Residues Present in Food Items Selected in Selected Markets and its Health Implications in South West Nigeria

INSTRUCTION: Please Tick or Provide the Correct Response Accordingly.

SECTION A: Socio-demographic Characteristics of Respondents

1. What is your age? A. 20 - 30 ( ) B. 31 - 40 ( ) C. 41 – 50 ( ) D. 51 – 60 ( ) E. > 60

2. What is your gender? A. Male ( ) B. Female ( )

3. What is your level of education? A. None ( ) B .Primary school ( ) C. Secondary school ( ) D. Tertiary Education ( ) E. Others ( )

4. Which ethnic group do you belong? A. Yoruba ( ) B. Hausa/Fulani ( ) C. Igbo ( ) D. Foreigner ( ) E. Others

5. What is your religious affiliation? A. Christianity ( ) B. Islam ( ) C. Traditional ( ) D. Others

6. What is your marital status? A. Single ( ) B. Married ( ) C. Divorce ( ) D. Separated ( ) E. Widow ( ) F. Widower ( )

7. How much do you earn as average monthly income? A. Below N20,000 ( ) B. 21,000 - 40, 000 ( ) C. 41,000 - 60,000 ( ) D. 61,000 - 80,000 ( ) E. 81,000 - 100,000 ( ) F. Above N100,000 ( )

8. What is your activity in the market? A. Grain Merchants ( ) B. Food vendor ( ) C. Buyer / Consumer ( )

Please read the following instructions carefully

In Question No 8, If you selected "A" i.e. grain merchants continue with number 9, if you selected "B or C" i.e. food vendor or buyer / consumer, Jump to 25

9. How long have you been a grain merchant? A. 1 - 10 ( ) B. 11 - 20 ( ) C. 21 - 30 ( ) D. Above 31 ( )

SECTION B: Attitudes of grain merchants towards grains preservation

10. Do you spray your grains with pesticides to preserve it? A. Yes ( ) B. No ( )

Please read the following instructions carefully

If "Yes", continue with No. 12, If "No", Jump to 23

11. Which type of pesticide do you use? A. Fungicides ( ) B. Insecticide ( ) C. Others ( )
12. Which of these forms of pesticides do you use in preserving grains? A. Tablet form ( ) B. Direct liquid mix with the grain ( ) C. The direct mix of dust with the grain ( )
13. At what time interval do you spray grains? A. 2 - 3 days ( ) B.4 - 6 days ( ) C. Weekly ( ) D. Others ( )
14. How many rounds do you spray grains per time? A. 1- 3 times ( ) B. 4 - 6 times C. 7 - 10 times D. More than 10 times
15. How long do you store your grains before selling? A. 1 month ( ) B. 3 months ( ) C. 6 months ( ) D. Above 6 months ( )

16. How potent are the pesticides being used? A. Very effective ( ) B. Moderately effective ( ) C. Not effective ( )

SECTION C: Knowledge of grain merchants towards pesticide application

17. How often do you read agrochemical instructions on pesticides before application? A. Always ( ) B. Occasionally ( ) C. Never
18. Do you use personal protective equipment (PPE) when applying pesticides? A. Yes ( ) B. No ( )
19. If yes, which PPE? A. Hand gloves ( ) B. Face Mask C. Coverall ( ) D. Safety boots ( ) E. Others ( )
20. Do you accidently get exposed to pesticide during application? A. Yes ( ) B. No ( ) C. I don't know
21. Do you attend any Professional training on pesticide application? A. Yes ( ) B. No ( )
22. If yes, can you effectively handle pesticides? A. Yes B. No C. I don't know
23. Are you aware that unsafe pesticide application is harmful to health? A. Yes ( ) B. No

SECTION D: Health implication of pesticide usage on humans

24. How do feel after exposure to a pesticide or consume grain treated with pesticides? A. Sick ( ) B. Not sick ( ) C. Indifferent ( )

S/N	**Which of these Health risks do you experience after pesticide application or after consumed grains treated with pesticides?**	**Yes**	**No**	**Maybe**
25	Headaches and dizziness			
26	Itching and redness of the eye			
27	Skin allergy			
28	Diarrhea and stomach disorder			
29	Vomiting and loss of appetite			
30	Weakness of the body			
31	Asthma			
32	Permanent Skin Patches			
33	Shortness of breath			
34	Excessive sweating			

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