Determination and Health Risk Assessment of Organophosphate Pesticide Residue in Different Varieties of Rice and Beans Consumed in Kaduna State, Nigeria

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Abstract- ***In many parts of Nigeria, cereal grains like rice and beans, among others, are the staple foods that provide the majority of the energy and bulk in diets. Organophosphates, including dichlorvos, ethion, dizinon, chlorthiophos, and phosphate sulfoxide, were determined and identified by pesticide residue analysis in cereals from the study's numerous sampling locations in Kaduna state. The rice samples from Zaria local government had the highest mean concentration of phorate sulfoxide (8.00E-02 mg/kg) above the maximum residue level (MRL) set by WHO, while the beans from Kaduna South and Zangon Kataf local government areas had the highest levels of dichlorvos and dizinon (1.00E-01 and 8.00E-01 mg/kg). Children in Kaduna south, Kaduna north, Zaria, and Zango Kataf showed values greater than 1 for both EDI and HRI due to their consumption of rice and beans.***

Indexed Terms- ***Beans, Kaduna, Organophosphate, Pesticide, Rice***

I. INTRODUCTION

In Nigeria, rice and beans are two of the staple foods that meet dietary requirements and make excellent animal feed [1, 2]. According to a report by statistica.com, milled rice production was estimated to be over 5 million metric tons between 2012 and 2020 and has increased tremendously since then. Rice is rich in starch, an excellent source of energy, iron and some proteins. Beans are the 4th most important source of protein in Nigeria and other parts of the world. It is a vital staple food in Nigeria and other parts of sub-Saharan Africa for more than 70 million people. Nigeria is the largest producer in Africa but 4th in the world after India, Canada and Burma. According to [3], beans are rich in protein, folate, and antioxidants. They also lower the chances of diabetes, heart disease, and cancer. Additionally, beans aid in glucose metabolism, prevent fatty liver disease, and regulate hunger. The World Health Organization (WHO)`s Global Environmental Monitoring System (GEMS) presented 0.027 kg/day as the bean consumption rate in Nigeria [4].

Pesticides are chemicals that are frequently used in agriculture and medicine to get rid of food pests, cut down on food loss, and manage the vectors that spread disease to people and animals [5]. The usage of pesticides has increased recently as a result of the growing global population, the need to produce more food, and the need to prevent crop losses. Pesticides known as organophosphates (OPPs) are a class of insecticides that are most commonly employed. They are generated from phosphorous compounds, specifically phosphoric and phosphorothioic acids. In 2020, the yearly rise of these compounds was anticipated to be 3.5 million tons, of which approximately 40% represent OPPs. Currently, approximately 2 million tons of pesticides are used worldwide each year [5, 6]. It is estimated that over 3 million individuals are exposed to OPs annually, resulting in 300,000 fatalities globally [7]. Farmers always use insecticides to reduce agricultural production and manage these insect pests [8, 9]. As a result, consumers and regulatory bodies are growing increasingly concerned about pesticide residues in vegetables when it comes to food safety [10, 11]. Although routine analysis of beans and rice for pesticide residues must be performed to ensure that they are safe for human consumption, no specific reports are available from Kaduna state. The objectives of this study includes; - i. to determine the concentration of five (5) organophosphate pesticide residues in rice and bean samples in four (4) major

local governments of Kaduna State. ii. To estimate the daily intake of organophosphate pesticides in rice and bean samples. iii. Determine the health risk index of organophosphate pesticides in rice and bean samples.

II. METHODOLOGY

2.1 Description of the Study Area

The study areas are Kaduna south local government area (10.46310 N, 7.41380 E), Kaduna north (10.54320 N, 7.44900 E), Zaria (11.12470 N, 7.72540 E), and Zango Kataf (9.89060 N, 0.22130 E). Kaduna is the state in north-west Nigeria. These local governments constitute about 45% of Kaduna State's total population (6,113,503). According to the 2006 census, each of them has a population as follows: Kaduna south (402,731; 46.2 km^2), Kaduna north (364,575; 70.2 km^2), Zaria (847,000; 563 km^2), and Zango Kataf (318.993; 167.2 km^2).

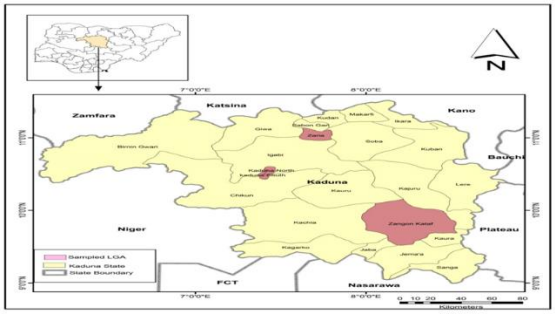

Figure 1: Map of the Study Area (GIS Kaduna Polytechnic, Kaduna State Nigeria)

2.2 Samples Collection

Rice (*Oryza sativa*) and brown beans (*Vigna unguiculata*) were the grain samples. Four (4) important local government areas in Kaduna state—Kaduna south, Kaduna north, Zaria, and Zango Kataf—were the locations from which the grains were acquired. Approximately 200 grams were bought (rice and beans) from five different sales locations in each local governments in order to provide a random sample. To keep the samples safe from contamination and moisture, they were given code names and kept in glass vials with tight lids. After that, they were kept in a 40°C refrigerator until we were ready for them.

2.3 Samples Preparation

Samples of cereal (rice and beans) were cleaned by removing stones, weevils, and other unnecessary objects. Next, the various samples were ground independently using a mortar and pestle before being ground into a powder using a hand grinder. The bean samples were already dry when they were acquired, thus no additional drying was necessary. Precautions were implemented to prevent sample cross-contamination both before and after milling.

2.4 Health Risk Assessment of Organophosphate Pesticides

The estimated daily intake (EDI) was calculated and compared with the established acceptable daily intake by multiplying the residual pesticide concentration (mg/kg) by the crop consumption rate (g/day) and dividing by body weight, the EDI was found [12]. For adult and children (Age 2-5 years), calculations will be conducted. The mean body weight of adults will be considered to be 60 kg, while the mean body weight of children was considered to be 16.7 kg [13], this was achieved based on the residue levels of organophosphates present in the rice and beans samples. Where F=Crop consumption data (165.9 g/day) [14, and Cr=Concentration of OPPs in rice and beans samples.

$$EDI = F(g/day) \times Cr\ (g/day)/Body\ weight\ (kg) \quad (1)$$

In the present research, based on pesticide residues found in rice and beans, health risk assessment will be determine. The indices of pesticide residue heath risk by dietary intake of crops were evaluated in accordance with the [15], regulations, where the estimated daily intake (EDI) was compared to the acceptable daily intake ADI (mg/kg bw) [16]. Risk assessment was done by calculating the health risk index (HRI) using

$$HRI = \frac{EDI}{ADi} \quad (2)$$

III. RESULTS AND DISCUSSION

1: Mean Concentration (mg/kg) of Organophosphate Pesticides Residue in Brown Beans (*Vigna unguiculata*) Samples

Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf	MRL [14]
Chlorthiophos	ND	8.00E-06	ND	ND	3.00E-01
Ethion	1.10E-04	ND	5.00E-04	1.00E-08	3.00E-01
Diazinon	1.20E-02	1.00E-02	1.00E-07	1.00E-03	5.00E-02
Dichlorvos	8.00E-04	1.00E-06	8.00E-03	1.50E-09	1.00E-02
PhorateSulfoxide	2.10E-04	1.20E-03	8.00E-02	ND	1.00E-02

Mean Concentration (mg/kg) of Organophosphate Pesticides Residue in Rice (*Oryza sativa*) Samples

Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf	MRL [14]
Chlorthiophos	ND	ND	2.10E-02	ND	3.00E-01
Ethion	ND	8.00E-02	8.00E-02	ND	3.00E-01
Diazinon	1.00E-01	1.00E-10	ND	1.00E-01	5.00E-02
Dichlorvos	3.00E-04	ND	ND	8.00E-01	1.00E-02
PhorateSulfoxide	2.10E-12	ND	2.00E-05	1.00E-03	1.00E-02

Keys: ND; Not detected, WHO; World Health Organization, MRL; Maximum Residue Level

Table 3: Estimated Daily Intake of Organophosphate Pesticides Residue in Brown Beans (*Vigna unguiculata*) Samples for Adults and Children

Adults (*kg/person/day)*				
Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf
Chlorthiophos	ND	2.21E-05	ND	ND
Ethion	3.04E-04	ND	1.38E-03	2.77E-08
Diazinon	3.32E-02	2.77E-02	2.77E-07	2.77E-03
Dichlorvos	2.21E-03	2.77E-06	2.21E-02	4.15E-09
PhorateSulfoxide	5.81E-04	3.32E-03	2.21E-01	ND
Children (*kg/person/day)*				
Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf
Chlorthiophos	ND	7.95E-05	ND	ND
Ethion	1.09E-03	ND	4.97E-03	9.93E-08
Diazinon	1.19E-01	9.93E-02	9.93E-07	9.93E-03
Dichlorvos	7.95E-03	9.93E-06	7.95E-02	1.49E-08
PhorateSulfoxide	2.09E-03	1.19E-02	7.95E-01	ND

Table 4: Estimated Daily Intake of Organophosphate Pesticides Residue in Rice (*Oryza sativa*) Samples for Adults and Children

Adults (*kg/person/day)*				
Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf
Chlorthiophos	ND	ND	5.81E-02	ND
Ethion	ND	2.21E-01	2.21E-01	ND
Diazinon	2.77E-01	2.77E-10	ND	2.77E-01
Dichlorvos	8.30E-04	ND	ND	2.21E+00
PhorateSulfoxide	5.81E-12	ND	5.53E-05	2.77E-03
Children (*kg/person/day)*				
Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf
Chlorthiophos	ND	ND	2.09E-01	ND
Ethion	ND	7.95E-01	7.95E-01	ND
Diazinon	9.93E-01	9.93E-10	ND	9.93E-01
Dichlorvos	2.98E-03	ND	ND	7.95E+00
PhorateSulfoxide	2.09E-11	ND	1.99E-04	9.93E-03

Table 5: Health Risk Index of Organophosphate Pesticides Residue in Brown Beans (*Vigna unguiculata*) Samples for Adults and Children

	Adults (*kg/person/day*)			
Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf
Chlorthiophos	ND	4.42E-05	ND	ND
Ethion	6.08E-04	ND	2.77E-03	5.53E-08
Diazinon	6.64E-02	5.53E-02	5.53E-07	5.53E-03
Dichlorvos	4.42E-03	5.53E-06	4.42E-02	8.30E-09
PhorateSulfoxide	1.16E-03	6.64E-03	4.42E-01	ND
	Children (*kg/person/day*)			
Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf
Chlorthiophos	ND	1.14E-04	ND	ND
Ethion	1.56E-03	ND	7.10E-03	1.42E-07
Diazinon	1.70E-01	1.42E-01	1.42E-06	1.42E-02
Dichlorvos	1.14E-02	1.42E-05	1.14E-01	2.13E-08
PhorateSulfoxide	2.98E-03	1.70E-02	1.14E+00	ND

Table 6: Health Risk Index of Organophosphate Pesticides Residue in Rice (*Oryza sativa*) Samples for Adults and Children

	Adults (*kg/person/day*)			
Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf

Chlorthiophos	ND	ND	1.16E-01	ND
Ethion	ND	4.42E-01	4.42E-01	ND
Diazinon	5.53E-01	5.53E-10	ND	5.53E-01
Dichlorvos	1.66E-03	ND	ND	4.42E+00
PhorateSulfoxide	1.16E-11	ND	1.11E-04	5.53E-03
	Children (*kg*/*person*/*day*)			
Pesticides	Kaduna South	Kaduna North	Zaria	Zango Kataf
Chlorthiophos	ND	ND	4.17E-01	ND
Ethion	ND	1.59E+00	1.59E+00	ND
Diazinon	1.99E+00	1.99E-09	ND	1.99E+00
Dichlorvos	5.96E-03	ND	ND	1.59E+01
PhorateSulfoxide	4.17E-11	ND	3.97E-04	1.99E-02

3.1 Concentration of Organophosphate Pesticides Residue in Rice and Beans Samples

The mean concentrations of OPP residues in the rice samples (Table 1) were found to be ND-1.20E-02 mg/kg, ND-1.00E-02 mg/kg, ND-8.00E-02 mg/kg, and ND-1.00E-03 mg/kg. The OPP residue mean concentrations for the bean samples (Table 2) ranged from ND-1.00E-01 mg/kg to ND-8.00E-02 mg/kg, ND-8.00E-02 mg/kg, and ND-8.00E-01 mg/kg. Among all the rice samples analyzed, phorate sulfoxide recorded the highest mean concentration in Zaria above (1.00E-02 mg/kg) the maximum residue level (MRL) set by [14]; similarly, bean samples recorded the highest level of dizinon and dichlorvos above the acceptable limits of 5.00E-02 and 1.00E-02 mg/kg in Kaduna South and Zangon Kataf, respectively. According to [17], OPPs used in this study have been documented in Nigerian rice and beans. These results are consistent with those reported by [18] Tutuwa *et al*. (2024), who observed that the high use of several pesticides during plantation, culture, and storage may have contributed to the bioaccumulation of these substances in individual grains.

3.2 Estimated Daily Intake of Organophosphate Pesticides Residue in Rice and Beans Samples

Tables 3 and 4 present the estimated daily intake (EDI) for the estimation of the risk effects of OPPs for adults and children. This result shows that EDI of adults in Zango Kataf recorded a values (2.21E+00 and 7.95E+00) greater than one through the consumption of dichlorvos. EDI values greater than 1 indicate a potential human health risk. Therefore, there is a greater health risk associated with the consumption of rice in the Zangon Kataf local government of Kaduna State, Nigeria. This finding is contradicts those reported by [19], who found that the health index (EDI) of OPP residue in different cereals was less than one (1).

3.3 Health Risk Index of Organophosphate Pesticides Residue in Rice and Beans Samples

Tables 5 and 6 show the health risk index (HRI) of organophosphate pesticides (OPPs) for adults and children. In all four (4) local government areas, children had the highest HRI values of greater than one. This implies children in Kaduna south, Kaduna north, Zaria, and Zango Kataf recorded a significant amount of Opp via rice consumption. Therefore, there is a greater health risk associated with the consumption of rice by children in these study locations. This result is contrary to the findings by [20], who observed the health hazard indices of OP pesticide residues in rice and beans in Gombe State, Nigeria, showed hazard indices for all the pesticides analyzed had values of less than 1.

CONCLUTION

The concentrations of organophosphate pestice residues in the rice and beans samples collected from four LGAs namely, Kaduna south, Kaduna north, Zaria, and Zango Kataf in Kaduna State were determined using gas chromatography coupled with a mass spectrophotometer. The results revealed that the

amounts of the phorate sulfoxide, dichlorvos and dizinon pesticide are generally above their respective MRLs by WHO standards. The EDI and the HRI for most of the rice samples recorded values greater than 1. These results portray the children as being at high risk through the consumption of rice samples from the study area.

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