



Analysis and Health Risk Assessment of Organochlorine Pesticide Residues in Selected Livestock from Awe, Nasarawa South, Nigeria

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Abstract: The analysis and Health risk Index of organochlorine (OC), and pesticide residues in Cow, Goat, Pig, and Ram meat samples in Awe sourced directly from the major feeding abattoir was carried out. Quick, Easy, Cheap, Effective and Robust (QuEChERS) Extraction method was employed for sample extraction. Instrumental analysis was performed on a gas chromatograph with a mass spectrometer detector (GC-MS). In all Meat samples varying concentrations of OC pesticide residue were detected. 20 OC pesticide was run across all Livestock samples. 17 pesticide residues were detected in Cow meat, 14 pesticide residues detected in Goat sample, 12 pesticide residues in Pig meat, and 15 pesticide residues were detected in Ram samples. Among the pesticide residues detected the most prevalent OC pesticide ranges from Endrin, P,P' – DDD, Endosulfan II, P,P' – DDT, Endrin Aldehyde, Endosulfan Sulfate, Methoxychlor, Endrin Ketone. Banned pesticides in Nigeria are found in the meat samples in Awe, though they do not exceed the maximum Residue Limits (MRLs) set by FAO/WHO. The Chronic Health Index values of the various meat samples are below 1. CHI value lower than 1 indicates no potential health risks, while more than 1 CHI value indicates a potential health hazard. Continuous monitoring and stricter enforcement of pesticide regulations are recommended to ensure food safety and minimize potential long-term health impacts.

Keywords: Pesticide, pesticide residues, livestock, meat, health risk, organochlorines

Introduction

Pesticides are widely used in agricultural and livestock production to control pests, increase yield, and ensure food security [1, 2]. Organochlorine pesticides (OCPs) have been extensively utilized due to their high efficiency, broad-spectrum activity, and persistence in the environment [3]. However, their prolonged use and bioaccumulative nature pose significant risks to human health and ecosystems [4, 5]. Despite global bans and restrictions, OCP residues are still detected in various food commodities, particularly in developing countries where regulatory enforcement is weak. The persistence of these chemicals in food chains, including livestock products such as meat, milk, and organs, raises concerns about potential health risks to consumers [6].

Nigeria, like many other sub-Saharan African countries, relies heavily on agriculture and livestock farming as major economic activities. The use of pesticides in these sectors is often indiscriminate, driven by a lack of awareness, poor regulatory oversight, and the continued availability of banned or restricted chemicals [7, 8, 9]. Livestock, being an integral part of rural livelihoods, are often exposed to pesticides through contaminated feed, water, and direct application for ectoparasite control [10]. In areas such as Awe, located in Nasarawa South Senatorial District, Nigeria, livestock farming is prevalent. However, limited studies have been conducted to assess the extent of OCP contamination in livestock from this region, necessitating research on the subject.

Organochlorine pesticides belong to a class of chlorinated hydrocarbons known for their lipophilicity, [11] environmental persistence, [12] and ability to bioaccumulate in fatty tissues [13]. Some of the most common OCPs include DDT (dichlorodiphenyltrichloroethane), aldrin, dieldrin, endrin, heptachlor, lindane, and chlordane. These compounds have been associated with various adverse health effects, including neurotoxicity, endocrine disruption, reproductive disorders, immunotoxicity, and carcinogenicity. Due to their potential hazards, many OCPs have been banned or restricted under international agreements such as the Stockholm Convention on Persistent Organic Pollutants (POPs) [14].

Health risk assessment (HRA) is a systematic approach used to evaluate the potential health hazards posed by contaminants in food and the environment [15]. It involves four key components: hazard identification, exposure assessment, dose-response assessment, and risk characterization. By assessing the levels of OCP residues in livestock products and estimating dietary exposure, HRA helps in determining the potential risks to human health, particularly for vulnerable populations such as children, pregnant women, and immunocompromised individuals [16]. This study aims to analyze the levels of organochlorine pesticide residues in selected livestock from Awe, Nasarawa South, Nigeria, and assess the associated health risks to consumers. The specific objectives include Determining the levels of pesticide residues in Ram, Cow, Goat and Pig meat samples in Awe and Evaluating the potential health risks associated with the presence of OC pesticide residues in livestock meat consumed in Awe, Nasarawa south senatorial district and comparing the residue levels with established safety limits set by regulatory agencies such as the World Health Organization (WHO), Food and Agriculture Organization (FAO), and the Codex Alimentarius Commission. The findings from this study will contribute to the existing body of knowledge on

pesticide contamination in livestock products and provide scientific evidence to support policymaking, food safety regulations, and consumer awareness initiatives.

Material and Methods

Sample collection

Samples of livestock cattle (meat), goat (meat), pig (meat), sheep (meat), were collected from Awe south senatorial districts in Nasarawa state. Samples of livestock (meat) were collected directly from the major feeding abattoir in Awe. The samples were identified by a technologist in the Biology Laboratory in Federal University of Health Sciences, Otuokpo. Samples were, labelled, placed on an ice box, and taken to the laboratory. Samples were stored at -20°C prior to analysis.

Reagents and materials

The reagents used in this study are acetonitrile (GFS Chemicals, Columbus), acetic acid (GFS Chemicals, Columbus), silica gel 60–200 mesh (Labtech Chemicals), and anhydrous sodium sulphate (Merck, Germany). These reagents were procured through various sales representatives of the producing company's resident in Nigeria.

Pesticide standards

A reference Pure pesticides standard of 20 Organochlorine pesticides which include (alpha, beta, gamma and delta BHC, heptachlor epoxide, endosulfan I, endosulfan sulphate, gamma and alpha chlordane, heptachlor, aldrin, dieldrin, endrin, endrin ketone, endrin aldehyde, endosulfan II, p-p' DDT, p-p' DDE, p-p' DDD, methoxychlor) were purchased from Bristol Scientific Company Limited, a subsidiary of Sigma Aldrich in Nigeria.

Sample extraction and clean up

The sample was properly mixed and 2 mL was weighed into a 50 mL centrifuge tubes. Anhydrous sodium sulphate (1 g) was added and mixed with the sample to absorb any moisture present. The sodium sulphate was previously heated at 650°C for 1 hour and stored in a desiccator. The main extraction involved the addition of 20 mL of acetic acid–water–acetonitrile (1:5:94, v/v). The tube was closed and shaken vigorously by hand for 1 minute. To induce phase separation and pesticide partitioning, a buffer–salt mixture (consisting of 0.5 g sodium acetate and 3 g anhydrous MgSO_4) was added to the suspension. The tube was closed, shaken vigorously by hand for 1 minute, and centrifuged for 5 minutes at 2500 rpm. The supernatant was carefully transferred into a flask. The residue was further extracted twice as described above. The solution was then transferred to a sample tube and reduced to about 1 mL under a gentle stream of nitrogen gas using a nitrogen evaporator at 36°C [7, 17].

During clean-up, 2 mL supernatant was transferred into another tube that contains 50 mg of primary and secondary amine (PSA), 50 mg of graphite carbon black (GCB), and 150 mg of magnesium sulphate. After proper agitation and centrifugation at 10000 rpm for 5 minutes, the aliquots of the extract were evaporated through the nitrogen system and reconstituted with 1 mL toluene for GC-MS analysis. Furthermore, each pesticide standard solution (1 mg/ml) were prepared by diluting acetonitrile at a different concentration for standard curve preparation. A 2% triphenyl phosphate (TPP) solution in acetonitrile with 1% acetic acid was used as a quality control (QC) standard for the GC-MS analysis.

Determination of limit of detection (LOD)

The limit of detection of the pesticide residues were determined by replicating chromatographic runs (6 times) of the least concentration of the pesticide standards and then multiplying the standard deviation by 3 [7].

Determination of limit of quantification (LOQ)

The limit of quantification of the pesticide residues were determined by replicating chromatographic runs (6 times) of the least concentration of the pesticide standards and then multiplying the standard deviation by 10 [7].

Health risk estimates

Probable daily pesticide exposure or Estimated Daily Intake (EDI) for each pesticide and individual (Adult) consumers was calculated using the following Equation 3.10 formula [18, 19].

This measures how much pesticide a person is likely to consume daily based on average residue levels in food, food consumption rates, and body weight known as EDI (Estimated Daily Intake) was calculated as in Equation 1 and CHI (Chronic Health Index) calculated in Equation 2.

$$EDI = \frac{\text{mean residue level} \times \text{food consumption}}{\text{body weight}} \quad (1)$$

$$CHI = \frac{EDI}{ADI} * 100 \quad (2)$$

The average body weight of an adult was considered as 60 kg [20].

Statistical analysis

Data collected for each sample location was summarized separately using descriptive statistics (Microsoft Excel 7.0 programme).

Results and Discussion

Twenty different Organochlorine pesticides were presented in Table 1. Organochlorine pesticides are very persistent pesticides their persistence in the soil ranges from five to fifteen years [21]. Table 1 also consist of the maximum residue limits, the class, type and the coefficient of variation of the pesticides.

The results of the pesticide residue analysis in cow samples from Awe as shown in Table 2 reveal varying levels of organochlorine pesticide contamination. The pesticides detected include Alpha-BHC, Beta-BHC, Heptachlor, Delta-BHC, Aldrin, Gamma-Chlordane, Alpha-Chlordane, Endosulfan I and II, *P, P'*-DDD, *P, P'*-DDT, and others. In a study by Hasan *et al.* multi residue organochlorine pesticide was detected in livestock meat and feed, all pesticide detected were within the MRLs which is in accordance with this study [22]. Several pesticides, such as Gamma-BHC, Heptachlor Epoxide, and *P, P'*-DDE, were below detection limits (BDL), suggesting minimal or no contamination with these compounds in the analyzed samples. Among the detected pesticides, Beta-BHC exhibited a relatively high mean concentration of 0.000270 mg/kg with a relative standard deviation (RSD) of 20.51%, indicating some variability in the residue levels. Delta-BHC recorded a higher mean concentration of 0.000390 mg/kg with a moderate RSD of 14.82%, reflecting more consistent residue levels compared to Beta-BHC. Heptachlor showed a mean concentration of 0.000220 mg/kg but had a significantly high RSD of 80.09%, indicating considerable variation in its presence. Endrin Aldehyde and Endosulfan Sulfate had the most stable residue levels, with very low RSD values of 2.11 and 3.30%, respectively, suggesting consistent contamination levels in the samples. In contrast, Aldrin and Methoxychlor showed extreme variability, with RSD values of 99.82 and 77.70%, respectively, pointing to irregular contamination patterns.

Table 1: Pesticide class, maximum residue limits and correlational coefficient

S/N	Pesticides	Class	Type	MRLs (Meat) FAO/WHO 2021	Linearity R ²
1.	Alpha - BHC	Organochlorine	Insecticide	0.01	0.9972
2.	Beta – BHC	Organochlorine	Insecticide	0.01	0.9945
3.	Gamma – BHC	Organochlorine	Insecticide	0.01	0.9979
4.	Heptachlor	Organochlorine	Insecticide	0.2	0.9961
5.	Delta – BHC	Organochlorine	Insecticide	0.01	0.9979
6.	Aldrin	Organochlorine	Insecticide	0.2	0.9926
7.	Heptachlor Epoxide	Organochlorine	Insecticide	0.2	0.9930
8.	Gamma – Chlordane	Organochlorine	Insecticide	0.2	0.9989
9.	Alpha – Chlordane	Organochlorine	Insecticide	0.2	0.9968
10.	Endosulfan I	Organochlorine	Insecticide	0.2	0.9953
11.	<i>P, P'</i> - DDE	Organochlorine	Insecticide	5.0	0.9900
12.	Dieldrin	Organochlorine	Insecticide	0.2	0.9943
13.	Endrin	Organochlorine	Insecticide	0.1	0.9923
14.	<i>P, P'</i> - DDD	Organochlorine	Insecticide	5.0	0.9963
15.	Endosulfan II	Organochlorine	Insecticide	0.2	0.9916
16.	<i>P, P'</i> - DDT	Organochlorine	Insecticide	5.0	0.9910
17.	Endrin Aldehyde	Organochlorine	Insecticide	0.1	0.9956
18.	Endosulfan Sulfate	Organochlorine	Insecticide	0.2	0.9958
19.	Methoxychlor	Organochlorine	Insecticide	n/a	0.9959
20.	Endrin Ketone	Organochlorine	Insecticide	0.1	0.9949

Table 2: Mean concentration, percentage relative Standard Deviation, correlation coefficient, LOD, and LOQ of cow in Awe

Pesticides	Standard Deviation	Mean ± SE	RSD (%)	LOD	LOQ
Alpha - BHC	1.86E-05	1.40E-04 ± 1.07E-05	13.27622	6.66E-07	2.22E-06
Beta Â– BHC	5.54E-05	2.70E-04 ± 3.20E-05	20.50899	2.39E-06	7.95E-06
Heptachlor	0.000176	2.20E-04 ± 1.02E-04	80.09214	6.28E-06	2.09E-05
Delta Â– BHC	5.78E-05	3.90E-04 ± 3.34E-05	14.81658	1.83E-06	6.09E-06
Aldrin	0.00016	1.60E-04 ± 9.22E-05	99.81679	2.10E-06	7.01E-06
Gamma Â– Chlordane	1.46E-05	2.50E-04 ± 8.43E-06	5.842164	3.27E-07	1.09E-06
Alpha Â– Chlordane	0.000263	3.30E-04 ± 1.52E-04	79.72315	5.50E-06	1.83E-05
Endosulfan I	2.81E-05	1.50E-04 ± 1.62E-05	18.71577	5.70E-07	1.90E-06
Dieldrin	2.52E-05	4.00E-05 ± 1.46E-05	63.04758	1.33E-07	4.43E-07
Endrin	9.34E-06	2.50E-04 ± 5.39E-06	3.737471	3.47E-07	1.16E-06
<i>P, P'</i> - DDD	0.000152	2.20E-04 ± 8.76E-05	68.93725	2.77E-06	9.24E-06
Endosulfan II	6.95E-05	2.00E-04 ± 4.01E-05	34.74944	2.96E-06	9.87E-06
<i>P, P'</i> - DDT	0.000155	1.90E-04 ± 8.97E-05	81.78882	3.05E-06	1.02E-05
Endrin Aldehyde	2.74E-06	1.30E-04 ± 1.58E-06	2.107646	5.57E-08	1.86E-07
Endosulfan Sulfate	1.32E-06	4.00E-05 ± 7.62E-07	3.299707	8.66E-09	2.89E-08
Methoxychlor	3.11E-05	4.00E-05 ± 1.79E-05	77.69567	6.82E-07	2.27E-06
Endrin Ketone	3.89E-05	1.70E-04 ± 2.25E-05	22.89018	1.20E-06	3.99E-06

SE- Standard Error, RSD- Relative Standard Deviation, LOD- Limit of Detection, LOQ- Limit of Quantification

The presence of *P, P'*-DDT and its metabolites, such as *P, P'*-DDD, with mean concentrations of 0.000190 and 0.000220 mg/kg respectively, indicates ongoing or historical use of DDT-based pesticides, which are persistent in the environment [21].

The pesticide residue analysis for goat samples in Awe, summarized in Table 3, shows the mean concentrations, relative standard deviations (RSD), limits of detection (LOD), and limits of quantification (LOQ) for various pesticides. Several compounds, such as Alpha-BHC, Gamma-BHC, Heptachlor, Heptachlor Epoxide, Dieldrin, and *P, P'*-DDE, were below detection limits (BDL), indicating no measurable contamination with these specific pesticides in the analyzed samples. Among the detected residues, Beta-BHC had a mean concentration of 0.00015 mg/kg and a high RSD of 49.37%, suggesting significant variability in contamination levels. Similarly, Delta-BHC recorded a mean concentration of 0.00012 mg/kg with an even higher RSD of 63.65%, reflecting inconsistent residue levels across samples. Aldrin showed a mean concentration of 0.00014 mg/kg and an RSD of 94.99%, indicating considerable variability in its presence. Gamma-Chlordane and Alpha-Chlordane exhibited lower contamination levels with mean concentrations of 0.00011 and 0.00009 mg/kg, respectively, and low RSDs of 7.94 and 6.78%, suggesting more consistent residue levels. Endosulfan I and II were present at mean concentrations of 0.0002 and 0.00021 mg/kg, with moderate variability (RSD: 37.79 and 18.02%). *P, P'*-DDD and *P, P'*-DDT were detected with mean concentrations of 0.00007 and 0.00014 mg/kg respectively, reflecting the persistence of DDT and its metabolites in the environment. Endrin Aldehyde and Endosulfan Sulfate recorded mean concentrations of 0.0002 and 0.00009 mg/kg, with RSDs of 83.15 and 28.66%, respectively. Methoxychlor showed a relatively high mean concentration of 0.00016 mg/kg but low variability (RSD: 10.12%), indicating stable contamination levels. Endrin Ketone, with a mean concentration of 0.0001 mg/kg, also displayed low variability (RSD: 16.41%).

In a study by Kamal *et al.* organochlorine pesticides were not detected in most samples except in cattle Feed which exceeded the MRLs [23]. In another study by Osesua and Omoniyi, the pesticide residue detected also was lower than the MRLs [24].

Table 3: Mean concentration, percentage relative Standard Deviation, correlation coefficient, LOD, and LOQ of Goat in Awe

Pesticides	Standard Deviation	Mean ± SE	RSD (%)	LOD	LOQ
Beta \hat{A} - BHC	7.41E-05	1.50E-04 ± 4.28E-05	4.94E+01	3.19E-06	1.06E-05
Delta \hat{A} - BHC	7.64E-05	1.20E-04 ± 4.41E-05	6.37E+01	2.41E-06	8.05E-06
Aldrin	1.33E-04	1.40E-04 ± 7.68E-05	9.50E+01	1.75E-06	5.84E-06
Gamma \hat{A} - Chlordane	8.74E-06	1.10E-04 ± 5.05E-06	7.94E+00	1.96E-07	6.53E-07
Alpha \hat{A} - Chlordane	6.10E-06	9.00E-05 ± 3.52E-06	6.78E+00	1.28E-07	4.25E-07
Endosulfan I	7.56E-05	2.00E-04 ± 4.36E-05	3.78E+01	1.54E-06	5.12E-06
Endrin	2.08E-04	2.40E-04 ± 1.20E-04	8.67E+01	7.73E-06	2.58E-05
<i>P, P'</i> - DDD	4.23E-05	7.00E-05 ± 2.44E-05	6.04E+01	7.72E-07	2.57E-06
Endosulfan II	3.78E-05	2.10E-04 ± 2.19E-05	1.80E+01	1.61E-06	5.38E-06
<i>P, P'</i> - DDT	6.76E-05	1.40E-04 ± 3.90E-05	4.83E+01	1.33E-06	4.42E-06
Endrin Aldehyde	1.66E-04	2.00E-04 ± 9.60E-05	8.31E+01	3.38E-06	1.13E-05
Endosulfan Sulfate	2.58E-05	9.00E-05 ± 1.49E-05	2.87E+01	1.69E-07	5.64E-07
Methoxychlor	1.62E-05	1.60E-04 ± 9.35E-06	1.01E+01	3.55E-07	1.18E-06
Endrin Ketone	1.64E-05	1.00E-04 ± 9.48E-06	1.64E+01	5.05E-07	1.68E-06

SE- Standard Error, RSD- Relative Standard Deviation, LOD- Limit of Detection, LOQ- Limit of Quantification

Table 4: Mean concentration, percentage relative Standard Deviation, correlation coefficient, LOD, and LOQ of pig in Awe

Pesticides	Standard Deviation	Mean ± SE	RSD (%)	LOD	LOQ
Beta \hat{A} - BHC	1.48E-04	1.80E-04 ± 8.54E-05	8.22E+01	6.37E-06	2.12E-05
Delta \hat{A} - BHC	1.57E-05	3.40E-04 ± 9.05E-06	4.61E+00	4.95E-07	1.65E-06
Alpha \hat{A} - Chlordane	1.36E-05	7.00E-05 ± 7.87E-06	1.95E+01	2.85E-07	9.51E-07
Endosulfan I	1.45E-04	1.50E-04 ± 8.36E-05	9.66E+01	2.94E-06	9.81E-06
Endrin	1.13E-04	2.40E-04 ± 6.51E-05	4.70E+01	4.19E-06	1.40E-05
<i>P, P'</i> - DDD	5.13E-06	1.50E-04 ± 2.96E-06	3.42E+00	9.37E-08	3.12E-07
Endosulfan II	1.49E-04	3.60E-04 ± 8.60E-05	4.14E+01	6.35E-06	2.12E-05
<i>P, P'</i> - DDT	2.02E-04	2.40E-04 ± 1.17E-04	8.43E+01	3.97E-06	1.32E-05
Endrin Aldehyde	1.42E-04	3.00E-04 ± 8.19E-05	4.73E+01	2.88E-06	9.61E-06
Endosulfan Sulfate	1.87E-05	1.10E-04 ± 1.08E-05	1.70E+01	1.23E-07	4.09E-07
Methoxychlor	3.05E-05	1.60E-04 ± 1.76E-05	1.91E+01	6.70E-07	2.23E-06
Endrin Ketone	1.83E-05	4.00E-05 ± 1.06E-05	4.57E+01	5.63E-07	1.88E-06

SE- Standard Error, RSD- Relative Standard Deviation, LOD- Limit of Detection, LOQ- Limit of Quantification

The analysis of pesticide residues in pig samples from Awe, as presented in Table 4, highlights the variability in contamination levels and the persistence of specific pesticide residues. Several pesticides, including Alpha-BHC, Gamma-BHC, Heptachlor, Aldrin, Heptachlor Epoxide, Gamma-Chlordane, *P, P'*-DDE, and Dieldrin, were below detection limits (BDL). This indicates absence or undetectable levels of these residues in the pig samples, reflecting either limited exposure or degradation of these compounds. Among the detected pesticides, Beta-BHC showed a mean concentration of 0.00018 mg/kg, with a high relative standard deviation (RSD) of 82.19%. Delta-BHC, with a mean concentration of 0.00034 mg/kg, exhibited low variability (RSD: 4.61%), suggesting a more consistent presence across samples. Alpha-Chlordane had a mean concentration of 0.00007 mg/kg with moderate variability (RSD: 19.48%), while Endosulfan I showed higher contamination at 0.00015 mg/kg and a very high RSD of 96.58%, reflecting considerable inconsistency. Endrin and Endosulfan II were detected at higher mean concentrations of 0.00024 and 0.00036 mg/kg, respectively. Their RSDs (46.99 and 41.37%) indicate moderate to high variability in residues. Notably, *P, P'*-DDD exhibited the least variability, with an RSD of 3.42% and a mean concentration of 0.00015 mg/kg, suggesting stable levels in the environment or samples. *P, P'*-DDT, a known persistent organic pollutant, was present at 0.00024 mg/kg with a high RSD of 84.30%, reflecting inconsistent exposure or degradation patterns. The metabolites of DDT found in the pig samples and other sample may be as a result of continuous usage of the banned pesticide or persistence in the environment. DDT and DDE were also found in these studies [24, 25].

Endrin Aldehyde and Endosulfan Sulfate were detected at 0.0003 and 0.00011 mg/kg, respectively, with variability levels of 47.27 and 17.01%, indicating differing persistence. Methoxychlor, with a mean concentration of 0.00016 mg/kg and an RSD of 19.08%, showed moderate consistency, whereas Endrin Ketone had the lowest concentration among the detected residues (0.00004 mg/kg) and a relatively high variability (RSD: 45.74%).

The analysis of pesticide residues in ram samples from Awe Table 5 reveals varying levels of contamination and highlights the persistence of certain pesticide compounds. Several pesticides, including Alpha-BHC, Gamma-BHC, Heptachlor, Heptachlor Epoxide, and *P, P'*-DDE, were below detection limits (BDL), suggesting either their absence or degradation to undetectable levels in the sampled rams. Among the detected pesticides, Beta-BHC exhibited a mean concentration of 0.00003 mg/kg with a relative standard deviation (RSD) of 40.48%, indicating moderate variability in contamination levels. Delta-BHC, with a mean concentration of 0.00042 mg/kg, showed less variability (RSD: 26.04%), suggesting more consistent exposure across samples. Gamma-Chlordane and Alpha-Chlordane were detected at 0.00017 and 0.00018 mg/kg, respectively. However, Alpha-Chlordane displayed a very high RSD of 95.82%, reflecting significant variability in its presence. Endosulfan I, Endosulfan II, Endosulfan sulfate had a mean concentration of 0.00014, 0.00051 and 0.00016 mg/kg respectively which are lower than MRLs. In a study by Mishra *et al.*, all three isomers of endosulfan was found in meat of chicken at concentrations lower than those in this study [26]. Aldrin, dieldrin and endrin are group of organochlorine pesticides which are found in the ram sample, they are known to be closely related chemically and are extremely persistent in the environment [27]. However, these groups of organochlorines have been banned [28]; residual concentrations have been reported in tissues of food animals by several researchers [29, 30, 31]. Methoxychlor and Endrin Ketone were detected at 0.00011 and 0.00014 mg/kg, respectively, with RSDs of 70.26 and 23.70%, highlighting differing degrees of variability. This study emphasizes the persistence and variability of certain pesticide residues in ram samples, underscoring the need for monitoring and regulation. The presence of persistent organic pollutants such as chlordane derivatives, endosulfan, and DDT metabolites raises concerns about environmental contamination and potential health risks to consumers.

Table 5: Mean concentration, percentage relative Standard Deviation, correlation coefficient, LOD, and LOQ of ram in Awe

Pesticides	Standard Deviation	Mean \pm SE	RSD (%)	LOD	LOQ
Beta \hat{A} - BHC	1.21E-05	3.00E-05 \pm 7.01E-06	4.05E+01	5.23E-07	1.74E-06
Delta \hat{A} - BHC	1.09E-04	4.20E-04 \pm 6.31E-05	2.60E+01	3.46E-06	1.15E-05
Aldrin	6.27E-05	1.40E-04 \pm 3.62E-05	4.48E+01	8.26E-07	2.75E-06
Gamma \hat{A} - Chlordane	5.77E-06	1.70E-04 \pm 3.33E-06	3.39E+00	1.29E-07	4.31E-07
Alpha \hat{A} - Chlordane	1.72E-04	1.80E-04 \pm 9.96E-05	9.58E+01	3.61E-06	1.20E-05
Endosulfan I	8.69E-05	1.40E-04 \pm 5.02E-05	6.21E+01	1.77E-06	5.88E-06
Dieldrin	4.50E-06	4.00E-05 \pm 2.60E-06	1.13E+01	2.37E-08	7.90E-08
Endrin	8.80E-05	5.00E-04 \pm 5.08E-05	1.76E+01	3.27E-06	1.09E-05
<i>P, P'</i> - DDD	4.66E-05	8.00E-05 \pm 2.69E-05	5.83E+01	8.52E-07	2.84E-06
Endosulfan II	1.40E-04	5.10E-04 \pm 8.11E-05	2.75E+01	5.99E-06	2.00E-05
<i>P, P'</i> - DDT	1.72E-04	2.70E-04 \pm 9.94E-05	6.37E+01	3.38E-06	1.13E-05
Endrin Aldehyde	3.17E-04	3.90E-04 \pm 1.83E-04	8.12E+01	6.44E-06	2.15E-05
Endosulfan Sulfate	1.77E-05	1.60E-04 \pm 1.02E-05	1.10E+01	1.16E-07	3.86E-07
Methoxychlor	7.73E-05	1.10E-04 \pm 4.46E-05	7.03E+01	1.69E-06	5.65E-06
Endrin Ketone	3.32E-05	1.40E-04 \pm 1.92E-05	2.37E+01	1.02E-06	3.40E-06

SE- Standard Error, RSD- Relative Standard Deviation, LOD- Limit of Detection, LOQ- Limit of Quantification

Table 6: Health risk estimation of cow, goat, pig and ram samples in Awe

Pesticides	COW			GOAT		PIG		RAM	
	ADI (mg/kg bw)	EDI (mg/kg bw)	CHI %	EDI (mg/kg bw)	CHI %	EDI (mg/kg bw)	CHI %	EDI (mg/kg bw)	CHI %
Alpha - BHC	5.00E-03	4.40E-07	8.77E-03	ND	ND	ND	ND	ND	ND
Beta \hat{A} - BHC	5.00E-03	8.50E-07	1.69E-02	4.55E-07	9.10E-03	2.04E-07	4.08E-03	1.00E-07	1.74E-03
Gamma \hat{A} - BHC	5.00E-03	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	1.00E-04	6.90E-07	6.89E-01	ND	ND	ND	ND	ND	ND
Delta \hat{A} - BHC	5.00E-03	1.22E-06	2.44E-02	3.64E-07	7.28E-03	3.85E-07	7.71E-03	1.20E-06	2.44E-02
Aldrin	1.00E-04	5.00E-07	5.01E-01	4.25E-07	4.25E-01	ND	ND	4.00E-07	4.06E-01
Heptachlor Epoxide	1.00E-04	ND	ND	ND	ND	ND	ND	ND	ND
Gamma \hat{A} - Chlordane	1.00E-04	7.80E-07	7.83E-01	3.34E-07	3.34E-01	ND	ND	5.00E-07	4.93E-01
Alpha \hat{A} - Chlordane	1.00E-04	1.03E-06	1.03E+00	2.73E-07	2.73E-01	7.93E-08	7.93E-02	5.00E-07	5.22E-01
Endosulfan I	6.00E-03	4.70E-07	7.83E-03	6.07E-07	1.01E-02	1.70E-07	2.83E-03	4.00E-07	6.77E-03
P, P' - DDE	1.00E-02	ND	ND	ND	ND	ND	ND	ND	ND
Endrin	1.00E-04	1.30E-07	1.25E-01	ND	ND	ND	ND	1.00E-07	1.16E-01
Endrin	2.00E-04	7.80E-07	3.92E-01	7.28E-07	3.64E-01	2.72E-07	1.36E-01	1.50E-06	7.25E-01
P, P' - DDD	1.00E-02	6.90E-07	6.89E-03	2.12E-07	2.12E-03	1.70E-07	1.70E-03	2.00E-07	2.32E-03
Endosulfan II	6.00E-03	6.30E-07	1.04E-02	6.37E-07	1.06E-02	4.08E-07	6.80E-03	1.50E-06	2.47E-02
P, P' - DDT	1.00E-02	6.00E-07	5.95E-03	4.25E-07	4.25E-03	2.72E-07	2.72E-03	8.00E-07	7.83E-03
Endrin Aldehyde	2.00E-04	4.10E-07	2.04E-01	6.07E-07	3.03E-01	3.40E-07	1.70E-01	1.10E-06	5.66E-01
Endosulfan Sulfate	6.00E-03	1.30E-07	2.09E-03	2.73E-07	4.55E-03	1.25E-07	2.08E-03	5.00E-07	7.73E-03
Methoxychlor	N/A	1.30E-07	ND	4.85E-07	ND	1.81E-07	ND	3.00E-07	ND
Endrin Ketone	2.00E-04	5.30E-07	2.66E-01	3.03E-07	1.52E-01	4.53E-08	2.27E-02	4.00E-07	2.03E-01

ADI- Acceptable Daily Intake, EDI- Estimated Daily Intake, CHI- Chronic Hazard Index, ND- Not Determined

Health risk assessment of pesticide residue in livestock

Table 6 provides an assessment of health risk estimations from pesticide residues in cow, goat, pig and ram samples from Awe in Nasarawa south senatorial district. The health risk is evaluated using the Estimated Daily Intake (EDI) of each pesticide, comparing it to the Acceptable Daily Intake (ADI) for each substance. The table also presents the Chronic Health Index (CHI) percentage, which helps to determine the level of health risk posed by the pesticide residues in each region. Alpha-BHC, Gamma-BHC and Heptachlor was not detected in goat, pig and ram samples with only a trace amount in Awe, indicating no significant risk across the meat samples. Similarly, Heptachlor Epoxide, and P, P'-DDE were not detected, reflecting low risk from these pesticides in the meat sampled. Beta \hat{A} -BHC, Delta \hat{A} - BHC, Aldrin, Gamma \hat{A} - Chlordane, Alpha \hat{A} - Chlordane, Endrin, P, P' - DDD, Endosulfan II, P, P' - DDT, Endrin Aldehyde, Endosulfan Sulfate, Methoxychlor, Endrin Ketone were all detected in the meat sampled at varying concentrations, but their overall health risks, reflected by the CHI percentages, were relatively low in most regions. While there are pesticide residues in cow, goat, pig and ram (meat) samples from these regions, the majority of the health risks are minimal, An index of >1 indicates that consumption is dangerous for human health [32]. The HI values of simultaneous exposure to different OCPs from the total food of animal origin (cow milk, beef, fish, chicken meat and egg) in [22] study were 0.829889954, 0.825673025, 0.035987457, 0.0557969 and 0.179828343 for aldrin, Σ p, p-DDE, DDD and DDT, Heptachlor, HCH and Endrin respectively which are also below 1 as indicated in this study. In a study by Morsi *et al.*, the health risk index was below 1 in milk sample in cattle [33]. The health risk estimation in the livestock meat samples in Awe showed that consumers are not at risk from the residues in cow, goat, pig and ram samples in this study.

Conclusion

The pesticides residues detected in the selected livestock samples are all below the maximum residue limits though banned pesticides such as DDT and its metabolites, Endrin and its metabolites were detected. There is no associated health risk from the pesticide residues detected in the selected food crops.

Conflict of interest: The authors declare that there is no conflict of interest.

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