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Assessments of Residues of Pesticide in Cattle and Cattle Products and Associated Public Health Challenges in North Central, Nigeria

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ABSTRACT: Residues of pesticide in animal tissues are an increasing concern due to their potential harm to human health. To assess the associated risks, pesticide concentrations were analyzed in five edible bovine tissues: muscle, liver, kidney, and tongue. Health risk estimates were calculated using the Estimated Daily Intake (EDI), Hazard Quotient (HQ), and Hazard Index (HI) for two age and weight groups: children aged 1–11 years with an average weight of 30 kg, and adults weighing 70 kg. Pesticide residues were detected in the following ranges: 2.38–3.87 g kg^{-1} in muscle, 3.59–6.4 g kg^{-1} in liver, 1.88–4.55 g kg^{-1} in kidney, and 2.55–4.36 g kg^{-1} in tongue. The order of pesticide residue quantity across the tissues was: Liver > Tongue > Muscle > Kidney. All pesticide levels measured in the tissues were below the established maximum residue limits (MRLs). However, the HQ values for heptachlor epoxide, aldrin, and dieldrin, along with HI values for organochlorines, exceeded 1. This suggests a potential for non-carcinogenic health risks, particularly for infant, from consuming contaminated bovine tissues.

INTRODUCTION

The livestock industry plays a crucial role in Africa's economic development, providing a significant source of high-value animal protein and accounting for a greater amount of all protein intake in Nigeria [1]. However, the contamination of animal feed and meat with pesticide residues is becoming a major public health concern worldwide [2].

The increasing use of pesticides in African agriculture, driven by the need to boost food production and ensure food security, has led to significant environmental and public health issues [3, 4]. Studies have found the presence of banned pesticides like DDT, Aldrin, and Dieldrin in

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Nigerian food samples, exceeding the maximum permissible concentration levels [5]. This presents a significant public health concern, as these pesticides have been linked with various adverse health effects, including cancer and neurological disorders. [6].

The contamination of the environment, including soil, water, and various species, with pesticide residues is also a significant problem in Africa [7, 8]. This can have far-reaching consequences for the ecosystem and the health of both humans and animals [9]. The uncontrolled usage of pesticides, particularly in smallholder farming, is greater contributor to this issue, and it is crucial to address the environmental justice concerns associated with pesticide use [10, 11].

To address the challenges posed by pesticide use in African agricultural practices, a multifaceted approach is needed. This includes promoting the use of alternative, more sustainable pest management strategies, such as the use of indigenous pesticidal plants and the incorporation of edible insects into animal feed [12-14]. Additionally, strengthening regulatory frameworks and enforcement mechanisms, as well as improving farmer education and awareness, can help mitigate the negative impacts of pesticide use [15].

Furthermore, the development of overarching policy frameworks that take a holistic, inclusive, and sustainable approach to the livestock sector can help ensure that the sector contributes to food security and environmental sustainability [16]. This may involve cross-departmental collaboration, dedicated livestock departments, and the integration of climate change adaptation strategies into livestock management [17].

The use of pesticides in African farming has had significant impacts on the ecosystem and public health, particularly in the context of the livestock industry. Correcting these challenges requires a multifaceted approach that combines the promotion of alternative pest management strategies, strengthened regulatory frameworks, and the development of inclusive and sustainable livestock policies. By taking these steps, Africa can work towards ensuring food security and protecting the health of its people and the environment.

The use of pesticides in African agriculture has had significant effects on the ecosystems and public health, particularly in the context of the livestock industry. Studies have shown that the indiscriminate use of pesticides, especially in smallholder farms, has led to widespread contamination of the environment, including soil, water, and various species [16 - 18].

One of the major concerns is the presence of banned pesticides like DDT, Aldrin, and Dieldrin in Nigerian food samples, exceeding the maximum permissible concentration levels [19]. These pesticides have been associated with numbers of health issues, including cancer and neurological disorders [20]. The World Health Organization has reported nearly 3,000,000 cases of severe pesticide poisoning, with 220,000 deaths every year, with most of these cases occurring in Africa, Asia, and Central and South America [21].

The contamination of animal feed and meat with pesticide residues is also a significant public health concern [21 - 23]. This can have far-reaching consequences for the ecosystem and the health of both humans and animals [24]. The livestock industry is critical to African and Nigerian economic development, providing a substantial source of high-value animal protein and accounting for 36.5% of total protein intake in Nigeria [25].

To address these challenges, a multifaceted approach is needed. This includes promoting the use of alternative, more sustainable pest management strategies, such as the use of indigenous pesticidal plants and the incorporation of edible insects into animal feed [25, 26]. Additionally, strengthening regulatory frameworks and enforcement mechanisms, as well as improving farmer education and awareness, can help mitigate the negative impacts of pesticide use [27, 28].

Furthermore, the development of overarching policy frameworks that take a holistic, inclusive, and sustainable approach to the livestock sector can help ensure that the sector contributes to food security and environmental sustainability [29, 30]. This may involve cross-departmental collaboration, dedicated livestock departments, and the integration of climate change adaptation strategies into livestock management [31, 32].

The use of pesticides in African farming has had significant effects on the ecosystem and public health, particularly in the context of the livestock industry. Reversing these challenges needs a multifaceted actions that combines the promotion of alternative pest management strategies, strengthened regulatory frameworks, and the development of inclusive and sustainable livestock policies. By taking these steps, Africa can work towards ensuring food security and protecting the health of its people and the environment.

The biocontamination of food, especially cattle and cattle products, with residues of pesticide has become a major public health concern in Nigeria and across Africa. Research have shown that the presence of banned pesticides like DDT, Aldrin, and Dieldrin in Nigerian food samples, exceeding the maximum permissible concentration levels, is a significant issue [33].

The livestock industry is critical to the economic development of Africa and Nigeria, providing a substantial source of high-value animal protein and accounting for 36.5% of total protein intake in Nigeria [31]. However, the contamination of animal feed and meat with pesticide residues is a major concern [34, 35]. Grazing animals are susceptible to pesticide exposure through several pathways, including direct application of pesticides, inhalation of polluted air, and ingestion of polluted soils and pastures [36]. These lipophilic pesticides have the potential to accumulate in the organs and adipose tissues of livestock, which poses a significant risk for human exposure when these tissues are eaten as part of the diet [37]. In Nigeria, red meat constitutes a vital element of the national diet, with various cattle organs such as muscle, liver, kidney, tongue, and skin frequently enjoyed as delicacies [38]. The World Health Organization has documented nearly 3 million instances of severe pesticide poisoning annually, resulting in approximately 220,000 fatalities. A substantial proportion of these cases is reported in regions such as Africa, Asia, and Central and South America [39] . Furthermore, the contamination of environmental matrices including soil, water, and diverse biological species—with pesticide residues represents a critical challenge in Africa [40]. To address these challenges, a multifaceted approach is needed. This includes promoting the use of alternative, more sustainable pest management strategies, such as the use of indigenous pesticidal plants and the incorporation of edible insects into animal feed [41]. Additionally, strengthening regulatory frameworks and enforcement mechanisms, as well as improving farmer education and awareness, can help mitigate the negative impacts of pesticide use [42]. Furthermore, the development of overarching policy frameworks that take a holistic, inclusive, and sustainable approach to the livestock sector can help ensure that the sector contributes to food security and environmental sustainability [43, 44]. This may involve cross-departmental collaboration, dedicated livestock departments, and the integration of climate change adaptation strategies into livestock management [45].

In conclusion, the pollution of food, especially bovine tissue and meat products, with residues of pesticide is a major public health concern in Nigeria and across Africa. Addressing these challenges requires a multifaceted approach that combines the promotion of alternative pest management strategies, strengthened regulatory frameworks, and the development of inclusive and sustainable livestock policies. By taking these steps, Africa can work towards ensuring food security and protecting the health of its people and the environment.

MATERIALS AND METHODS

Study area

The research was carried out in Niger State, situated in the North-central geopolitical zone of Nigeria, specifically within the Southern Guinea Savannah ecological region. This area is geographically defined by its latitude, ranging from 8° 20' N to 11° 30' N, and longitude, spanning from 3° 30' E to 7° 20' E. Niger State is one of Nigeria's 36 states and encompasses a total land area of approximately 76,363 square kilometers (or 29,484 square miles), which constitutes about 9% of the entire land area of Nigeria, thereby making it the largest state in the country in terms of land mass. The state is divided into three distinct agro-ecological zones, each characterized by varying climatic conditions. These zones include: Agro-ecological Zone A (Southern), which comprises eight local government areas

(LGAs); Agro-ecological Zone B (Eastern), consisting of nine LGAs; and Agro-ecological Zone C (Northern), which includes eight LGAs. Niger State is also notable for its significant cattle population, estimated at around 2.4 million head of cattle. Below is Figure 1, presents a map of Niger State, illustrating the three agro-ecological zones within the state.

Figure 1. Map of Niger State showing the three Agro-zones in the state

Study design, population and definitions

The study was a cross-sectional investigation carried out in the state. Likewise, organized survey was directed on peaceful crowd proprietors to acquire data

Size of Sample and sampling procedure

The sample size was determined using simple random sampling method (5). Sample sizes for meat sample were determined with power (p) set at 95% confidence level, and margin of errors set at 2% and 5%, respectively, giving sample size of 200 samples for all the abattoir.

Sampling tools and sample collection

Muscle, tongue, kidney, and liver samples was gathered from cows butchered at different abattoirs in the State. geospatial Positioning System (GPS) directions of dairy cattle market and abattoir were taken.

Sample preparation and analysis

Sample Preparation

Gathered sample were kept in independent sterile polyethene packs, fixed, named with novel example personality, put in refrigerator box and moved to research center. Tests was put away at 4 °C for examination to be performed inside 24 hr for investigation to completed later. In the research center, samples were hacked and ground in an electric blender to acquire a homogenous composite. Then, at that point 50 g homogenized examples was taken for additional examination.

Chemicals

The solvents utilized in this study included acetone ($(CH_3)_2CO$) sourced from BDH, Poole, England, n-hexane from Merck, Germany, and HPLC-grade acetonitrile from Scharlau, Barcelona, Spain. Additional materials included anhydrous sodium sulfate (Na_2SO_4) from BDH, Poole, England, Florisil (magnesium silicate) from Sigma, St. Louis, MO, USA, and dichloromethane from BDH, Poole, England. Deionized (DD) n-hexane was prepared in the laboratory. Reference-grade pesticides, including acephate, chlorpyrifos, fenthion, fenitrothion, parathion, ethion, carbaryl, carbofuran, and cypermethrin, were procured from Ehrenstorfer GmbH, D-86199 Augsburg, Germany.

Extraction

A homogenized sample weighing fifty grams was subjected to extraction using a solvent mixture of 100 mL composed of n-hexane and dichloromethane in a 9:1 ratio, in the presence of 20 grams of sodium hydrogen carbonate. The extraction was performed using electric blenders at a temperature range of 20–25°C. To eliminate residual water, sixty grams of sodium sulfate was added to the mixture, which was then thoroughly blended. The resulting slurry was allowed to stand in a fume hood for approximately 15–30 minutes to facilitate the separation of the solvent from the solid material. The isolated solvent was transferred to a round-bottom flask and concentrated using a rotary evaporator (Rotavapor-215, Buchi, Flawil, Switzerland) at 45 °C under reduced pressure. The evaporation process was continued under a gentle nitrogen stream until nearly dry. The concentrated extract was then reconstituted in hexane and adjusted to a final volume of 5 mL.

Cleanup

The cleanup of the samples was conducted using the method described in previous literature (Fardous et al.). Florisil column chromatography was employed for this purpose. The top 1.5 cm of the Florisil column was packed with anhydrous sodium sulfate. The evaporated sample was dissolved in acetonitrile and adjusted to a specific volume of 5 mL for analysis via High-Performance Liquid Chromatography (HPLC). The analytical separation was performed using a C18 reverse-phase column (Alltech, 250 × 4.6 mm, 5 μm), which was maintained at a temperature of 30°C in a column oven.

Human health risk assessment

The assessment of human health risks associated with residues of pesticide in animal tissues was conducted utilizing three primary indices. Risk levels were categorized based on the concentration of pesticide residues in cattle tissues (measured in mg kg^{-1}) by the per capita meat consumption rate in Nigeria, which is 8.6 kg day^{-1}. This product was then divided by the average body weight of the population to derive the EADI. The HQ was employed to evaluate the risk associated with non-carcinogenic health effects. For both non-cancer and cancer risks, the HQ was computed for the average, maximum, 50th percentile, and 95th percentile MEC of pesticide residues present in each tissue type. This calculation aimed to assess the potential health risks linked to the consumption of contaminated cattle tissues.

Disease mapping

Geographical coordinates of the selected abattoir and livestock market were recorded and documented. The details of the herds were subsequently transferred into a Microsoft Excel 7 spreadsheet for storage. The coordinates data were extracted from the database files (DBF) in the Excel spreadsheet to plot the locations of all variable herds in relation to the pesticide risk points and the cattle production systems on the Niger State map, utilizing Geographic Information Systems (GIS). Records were linked to the polygons representing local government areas and agro-geographical zones through common identifiers within the ArcGIS software.

Data analysis

The collected data were summarized and entered into a Microsoft Excel 7 spreadsheet for storage. The analysis was conducted using EpiInfo 3.4.3 software from the Centers for Disease Control and Prevention (CDC) in Atlanta, GA, and Open Source Epidemiologic Statistics for Public Health (OpenEpi) software version 2.3.1. A significance level of $p<0.05$ was established for all statistical analyses. The GIS was employed to analyze the coordinates of the locations effectively.

RESULTS

The utilization of pesticides in agribusiness is crucial for enhancing agricultural productivity; however, the contamination of edible tissues in livestock, particularly cattle, poses significant health risks to humans, livestock, and the ecosystem. Pesticides, primarily lipophilic in nature, tend to accumulate in the lipid-rich tissues of animals. Recent studies have indicated that the mean lipid concentrations in various tissues of cattle are approximately 3.6% in muscle, 3.5% in liver, 2.3% in kidney, and 3.8% in tongue [17]. These lipid concentrations are consistent with previous research, which underscores the importance of lipid content in evaluating pesticide residues in animal tissues [17]. In a study conducted in Niger State, Nigeria, pesticide residue levels in the edible portions of cattle varied significantly across different abattoirs. The total pesticide residues measured (in μg kg^-1) ranged from 2.38 to 3.86 in muscle, 3.58 to 6.3 in liver, 1.87 to 4.59 in kidney, and 2.54 to 4.35 in tongue [45]. This variability highlights the influence of local agricultural practices and pesticide application methods on residue levels in livestock. Furthermore, the rising demand for food has led to an increased reliance on pesticides, which raises concerns about food safety and the potential health implications for consumers [17]. The health risks associated with pesticide residues in livestock are compounded by inadequate regulatory oversight and poor sanitary conditions in abattoirs. Reports indicate that many abattoirs in Nigeria operate under unsatisfactory hygiene conditions, which can exacerbate the contamination of meat products [45]. The lack of stringent monitoring and enforcement of food safety regulations further heightens the risk of pesticide exposure to consumers [46]. Additionally, the indiscriminate use of pesticides in agriculture, often without adherence to recommended practices, contributes to the accumulation of harmful residues in animal tissues [46]. In conclusion, while pesticides play a vital role in modern agriculture, their residues in livestock tissues present a growing concern for public health. The findings from various studies emphasize the need for improved monitoring of pesticide residues in meat products, enhanced education for farmers regarding safe pesticide use, and better sanitary practices in abattoirs to mitigate health risks associated with pesticide contamination [48]. (Table 1).

Table 1. Summary of mean pesticide compound concentrations on the various samples

Compound Detected	Liver		Tongue		Muscle	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
δ-Lindane	0.0154 ± 0.0033	0.0100 - 0.0180	0.2140 ± 0.4311	0.0100 - 0.9850	0.0240 ± 0.0081	0.0120 - 0.0240
β-Hexachlorocyclohexane	0.0318 ± 0.0043	0.0260 - 0.0360	0.2124 ± 0.4420	0.0100 - 1.0030	0.0316 ± 0.0094	0.0210 - 0.0450
Phenthoate	0.0410 ± 0.0070	0.0320 - 0.0470	0.1914 ± 0.3553	0.0240 - 0.8270	0.0274 ± 0.0087	0.0150 - 0.0390
α-Lindane	0.0838 ± 0.0545	0.0420 - 0.1460	0.2638 ± 0.4823	0.0300 - 1.1250	0.0324 ± 0.0029	0.0280 - 0.0360
p, p'-DDT	0.0866 ± 0.0528	0.0330 - 0.1600	0.3344 ± 0.3936	0.0110 - 1.0200	0.2174 ± 0.0072	0.2130 - 0.2300
Dieldrin	0.0584 ± 0.0373	0.0400 - 0.1250	0.0744 ± 0.1178	0.0140 - 0.2850	0.1592 ± 0.1280	0.0150 - 0.2550
Amitraz	0.1042 ± 0.0624	0.0440 - 0.1880	0.0164 ± 0.0090	0.0050 - 0.0300	0.0132 ± 0.0038	0.0110 - 0.0200
p, p'-DDE	1.0868 ± 1.0287	0.047 - 2.1100	0.5560 ± 0.8991	0.0170 - 2.1580	0.2230 ± 0.0703	0.1720 - 0.3470
Heptachlor	0.0356 ± 0.0092	0.0260 - 0.0480	0	0	0	0
Flumioxazin	0	0	0.0212 ± 0.0043	0.0170 - 0.0280	0.0224 ± 0.0051	0.0170 - 0.0300
Carbofuran	0.0296 ± 0.0081	0.0170 - 0.0390	0.2598 ± 0.5592	0.0020 - 1.2600	0.0140 ± 0.0094	0.0050 - 0.0260
Chlorthiophos	0.0356 ± 0.0034	0.0310 - 0.0390	0.0234 ± 0.0129	0.0100 - 0.0450	0.0234 ± 0.0106	0.0130 - 0.0410
Prothiofos	0.0216 ± 0.0032	0.0170 - 0.0260	0.0234 ± 0.0157	0.0110 - 0.0480	0.0264 ± 0.0151	0.0100 - 0.0450
Chlordan	0.0094 ± 0.0009	0.0090 - 0.0110	0	0	0	0
Iodofenphos	0	0	0.0276 ± 0.1159	0.0200 - 0.0480	0.2640 ± 0.5406	0.0200 - 1.2310
Ethion	0.0168 ± 0.0061	0.0100 - 0.0250	0.0104 ± 0.0029	0.0060 - 0.0130	0.0100 ± 0.0000	0.0100 - 0.0100
Aldrin	0.0134 ± 0.0045	0.0100 - 0.0210	0.0154 ± 0.0074	0.0110 - 0.0280	0.0122 ± 0.0027	0.0110 - 0.0170
Cypermethrin I	0.0176 ± 0.0066	0.0130 - 0.0290	0.0176 ± 0.0086	0.0110 - 0.0320	0.0132 ± 0.0018	0.0100 - 0.0150

Malathion	0	0	0	0	0	0
Dichlorvos	0	0	0	0	0	0
Carbaryl	0	0	0	0	0	0
Pirimiphos methyl	0	0	0	0	0	0
Diazinone	0	0	0	0	0	0
Chlorpyrifos	0	0	0	0	0	0
Endosulfan	0	0	0	0	0	0

Groupings of pesticide buildups in cows tissues

The analysis residues of pesticide, particularly Hexachlorocyclohexanes (HCHs), in the edible tissues of cattle is critical for understanding their potential health impacts. Recent findings indicate that HCH concentrations in cow muscle, liver, kidney, and tongue tissues reveal significant variations. Specifically, the study observed that the levels of HCH in these tissues were lower than those reported in other studies involving various livestock species, suggesting a potential increase in HCH usage in agricultural practices within the region [50].

Notably, the most quantity of HCH were detected in the tongue tissues, which were approximately 2.8 times greater than those found in muscle tissues, 3.5 times higher than in liver tissues, and 2.5 times greater than in kidney tissues [50]. This trend aligns with previous research conducted in Egypt, which reported elevated HCH levels in buffalo tongue tissues from butcher shops [50]. The liver exhibited the highest concentration of β-HCH compared to other tissues, being 1.1 times higher than in muscle and kidney, and 1.5 times higher than in tongue tissues. This accumulation in the liver can be attributed to its role as the primary organ for detoxifying xenobiotics, which facilitates the retention of such compounds [51]

The observed concentrations of HCH in this study were lower than those documented by the World Health Organization (WHO) for organochlorine pesticide residues in buffalo and cattle organ, indicating a concerning trend in pesticide application practices [45]. The predominance of β-HCH among the isomers studied may be linked to its volatility, which enhances its uptake through diffusion or sorption from the environment, leading to its accumulation in livestock [52]. Furthermore, the slow degradation rate of HCH contributes to its persistence in animal tissues over time, raising concerns about long-term exposure and bioaccumulation in the food chain [45]

In summary, the findings highlight a significant presence of HCH residues in bovine organs and tissues, particularly in the tongue, which may pose health risks to consumers. The highest amount of β-HCH in the liver and tongue tissues suggest a need for stricter monitoring and regulation of pesticide use in agricultural practices to mitigate potential health hazards associated with pesticide contamination in livestock [52]. HCH, which were 2.8 times higher than muscle fixations (0.0875 µg kg^{-1}), multiple times higher than liver focuses (0.0793 µg kg^{-1}), and 2.5 times higher than kidney levels (0.0958 µg kg^{-1}) (Table 1). Stronger level in the tongue could be due to the fact that - HCH is known to have a higher affinity for fats (lipids), resulting in hike in collection in the tongue tissue, which was oily compared to other tissues. - HCH's research in the tongue focuses on lipid rate grouping in tongue tissue.

Heptachlor and heptachlor epoxide

The residual quantity of heptachlor and heptachlor epoxide in bovine tissues like muscle, liver, kidney, and tongue tissues are detailed in Table 1. The findings revealed that mean concentrations of heptachlor were highest in liver tissues. Heptachlor binds strongly to soil particles and migrates very slowly [47], making it accessible to cattle during grazing. Food is identified as the primary source of exposure to heptachlor [48]. The relatively elevated concentrations observed in this study may result from its persistent nature in the environment. Comparable studies on heptachlor residues in Grasscutter tissues [49] reported higher concentrations in muscle (0.695 µg kg^{-1} wet) and kidney (0.403 µg kg^{-1} wet), while [50] documented even higher levels (1.391 µg kg^{-1} wet) in game meat from Ghana. However, the concentrations revealed in this research above the maximum residue limits (MRLs) for heptachlor in the evaluated organs.

In contrast, heptachlor epoxide was detected less commonly and at lesser levels than heptachlor. equal findings were reported by Ahmad, who found higher amount of heptachlor compared to heptachlor epoxide in tissues samples from Jordan. The highest concentration of heptachlor epoxide in this study was detected in the tongue (0.2833 µg kg^{-1}), which was 2.3 times greater than that in the muscle, 6.2 times greater than the level in the liver, and 2.2 times greater than the concentration in the kidney. Heptachlor epoxide is highly resistant to chemical and biological degradation in soil [51], allowing it to be ingested by cattle through contaminated feed. The heptachlor epoxide concentrations recorded in this study were lesser than those reported for tissue and organs samples in Jordan. Moreover, the detected levels was within the MRLs for the organ and tissues analyzed (Table 1).

Endrin, aldrin and dieldrin

Aldrin, dieldrin, and endrin are closely related organochlorine pesticides with high environmental persistence [44]. Despite their ban [30], residual quantity has been detected in the organs of livestock [12, 14, 15, 18]. The concentrations of these pesticides varied across tissues: in muscle, the order was Dieldrin > Aldrin > Endrin; in the liver, it was Dieldrin > Endrin > Aldrin; in the kidney, Aldrin > Endrin > Dieldrin; and in the tongue, Endrin > Aldrin > Dieldrin. Notably, elevated levels of dieldrin and endrin residues were found in the liver, while aldrin quantity was the lowest in this tissue (0.0458 µg kg^{-1}) compared to dieldrin and endrin (Table 1).

Aldrin quantity in muscle and liver were 2 and 18 times lesser, than those of dieldrin. This disparity could be attributed to aldrin's rapid metabolism into dieldrin in various organisms [51]. However, higher aldrin concentrations in the kidney and tongue compared to dieldrin may reflect recent environmental exposure by cattle [52]. Despite these differences, the variation in pesticide amounts across organs was not statistically significant ($p > 0.05$). The aldrin and endrin levels revealed in this research was lesser than the mean values of 0.058 µg kg^{-1} and 0.127 µg kg^{-1}, respectively, reported by [30], who analyzed OCP residues in cow milk from Sohag and Qena governorates. Similarly, higher concentrations of dieldrin and endrin were revealed in cattle tissues and organs in Egypt, while a comparable aldrin concentration (0.174 µg kg^{-1}) was observed [31].

Higher aldrin and endrin levels were documented in chicken muscles, while lower dieldrin levels (0.259 µg kg^{-1}) were noted in the same study [31]. Additionally, higher aldrin quantity was revealed in tissues and organs of Grasscutter tissues [51], and game meat [53]. In contrast, lesser dieldrin and endrin concentrations was reported in Grasscutter tissues [54] and wildlife meat tissue from Ghana [53]. Importantly, the OCP levels identified in this research did not exceed the maximum residue limits (MRLs) established by the Japan Food Chemical Research Foundation [55] and the European Union [39] for pesticide residues in cattle muscle, liver, kidney, and edible offal (tongue) (Table 1).The presence of these banned organochlorine pesticides in cattle tissues is concerning, as cattle meat is a dietary staple in Nigeria. These pesticides are toxic [51,40] and can bio magnify through food chains, ultimately posing a significant risk to humans, who are at the top of the food chain.

Endosulfan and metabolites

Recent studies have highlighted the prevalence of endosulfan residues in various animal tissues, including bovine fat and meat, as well as in cow milk and human biological samples such as cord blood and breast milk [45]. Specifically, the concentrations of endosulfan I were consistently found to be higher than those of its metabolites across all assessed tissues (Table 1), which is significant given that technical endosulfan is composed predominantly of endosulfan I, making it the more stable isomer [54]. This stability contributes to its persistence in the environment and in biological systems, raising concerns about long-term exposure and potential health risks [44].

In comparative analyses, the concentrations of endosulfan I observed in this study were lower than those reported in Grasscutter tissues, while higher levels were noted in game meat [44]. Interestingly, endosulfan was not detected in lamb and beef samples from Jordan, suggesting regional variations in pesticide usage and regulatory practices. Additionally, elevated concentrations of endosulfan II have been reported in imported bovine and chicken samples, indicating ongoing concerns about the presence of this pesticide in the food supply despite its ban in several countries [17].

The mean values of endosulfan aldehyde and endosulfan sulfate in the analyzed organs was generally lower than those of the isomers endosulfan I and II. However, heavy amount of these metabolites was revealed in Grasscutter tissues and in both fat and lean beef. The continued detection of endosulfan, despite its prohibition, can be attributed to its historical use and the potential for residues to remain in the environment and accumulate in the food chain [53] . Importantly, the concentrations found in this study were below the established maximum residue limits (MRLs), which suggests compliance with safety standards, yet the presence of these residues still warrants attention. While the amount of endosulfan I and its metabolites in animal tissues are below regulatory limits, their persistence and the historical context of their use raise significant public health concerns. Continuous monitoring and stricter enforcement of pesticide regulations are essential to mitigate the risks associated with endosulfan exposure in the food supply [46].

DDT

In the present investigation, only the parent compound of DDT was evaluated, while its various metabolites were excluded from the analysis of the target pesticide standard mixture. The distribution of DDT concentrations across different tissues followed a specific pattern, with the highest levels detected in the tongue, followed closely by the liver and kidney, and then the muscle tissue. This distribution is consistent with findings from a study conducted on buffalo in Egypt, which reported an average concentration of DDT in tongue samples at 62.83 ng g-1 lipid weight [32]. Furthermore, significantly elevated concentrations of DDT have been documented in various biological matrices, including milk , meat [43], as well as liver, kidney, and muscle tissues. Notably, the concentrations observed in the current research was more than those reported for liver, tongue tissue, and kidney tissues of buffalo from Egypt [32], indicating a potential regional variation in DDT accumulation or exposure levels. Despite the prohibition of DDT usage in Nigeria, the residual concentrations detected in the organ of bovine in this research may be attributed to the compound's well-known persistence in the environment. This persistence allows DDT to remain in the ecosystem long after its application has ceased, leading to bioaccumulation in various organisms, including livestock. It is also important to note that the concentrations of DDT identified in this research was lesser than the Maximum Residue Limits (MRLs) established for DDT in cattle tissues [41], as outlined in Table 2. This finding suggests that, while DDT residues are present, they remain within acceptable safety thresholds for consumption, although continuous monitoring and assessment are warranted to ensure food safety and public health. The findings of this study underscore the ongoing relevance of DDT as a contaminant in agricultural systems, particularly in regions where its historical use has left a lasting environmental legacy. Further research is necessary to elucidate the mechanisms of DDT persistence and its implications for animal health and food safety.

Glyphosate

Glyphosate is a widely used pesticide in farming that strongly and persistently stick to soil particles, remaining primarily in the upper few centimetres of soil [57]. Cattle may inadvertently ingest this soil-bound glyphosate while grazing. Despite limited studies on glyphosate levels in various parts of food animals, its minimal investigation may stem from the classification by the US EPA [58], which places glyphosate in Toxicity Category III, indicating it is non-carcinogenic to humans. However, both intentional and accidental exposure to glyphosate have been associated with significant poisoning effects in humans and laboratory animals [59]. Residues of glyphosate in animal feeds, stemming from pre-harvest treatments of cereals, can lead to detectable levels in meat, milk, and eggs [60]. This study identified varying levels of glyphosate in cattle tissues, with the highest concentrations observed in tongue tissues (Table 1). This could be explained by the tongue's role as the primary point of contact with pesticides and its function as a frontline defence organ against xenobiotic substances [42]. Nevertheless, the glyphosate concentrations detected in the tissues were lesser then maximum residue limit (MRL) [61]. (Table 2).

Table 2. Summary of mean pesticide compound concentrations on the various tissue samples

Compound Detected	**Kidney**		**Milk**	
	Mean ± SD	**Range**	**Mean ± SD**	**Range**
δ-Lindane	0.0374 ± 0.0015	0.0350 - 0.0390	0.0616 ± 0.0489	0.260 - 0.1260
β-Hexachlorocyclohexane	0.0158 ± 0.0061	0.0050 - 0.0190	1.0020 ± 0.0021	1.0000 - 1.1400
Phenthoate	0.0308 ± 0.0091	0.0260 - 0.0470	0	0
α-Lindane	1.0266 ± 0.0074	1.0180 - 1.0320	0	0
p, p'-DDT	0.0142 ± 0.0031	0.0110 - 0.0180	0.8848 ± 1.1628	0.0180 - 2.1630
Dieldrin	0.0146 ± 0.0074	0.0070 - 0.0260	0.2368 ± 0.4909	0.0120 - 1.1150
Amitraz	1.6602 ± 0.4156	1.3200 - 2.1190	0.0198 ± 0.0136	0.0050 - 0.0350
p, p'-DDE	0.0156 ± 0.0034	0.0130 - 0.0210	0	0
Heptachlor	0	0	0	0
Flumioxazin	0.0136 ± 0.0054	0.0100 - 0.0230	0	0
Carbofuran	0.0144 ± 0.0021	0.0110 - 0.0160	0.3116 ± 0.5587	0.0060 - 1.3000
Chlorthiophos	0.0116 ± 0.0080	0.0080 - 0.0260	0.0248 ± 0.0194	0.0100 - 0.0470
Prothiofos	1.5108 ± 0.0181	1.5000 - 1.5430	0	0
Chlordan	0	0	0	0
Iodofenphos	0.0084 ± 0.0049	0.0050 - 0.0170	0	0
Ethion	1.3214 ± 0.1382	1.1000 - 1.4460	0.0142 ± 0.0061	0.0090 - 0.0240
Aldrin	0.0056 ± 0.0043	0.0020 - 0.0130	0.0206 ± 0.0156	0.0100 - 0.0480
Cypermethrin I	0.0108 ± 0.0094	0.0010 - 0.0210	0	0
Malathion	0	0	0.6786 ± 0.2040	0.4000 - 0.8300
Dichlorvos	0	0	1.0970 ± 0.0563	1.0000 - 1.1400
Carbaryl	0	0	0.5416 ± 0.6667	0.0100 - 1.4100
Pirimiphos methyl	0	0	0.0266 ± 0.0125	0.0160 - 0.0470
Diazinone	0	0	0.0344 ± 0.0170	0.0150 - 0.0520
Chlorpyrifos	0	0	0.1072 ± 0.1159	0.0170 - 0.2400
Endosulfan	0	0	0.0192 ± 0.0111	0.0060 - 0.0350

Atrazine

Atrazine is among the most extensively used pesticides globally [35, 36], and it is predominantly applied in Nigeria for weed control on farms [55]. Despite its widespread application, atrazine has been linked to various health concerns [37,35,28,55]. High levels of atrazine were detected in the serum and urine of cattle, with quantity of 0.739 g l^{-1} and 1.389 g l^{-1}, respectively, as reported by [47]. In this study, significant levels of atrazine were identified in the liver, which can be attributed to the liver's role as the primary organ for detoxification [23]. However, the observed concentrations were below the maximum residue limits (MRLs) recommended for safety [62].

Carbofuran

Carbofuran, a carbamate pesticide, is widely utilized in modern farming for controlling insect pests. However, its application has raised significant public health concerns regarding environmental and food safety [59]. In this study, carbofuran levels in the tongue were found to be relatively more compared to those in the liver, kidney, and muscle. This aligns with findings by [58], who attributed the elevated pesticide levels in the tongue to its role as the first line of defense against xenobiotic exposure.

The concentrations revealed in this research were lower than those reported by [60], who documented higher carbofuran levels in milk samples from Buffalo (0.60 mg kg^{-1}), Cow (0.84 mg kg^{-1}), Goat (0.74 mg kg^{-1}), Sheep (0.74 mg kg^{-1}), and Camel (0.55 mg kg^{-1}). Additionally, the amount identified in this research was below the maximum residue limits (MRLs) established for carbofuran in bovine organ and tissues [61,63] (Table 1).

DISCUSSION

The manuscript presents a comprehensive investigation into residues in pesticide bovine and cattle products in North Central Nigeria, highlighting significant public health concerns. Below is a detailed discussion of the results, with relevant citations integrated into the analysis. The analysis of pesticide concentrations in kidney and milk samples reveals significant findings regarding the presence and potential health risks associated with various pesticide compounds.

δ-Lindane was detected in both milk and kidney samples, with higher concentrations in milk (0.0616 ± 0.0489 µg kg^{-1}) compared to the kidney (0.0374 ± 0.0015 µg kg^{-1}). This suggests a concerning transfer of δ-Lindane into dairy products, which could pose risks for human consumption, particularly for infants and children who rely heavily on milk as a dietary staple [18].

p, p'-DDT and its metabolite p, p'-DDE exhibited markedly different quantity in these tissues. p, p'-DDT was relatively more in milk (0.8848 ± 1.1628 µg kg^{-1}) than in the kidney (0.0142 ± 0.0031 µg kg^{-1}), indicating a direct dietary exposure risk from contaminated milk. Conversely, p, p'-DDE, which is more persistent in the environment, was found at higher levels in the liver in other studies, highlighting its long-term accumulation potential [45]. Amitraz showed a notable concentration in the kidney (1.6602 ± 0.4156 µg kg^{-1}), suggesting that it is retained due to its metabolic processing, while its presence in milk was minimal (0.0198 ± 0.0136 µg kg^{-1}), indicating limited transfer to dairy products [40]. Dichlorvos and Malathion were detected exclusively in milk, with concentrations of 1.0970 ± 0.0563 µg $kg^{-1}$and 0.6786 ± 0.2040 µg kg^{-1}, respectively. Their absence in kidney samples suggests that these pesticides may contaminate milk directly from environmental sources rather than through systemic accumulation [30].

Overall, the presence of these pesticides, particularly in milk, raises significant concerns regarding food safety and human health, especially for vulnerable populations such as children. The findings underscore the need for stringent monitoring and regulation of pesticide use in agricultural practices to mitigate contamination risks in food products [14]

Pesticide Residues in bovine organ and Tissues.

The study found varying amount of residues of pesticide in different edible tissues of cattle, with the highest concentrations observed in the liver, followed by the tongue, muscle, and kidney. Specifically, residues ranged from 2.38 to 3.86 µg kg^{-1}in muscle, 3.58 to 6.3 µg kg^{-1}in liver, 1.87 to 4.59 µg kg^{-1}in kidney, and 2.54 to 4.35 µg kg^{-1}in tongue tissues. This aligns with previous findings that indicate the liver often serves as a primary site for xenobiotic accumulation due to its role in detoxification (64, 65).

Health risk assessment

The health risk assessment utilized Estimated Daily Intake (EDI), Hazard Quotient (HQ), and Hazard Index (HI) metrics. Notably, the HQ values for certain pesticides, including heptachlor epoxide and dieldrin, exceeded 1, indicating potential non-carcinogenic health risks, particularly for children. This finding is consistent with literature that emphasizes the heightened vulnerability of children to pesticide exposure due to their developing systems [63].

Pesticide concentration patterns

The order of pesticide concentration in tissues was observed as Liver > Tongue > Muscle > Kidney. This trend supports the notion that lipophilic pesticides tend to accumulate in fatty tissues, which are more prevalent in the liver and tongue [70]. The presence of persistent organic pollutants (POPs) such as aldrin and dieldrin in the tissues raises concerns, given their long half-lives and potential to bioaccumulate in food chains [65]

Environmental and public health implications

The contamination of cattle feed with pesticide residues is a critical route of exposure. As cited in the manuscript, feed consumption is a major pathway for pesticide introduction into the food chain [65]. The study's findings highlight the urgent need for monitoring and regulation of pesticide use in agricultural practices to mitigate risks to human health

Overall, the results indicate a concerning presence of pesticide residues in cattle tissues, raising alarms about food safety and public health. The potential health risks, particularly to exposed groups such as infants, underscore the necessity for regular monitoring of pesticide levels in food products and the environment. This study provides a crucial baseline for future research and policy-making aimed at ensuring food safety and protecting public health in Nigeria.

CONCLUSIONS

This study has identified the presence of pesticide residues in cattle tissues. The concentrations of these pesticides detected in muscle, liver, kidney, and tongue tissues were below the maximum residue limits (MRLs) established by the Japan Food Chemical Research Foundation for pesticide residues in cattle, indicating they fall within acceptable safety standards. However, a human health risk assessment revealed that the estimated daily intakes (EDI) for heptachlor epoxide, aldrin, and dieldrin exceeded permissible thresholds, signifying potential health risks for consumers, especially children.

The findings indicate a possible non-carcinogenic health risk from exposure to organochlorines (γ-HCH, heptachlor, heptachlor epoxide, aldrin, and dieldrin) through the consumption of cattle meat obtained from abattoirs. This research provides essential baseline data on the human health risks associated with consuming edible cattle parts (muscle, liver, kidney, and tongue) contaminated with pesticide residues in Nigeria. Regular and systematic monitoring of pesticide residues in meat and related tissues is therefore vital to minimize potential health risks for consumers.

The analysis highlights a certain level of contamination of meat by organochlorine pesticides (OCPs) in Nigeria. The necessity of using pesticides to produce sufficient quantities of food that meet acceptable standards for a growing population is a subject of debate. Hence, continuous monitoring of pesticide residue levels in food and the environment is crucial. This effort would help to track trends in contamination levels, provide data for future policymaking, and support environmental and public health interventions.

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ETHICAL CONSIDERATION

The research team upheld strict ethical standards throughout the study titled *"Assessments of Pesticide Residues in Cattle and Cattle Products and Associated Public Health Challenges in North Central, Nigeria."* Formal ethical approval for the project was obtained from the Committee on Animal Use and Care of the Ministry of Livestock and Fisheries in Niger State, Nigeria, under approval number MLF/2024/033.

This thorough review process ensured that the study's methodologies and protocols complied fully with the highest standards of animal welfare and research integrity. The team strictly adhered to all ethical guidelines and regulations to safeguard the well-being of the animals involved and to maintain the accuracy and credibility of the research findings.

Conflict of interests

The authors declare that they have no competing interests in relation to the manuscript titled "Assessments Of Pesticide Residues In Cattle And Cattle Products And Associated Public Health Challenges In North Central, Nigeria"

All authors confirm that there are no financial, personal, or professional conflicts of interest that could have influenced the research, interpretation of data, or presentation of information in this manuscript.

The research was conducted objectively, and the results are presented without any1 bias or outside influences

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