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Relationship between toxic metals in Poultry feeds and offal sold in Uyo Urban, southern Nigeria

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Abstract: Poultry farming is becoming more popular in both the developing and developed nations of the world; however, there are some related negative consequences. This work examined the correlation between toxic metals in poultry feeds and the offal of some poultry farms in Southern Nigeria. Layer feeds from a common source and offal were obtained in poultry farms along Abak, Ikot Ekpene, Aka, Oron, and Nwanaiba Roads within Uyo Urban, southern Nigeria and treated analytically. These samples were analyzed using atomic absorption spectrophotometer for their Cd, Cr, Ni, and Pb contents. The results revealed that, every one of the metals in feeds was within their acceptable limits apart from Cr, while the values of the entire metals in offal were safe with regards to their limits. The levels of Cd and Cr were higher in feeds than in the offal, whereas the levels of Ni and Pb were relatively higher in the offal than in the feeds. The analysis of variance showed significant variations between the metals in feeds and offal at 95% confidence limit. The principal component analysis identified two fundamental sources of these metals in both the feeds and offal examined. Cluster analysis also corroborated the variability in the concentrations of toxic metals in the feeds and offal with respect to the different locations. The results revealed strong correlations between the metal loads in the feeds and organic wastes. Thus, highly contaminated poultry feeds may result in highly contaminated poultry wastes. Hence, this study could be useful for both the producers of poultry feeds and the farmers in their management procedures.

1. Introduction

Currently, poultry farming is one of most popular economic activities in the world because is a source of income and poultry-related foods. Poultry-related foods are commonly consumed in Nigeria and other developing nations of the world due to (i) absence of restrictions (Adedokun *et al*., 2019), (ii) presence of high levels of vitamins and protein (Emami *et al*., 2023), and (iii) acquisition of exceptional attributes as white meat (Connolly *et al*., 2022; Morshdy *et al*., 2022; Miyah *et al*., 2022). Reports have shown that amongst the poultry family, *Gallus gallus* is the species most widely consumed in the world (Skarp *et al*., 2016; Etuk *et al*., 2023). Nonetheless, due to the contamination of poultry feeds with toxic metals during processing, these poultry-related foods and products have their deleterious impacts (Adekanmi, 2021). These toxic metals transferred from feeds into the birds are eventually transmitted to the consumers. According to Adekanmi (2021), poultry wastes accumulate more toxic metals than other animal wastes due to the elevated levels of toxic metals in poultry feed which may not be absorbed by the body of the birds hence, are egested as waste.

The sources of contamination of the environment with heavy metals (Cd, Cr, Ni, and Pb…) are the mining industry and various mechanical, thermal, and chemical processing using metallurgy (Ray & Vashishth, 2024; El Hammari *et al*., 2022). Survey literature on drinking water, plants, soils, as well as fish or animals and their products (meals, fish, milk, eggs, honey…), indicate considerable variability of heavy metal concentrations in this material, from trace to many times exceeding permissible values (Afzal & Mahreen, 2024; Karim *et al*., 2019).

Recently, the application of organic wastes from poultry farms (offal) has become very popular; however, it may negatively impact the quality of soil and crops cultivated (Ebong *et al*., 2022; Dan *et al*., 2023). Nevertheless, some properties such as Cation exchange capacity, pH, temperature, and concentration of metals can regulate the availability of both the nutrients and toxic metals for plant uptake (Mkpenie *et al*., 2007; Ebong *et al*., 2014; Fu *et al*., 2018). Currently, organic wastes from poultry farms are in high demand in southern Nigeria due to their intensive use by farmers. Thus, if these wastes are highly contaminated with toxic metals, the adverse effects might result in widespread problems within and outside the area. Organic wastes from poultry farms (offal) are mainly used as organic fertilizers, and if they are contaminated, it might negatively affect the soil environment (Zhen *et al*., 2020; Etuk *et al*., 2022). Contaminated poultry wastes can affect air quality and aquatic environments (Oyewale *et al*., 2019; Abioye *et al*., 2022; Gržinić *et al*., 2023). According to Priya *et al*. (2023), edible crops can absorb contaminants from the soil and transfer them to their consumers. Obviously, when contaminated poultry feeds and wastes are utilized by humans for their respective purposes, their negative impacts will eventually end up with humans.

Consequently, poultry wastes (offal) should be closely monitored to determine their suitability as organic fertilizer to forestall the accumulation of these metals in edible crops and the associated consequences (Onakpa *et al*., 2018; Wan *et al*., 2020; Kodani *et al*., 2022). Studies have indicated that consuming contaminated poultry-related foods increases toxic metal loads in humans and manifests as severe ailments (Attiq, 2023; Tindwa and Singh, 2023). These metals have the probability of resulting in non-carcinogenic and carcinogenic health risks in the consumers (Kamaly and Sharkawy, 2023; Shi *et al*., 2023; Chowdhury and Alam, 2024).

Several studies outside Nigeria have shown that, poultry feeds and wastes are highly loaded with metals including the toxic ones (Korish and Attia, 2020; Aljohani *et al*., 2023; Iqbal *et al*., 2023; Islam *et al*., 2023; Mamun *et al*., 2024). Similar researches within Nigeria have also confirmed high concentrations of toxic metals in poultry feeds and wastes (Ukpe and Chokor, 2018; Igwemmer *et al*., 2020; Etuk *et al*., 2023; Gav *et al*., 2023; Oladeji *et al*., 2023; Ebong *et al*., 2024a). However, little or nothing has been done to establish the relationship between the accumulation of metals in poultry feeds and wastes both within and outside Nigeria. Thus, this study was undertaken to ascertain the association between the concentrations of metals in poultry feeds and the ones accumulated in the wastes. This research employed the analysis of variance (ANOVA), correlation, cluster, and principal component analyses to conclude. The results of this study might be used as baseline data for subsequent studies both in the study area and outside the region. The outcome of this study could be a panacea for saving the lives of the consumers of poultry-related foods and assist in legislation concerning poultry farming (Mitra *et al*., 2022; Hassan *et al*., 2023; Zhang *et al*., 2023).

2. Materials and methods

2.1 Study Area

Uyo Urban is within the Headquarters of Akwa Ibom State in the South-Eastern Nigeria. The Urban lies from latitude 04° 59! N to Longitude 07° 57! E. Akwa is one of the major oil-producing areas of

Nigeria within the rain forest zone, with a land mass of approximately 28.48 km^2 (Udoh and Igbokwe, 2014). The region has dry and wet seasons as their major seasons in a year with an annual temperature ranging from 25 to 29 °C (Afangideh *et al*., 2005). With the current Rural-Urban drift, the population of Uyo Urban has increased drastically, hence the high volume of poultry-related foods and products consumed in the area. The use of contaminated poultry feeds and wastes in the area could be disastrous. Consequently, a proper evaluation of poultry-related foods and products within the area is an essential approach to forestall consequences connected with the contamination of these products.

2.2 Collection and Treatment of Poultry Feeds and Offal

Twenty grams of layer feed from the same Company were obtained from designated poultry farms along Abak, Ikot Ekpene, Aka, Oron, and Nwanaiba Roads in Uyo Urban in polyethylene bags and transported to the laboratory. The feeds were air-dried for three weeks, homogenized, filtered, and preserved for digestion. Two grams of each sample was mixed with 20 mL of Aqua regia in a flask and digested on a hot plate. The digestion process proceeded until a clear solution was achieved. The flask was cooled, and the mixture was filtered into a 50 mL volumetric flask using Whatman No. 1 Filter paper. The mixture was filled with deionized water and preserved for metal analysis (Korish & Attia, 2020).

Organic poultry wastes (offal) were obtained from the same poultry farms where feeds were collected according to the procedures of Okolo *et al*. (2022). The samples collected were transported in well-labeled polyethylene bags to the University of Uyo Laboratory. The samples were oven-dried at 105 °C until a stable weight was achieved. Two grams of each dried sample in a volumetric flask containing a 3:1v/v mixture of HNO_3 and H_2SO_4 was digested on a hot plate until the mixture became clear in color. The residue obtained was transferred into a 25 mL volumetric flask and made to mark with deionized water (AOAC, 2004). These samples were stored at 4 °C for metal analysis with AA Dual atomic absorption spectrophotometer (Ande *et al*., 2020).

2.3 Data analysis

This study used IBM SPSS Statistic version 29.0.2.0 (20) Software to analyze the data achieved. The software obtained the average, maximum, minimum, and standard deviation values. The principal component and Cluster analyses were performed using Varimax Factor analysis and Dendogram, respectively, on the toxic metals assessed, and values lower than 0.608 were considered insignificant. The correlation analysis and analysis of variance (ANOVA) were carried out using the IBM SPSS Statistic software.

3. Results and discussion

3.1 Concentrations of Toxic Metals in Poultry Feeds

The concentrations of toxic metals in poultry feeds and offals are indicated in Table 1. The results obtained in poultry feeds indicated that, Cd ranged between 0.18 and 0.195 $mgkg^{-1}$. The range obtained is lower than 1.05–1.83 $mgkg^{-1}$ reported for Cd in poultry feeds sold within Nalitabari, Bangladesh by Islam *et al*. (2024). Though, the obtained range is higher than the 0.097-0.111 $mgkg^{-1}$ recorded by Korish and Attia (2020) in poultry feeds sold in Jeddah City, Saudi Arabia. The average concentration of Cd obtained (0.189±0.005 $mgkg^{-1}$) is within the recommended safe limit of 1.0 $mgkg^{-1}$ by FAO/WHO (2000). Thus, Cd may not cause severe health issues to the birds fed with the studied feeds. Nevertheless, as a highly poisonous metal, the trend should be examined effectively to avoid bioaccumulation and related problems along the food chain (Belbachir *et al*., 2013; Dar *et al*., 2019; Alengebawy *et al*., 2021).

Cr in the studied feeds varied from 0.039 to 0.045 mgkg^{-1} with a mean value of 0.042±0.002 mgkg^{-1}. The reported range is lower than 0.61-10.20 mgkg^{-1} obtained for Cr in poultry feeds marketed within Rawalpindi and Islamabad, Pakistan (Iqbal *et al*., 2023). The range is also lower than the 0.00-0.29 mgkg^{-1} reported for Cr in poultry feeds available in Makurdi, Nigeria, by Gav *et al*. (2023). Nonetheless, the mean value of Cr is higher than the permissible limit of 0.01 mgkg^{-1} by FAO/WHO (2000). Consequently, the high levels of Cr in the studied feeds could be detrimental to both the birds and their consumers over time.

Table 1: Concentrations of Toxic metals in Poultry feed and Offal

		Cd	Cr	Ni	Pb
POULTRY FEEDS	AR	0.191	0.045	0.007	0.006
	IR	0.186	0.040	0.006	0.005
	KR	0.195	0.039	0.006	0.007
	OR	0.183	0.041	0.007	0.008
	NR	0.190	0.043	0.007	0.006
	MIN	0.183	0.039	0.006	0.005
	MAX	0.195	0.045	0.007	0.008
	MEAN	0.189	0.042	0.007	0.006
	SD	0.005	0.002	0.001	0.001
POULTRY OFFAL	AR	0.165	0.024	0.009	0.451
	IR	0.159	0.022	0.007	0.460
	KR	0.160	0.026	0.009	0.458
	OR	0.152	0.028	0.008	0.477
	NR	0.157	0.027	0.008	0.450
	MIN	0.152	0.022	0.007	0.450
	MAX	0.165	0.028	0.009	0.477
	MEAN	0.159	0.025	0.008	0.459
	SD	0.005	0.002	0.001	0.011

AR = Abak Road; IR = Ikot Ekpene Road; KR = Aka Road; OR = Oron Road; NR = Nwanaiba Road; MIN = Minimum; MAX = Maximum; SD = Standard deviation

The concentrations of Ni in the studied poultry feeds ranged from 0.006 to 0.007 mgkg^{-1} with an average value of 0.007±0.001 mgkg^{-1}. The range obtained is less than 0.49-2.77 mgkg^{-1} reported in commercial poultry feeds within Abuja, Nigeria by Igwemmar *et al*. (2022). The range is as well lower than 4.40-23.00 mgkg^{-1} obtained in poultry feeds within Chittagong, Bangladesh by Kabir *et al*. (2019). The mean value of Ni reported is within the safe limit of 0.5 mgkg^{-1} recommended by FAO/WHO (2000). Hence, the levels of Ni in poultry feeds assessed may not have adverse health problems on the birds and their consumers.

The levels of Pb in the poultry feeds examined ranged between 0.005 and 0.008 mgkg^{-1} with a mean value of 0.006±0.001 mgkg^{-1}. The obtained range is lower than 0.046-0.161 mgkg^{-1}reported by Amitaye and Okwagi (2019) in feeds available in Delta State, Nigeria. The range of Pb obtained in this work is also lower than 0.09-0.17 mgkg^{-1} reported in commercial poultry feeds within Mymensingh and Tangail districts, Bangladesh by Tithi *et al*. (2020). However, the reported range is higher than 0.002-0.006 mgkg^{-1} obtained in poultry feeds sold in Uyo, Nigeria by Etuk *et al*. (2023). The mean value of Pb reported in the studied poultry feeds is within the safe limit (5.00) by FAO/WHO (2000). Thus, the concentrations of Pb in the studied feeds may not have serious adverse effects on the birds and their consumers. However, the concentration in poultry farms should be observed closely to forestall problems associated with its toxicity on the birds and consumers (Okon *et al*., 2023).

3.2 Concentrations of Toxic Metals in Poultry Organic Wastes (Offal)

The results for the concentrations of toxic metals in the studied organic poultry wastes are shown in Table 1. The Cd concentrations in poultry offal ranged from 0.152 to 0.165 mgkg^{-1} with an average value of 0.159±0.005 mgkg^{-1}. The obtained range is lower than the 0.130-0.185 mgkg^{-1}reported by Ebong *et al*. (2024b) in poultry offal from some poultry farms within Uyo, Nigeria. The range is also lower than 0.137 – 0.172 mgkg^{-1} obtained by Korisk and Attia (2020) in poultry offal from Jeddah City, Saudi Arabia. However, the mean value recorded for Cd in this study is within the recommended safe limit (1.5 mgkg^{-1}) by EU (2019). Hence, the use of poultry wastes from the farms assessed may not create problems for the crops though; the level should be checked to avert bioaccumulation and related risks (Ebong *et al*., 2022b; Ebong *et al*., 2023; Okon *et al*., 2023).

The results in Table 1 indicate that concentrations of Cr in the studied poultry offal varied between 0.022 and 0.028 mgkg^{-1}. This range is lower than the 0.106 – 0.143 mgkg^{-1} reported by Okeke *et al*. (2015) in poultry offal from Awka, Nigeria. The mean value of Cr in the poultry offal (0.025±0.002 mgkg^{-1}) is within the permissible limit of 2.0 mgkg^{-1} by EU (2019). Thus, the levels of Cr in the studied poultry offal might not have adverse effects on the plants; instead, they can promote average growth of the roots (Saud *et al*., 2022).

The results in Table 1 indicate the range and mean concentration of Ni in the studied poultry offal as 0.007-0.009 mgkg^{-1} and 0.008±0.001 mgkg^{-1}, respectively. The reported range is lower than 23.0-54.3 mgkg^{-1} obtained by Korisk and Attia (2020) in poultry wastes from Jeddah City, Saudi Arabia. The range is also lower than 1.71 – 276.0 mgkg^{-1} reported in poultry offal from Amathole District, South Africa by Ravindran *et al*. (2017). Nevertheless, the mean value of Ni obtained is within the safe limit of 50.0 mgkg^{-1} by EU (2019). Hence, the levels of Ni in the studied poultry offal may assist in nitrogen fixation in soil for proper plant growth (Kamboj *et al*., 2018).

Concentrations of Pb in the studied poultry offal varied from 0.450 to 0.477 mgkg^{-1} with a mean value of 0.459±0.011 mgkg^{-1}. This range is lower than the 0.220-0.599 mgkg^{-1} reported by Ebong *et al*. (2024a) in poultry offal from some poultry farms within Uyo, Nigeria. However, the range obtained is higher than the 0.014-0.017 mgkg^{-1} reported for Pb in poultry wastes from Awka, Nigeria by Okeke *et al*. (2015). The mean value reported for Pb in the studied poultry wastes is lower than 1.17±0.071 mgkg^{-1}obtained by Ukpe and Chokor (2018). The mean is also lower than 120.0 mgkg^{-1} recommended safe limit for Pb in organic offal by EU (2019). Thus, the application of poultry offal from poultry farms examined may not have a severe negative impact on the edible crops.

Generally, the results obtained revealed that, concentrations of Cd and Cr in poultry feeds were higher than in the offal. This is similar to the results obtained in similar studies by Arroye *et al*., (2014) and Vukobratovi´c *et al*. (2014), but different from the report by Ukpe and Chokor (2018). The lower concentrations of Cd in the studied offal could be attributed to the accumulation of Cd in the liver and kidney of the birds (Rahimzadeh *et al*., 2017). It could also be caused by the replacement of Zn by Cd in the enzymes within the birds (Tang *et al*., 2014; Kostova, 2023). The observed lower concentrations of Cr in the feed may be due to the utilization of the element for the normal growth, metabolism, and enzymatic activities by the birds (Farag *et al*., 2017; Feng *et al*., 2021). It was also deduced from the results that, concentrations of Ni and Pb in the studied poultry wastes were higher than their concentrations in the feeds. This is consistent with the results obtained by Okeke *et al*. (2015) and Yasmeen *et al*. (2023). The relative higher concentrations of Ni and Pb in the offal could be because they are not absorbed by the body of the birds and are egested as wastes (Adekanmi, 2021).

3.3 Analysis of variance (ANOVA) of toxic metals in poultry feeds and offal

The results of analysis of variance for the toxic metals between and within groups (feeds and offal) are shown in Table 2 below. The results of the analysis of variance (ANOVA) in Table 2 indicate that, variations in the concentrations of Cd between poultry feeds and offal (combine) has F statistic value of 105.498 with a p value of 0.000. The F statistic values for Cr and Ni as indicated in Table 2 are 113.121 and 12.800 with p values of 0.000 and 0.007, respectively. The variation between the concentrations of Pb in the studied feeds and offal recorded F and P values of 8614.615 and 0.000, respectively. Consequently, variations between the concentrations of Cd, Cr, Ni, and Pb in the studied poultry feed and offal were significant at 95% confidence limit. This confirms a high degree of variability in the concentrations of all the toxic metals in the studied poultry feeds and offal.

Table 2: Results of the analysis of variance (ANOVA)

		Sum of Squares	df	Mean Square	F	P-value
Cd *1=Feeds, 2= Offal	Between Groups (Combine)	0.002	1	0.002	105.498	0.000
	Within Groups	0.000	8	0.000		
	Total	0.002	9			
Cr * 1=Feeds, 2= Offal	Between Groups (Combine)	0.001	1	0.001	113.121	0.000
	Within Groups	0.000	8	0.000		
	Total	0.001	9			
Ni * 1=Feeds, 2= Offal	Between Groups (Combine)	0.000	1	0.000	12.800	0.007
	Within Groups	0.000	8	0.000		
	Total	0.000	9			
Pb * 1=Feeds, 2= Offal	Between Groups (Combine)	0.513	1	0.513	8614.615	0.000
	Within Groups	0.000	8	0.000		
	Total	0.513	9			

3.4 Pearson Correlation Analysis of toxic metals in poultry feed and offal

The results of the correlation analysis of toxic metals between poultry feed and offal are indicated in Table 3.

Table 3: Correlation analysis of toxic metals between Poultry feeds and Offal

	Cd	Cr	Ni	Pb
Cd	1			
Cr	0.910**	1		
Ni	-0.729*	-0.679*	1	
Pb	-0.968**	-0.964**	0.780**	1

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level (2-tailed).

The results of correlation analysis of toxic metals in poultry feeds and offal in Table 3 indicate that, Cd in feeds correlated positively and significantly with Cr in the offal at P = 0.01 with r value of 0.910. However, Cd in feed correlated negatively and significantly with Ni and Pb at 95 and 99% confidence limits with r values of -0.729 and -0.968, respectively. Thus, increase in the concentration of Cd in the poultry feeds assessed may result in a correspondingly and perfect increase the concentration of Cr, but a decrease in the concentrations of Ni and Pb in the offal and vice versa. The concentrations of Cr in the studied poultry feeds correlated negatively and significantly with the concentrations of Ni and Pb in the offal at 95 and 99% with r values of -0.679 and -0.964, respectively. Hence, an increment in the concentrations of Cr in the studied poultry feeds may cause a reduction in the concentrations of Ni and Pb in the offal and vice versa. Results in Table 3 also indicate that, concentrations of Ni in the studied poultry feeds correlated positively and significantly with Pb in the offal at 99% confidence limit with r value of 0.780. The correlation analysis also confirmed that, an increment in the concentrations of Cd, Cr, Ni, and Pb in the poultry feeds may result in a corresponding increase their concentrations in the offal.

3.5 Principal component analysis (PCA) of toxic metals in the studied poultry feeds and offal

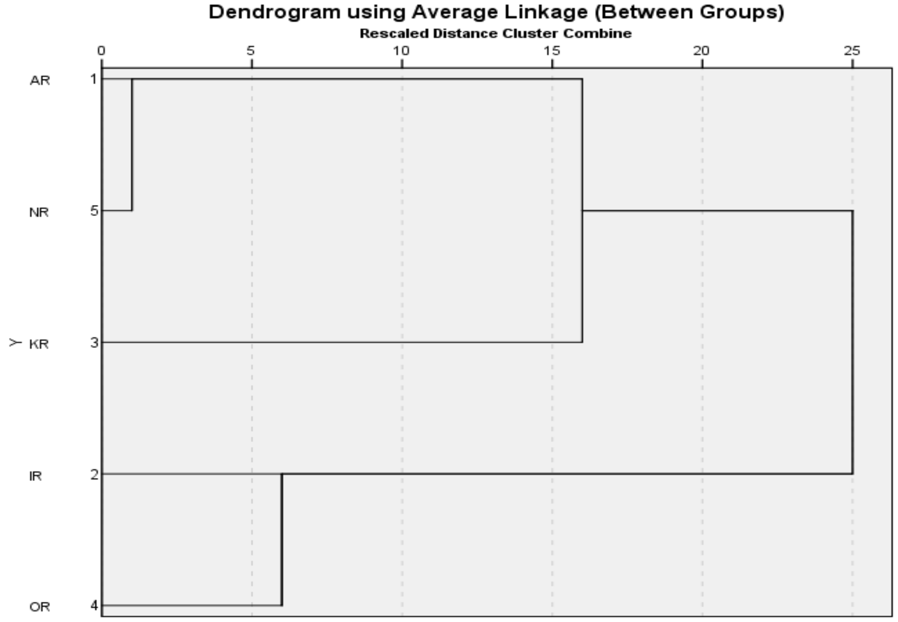
The results of principal component analysis (PCA) of toxic metals in the studied poultry feeds and offal are shown in Table 4. PCA is usually used for analytical studies to identify and confirm the source(s) of the parameters determine in the studied samples (Etuk *et al*., 2022; Ebong *et al*., 2023). In this study, PCA was used to recognize the actual sources of these toxic metals in the studied poultry feeds and offal (Ebong *et al*., 2024a). The results of PCA in Table 4 specify two key factors accountable for the presence of toxic metals in the studied poultry feeds. The two factors with Eigen values more than one had a total (cumulative) variance of 77.9%. The initial factor (F1) with Eigen value 1.86 added 46.6% to the total cumulative variance and strong positive loadings on Cr and Ni (Table 4). This could be the results of applications of salts of these metals as supplements in poultry feeds (Baloš *et al*., 2017; Farag *et al*., 2017). The second factor (F2) with Eigen value of 1.25, donated 31.3% of the cumulative variance with significant positive loading on Pb and moderate positive loadings on Cd and Cr (Table 4). This is could be a combine effects of feeds and anthropogenic factor during processing (Adekanmi, 2021; Kabeer *et al*., 2021; Ebong *et al*., 2024b). The PCA results in Table 4 also indicate two outstanding factors responsible for the high levels of these metals in the studied poultry offal. Factor one with Eigen value 2.28 donated 57.0% of the cumulative variance (89.8%). The factor indicated strong positive loadings for Cr and Pb, and a significant negative loading on Cd. This could be attributed to the negative impacts of supplements and the environment (Farag *et al*., 2017; Voica *et al*., 2023). The second factor (F2) with Eigen value 1.31, contributed 32.8% of the cumulative variance with significant positive loadings on Cr and Ni. This may be the impacts of poultry feeds, raw materials, and the environment (Aljohani, 2023; Voica *et al*., 2023; Edet *et al*., 2024).

Table 4: Results of Principal component analysis of toxic metals in poultry feeds and offal

	POULTRY FEEDS		**POULTRY WASTES**	
	F1	F2	F1	F2
Cd	-0.352	0.570	-0.982	0.057
Cr	0.847	0.519	0.651	0.713
Ni	0.985	-0.056	-0.384	0.891
Pb	0.227	-0.808	0.863	-0.076
Eigen value	1.86	1.25	2.28	1.31
% Variance	46.6	31.3	57.0	32.8
% Cumulative	46.6	77.9	57.0	89.8

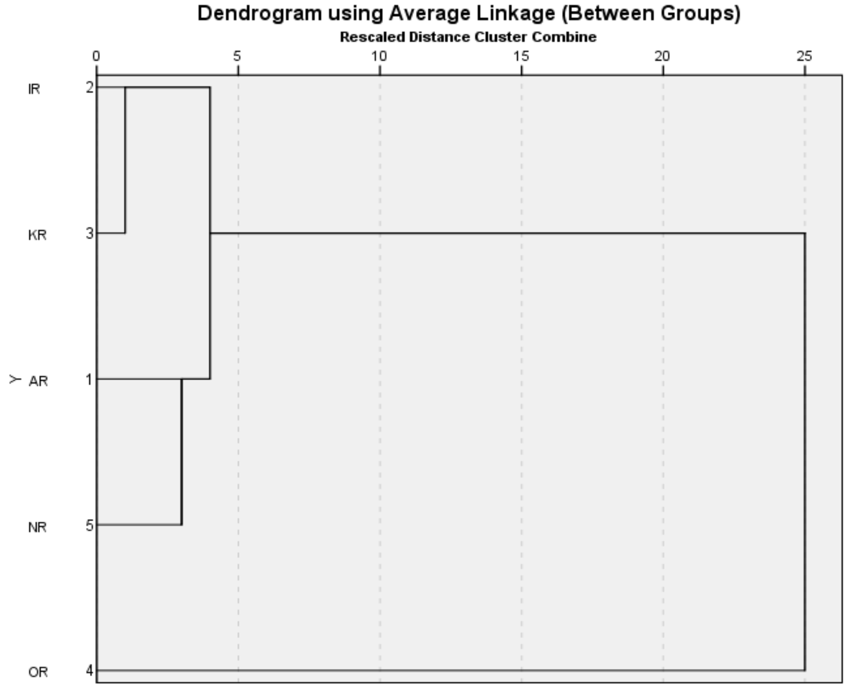
3.6 Cluster analysis of the various poultry farms examined

The results of Hierarchical Cluster Analysis (HCA) for the levels of toxic metals accumulated in the various studied poultry feeds examined are demonstrated in Figure 1. The HCA in Figure 1 indicates the following three fundamental clusters: (i) The one between Abak and Nwanaiba Roads, (ii) The other one that connects Aka Road only, and (iii) The one that relates Ikot Ekpene and Oron Roads together. Hence, the concentrations of toxic metals in poultry feeds sampled from poultry farms along Abak and Nwanaiba Roads might have been closely related. The levels of toxic metals in feeds from Aka Road could have been different from other poultry farms. Lastly, the concentrations of toxic metals in feeds from poultry farms at Ikot Ekpene and Oron Roads could have also been similar (Gates *et al*., 2019; Acito, 2023).



AR = Abak Road; IR = Ikot Ekpene Road; KR = Aka Road; OR = Oron Road; NR = Nwanaiba Road

Figure 1: Hierarchical cluster analysis of toxic metals loads in poultry feeds from the studied farms



AR = Abak Road; IR = Ikot Ekpene Road; KR = Aka Road; OR = Oron Road; NR = Nwanaiba Road.

Figure 2: Hierarchical cluster analysis of toxic metals loads in poultry offal from the studied farms

The results of Hierarchical cluster analysis for the concentrations of toxic metals in poultry offal from the different farms investigated are illustrated in Figure 2. Figure 2 shows three main clusters namely: (i) The one that correlates Ikot Ekpene and Aka Roads, (ii) The cluster that connects Abak with Nwanaiba Road, and (iii) The one that links Oron Road only. Thus, there may be a relationship in the concentrations of toxic metals between Ikot Ekpene and Aka Roads in the studied offal. The concentrations of toxic metals in poultry offal from farms at Abak and Nwanaiba Roads may have also been related. The results as well revealed that, the levels of toxic metals in offal from Oron Road farm may have been dissimilar from other studied slocations (Galbraith *et al*., 2010; Ebong *et al*., 2022).

Conclusion

The study has shown that, the concentrations of all the metals in the wastes were within their safe limits by the European Union, while the concentrations of Cr in the feeds were higher than the recommended safe limit. Despite the significant variations observed between the concentrations of toxic metals in the poultry feeds and the wastes it could be inferred that, the concentrations of metals in the feeds has a direct impact on the quality of wastes harvested from a farm. It could also be concluded that, the quality of raw materials, method of processing, and the environment have significant influence on the metals loads of poultry feeds and the wastes. Consequently, since the quality of poultry feeds and wastes has direct relationship with the health of the consumers, the quality of these products and the poultry-related foods and products should be closely examined. By so doing, the suitability of poultry-related foods and products for human consumption will be guaranteed. Accordingly, human health problems related with the utilization of poultry-related foods and products will be drastically minimized or eliminated completely.

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