Determination of Potentially Toxic Elements from Poultry Feeds in Ebonyi State, Nigeria

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Abstract:
This study examined potentially toxic elements (PTEs) from poultry feeds. The presence of PTEs in the environment raises health concern because these elements can be toxic, ubiquitous and cannot be degraded to non-toxic forms by any known method and as a result remain in the environment for decades. This is a potential pathway through which these PTEs could easily enter the food chain. Six PTEs (Cd, Cr, Cu, Pb, Mn, Ni and Zn) were determined from four feed types (starter, grower, finisher and layer) from four manufacturers coded A, B, C and D. The samples were prepared, digested and analysed for PTEs using atomic absorption spectrophotometer. The mean concentrations obtained were in the following ranges: 0.49 – 0.76 mg/kg (Cd); 11.9 – 7.90 mg/kg (Cr); 5.10 - 7.91 mg/kg (Cu); 7.17 - 9.47 mg/kg (Pb); 26.9 - 34.9 mg/kg (Mn); 3.80 - 6.50 mg/kg (Ni) and 27.8 - 38.4 mg/kg (Zn). These results were compared with the maximum acceptable concentration for PTEs in feeds as stipulated by the European Union standard and the concentrations of Pb and Ni exceeded maximum acceptable concentration. When concentrations exceed set standard, it implies risk to human health. Thus, the need for continuous monitoring of feed compositions.

Keywords: Concentration, birds, environment, health risk, pollution, acceptable limit

1.0. Introduction

The pollution of the environment continues to be a major concern in modern society [1-2]. Thus, historical human activities since the mid-nineteenth century with little or no environmental impact consideration have resulted in significant legacies of environmental contamination [3-4]. Such activities which could be industrial, commercial or domestic include; mining, smelting, lead-works, chemical production, foundries, incineration, transportation and illegal waste disposal [5].These unregulated practises particularly in developing countries release potentially toxic elements (PTEs) into the environment. Environmental pollution due to the presence of PTEs, particularly soils, have been a major concern for humans [6]. This is because once deposited, it cannot be degraded chemically or biologically to non-toxic forms but accumulate in the soil. Thus, representing a threat to the ecosystem.

The following elements: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), Nickel (Ni) and Zinc (Zn) have been listed as PTEs [7]. Whilst some are beneficial to man, plants and animals, others are toxic. However, their toxicity levels depend on sources, forms, concentration, bioaccessibility and bioavailability [8]. Studies [9-10] have shown that Cr^{3+}, Cu, Mn, Ni and Zn have health benefits at low concentration whereas, As, Cr^{6+}, Cd and Pb have no health benefit even at low concentration.

Poultry are domesticated birds kept by man for the purpose of collecting their eggs, killing for their meat or for commercial purposes. It is food for farm poultry, including chickens, ducks, geese and other domestic birds. In Abakaliki Capital Territory (ACT), chicken is the most popular bird. Poultry feeds are either plant or animal origin [11] and it has been reported [12-13] that PTEs are ubiquitous in the environment. Obviously, since PTEs are ubiquitous in the environment, plants and animals are unavoidably exposed to them and could enter the feeds through the food chain. Plants grow on soil and PTEs could enter the plants via the roots. In addition, irrigation is also a source of PTEs to the plants since most of the water bodies contain significant concentration of PTEs. Furthermore, animals depends on the environment for their food and there is every possibility that these PTEs could enter their body.

There are over two thousand (2000) poultry farms comprising of private and commercial farms in ACT and as such poultry feeds are highly patronised. Literature survey shows that no study has investigated the PTE levels in these feeds. Thus, this study has been designed to determine the concentration of Cd, Cr, Cu, Mn, Pb, Ni and Zn of four brands (starter, grower, finisher and layer) from four manufacturers coded as A, B, C and D to conceal their identity.

2.0. Materials and Methods

2.1. Sample collection

50 g each of the four brands (starter, grower, finisher and layer) of four different manufacturers coded as A, B, C and D were purchased from Abakpa main market Abakaliki on November 3, 2019. They were stored in a sealed nylon bag and later grounded to a finer particle size fractions and sun dried for 48 hours.

2.2. Sample preparation for FAAS analysis

Samples to be used for the determination of elemental content via flame atomic absorption spectrometer (FAAS) was further sieved using a nylon sieve (<125 µm diameter).

2.2.1 Sample digestion

Reagent grade chemicals were used in all cases. Sample digestions were carried out by adopting method 3050B sample digestion protocol (US EPA 3050B) [14]. 10 ml nitric acid (HNO_3) was added to beakers containing 1g soil sample, then covered with watch glass and heated for 15 minutes without boiling. Samples were cooled, 5 ml HNO_3 was added and heated for 30 minutes (brown fumes was given off). More 5 ml HNO_3 was added and no brown fumes was given off. Solution was allowed to evaporate to < 5 ml and allowed to cool. 2 ml water and 3 ml 30% hydrogen peroxide (H_2O_2) was added and heated for 2 hrs until effervesces ceased. Solution was reduced to 5ml via evaporation. 10 ml hydrochloric acid (HCl) was added and heated for 15 minutes without boiling. After cooling, the digested samples were filtered using a whatman filter paper (grade 41, pore size 20 µm) into 100 ml volumetric flask. The filtrate was diluted to the mark with ultrapure water of resistivity 18.2 $M\Omega^{-cm}$ at 25^{0}C and ready for analysis using Flame atomic Absorption Spectrophotometer (FAAS). Each sample was digested in triplicates for the purpose of reproducibility.

2.3. Flame atomic Absorption Spectrophotometer (FAAS) protocol

The samples were prepared in triplicates. Reagent blanks were included to check contamination. Six calibration standards over the range 0-10 µgmL^{-1} (mgL^{-1}) were prepared from 1000 µgmL^{-1} Pb stock solution; this was used to calibrate the instrument and also to plot the calibration graph and the regression coefficient (R^2) obtained was 0.999 (linear graph). Based on the excellent R^2 value, the samples were analysed.

3.0. Results

The mean concentrations of the Cd, Cr, Cu, Pb, Mn, Ni and Zn are shown in Tables 1 to 7 respectively.

Table 1: Mean concentration of Cd (mg/kg) in all the brands of feed (n = 3)

Type of feed	**Manufacturers (coded in letters)**				
	A	B	C	D	Mean
Starter	0.16± 0.02	0.11 ± 0.04	0.76 ± 0.10	0.84 ± 0.40	0.74 ± 0.14
Grower	0.34 ± 0.11	0.76 ± 0.03	0.53 ± 0.12	0.61 ± 0.22	0.56 ± 0.12
Finisher	0.88 ± 0.06	0.77 ± 0.05	0.43 ± 0.20	0.96 ± 0.09	0.76 ± 0.10
Layer	0.46 ± 0.04	0.54 ± 0.06	0.32 ± 0.01	0.64 ± 0.07	0.49 ± 0.05

Table 2: Mean concentration of Cr (mg/kg) in all the brands of feed (n = 3)

Type of feed	**Manufacturers (coded in letters)**				
	A	B	C	D	Mean
Starter	13.21 ± 0.4	14.65 ± 0.1	10.32 ± 2.2	9.76 ± 0.7	11.9 ± 0.9
Grower	8.07 ± 1.2	6.43 ± 0.3	9.32 ± 0.7	7.64 ± 0.1	7.90 ± 0.6
Finisher	11.4 ± 3.4	9.46 ± 2.1	13.3 ± 0.3	10.4 ± 1.4	11.14 ± 1.8
Layer	7.06 ± 0.9	9.12 ± 0.7	7.5 ± 2.3	8.21 ± 0.6	7.97 ± 1.1

Table 3: Mean concentration of Cu (mg/kg) in all the brands of feed (n = 3)

Type of feed	**Manufacturers (coded in letters)**				
	A	B	C	D	Mean
Starter	7.43 ± 0.6	6.43 ± 1.3	9.03 ± 2.1	8.30 ± 0.9	7.79 ± 1.2
Grower	5.81 ± 1.6	4.16 ± 0.6	7.32 ± 0.4	6.21 ± 1.1	5.87 ± 0.9
Finisher	10.4 ± 0.5	5.17 ± 0.7	9.01 ± 2.3	7.40 ± 3.1	7.91 ± 1.7
Layer	6.73 ± 1.5	5.13 ± 0.4	4.73 ± 0.6	3.91 ± 0.6	5.10 ± 0.8

Table 4: Mean concentration of Mn (mg/kg) in all the brands of feed (n = 3)

Type of feed	**Manufacturers (coded in letters)**				
	A	B	C	D	Mean
Starter	36.1 ± 4.1	28.3 ± 6.2	42.9 ± 2.6	32.6 ± 0.7	34.9 ± 3.4
Grower	41.1 ± 3.5	29.7 ± 2.4	19.4 ± 3.9	26.8 ± 6.7	29.3 ± 4.1
Finisher	31.6 ± 0.9	21.2 ± 3.4	30.7 ± 0.4	24.0 ± 3.1	26.9 ± 1.9
Layer	42.7 ± 2.1	26.8 ± 1.4	36.8 ± 2.5	31.4 ± 7.3	34.4 ± 3.3

Table 5: Mean concentration of Pb (mg/kg) in all the brands of feed (n = 3)

Type of feed	**Manufacturers (coded in letters)**				
	A	B	C	D	Mean
Starter	10.3 ± 0.9	7.19 ± 1.3	9.43 ± 0.7	8.17 ± 0.4	8.78 ± 0.8
Grower	7.15 ± 0.4	11.0 ± 0.7	13.6 ± 1.2	6.14 ± 1.8	9.47 ± 1.0
Finisher	7.14 ± 2.1	4.67 ± 0.9	7.32 ± 0.4	9.54 ± 2.3	7.17 ± 1.4
Layer	11.2 ± 1.2	9.12 ± 0.6	7.86 ± 1.3	9.41 ± 0.4	9.40 ± 0.9

Table 6: Mean concentration of Ni (mg/kg) in all the brands of feed (n = 3)

Type of feed	**Manufacturers (coded in letters)**				
	A	B	C	D	Mean
Starter	6.71 ± 0.4	5.51 ± 0.7	6.42 ± 0.8	6.72 ± 0.1	6.34 ± 0.5
Grower	3.12 ± 0.6	4.72 ± 0.1	3.31 ± 1.3	4.03 ± 0.9	3.80 ± 0.7
Finisher	8.42 ± 2.6	5.01 ± 1.0	7.82 ± 0.6	4.75 ± 2.1	6.50 ± 1.6
Layer	4.57 ± 0.4	3.42 ± 1.0	6.31 ± 2.3	5.32 ± 0.5	4.91 ± 1.1

Table 7: Mean concentration of Zn (mg/kg) in all the brands of feed (n = 3)

Type of feed	**Manufacturers (coded in letters)**				
	A	B	C	D	Mean
Starter	33.8 ± 4.1	40.9 ± 2.7	27.3 ± 0.6	36.5 ± 3.6	34.7 ± 2.8
Grower	27.9 ± 3.1	36.1 ± 3.6	30.3 ± 1.6	29.4 ± 7.6	30.9 ± 4.0
Finisher	40.3 ± 2.7	37.4 ± 2.9	43.1 ± 0.3	32.7 ± 3.1	38.4 ± 1.9
Layer	29.1 ± 4.3	22.6 ± 3.3	31.4 ± 2.6	27.9 ± 5.7	27.8 ± 4.0

4.0. Discussion of results

4.1. Cadmium

It can be seen from Table1 that the concentration of Cd in starter varied from 0.11 to 0. 84 mg/kg with a mean concentration of 0.74 mg/kg. In grower it varied from 0.22 to 0.76 mg/kg with a mean concentration of 0.56 mg/kg, the concentration of Cd in finisher varied from 0.43 to 0.96 mg/kg with a mean concentration of 0.76 mg/kg and in layer, it varied from 0.32 to 0.46 mg/kg with a mean concentration of 0.49 mg/kg. It can be seen that the highest concentration of Cd (0.76 mg/kg) was found in finisher. The mean concentration of cadmium in this study is lower than the maximum acceptable limit of 1 mg/kg cadmium in feed as stipulated by European Union [15]. The result of this study is in line with other studies. For example, a study [16] that assessed heavy metals in chicken feeds obtained a mean concentration range of 0.038 to 0.463mg/kg. Another study [17] that analysed heavy metals concentration in selected poultry feeds from Kano metropolis recorded a concentration range of 0.53-03.19 mg/kg.

4.2. Chromium

Table 2 shows the results of Cr in the four types of feed from the four different manufacturers. The concentration of Cr in the starter ranges from 9.76 to 14.65 mg/kg with a mean concentration of 11.9 mg/kg. In grower, it varied from 6.43 to 9.32 mg/kg with a mean concentration of 7.90 mg/kg. In finisher, it varied from 9.46 to 13.3 mg/kg with a mean concentration of 11.14 whilst in layer type Cr varied from 7.06 9.12 mg/kg with mean concentration of 7.97 mg/kg. The maximum acceptable limit of Cr is not stated by the European Union (EU) and most studies that investigated PTEs levels in poultry feed did not determine the concentration of Cr. It is to be noted that Cr exists basically in two oxidation states, Cr^{3+} and Cr^{6+} and its effects both on animals and humans depend on the oxidation state. Chromium (VI) is about 300 times more toxic than Cr^{3+} and the health effects include: health effects include: damage to nose and throat lining, anaemia, pulmonary disorder, skin and mucous irritation [18]. However, this study did not involve speciation studies to determine which of the oxidation state the concentration represents.

4.3. Copper

Table 3 indicates the concentration of Cu obtained in this study. In starter, it ranged from 6.43 to 9.03 mg/kg with a mean concentration of 7.79 mg/kg, in grower, the concentration of Cu varied from 4.16 to 7.32 mg/kg with a mean concentration of 5.87 mg/kg and in layer it ranged from 3.91 to 6.73 mg/kg with a mean concentration of 5.10 mg/kg. It can be seen that the highest concentration (7.91 mg/kg) of Cr is in finisher. When the result of this study was compared with other studies, it competed favourably with them. A study that assessed heavy metals in chicken feeds obtained a mean concentration range of 6.52 to 14.20 mg/kg whilst other authors that analysed heavy metals concentration in selected poultry feeds from Kano metropolis recorded a concentration range of 2.03 to 5.41mg/kg. As at the time of this study there is no EU standard for Cu. The availability of reasonable concentration of Cu in all the different types of feed is expected because is ubiquitous in the environment resulting from various sources. In the agricultural sector, it is used in the manufacturing of fertilizers and fungicides [19].

4.4. Manganese

Manganese is an essential element (micro nutrient) needed in the human body for bone formation and development; however, an excess dose could lead to DNA damage and chromosome abnormality particularly in adults [20]. Hence the reason why it was investigated in this study. Table 4 shows the concentration of Mn in the feeds under study. In starter it ranged from 28.3 to 42.9 mg/kg with a mean concentration of 34.9 mg/kg, in grower, it varied from 19.4 mg/kg 41.1 mg/kg with a mean concentration of 29.3 mg/kg. In finisher, it was found be in the range of 21.2 mg/kg to 31.6 mg/kg with a mean concentration of 26.9 mg/kg and in layer, it varied from 26.8 mg/kg to 42.7 mg/kg with a mean concentration of 34.4 mg/kg. The EU standard did not list the concentration of Mn and so the result obtained in this work cannot be compared with the standard.

4.5. Lead

The mean concentration of Pb in the feeds (Table 5) varied widely. In the starter, it varied from 7.19 mg/kg to 10.3 mg/kg with a mean concentration of 8.78 mg/kg. In the grower, it ranged from 6.14 mg/kg to 13.6 mg/kg with a mean concentration of 9.47 mg/kg. In the finisher, it varied from 4.67 mg/kg to 9.54 mg/kg with a mean concentration of 7.17 mg/kg and in the layer, the concentration was found to vary from from 7.86 mg/kg to 11.2 mg/kg with a mean concentration of 9.40mg/kg. The concentration of Pb obtained in the four different types were found to be higher than EU standard of 5 mg/kg for Pb. Concentration of Pb in excess of a set standard implies risk. Previous work got a concentration range of 1.10 to 7.85 mg/kg which is in line with the current study. Lead is toxic and the continuous exposure to this element remains a potential public health problem which could result in many health effects and death. It competes with calcium in the body at cellular sites and prevents calcium from entering into cells [21].

4.6. Nickel

Table 6 shows the concentrations of Ni across the feeds. In starter, the concentration of Ni varied from 5.51 to 6.71 mg/kg with a mean concentration of 6.34 mg/kg. In grower, it ranged from 3.12 to 4.72 mg/kg with a mean concentration of 3.80 mg/kg. In finisher, the concentration of Ni varied from 5.01 to 8.42 mg/kg with a mean concentration of 6.50 mg/kg and in layer, it ranged from 3.42 to 6.31 mg/kg with a mean concentration of 4.91 mg/kg. Comparing with the maximum acceptable concentration of 0.05 mg/kg for Ni in feed as stipulated by European Union, all the samples were above the maximum acceptable concentration. In humans, Ni influences Fe absorption and metabolism, and may be an essential component of the haemopoietic process. However, when in excess, it can cause respiratory diseases [22]. Thus, the need to maintain already established standard in all feeds. The mean concentration range of Ni (2.250 to 4.875 mg/kg) obtained by earlier authors are similar to the current result from this study.

4.7. Zinc

The concentration of Zn was found to be highest in all the feeds compared to the other PTEs. The concentration of Zn obtained in this study are shown in Table 7. In starter, Zn concentration varied from 27.3 mg/kg to 40.9 mg/kg with a mean concentration of 34.7 mg/kg. In grower, the concentration was in the range of 27.9 to 36.1 mg/kg with a mean concentration of 30.9 mg/kg. In the finisher, it varied from 32.7 mg/kg to 40.3 mg/kg with a mean concentration of 38.4 g/kg and in layer it varied from 22.6 mg/kg to 31.4 mg/kg with a mean concentration of 27.8 mg/kg. Result from other study showed that the concentration of Zn ranged from 34.038 to 49.950 mg/kg which is in line with this study. Comparing with the maximum acceptable concentration of 500 mg/kg for Zn in feed as stipulated by European Union, all the samples were below the acceptable concentration. Though, Zn is one of the micro nutrients required by the human body for cell growth, development and proper functioning of the immune system but high zinc concentration in the human body are known to cause vomiting, diarrhea and abdominal cramps, chest pain, cough and irritation [23].

5.0. Conclusions and Recommendations

The presence of PTEs in the environment raises health concern because these elements can be toxic, ubiquitous and cannot be degraded to non-toxic forms by any known method and as a result remain in the environment for decades, thus, humans are exposed to these PTEs directly or indirectly. Lead and Ni exceeded maximum acceptable concentration in the feeds as stipulated by European Union but the essential elements Cr, Cu and Zn were also high in the feeds. However, there is a need for continuous monitoring of feed compositions and also adopt practices that will not introduce PTEs into the environment.

It is recommended that a proximate analysis be carried on the poultry feeds in order to ascertain its moisture content, ash content, crude fibre, lipid, crude protein, carbohydrate and metabolizable energy.

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7.0. Declaration of Competing Interest

The authors hereby declare that there is no conflict of interest with regards to this paper.

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