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DETERMINATION OF SOME TRACE ELEMENTS ACCUMULATION BY RABBITS RAISED ON CABBAGE AND CARROTS FROM CONTAMINATED IRRIGATED GARDEN IN KANO, NIGERIA: USING INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS

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ABSTRACT

This study focused on determination of eight trace elements - aluminum (Al), iron (Fe), cobalt (Co), chromium (Cr), zinc (Zn), manganese (Mn), rubidium (Rb) and vanadium (V) concentrations in cabbage and carrots raised on an irrigated farm within the catchment area of River Jakara in Kano, Nigeria and in selected tissues notably liver, meat and bone and faeces of rabbits that fed on them. The samples of the vegetable feeds, tissues and faeces were analyzed for the presence of the trace elements using Neutron Activation Analysis. The results show that the concentrations of the trace elements in the selected studied vegetable diets, tissues and faeces are varied. In the mean combined diets, livers, meat, bones and faeces, the order of the trace elements were Al>Fe>Zn>Mn>Rb>Cr>Co>V, Fe>Zn>Al>Rb>Mn>Cr>Co and V, Zn>Fe>Al>Rb>Co,Cr,Mn and V, Zn>Al>Rb>Mn>Fe, Co, Cr and V, and Fe>Al>Zn>Mn>Rb>Cr>V>Co respectively. The concentrations of the trace elements except those of Co, Cr and V were high in the vegetable diets, some of which were above the international permissible limits and their accumulation in the liver, meat and bones of rabbits varied with the highest in the liver.

Keywords: Trace-elements, bioaccumulation, vegetable-diets, rabbits, liver, meat, bone and faeces.

INTRODUCTION

Vegetables constitute an important component of the diet of most people in the world. They contain essential elements and are rich in vitamins, dietary fibres and minerals.

They are essential for growth and maintenance of good health and some are suitable for medical and other applications (Dike and Odunze, 2016). Vegetable farming in Nigeria is mainly conducted by farmers with low socio-economic status. These farmers toil year after year in the production of the vegetables as means of livelihood primarily through food provision, income generation and employment.

Some of these vegetables are however irrigated with contaminated waste water. Recent surveys across 50 cities in Asia, Africa and Latin America show that waste water irrigation is a common reality in three-fourths of the cities and global estimates of the total area under raw and diluted waste water irrigation range from 3 – 3.5 million hectares; however the proportion of harvested area that is irrigated is largest in Asia and smallest in sub-saharan Africa (International Management Institute, 2006, 2013). Irrigation of plants particularly with sewage and solid waste water disposal ends to contamination and heavy metal accumulation both in soil and crops (Doyle, 1998); the crops contain metals in higher concentrations than those irrigated using uncontaminated water (Change, Graneto and Page, 1992; Nrghole, 2007).

Literature on the heavy metals contamination of vegetables through anthropogenic activities abound nationally (Ojeka and Achi, 2004; Chioma, Ebewale and Hymere, 2012) and internationally (Kisku and Barman, 2000; Behhahaninia and Mirbagheri, 2008; Bigdeli and Seilsepour, 2008). Crops raised on metal contaminated soils accumulate metals in quantities excessive enough to cause clinical problems both to animals and human beings consuming the metal rich plants (Tiller, 1986).

Food chain contamination is one of the major routes for entry of metals into the animal and human systems. Heavy metals often have direct physiologically toxic effects and are stored or incorporated in living tissues (Baykov *et al*., 1996). Ingestion of heavy metal contaminants by animals causes deposition of residues in meat (Akan *et al*., 2010). Another study John and Jeanne (1994) reported high levels of arsenic, cadmium, mercury and lead in several tissues of goats that were generally above the permissible levels. Zinc (Zn) concentrations were found to be highest in meat, liver, fish and eggs (Janet and Carl, 1994). The distribution and localization of some heavy metals in the tissues of some calf organs were detected; the most affected organs with high levels

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of trace metals were the livers, kidneys and small intestines (Horky *et al*., 1998). Parker and Hamr (2001) opined that the metal levels in body tissues, forage and fecal pellets of elk living near the ore smelters at Sudbury, Ontario exceeded the WHO guidelines and Canadian regulatory standards. Due to the grazing of cattle on contaminated soil, higher levels of metals have been found in beef and mutton (Sabir*et al*., 2003). Tissue accumulation of metals in animals was found to be related to concentration of the metals in soils and forage (Miranda *et al*., 2009). It has been reported (Izadiyar and Yargholi, 2010) that the use of polluted plants by both farm and domestic animals has also caused some disturbance in them which included reduction in milk and the rate of animal growth; reduction in resistance to some diseases and infections and disruption in reproduction process. Toxic effects of metals in animals have been described in animals under relatively low levels of element metabolism (Lopez-Alonso *et al*., 2002).

Both humans consuming vegetables grown in contaminated soils and animals raised in such an area stand at a risk (Sedki *et al*., 1995) as they also pose a direct threat to human health. Mahoffey (1977) and Santhi *et al.* (2008) are of the view that the risk of heavy metal contamination in meat is of great concern for both food safety and human health because of the toxic nature of these metals at relatively minute concentrations. These elements have carcinogenic and mutagenic effects in humans with long-term cumulative exposure (Das, 1990). Some elements such as chromium (Cr) act as carcinogens. Olafisoye Adefisoye and Osibote (2013) observed that excess of zinc (Zn) can lead to copper (Cu) deficiency immune system disorders, fatigue, nausea, hairless, mental apathy, and reproductive and growth disorders. High toxicity than general toxicity has been indicated (Donald *et al*., 1986) as a result of high levels of cobalt (Co) in the kidney, liver and testes.

Concentrations of vegetables with toxic elements are therefore a serious threat because of their toxicity, bioaccumulation and biomagnifications in the food chain. The seriousness of this problem cannot be underestimated in the light of the findings of Dike *et al.* (2004, 2014) and Dike and Oniye (2016) which revealed that the water and soil used to cultivate the vegetables are contaminated with heavy metals. The current investigation is carried out to determine the levels of some trace metal accumulation in cabbage and carrots cultivated in the contaminated soil and irrigated with the polluted water from River Jakara, in Kano, Nigeria, and rabbits fed with them.

MATERIALS AND METHODS

Study area

The study was conducted at Kano in the Sudan Savanna zone of Nigeria. It lies within longitude 8^0 32' E and latitude 11^0 53'N within a topographical drainage of River Jakara flowing north east. The Abattoir and Katsina roads junction of River Jakara (Fig. 1, site 3) was selected for the collection of the vegetables due to the presence of heaps of solid wastes generated by a housing estate and Abattoir in close proximity to the river and agricultural farm which may be contributing to the contamination of the vegetables grown in it.

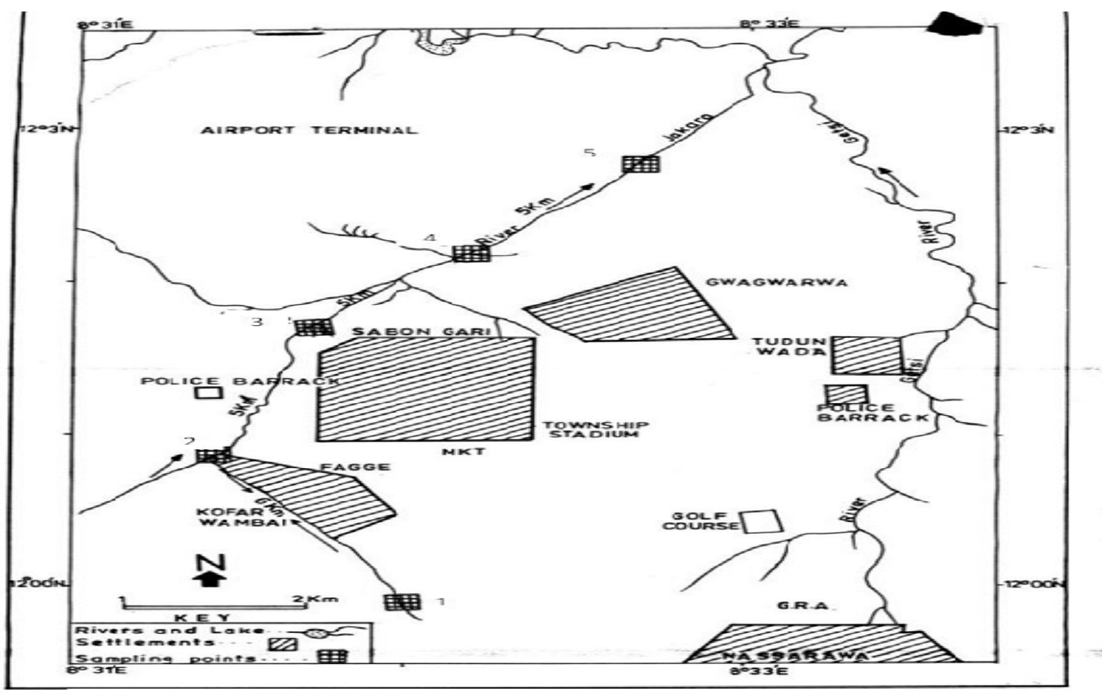

Fig. 1. Map of study area showing the sampling points.

Choice of experimental animals and feeds

Rabbits were chosen for the experiment because they are highly prolific breeders and non-ruminant herbivores with excellent ability to utilize wide range of diets including vegetables and hence also the choice of cabbage (Brassica olerancea Capitata group) and carrots (Daucus Carota) grown at the study area.

Mature cabbages and carrots were collected from the four levees of the study area using the random sampling technique. The samples were packed lightly in loose woven bags to the laboratory.

Sample preparation of vegetables into feeds

In the laboratory, each sample was separated and washed carefully with running water to clean attached impurities and air dried. They were then coarsely ground using the commercial grinding machine which was carefully cleaned to avoid the introduction of other substances and impurities into the samples. Samples were poured into feed bags and labeled properly after removing some for analysis. The feeding trial also included a control diet which was prepared using the methods of Ugwuene (2003). The components were separated, weighed and mixed before pouring it into a feed bag and properly labeled after also removing some for analysis.

Design of the feeding experiment

Twelve (12) newly weaned rabbits were used for the feeding experiment. The rabbits which were of different sexes but the same breeds were purchased from the Rabbitory Unit of Ahmadu Bello University, Zaria, where the experiment was conducted. The animals were held in pens which have been thoroughly cleaned, disinfected and dried. The rabbits were acclimated for two weeks during which they were fed commercial broiler starter diet ad *libitum.* Thereafter, all rabbits were given prophylactic treatment with ivomec. Four rabbits were randomly allotted to each of the dietary treatments in a completely randomized block design and the age, sex and group weights were balanced as much as possible. The rabbits were ear-tagged and assigned to individual wire cage equipped with feed and water troughs. A loosely woven bag was placed beneath the pen for the collection of faeces during the experiment. The experimental period lasted for 8 weeks during which 100g of the treatment diets was provided once daily to each of the animals in the morning from 7:30am to 8:00am. Four rabbits each were fed on control diet, cabbage, carrots and combined mixture of cabbage and carrots diets. One rabbit was removed from each diet group at two weeks interval, sacrificed and dissected to remove the liver, meat/muscle/flesh and bones. Faeces were also collected from the woven bag beneath the pen.

Sample preparation of vegetable/treatment and control diets for Neutron Activation Analysis

Vegetable/treatment diet samples together with the control diet were prepared for analysis using APHA (1985). The samples were ground to fine powder using micro blender; subsequently, about 40g was weighed out on a Mottler balance and placed in Pyrex glass beaker, covered and put in a Muffle furnace at 550^0C for ashing. Ashes of the samples were then poured into their various sterilized tightly corked specimen tubes and labeled accordingly for the neutron activation analysis.

Preparation of tissues and faecal samples for Neutron Activation Analysis

The methods described by Hodson *et al.* (1978) and APHA (1985) were used to prepare the rabbit tissues and faeces for neutron activation analysis. Acid washed, dried pre-weighted petri-dished and crucibles were used to take wet weight of the samples and thereafter, oven – dried separately in different petri-dishes at 60^0C for 48 hours. The samples were then ground with a mortar and pestle and ashed in crucibles in a Muffler furnace at 450^0C for 12 hours when white ash was formed. Equal weights of ash of the tissues and faeces on the same treatment diet were appropriately pooled, properly mixed and poured into a sterilized tightly corked specimen tube and labeled accordingly. The ashed tissue and faecal samples together with the samples of the treatment diets were sent to Centre for Energy and Research Training (CERT), Ahmadu Bello University, Zaria for the elemental analysis.

Elemental analysis of treatment diets, tissues and faeces

The Nigerian Research Rector-1 (NIRR-1), a Miniature Neutron Source Rector (MNSR) that has a tank-in-pool structured configuration with a nominal thermal power rating of 31kw was used. The neutron activation analysis technique as described by Jona *et al.* (2006) was employed for the elemental analysis. Radioactivity measurement of induced radionuclides was performed by the PC-based gramma-ray spectrometry setup involving both short and long irradiation regime.

RESULTS AND DISCUSSION

The mean concentrations of the trace elements (ppm) in the control diet and liver, muscle/meat, bone and faeces of rabbits fed on it are presented in Table 1. The concentrations of the elements except those of Cr and V which were below detection limits (BDL) in the diet tissues and faeces, are varied as follows: Al (BDL in faeces – 1799 $\pm$ 1.60ppm in diet), Fe(BDL in liver, meat and bone – 15300 $\pm$ 13.00ppm in faeces), Co (BDL in liver, meat and bone – 7.38 ± 1.82ppm in faeces), Zn (106.30 ± 12.00ppm in diet – 3693 ±0.80ppm in faeces), Mn(BDL in liver and meat – 2186 ±11.00ppm in faeces) and Rb (3.997 ± 15.30ppm in diet – 756 ±33.00ppm in meat).

Table 2 shows the mean concentrations of the trace elements(ppm) in the cabbage diet, liver, meat, bone and faeces of rabbits that fed on it. The mean concentrations of the trace elements except that of V which was below detections limit in the diet and all the tissues and faeces, were varied. Aluminum varied from BDL in meat to 3141 ±2.40ppm in faeces, Fe(BDL in meat and bone – 31600 ± 0.28ppm in liver) Co(BDL in liver, meat and bone – 44.30 ± 7.30ppm in faeces), Cr(BDL in diet, meat and bone – 44.3 ± 7.30ppm in faeces), Zn (63.79 ±18.00ppm in diet – 3294 ± 152.00ppm in liver),Mn(BDL in liver and meat – 1110 ±6.00ppm in faeces and Rb (BDL in bone - 578 ± 48.00ppm in liver).

Table 1. Trace Elements Concentrations (ppm) in diet 1 (Control Feed), Tissues and Faeces of Rabbits.

Diets, tissues and faeces	**Concentrations of trace elements**							
	Al	**Fe**	**Co**	**Cr**	**Zn**	**Mn**	**Rb**	**V**
Diet 1 (control feed)	1799 ± 1.6	1603 ± 12.8	0.3449±23.7	BDL	106.30±12.0	190.0 ± 3.4	3.997 ±15.3	BDL
Liver	496±15	BDL	BDL	BDL	1012±112	BDL	137.2±54	BDL
Muscle (Meat/flesh)	1440±317	BDL	BDL	BDL	1103±97	BDL	756±33	BDL
Bone	355±15	BDL	BDL	BDL	414±66	8.92±0.94	87.0±20.3	BDL
Faeces	BDL	15300±13	7.38±1.82	BDL	3693±0.8	2186±11	151±25	BDL

Table 2. Trace Elements Concentrations (ppm) in Diet 2 (Cabbage), Tissues, and Faeces of Rabbits.

Diets, tissues and faeces	**Concentrations of trace elements**							
	Al	**Fe**	**Co**	**Cr**	**Zn**	**Mn**	**Rb**	**V**
Diet 2 (cabbage)	2286. ±12.0	1849±11.5	0.1855±34.5	BDL	63.79±18.0	24.01±19	3.475±18.5	BDL
Liver	720±17	31600±0.28	BDL	35.6±4.5	3294±152	BDL	578±48	BDL
Muscle (Meat/flesh)	BDL	BDL	BDL	BDL	833±93	BDL	311±31	BDL
Bone	250±18	BDL	BDL	BDL	463±62	7.74±0.77	BDL	BDL
Faeces	3141±4	18500±0.11	BDL	44.3±7.3	1467±72	1110±6	72.6±16.6	22.4±2.9

Table 3 reveals the mean concentrations of the trace elements (ppm) in the carrots diet, liver, meat, bone and faeces of rabbits that fed on it. The mean concentrations of the trace elements except that of V which were below detection limits in the diet, tissues and faeces varied as follows: Al (BDL in bone – 27590 ± 1.00ppm in faeces), Fe(BDL in meat and bone – 25850 ± 2.60ppm in faeces), Co(BDL in liver, meat and bone – 2.465 ±10.60ppm in faeces), Cr(BDL in liver, meat and bone – 7.102 ± 10.60ppm in faeces), Zn (38.41 ±21.40ppm in diet – 2494 ± 13.20ppm in liver), Mn (BDL in liver – 755 ±0.70ppm in faeces) and Rb(BDL in meat – 426 ± 46.00ppm in liver).

The mean concentrations of the trace elements (ppm) in the combined cabbage and carrots diet, liver, meat and faeces of the rabbits that fed on it are presented in Table 4. The concentrations except that of V which was below detection limit in the diet, tissues and faeces as in Tables 1 - 3, were also varied. Aluminum varied from BDL in meat to 36190 ± 1.70ppm in faeces, Fe (BDL in bone – 24350 ±2.40ppm in faeces), Co(BDL in liver, meat and bone – 3.171 ± 7.10ppm in faeces), Cr(BDL in diet, liver, meat and bone – 7.248 ± 7.90ppm in faeces), Zn (57.40 ± 18.10ppm in diet – 3884 ± 30.00ppm in liver), Mn(BDL in meat and bone – 850.40 ± 2.10ppm in faeces) and Rb(3.464 ± 18.50ppm in diet – 546 ±44.00ppm in liver).

Table 3. Trace Elements Concentrations (ppm) in diet 3 (Carrots), Tissues and Faeces of Rabbits.

Diets, tissues and faeces	**Concentrations of trace elements**							
	Al	**Fe**	**Co**	**Cr**	**Zn**	**Mn**	**Rb**	**V**
Diet 3 (carrots)	3470±3.9	1849±12.1	0.2010±48.6	1.518±26.8	38.46±21.4	50.99±14.0	5.058±13.2	BDL
Liver	805±23	16000±0.18	BDL	BDL	2494±132	BDL	426±46	BDL
Muscle (Meat/flesh)	1960±157	BDL	BDL	BDL	800±81	BDL	BDL	BDL
Bone	BDL	BDL	BDL	BDL	349.10±6.2	BDL	3.860±24.5	BDL
Faeces	27590±1.0	25850±2.6	2.465±10.4	7.102±10.6	1349±3.1	7.55±0.7	12.990±12.0	BDL

Table 4. Trace Elements Concentrations (ppm) in diet 4 (Cabbage + Carrots), Tissues and Faeces of Rabbits.

Diets, tissues and faeces	**Concentrations of trace elements**							
	Al	**Fe**	**Co**	**Cr**	**Zn**	**Mn**	**Rb**	**V**
Diet 4 (cabbage + carrots)	2145±2.2	1419±15.0	0.2147±40.7	BDL	57.40±18.1	47.63±4.3	3.464±18.5	BDL
Liver	127.1±10.8	39700±16.50	BDL	BDL	3884±30.0	56.42±4.8	546±44	BDL
Muscle (Meat/flesh)	BDL	2397±13.6	BDL	BDL	1326±3.1	BDL	66.77±2.9	BDL
Bone	121.50±22.2	BDL	BDL	BDL	476±5.0	BDL	6.969±13.0	BDL
Faeces	36190±1.7	24350±2.4	3.171±7.1	7.248±7.9	1876±2.2	850.4±2.1	15.740±8.9	4.325±23.1

Significant difference exists ($p<0.05$) between the concentrations of Fe, Co, Cr, Mn, Rb and V in Table 1 (with control diet) and those of Tables 2, 3 and 4 (with cabbage, carrot and combined cabbage and carrot diets respectively) as shown in Tables 5b, c, d, f, g and h. Aluminum and Zn however showed insignificant difference ($p>0.05$) (Tables 5a and 5e).

Table 5a. One Way ANOVA Al.

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	33672637.367	3	11224212.456	.157	.925
Within Groups	11143287805.675	156	71431332.088		
Total	11176960443.043	159			

Table 5b. One Way ANOVA Fe

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	272446618.950	3	90815539.650	2.522	023
Within Groups	2785340067.600	16	174083754.225		
Total	3057786686.550	19			

Table 5c. One Way ANOVA of Co

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	5.909	3	1.970	2.571	.042
Within Groups	55.180	16	3.449		
Total	61.089	19			

Table 5d. One Way ANOVA Cr

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	843.594	3	281.198	2.213	.016
Within Groups	2032.957	16	127.060		
Total	2876.551	19			

Table 5e. One WayANOVA Zn

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	676532.732	3	225510.911	.143	.926
Within Groups	27198067.318	16	1699879.207		
Total	27874600.051	19			

Table 5f. One Way ANOVA Mn

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	312729.623	3	104243.208	2.296	.028
Within Groups	5638362.697	16	352397.669		
Total	5951092.320	19			

Table 5g. One Way ANOVA Rb

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	57903.066	3	19301.022	2.317	0.013
Within Groups	975629.367	16	60976.835		
Total	1033532.434	19			

Table 5h. One Way ANOVA V

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	68.382	3	22.794	2.800	0.041
Within Groups	416.372	16	26.023		
Total	484.754	19			

The mean trace element concentrations in all combined diets and livers, meat, bones and faeces (ppm) (Tables 2, 3 and 4) of rabbits that fed on them are presented in Table 6 and Figures 2 - 9. In the combined diets, livers, meat, bones and faeces the trace element concentrations are in the order of Al>Fe>Zn>Mn>Rb>Cr>Co>V, Fe>Zn>Al>Rb>Mn>Cr>Co and V, Zn>Fe>Al>Rb>Co, Cr, Mn and V, Zn>Al>Rb>Mn>Fe, Co, Cr and V, and Fe>Al>Zn>Mn>Rb>Cr>V>Co respectively. Table 6 and Figure 2 show that the concentration of Al in the mean combined diets (2633.33 ± 6.00ppm)was the highest. Its highest concentration in the tissues was observed in meat (653.33 ± 52.30ppm) followed by livers (550.70 ± 16.90ppm) and then bones (123.83 ± 13.40ppm). Bulk of the element (22307 ± 2.20ppm) was exceated in the faeces. The concentration of Al in the diets was high and accumulated in the tissues. This finding does not agree with Uluozlu *et al*. (2009), Mohamed and Nosier (2009), Lucia *et al*. (2010), Abduljaleel (2014) and Donia (2015) who found lower concentrations of Al in different poultry parts studied. Donia (2015) stated that aluminum has deleterious effects on the central nervous, skeletal and hematopoietic systems of humans; the neurotoxicity of Al to patients with chronic renal disease is well established. Its presence in the blood stream leads to accumulation in bone and brain causing encephalopathy called dementia dialytica. Its accumulation in the brain altered amino acid neurotransmitters and it has been suggested to be an associated phenomenon in various neurological disorders as dementia, senile dementia and Alzheimer (Mahmoud and Abbdel-Mohsein, 2015).

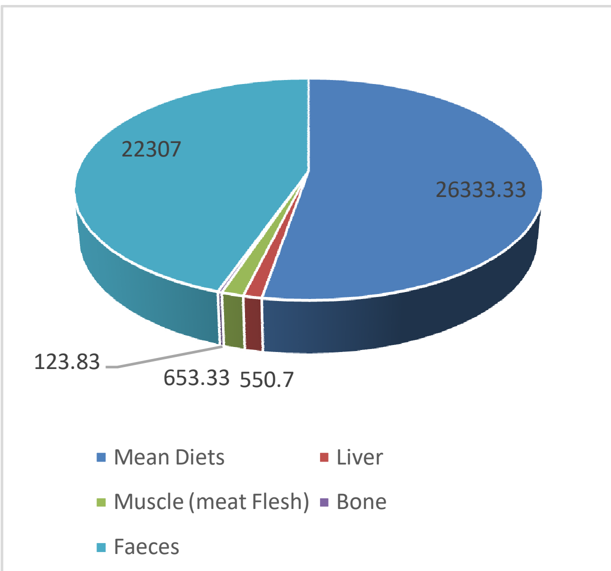

Fig. 2. Al mean concentrations.

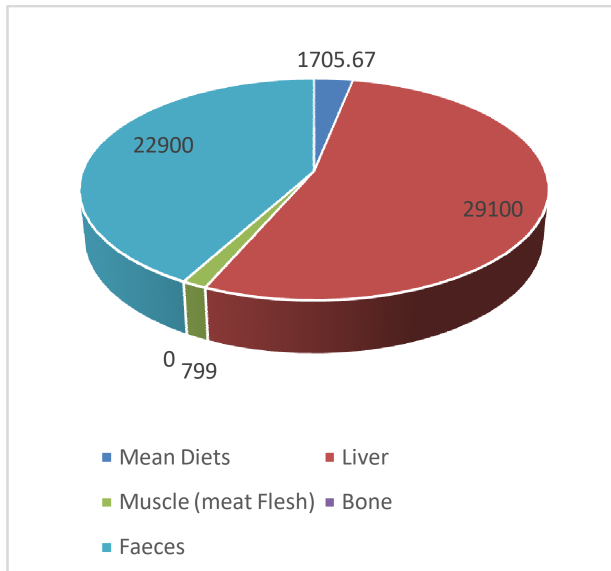

Fig. 3. Fe mean concentrations.

Table 6 and Figure 3 reveal that the concentration of Fe (1705.67 ± 12.4ppm) in the combined diets was the second highest. Its highest concentration in the tissues was found in liver (291000 ± 5.70ppm) followed by meat (799 ± 4.50ppm); the least concentration was in bones where it was below detection limit. Bulk of the element (22900 ±1.70ppm) was excreated in faeces. Its high concentration in the tissues except in bones may be due to its major roles in maintaining the proper physiological functions of the organism; it plays an important role as an essential element in all the living system from invertebrates to humans (Kanakaraju *et al*., 2008). Its concentrations in the diets were above the 425mg/kg WHO/FAO recommended permissible limits for vegetables which accumulated in the tissues except the bone. This finding is in consonance with Kamaz and Filazi (2011) who also found high concentrations of Fe in samples of chicken liver and muscle but it does not however agree with Akan *et al*. (2010) who observed low concentrations of Fe in liver, kidney, and meat of beef (cow), mutton (sheep), Caprine (goat) and chicken from Bornu State, Nigeria, and Ghimpeteanu *et al*. (2012) who found low levels of Fe in poultry liver samples from Romania and Belgium. Andrews (1999) reported that when Fe is increased in the body acutely, nausea, vomiting, diarrhea occur along with hepatic damage while hepatic failure, diabetes, testicular atrophy, arthritis, cardiomyopathy, peripheral neuropathy and hyper pigmentation occur from chronic or prolonged accumulation of Fe in the body. Iron may also play a role in oesophageal carcinogenesis (Boult *et al*., 2008).

As revealed in Table 6 and Figure 4, the mean concentration of Co in the combined diets (0.2004 ± 41.3ppm) was second to the least and was within the WHO/FAO permissible limit of 50mg/kg for vegetables.

Its concentrations in the liver, meat and bone were below detection limits and therefore did not accumulate in them as it was excreated in faeces (1.878 ± 5.80). This may be attributed to the fact that Co is not easily absorbed from the digestive tract (Taylor and Marks, 1974). Cobalt is beneficial to humans because it is part of vitamin B_{12} which is essential to maintain human health; its deficiency leads to decreased availability of the vitamin and there is an increase of many symptoms and problems related to the vitamin B_{12} deficiency particularly pernicious anaemia and nerve damage (Patemain *et al*., 1988).

Table 6. Mean trace elements concentrations (ppm) in combined diets 5, Tissues and Faeces of Rabbits.

Diets, tissues and faeces	**Concentrations of trace elements**							
	Al	**Fe**	**Co**	**Cr**	**Zn**	**Mn**	**Rb**	**V**
Mean Diet (2,3and4)	2633.33±6.0	1705.67±12.9	0.2004±413	0.506±8.9	53.22±19.2	40.88±12.6	3.999±16.7	BDL
Mean Liver	550.70±16.9	29100±5.7	BDL	1.87±1.5	3224±104.7	18.807±4.9	516.67±46	BDL
Mean Muscle (Meat/flesh)	653.33±52.3	799±4.5	BDL	BDL	986.33±59	BDL	125.92±11.3	BDL
Mean Bone	123.83±13.4	BDL	BDL	BDL	429.37±24.4	2.58±0.3	3.59±12.5	BDL
Mean Faeces	22307±2.2	22900±1.70	1.878±5.8	19.55±8.6	4692±25.8	905.13±2.9	33.78±12.5	7.47±1.0

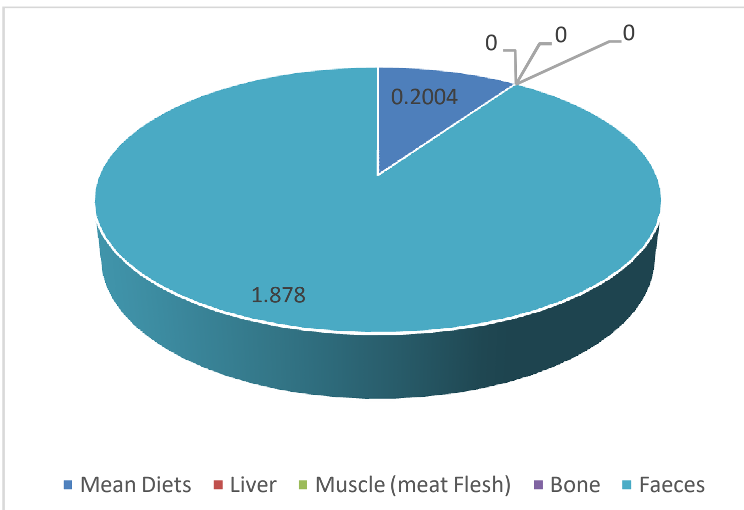

Fig. 4. Co mean concentrations.

The mean concentration of Cr in the combined diets (0.506 $^{+}$ - 8.90ppm) was third least and was within the WHO/FAO permissible limit of 1.30mg/kg for vegetables Its highest concentration (1.87 ± 4.50ppm) in the tissues which was above the permissible limit of 0.10ug/g was in liver. It however did not accumulate in meat and bones as its concentrations in them were below detection limits. A high concentration of the trace element (9.55 ± 4.50ppm) was exceated in faeces (Table 6 and Fig. 5). The finding supports those of Akan *et al.* (2010) and Ihedioha *et al.* (2014) who found the concentrations of Cr in their various liver samples studied to be higher than the permissible limit. It does not however support the studies carried out by Iwegbue (2008) and Iwegbue *et al.* (2008) who found levels of Cr below the acceptable limit in beef and some chicken and turkey meat from southern Nigeria. Chromium is an essential element that helps the body to use sugar, proteins and fat and at the same time, it is carcinogenic for organisms (Institute of Medicine, 2002). Long standing exposure with Cr will also cause chronic ulcers of the skin and acute irritative dermatitis which have been consistent in workers exposed to Cr containing materials (Lingamanemi *et al*., 2015).Human ingestion of high doses of chromium VI can also result in other human health problems including gastrointestinal bleeding and necrosis of the proximal and distal tubules in the kidney (Langard, 1983).

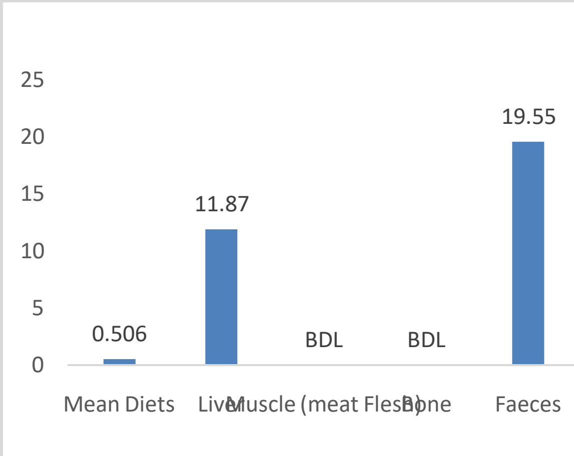

Fig. 5. Cr mean concentrations.

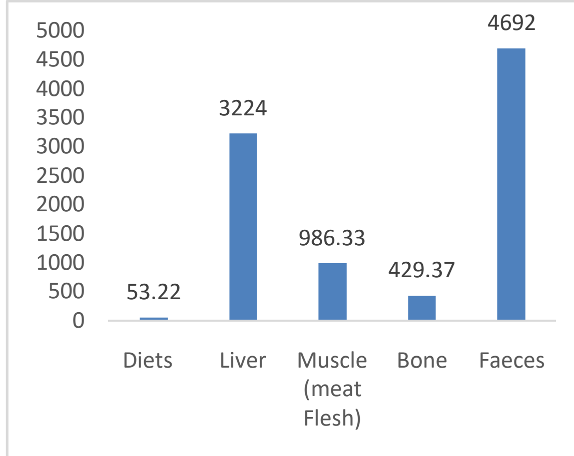

Fig. 6. Zn mean concentrations.

Table 6 and Figure 6 reveal that even though the mean concentration of Zn in the combined diets (53.22 ± 19.00ppm) was the third highest, it was within the WHO/FAO permissible limit of 99.40mg/kg for vegetables. It bio accumulated with values above FAO/WHO permissible limits of 10-50ppm with the highest mean concentration of 3224 ±104.70ppm in livers followed by meat (986.33 ± 59.00ppm) while the bone showed the least (429.37 ± 24.40ppm). Bulk of the trace element (4692 ±25.80ppm) was also excreated in faeces. The finding supports those of Miranda *et. al.* (2005) and Ihedioha *et al*. (2014) who reported that liver and muscle are tissues where Zn is most likely to accumulate. It however disagrees with Akan *et al*., (2010) who observed low concentration of Zn in meat and liver samples of chickens. Too much Zn has been reported to be harmful to human health (ATDSR, 2004). Olafisoye *et al*. (2013) stated that excess of Zn can lead to copper deficiency, immune system disorders, fatigue, nausea, hair loss, mental apathy and reproductive and growth disorders., It has also been reported (Saeed, 1998) that very high exposure to Zn can damage the pancreas, disturb protein metabolism and cause arteriosclerosis.

The mean concentration of Mn in the combined diets (40.88 ± 12.60ppm) which was the fourth highest was below the WHO/FAO highest permissible limit of 500mg/kg for vegetables. Its concentration in the tissues was found to be highest in livers (18.81 ±4.90ppm) followed by bones (2.58 ±0.30ppm) while the least was in meat where it was below detection limit. Bulk of the trace element (905.13 ± 2.90ppm) was excreated in the faeces (Table 6 and Fig. 7). This finding is in agreement with the studies carried out by Abdulajeel *et al*. (2013) and Donia (2015) who also reported high levels of Mn in liver samples of quail and chicken and quail respectively. Manganese is not only necessary for humans to survive but it is also toxic when too high concentrations are present in the human body; acute toxicity to humans is manifested by a psychologic and neurologic disorder, central nervous system is the chief site of damage (Akoto *et al*., 2014).

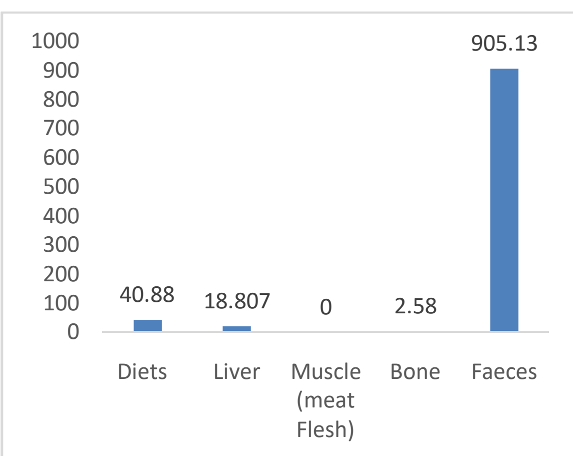

Fig. 7. Mn mean concentrations.

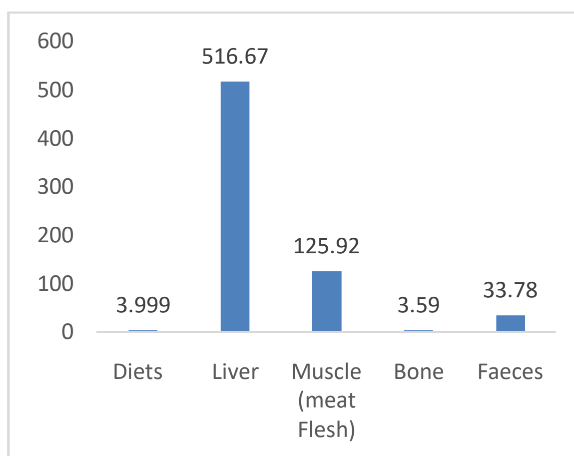

Fig. 8. Rb mean concentrations.

Table 6 and Figure 8 reveal that the mean concentration of Rb in the combined diets (3.99 ±16.70ppm) was the fourth lowest. Its highest concentration in the tissues was contained in livers (516.17 ±46ppm) followed by meat (125.92 ± 11.30ppm) while the least was in bones (3.59 ±12.50ppm). Some of the rubidium (33.71 ±10.57ppm) was also excreated in faeces. Rubidium readily reacts with skin moisture to form rubidium hydroxide which causes chemical burns of eyes and skin; over exposure results in failure to gain weight, ataxia, hyper irritation, skin ulcers and extreme nervousness (Lenntech, 2018).The mean concentration of V in the combined diets was the least and was below detection limit. Its concentrations in the liver, meat and bones were also below detection limits and bulk of it was excreated in faeces (7.47 ± 1.00ppm) (Table 6 and Fig. 9). The main use of vanadium is in alloys especially with steel; 85% of all vanadium produced goes into steel, 10% goes into alloys of titanium and 5% into all other uses but a number of its compounds are toxic and the higher its oxidation state, the more toxic the compound (Chemicool, 2018).

Fig. 9. V mean concentrations.

The overall trace element concentrations were found to be highest in liver followed by meat while the least was in bones. Horky *et al.* (1998) also reported that the liver of calf studied was one of the most affected organs with high levels of trace metals. The highest accumulation of trace elements in the liver may be attributed to the fact that it is the first organto encounter the ingested nutrients, drugs and environmental toxicants that enter the hepatic portal vein from the digestive system (ElOkle and Lebda, 2014).

CONCLUSION

The results of the study showed that of all the trace elements investigated, the concentrations of Co and V in the tissues were below detection limits while Cr accumulated only in livers with the bulk of the three elements excreated in faeces. Aluminum, Fe, Zn, Mn and Rb however accumulated in livers, meat and bones of the rabbits irrespective of their high concentrations in faeces and is attributed to the vegetable diets/feeds which the rabbits were fed on which were also contaminated with some of the elements with values that have exceeded the international permissible limits, resulting in their accumulation in the tissues. Since some of these trace elements were found to be in high levels in the vegetables and tissues, consistent surveillance and monitoring should be employed as their accumulation could lead to serious human health problems among consumers and in this regard, the Nigerian government should create, implement and enforce policies to address the problems of waste management in the country in order to drastically reduce these environmental contaminants.

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