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## PROXIMATE COMPOSITION, MINERAL CONTENTS AND FATTY ACIDS PROFILE OF SELECTED CROP RESIDUES ACROSS SAVANNAH AGRO-ECOLOGICAL ZONES OF NORTHERN NIGERIA

<sup>1</sup>Yusuf, H.K., <sup>2</sup>Garba, Y. and <sup>3</sup>Adam, M.A.

<sup>\*1</sup>Department of Animal Science, Faculty of Agriculture, Bayero University, Kano.

<sup>2,3</sup>Centre for Dryland Agriculture, Bayero University, Kano.

Corresponding author: [hyskibiya@gmail.com](mailto:hyskibiya@gmail.com) (08035753613)

### ABSTRACT

Characterization of the chemical composition of animal feed for major nutrients is one of the most vital considerations in the field of animal nutrition. In this study, the proximate constituents, mineral contents and fatty acid profile of selected crop residues across savannah agro-ecological zones of Northern Nigeria were evaluated. The crop residues were collected using multi-stage sampling techniques where three agro-ecological zones were selected from northern part of Nigeria. One local government area (LGA) was then selected from each zone and nine different forms of cereal and legume crop residues (cowpea hay, cowpea husk, groundnut hay, groundnut shell, maize cobs, maize husk, maize stalk, millet stalk and sorghum stalk) among the common residues used as feedstuffs by farmers were selected from each LGA. The collected samples were processed and analyzed using standard analytical procedures and the data obtained were subjected to analysis of variance (ANOVA). The results indicated that, there is significant ( $p < 0.05$ ) differences among the crop residues in the proximate composition. Maize cobs had the highest dry matter contents (92.99%) and least ash contents of 2.07% and the highest ash content was recorded in cowpea husk (7.56%). Groundnut shell had the highest crude fiber contents (57.29%) and least nitrogen free extracts (33.19%). However, there was no significant ( $p > 0.05$ ) difference among the crop residues in terms of mineral contents except in zinc where significant ( $p < 0.05$ ) difference was observed. Similarly, fatty acids profiles were not significantly ( $p > 0.05$ ) different among the crop residues evaluated. The crop residues are endowed with high nutrients therefore should be fed to ruminants.

**Keywords:** crop residues; feed evaluation; proximate composition; mineral contents; fatty acid profile

### INTRODUCTION

Feeding is the major constraint to livestock production especially in sub-Saharan Africa. Usually, the constraint of feed scarcity is more pronounced during prolonged dry season when fresh roughages are not available and animals are at the mercy of nature to survive (Tesfaye & Chairatanayuth, 2007). Most countries in the tropics do not have enough feed resources to sustain high level of livestock production; therefore development of rations based on readily available resources is imperative (Aregheore & Ikhatua, 1999). A study by Iyeghe-Erakpotobor *et al.* (2002) revealed that, due to the increases in human population and consequent high cost and demand for conventional feedstuffs, it has become increasingly necessary to alternate these feedstuffs with other feed resources so as to reduce the competition between, Man and livestock. The abundant supply of crop residues and agro-industrial by-products at reasonable prices could enhance production and reduce cost of compounded feeds while not adversely affecting the performance of the animals. The trend in which agricultural by-products such as crop residues were considered as waste has changed and is now being used extensively for

animal feed where they are converted into animal protein for human consumption (Onyeonagu & Njoku, 2010).

Crop residues are considered as the fibrous parts of crops that remain after the parts edible by humans are removed (Bhandari, 2019). They are a valuable source of animal feed and also assume great importance in decreasing the level of feed deficit in arid and semi-arid tropics where natural pastures are only seasonally available because of the shortage of moisture (Tesfaye & Chairatanayuth, 2007). Since time immemorial, these feed resources are used as livestock feed. These crop residues are relatively abundant across all the agro-ecological zones of Nigeria. Despite their abundance, there is limitation in their use as animal feed due to insufficient knowledge about their feeding potentials (Lopez *et al.*, 2005) and inefficient processing method.

Most of the crop residues are low in nutritive value and high in fibre content, and animals especially ruminant are characterized by the ability to convert these low quality roughages into high quality products (milk, meat, natural fibre, leather and manure). Having information on the quality of feedstuff in relation to animal nutrients' requirement

could make these residues fulfill the dietary requirements of the animals. Therefore, evaluation of the nutritive potentials of crop residues is essential as this could make an important contribution to the field of livestock nutrition (Taphizadeh *et al.*, 2008). Understanding the chemical and nutritive characteristics of these residues would aid in designing optimal utilization strategies at farm and/or national levels. Furthermore, these characteristics indicate the feeding value of the feedstuffs (Eyob *et al.*, 2017). Therefore, this study was designed to evaluate the chemical compositions (proximate constituents, mineral contents and fatty acid profile) of selected cereal and legume crop residues across the savannah agro-ecological zones of northern Nigeria.

## MATERIALS AND METHODS

### Description of the study location

The representative samples of Sudan savannah were collected from Kibiya Local Government Area (LGA) Kano state located on the coordinates of 11°32'N and 8°40'E. The zone has an average rainfall of 600 mm – 900 mm (Daniel *et al.*, 2013) and an average annual temperature of 26.1°C. Tudun Wada LGA of Kano state having a coordinate of 11°59'N and 8°24'E represented the Northern Guinea Savannah zone with that of Sahel Savannah collected from Wamakko LGA Sokoto state situated along the coordinates of 11°30' to 13°50' N and 4°00' to 6°00' with average rainfall and temperature of 630 mm and 39°C respectively (Jibrillah *et al.*, 2018).

### Field sampling and experimental design

The samples were collected from three agro-ecological zones of Nigerian Savannah namely, Northern Guinea Savannah (NGS), Sudan Savannah (SS) and Sahel Savannah (SHS). The zones were purposively selected based on availability of crop residues, rainfall availability and livestock production potentials of the study sites. A multi-stage sampling technique was used to collect the crop residues where the first stage involved selection of three agro-ecological zones (Northern Guinea savanna, Sahel savanna and Sudan savanna). The second stage involved selection of one state from each agro-ecological zone (samples from Sudan and Northern Guinea savanna were collected from Kano state while that of Sahel were collected from Sokoto State). The third stage involved selection of three Local Government Areas (LGAs) from the states (i.e two LGAs from Kano; Kibiya & Tudun Wada and one LGA from Sokoto; Wamakko) while the fourth stage involved the selection of nine cereals and legumes crop residues among the commonly grain crops in the

study area, giving a total of twenty seven (27) samples.

The nine (9) crop residues namely; cowpea hay, cowpea husk, groundnut hay, groundnut shell, maize cobs, maize husk, maize stalk, millet stalk and sorghum stalk were laid in a randomized complete block design (RCBD).

### Samples preparation and analyses

The collected samples were shade dried, ground into powder using a grinder, sieved with a 2 mm mesh size and sealed in airtight plastic containers and stored inside sacks for the laboratory analysis. The proximate constituents, mineral contents and fatty acids profile of the samples were evaluated at the instrumentation laboratory of Centre for Dryland Agriculture, Bayero University Kano.

### Proximate compositions of the crop residues

The proximate compositions of the samples were determined using the methods described by AOAC (2016) for moisture content estimation, ash, crude protein, crude fat, crude fibre and nitrogen free extract determination.

**Estimation of moisture:** Two (2) gram (W<sub>1</sub>) of each sample was taken in a flat-bottom dish and kept overnight in an air oven at 100-110°C and weighed. The loss in weight was regarded as a measure of moisture content.

% Moisture =  $\frac{\text{Weight of sample before oven drying} - \text{Weight of sample after oven drying}}{\text{Weight of sample before oven drying}} \times 100$

**Determination of ash:** One (1) gram of each sample was weighed (W<sub>1</sub>) in a crucible of known weight (W<sub>0</sub>) and heated in muffle furnace for about 5 hours at 550°C. It was allowed to cool in a desiccator and weighed to ensure completion of ashing. The final weight of the crucible and content was determined and recorded as W<sub>2</sub>. The % ash was calculated using the following formula:

$$\% \text{ Ash} = \frac{W_2 - W_0}{W_1} \times 100$$

**Determination of crude protein:** The crude protein was determined using micro Kjeldahl method. The total protein was calculated by multiplying the evaluated amount of nitrogen obtained by 6.25 to get the proximate protein content of the sample.

**Determination of crude fat:** The crude fat was determined using an automatic fat extraction machine (Soxtec 8000). One (1) gram of each sample was weighed in a thimble, defatted cotton was placed on the top of the samples and pressed down to the centre, and the thimbles were then moved into a thimble stand and inserted into the machine. The machine was switched on and set for the extraction. After the extraction, the cups were removed and dried at 103<sup>0</sup> C for 30 minutes and then weighed. The fat content was calculated as:

$$\% Fat = \frac{W3 - W2}{W1} \times 100$$

Where,

W<sub>1</sub> = Weight of sample (g)

W<sub>2</sub> = Weight of empty extraction cup (g)

W<sub>3</sub> = Weight of extraction cup + residue (g)

**Determination of fibre:** One (1) gram of celite was weighed into a crucible and tared, one gram of the sample was added and the crucibles were positioned in a fibretec cold extraction unit twenty five (25) ml acetone was added to each crucible and allowed for cold extraction. The crucibles were then removed, transferred to crucible stand and left at room temperature until the acetone was evaporated. The crucibles were later inserted into a fibretec hot extraction unit for automatic hot extraction using (Fibretec 8000). The crucibles were dried for 2 hours at 130<sup>0</sup> C, transferred into a dessicator and allowed to cool to room temperature and weighed. The samples in the crucibles were heated to ash in a furnace at 535<sup>0</sup> C for 3 hours. The crucibles were allowed to cool again in a dessicator and weighed. The crude fibre was calculated as:

$$\% Crude Fibre = \frac{W2 - (W3 + C)}{W1} \times 100$$

Where,

W<sub>1</sub> = Weight of sample (g)

W<sub>2</sub> = Crucible + residue weight after drying (g)

W<sub>3</sub> = Crucible + residue weight after ashing (g)

C = Blank

**Determination of nitrogen free extract:** Nitrogen Free Extract (NFE) was calculated by difference after analysis of all the other constituents that was obtained in the proximate analysis.

$$NFE = (100 - \% moisture + \% crude protein + \% crude fat + \% crude fiber + \% ash)$$

**Determination of energy:** The energy contents of the crop residues were calculated using Atwater factor;

$$Energy (kcal/kg) = [3.5 \times CP (\%) + 8.5 \times crude fat (\%) + 3.5 \times CHO (\%)]$$

Where;

CHO = Carbohydrate = 100 – (% moisture + % crude protein + % crude fat + % crude fiber + % ash)

CP = Crude protein

#### **Determination of mineral contents of the crop residues**

The mineral contents (Ca, Mg, Mn, S, Fe, Cu, K, P, Zn) of the samples were determined by heating using a microwave digestion system (Ethos easy). Two hundred (200) milligram of each sample was weighed and transferred into Teflon vessels, 7 mg HNO<sub>3</sub>, 2 ml H<sub>2</sub>O<sub>2</sub> and 1 HClO<sub>4</sub> ml were added into the vessels. The digestion rotor containing the vessels was placed into a microwave digestion system and the digestion was carried out under plant tissue specified program of the machine. After the digestion, the digest was filtered using whatman filter paper and diluted to a volume of 50 ml. Two 2 ml of the solution was used for the mineral determination using Micro-Plasma Atomic Emission Spectroscopy (MP-AES).

#### **Determination of fatty acid profile of the crop residues**

The fat contents of the samples were extracted according to the method described by AOAC (2019) using an automatic soxtec machine (Soxtec 8000). Five (5) grams of each sample was weighed in a thimble, defatted cotton was placed on the top of the samples and pressed down to the centre, and the thimbles were then moved into a thimble stand and inserted into the machine. The machine was switched on and set for the extraction.

Fatty acid standards were prepared at different concentration ranges from 0.25 M to 20 M by

diluting 0.1 g of each standard in 5 ml n-hexane. Later on, serial dilution was followed. The fatty acids were determined according to the method described by Dumancas *et al.* (2011). The procedure entails placing a 10 µl aliquot of the fatty acid methyl esters (FAME) standards and the sample extract into a glass test tube followed immediately by the careful addition of 1.0 ml Acetyl Chloride then 40 µl of perchloric acid. The test tube was sealed tightly with parafilm and gently shaken for 20 seconds. The supernate was then transferred by pipette to a 10 mm pathlength optical glass cuvette and placed in the sample holder of a micro plate spectrophotometer (Multiskan Sky). The absorbances were taken from 300-800 nm at every 2 nm. The fatty acid profiling at different sample was then determined following the procedure documented by Dumancas *et al.* (2011).

The data on proximate composition, mineral contents and fatty acids were subjected to Analysis of Variance (ANOVA) using mixed model procedure of JMP software (1989-2019) and significant mean differences were separated at 5% level of probability using studentized t-test.

## RESULTS

The results of variability in the proximate composition among crop residues (cowpea husk, cowpea hay, groundnut hay, groundnut shell, maize cobs, maize husk, maize stalk, millet stalk and sorghum stalk) are presented in Table 1. The result revealed that at 5% level of significance ( $p < 0.05$ ), the percentage ash content was highest in cowpea husk (7.56%) which was statistically similar to groundnut hay, cowpea hay, groundnut shell, maize stalk and sorghum stalk and different with maize cobs, maize husk and millet stalk. The highest and least dry matter contents were observed in maize cobs (92.99%) and sorghum stalk (91.02%) respectively; however, all the crop residues were

statistically the same. There was no significant ( $p > 0.05$ ) difference observed in the crude protein content among the crop residues. The highest crude fibre content was recorded in groundnut shell (57.29%) and is the same with sorghum stalk, millet stalk and maize stalk. In terms of ether extract, sorghum stalk (1.20%) was the highest with maize cobs been the least (0.35%) but all the crop residues are similar statistically. The mean value for nitrogen free extract ranged between 64.74% (maize husk) to 33.19% (groundnut shell); groundnut hay, cowpea hay and maize cobs were similar to maize husk and statistically significant with other crop residues evaluated.

Table 2 presents the result of the variability in mineral contents among crop residues in the study location. The result revealed that all the crop residues were statistically the same at 5% level of significance ( $p < 0.05$ ) in terms of mineral contents with the exception of Zinc (Zn) where significant different was observed. However, the highest P and K contents were recorded in maize cobs (6.58 and 41.50 ppm respectively), and maize stalk had the highest Ca contents of 14.98 ppm. Highest Zn content (0.27 ppm) was observed in ground hay and the least (0.11 ppm) was recorded in groundnut shell, maize cobs and maize husk.

The fatty acid contents of the crop residues analyzed are presented in Table 3. The values for fatty acids were not significantly ( $p < 0.05$ ) different among the crop residues. However, higher values were observed in cowpea husk and cowpea hay for methyl eicosanoate (472.10 mg/kg) and methyl undecanoate (208.99 mg/kg) respectively. Furthermore, methyl tridecanoate was found in a very trace amount in all the crop residues except cowpea hay where higher value of 170.69 mg/kg was recorded.

Table 1: Variability in proximate composition among crop residues in the study location

	<b>Parameters</b>												
	Ash %		DM %		CP %		CF %		EE %		NFE %		Energy (kcal/kg)
	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	
Cowpea hay	5.21 <sup>abc</sup>	0.88	91.83	0.51	2.60	0.69	34.08 <sup>bcd</sup>	6.12	0.57	0.34	57.54 <sup>abc</sup>	6.20	1867.40
Cowpea husk	7.56 <sup>a</sup>	1.08	92.98	0.62	3.77	0.84	27.22 <sup>cd</sup>	7.50	1.01	0.42	60.46 <sup>abc</sup>	7.59	2087.50
Groundnut hay	6.76 <sup>ab</sup>	0.88	91.82	0.51	2.94	0.69	29.61 <sup>cd</sup>	6.12	0.91	0.34	59.78 <sup>ab</sup>	6.20	1986.25
Groundnut shell	5.00 <sup>abc</sup>	0.88	92.15	0.51	3.74	0.69	57.29 <sup>a</sup>	6.12	0.79	0.34	33.19 <sup>d</sup>	6.20	1084.60
Maize cobs	2.07 <sup>d</sup>	0.88	92.99	0.51	4.18	0.69	33.38 <sup>bcd</sup>	6.12	0.35	0.34	60.01 <sup>ab</sup>	6.20	2031.05
Maize husk	4.50 <sup>bcd</sup>	0.88	91.33	0.51	2.49	0.69	27.55 <sup>d</sup>	6.12	0.72	0.34	64.74 <sup>a</sup>	6.20	2110.80
Maize stalk	5.90 <sup>abc</sup>	0.88	91.65	0.51	2.89	0.69	45.46 <sup>abcd</sup>	6.12	0.63	0.34	45.11 <sup>bcd</sup>	6.20	1441.30
Millet stalk	3.53 <sup>cd</sup>	0.88	91.82	0.51	4.57	0.69	46.63 <sup>abc</sup>	6.12	0.91	0.34	44.36 <sup>bcd</sup>	6.20	1503.60
Sorghum stalk	5.07 <sup>abc</sup>	0.88	91.02	0.51	2.82	0.69	50.09 <sup>ab</sup>	6.12	1.20	0.34	40.82 <sup>cd</sup>	6.20	1309.50

a,b,c,d means with different superscripts across column are significantly ( $p < 0.05$ ) different, SE= standard error MC = moisture content, DM = dry matter, CP = crude protein, CF = crude fibre, EE = ether extract, NFE = nitrogen free extract

Table 2: Variability in mineral contents among crop residues in the study location

Parameter (ppm)	Cowpea hay	Cowpea husk	Groundnut hay	Groundnut shell	Maize cobs	Maize husk	Maize stalk	Millet stalk	Sorghum stalk
P	5.84	3.74	5.30	4.78	6.58	2.29	2.77	3.06	3.02
SE±	1.78	2.19	1.78	1.78	1.78	1.78	1.78	1.78	1.78
S	0.88	0.76	0.52	0.48	0.52	0.77	0.71	0.93	0.70
SE±	0.23	0.28	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Ca	3.47	7.33	3.80	12.55	5.31	4.34	14.98	3.87	13.41
SE±	6.42	7.87	6.42	6.42	6.42	6.42	6.42	6.42	6.42
Fe	0.90	2.05	0.90	2.73	1.07	0.43	0.49	1.07	0.92
SE±	0.54	0.66	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Cu	0.04	0.04	0.05	0.05	0.05	0.03	0.04	0.04	0.03
SE±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
K	19.36	27.70	39.01	39.90	41.50	37.29	22.51	18.08	29.74
SE±	8.30	10.17	8.30	8.30	8.30	8.30	8.30	8.30	8.30
Mg	7.01	11.41	2.62	7.83	8.87	4.68	5.97	4.88	8.75
SE±	2.86	3.50	2.86	2.86	2.86	2.86	2.86	2.86	2.86
Mn	0.15	0.11	0.25	0.13	0.20	0.08	0.11	0.06	0.15
SE±	0.08	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Zn	0.25 <sup>a</sup>	0.23 <sup>ab</sup>	0.27 <sup>a</sup>	0.11 <sup>c</sup>	0.11 <sup>c</sup>	0.11 <sup>c</sup>	0.14 <sup>bc</sup>	0.15 <sup>bc</sup>	0.15 <sup>bc</sup>
SE±	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

a,b,c,d means with different superscripts across rows are significantly ( $p < 0.05$ ) different, SE= standard error

Table 3: Variability in fatty acid contents among crop residues in the study location

Parameters (mg/kg)	Crop residues								
	Cowpea hay	Cowpea husk	Groundnut hay	Groundnut shell	Maize cobs	Maize husk	Maize stalk	Millet stalk	Sorghum stalk
Methyl eicosanoate	89.21	472.10	59.91	39.21	59.58	43.81	35.99	100.79	66.19
SE±	81.54	99.86	81.54	81.54	81.54	81.54	81.54	81.54	81.54
Methyl tridecanoate	170.69	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
SE±	51.50	63.07	51.50	51.50	51.50	51.50	51.50	51.50	51.50
Methyl nonanoate	10.52	7.73	4.94	9.65	16.69	14.53	20.29	15.68	6.36
SE±	5.33	6.53	5.33	5.33	5.33	5.33	5.33	5.33	5.33
Methyl undecanoate	208.99	58.98	28.84	39.82	15.83	30.78	8.49	22.63	37.58
SE±	53.81	65.91	53.81	53.81	53.81	53.81	53.81	53.81	53.81

## DISCUSSION

Evaluation of nutrients composition of feed materials is paramount for feed formulation (Adeolu and Enesi, 2013). Proximate analysis gives information on the basic nutrients present in feed samples (Akiode *et al.*, 2018). The proximate parameters include moisture, crude protein, ash, crude fiber, ether extract and nitrogen free extract. The moisture contents of the samples were within the range of 7.01% and 8.98%. The moisture contents of the samples were higher than the recommended value (5.43%) for animal feeds (USDA, 2005) and this could be due to the drying method and period of experiments. Moisture content of a feed is an indicator of its freshness, and high levels predispose feeds to deterioration from increased microbial activity (Adepoju, & Onasanya, 2008), thereby affecting their palatability (Oko & Onyekwere, 2010). Moisture contents are influenced by crop type and climatic conditions, such as precipitation and temperature (Méndez-Montealvo *et al.*, 2005).

Dry matter content of feeds gives room for the comparison of feeds' nutritional potentials (Malebana *et al.*, 2018). Dry matter content of cowpea husk is higher (though not statistically) compared to other crop residues, and this implied that cowpea husk had higher nutrient biomass than others.

Protein is an important constituent of feed required for survival by both humans and animals, and they primarily supply amino acids required for normal functioning of the body system (Akiode *et al.*, 2018). Crude protein content is an essential indicator of the nutritional quality of feed ingredients (Okunade *et al.*, 2014). The crude protein levels of the samples ranged from 2.49 to 4.57% which are below the minimum threshold (7.0–8.0 g/100 g DM) for forage intake by ruminants and rumen microbial activity (Van Soest, 1994). Therefore, these crop residues must be supplemented with good protein feed ingredients so as to satisfy animals' nutrient requirements. However, the crude protein value of groundnut shell obtained in this study (3.74%) was lower than the value (4.43%) documented by Abdulrazak *et al.* (2014). Similarly, the crude protein value of cowpea husk obtained in this study (3.77%) was lower than the value (11.21%) documented by Amadioha and Nwazuo (2019). Nevertheless, the crude protein value of maize cob obtained in this study (4.18%) was much similar to the value (4.19%) documented by Abubakar *et al.* (2016). The variations in the crude protein of the crop residues reported could be due to plant variety, harvesting time, storage period, method of processing and environmental factors (Ghorbani *et al.*, 2018).

Fibre is an essential component of carbohydrate; it is a general term for the fractions that are not readily digestible (Tasie & Gebreyes, 2020). The crude fibre content of the samples ranged from 27.22% (for cowpea husk) to 57.29% (groundnut shell). The crude fibre values in the present study were comparable to the values for other crop residues such as mango endocarp (49.47%), melon seed husk (51.61%) and moringa pod (58.10%) documented by Akiode *et al.* (2018), coconut husk (30.34%), cocoa pods (33.60%) and kola nut pod (26.84%) documented by Adeyi (2010), but higher than 8.10% to 15.50% values of plantain wastes documented by Okareh *et al.* (2015). Increased removal of potential mutagens, xenobiotics and steroids have been attributed to high fibre content in diets because of adherence to dietary fibre components, thereby aiding digestion. Consequently, the health of the animals is improved (Okareh *et al.*, 2015). Hence, the high fibre content of the crop residues makes them suitable to be included in ration formulation.

Dietary fats have been reported to improve palatability of feed by absorbing and retaining flavours (Antia *et al.*, 2006). The values obtained for ether extract in the present study were very low (0.35% to 1.20%). The results of this study were similar to the values reported by Yalchi and Hajieghrari (2011) for maize straw (1.27%), wheat straw (1.07%), rapeseed straw (1.14%), and soybean meal straw (0.51%). However, the ether extract value of groundnut shell (0.79%) obtained in this study was higher than the value (0.50%) documented by Abdulrazak *et al.* (2014). The implication of the low ether extract levels of the samples is that the crop residues are low in energy and therefore needed to be supplemented with energy concentrates (Babayemi and Bamikole, 2006). The nitrogen-free extract values obtained in the present study (33.19% to 64.74%) were comparable to the values documented by Tona *et al.* (2015) for rice husk (26.93%), maize stover (72.74%), citrus pulp (40.11%), and bean waste (70.86%).

Plant materials have been reported to be good sources of mineral elements (Adedeji, 2020). The ash content of a feed provides an estimation of its mineral content (Ayoola *et al.*, 2012) Ash content of the samples varied from 2.07% to 7.56%, revealing high mineral content of the samples. High ash content may affect the sensory quality of feed (Juliano, 1985). However, the values were lower than the values of other crop residues such as cocoa pods (12.67%), kola nut pod (7.67%), and ripe plantain peel (11.73%) documented by Adeyi (2010). The variations in the ash contents of the crop residues might be due to the differences in mineral content of



the soils and the water used for irrigation (Shayo *et al.*, 2006).

The mineral analysis of the samples revealed appreciable levels of calcium, phosphorus, potassium, magnesium, manganese, sulphur, iron, and zinc. The level of copper is negligible in all the samples. The mineral contents of the crop residues analysed in the present study were low compared to those documented by and Abubakar *et al.* (2016) and Awosusi *et al.* (2017). The variations observed in the mineral contents of the crop residues might be attributed to environmental factors such as elevated ozone levels, water availability, and presence of light (Nour *et al.*, 2014). Minerals are important because they play essential role in metabolic processes of the body and their deficiency can be detrimental to animals (McDonald *et al.*, 1995; Gafar & Itodo, 2011). Calcium helps in muscle contraction, bone mineralization, regulation of cell metabolism, mediating the death of a cell, and cell signaling (Oladele, 2007).

Iron is a fundamental element in the synthesis of myoglobin and haemoglobin (Nkhata *et al.*, 2013). Its deficiency could lead to anaemia and immunity problems (Gaucheron, 2000). Furthermore, iron play a part in the formation of heme enzymes and other iron-containing enzymes that are essential for energy production, thyroid function, and immune defense, whereas zinc act as a reducing agent. It can easily form a complex with other compounds including phosphates, carbonates, oxalates, sulfates, and phytates (Tasie & Gebreyes, 2020). Zinc deficiency could cause diarrhea and growth retardation (Dary & Hurrell, 2006). Manganese contributes to energy production and also aid the immune system (Muhammad *et al.*, 2011).

Fatty acids are essential food components due to the role they play in relation to growth, development and physiological functions of body (FAO/WHO, 1993). The fatty acid analysis of the samples revealed appreciable levels of methyl eicosanoate, methyl nonanoate, and methyl undecanoate. The level of methyl tridecanoate is negligible in all the samples with the exception of cowpea hay. According to Ogalde *et al.* (2020), eicosanoids are essential for normal kidney and cardiovascular function. However, the finding of this study was contrary to the author's report who worked on *Lluteno* maize. The differences observed might be attributed to plant variety and study location.

## CONCLUSION

The proximate, mineral and fatty acid analyses provides information about the feeding potentials of the crop residues thereby increasing their utilization as animal feed during dry season in order to increase

livestock productivity. Based on the result obtained, the crop residues are endowed with high nutrients, however, their crude protein level was lower than the 7 % required for proper rumen functioning. Therefore, these crop residues must be supplemented with good protein feed ingredients so as to satisfy animals' nutrient requirements.

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