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Nutrient Digestibility, Metabolizable Energy and Carcass Traits of Broilers Fed White and Yellow Cassava Root Meals Supplemented with Different Additives

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ABSTRACT

Cassava root is rich in energy but low in protein. New varieties developed exhibit better nutritional profile. An 8-week experiment was conducted to investigate the effect of dietary supplementation of 2 varieties of cassava root meal (CRM) with various additives on nutrient digestibility energy, metabolizable and carcass traits of broilers. Two hundred and forty unsexed day-old broilers were allotted to 8 dietary treatments in a 2 x 4 factorial arrangement of white (TME 419) and yellow (ITA/IBD/1368) CRM supplemented with no additive, amino acids (methionine and lysine), enzyme and amino acids + enzyme (A.A + Enz). The experiment lasted for the starter (0 - 4 weeks) and finisher (5-8weeks) phases. Variety effect showed higher ($p<0.05$) nutrient digestibilities in finisher broilers fed with white cassava than yellow. White cassava + amino acids showed higher EED and ASHD while yellow cassava with amino acids + enzyme yielded improved nutrient digestibilities. White cassava variety revealed higher ($p<0.05$) metabolizable energy values than yellow. Broilers fed white cassava + enzyme had the highest ($p<0.05$) metabolizable energy values. In conclusion, supplementing yellow CRM with A.A + Enz improved nutrient digestibility only at the starter phase. Supplementation of white cassava diet with enzyme and amino acid at the starter

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and finisher phases respectively, improved energy metabolizablility.

Keywords: Additives, broilers, carcass, cassava, energy metabolizablility, nutrient digestibility

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) root is a cheap and sustainable energy feedstuff with potential to replace most conventional cereal grains in the tropics (Oso et al., 2014). Cassava root is rich in digestible starch, gross energy content (El-sharkawy, 2012) and has been used to a limited extent in poultry nutrition (Eruvbetine et al., 2003; Oso et al., 2014). However, high fibrous content (of its peel), the presence of hydrocyanide (HCN) residues, reduced protein levels, poor protein quality and reduced concentration of sulphur containing amino acids in cassava root, constitute the major constraints to its maximal utilization as energy feedstuff in poultry nutrition (Banea-Mayambu et al., 1997). During cassava processing which converts cyanide to a less toxic thiocyanate, the enzyme 'rhodanese' contained in cassava root utilizes the constituent methionine and other sulphur containing amino acids as sulfur donor (Cardoso et al., 2005). Thus, sulphur amino acids become grossly deficient in cassava-based diets fed to poultry birds. Hence, to harness the rich energy potential of cassava root maximally in poultry nutrition, it is essential to supplement cassava root-based diets with limiting amino acids. Supplementation of fibrous feed ingredients with feed additives like enzyme improves utilization of the feed and reduces intestinal viscosity, thereby improving gut health and nutrient digestibility (Abdulrashid et al., 2007; Kayode, 2009).

The conventional white cassava roots and products are deficient in β-carotene and other carotenoids (Khajarern & Khajarern, 2007; Omole, 1977) which are needed in poultry diet to prevent *in vivo* oxidative stress with the attendant effects on animal products (Ngiki et al., 2014). Yellow cassava on the other hand contains high levels of β-carotene, which is a precursor to vitamin A. β-carotene will enhance nutritional properties of yellow cassava and this could take care of some of the deficiencies that may be associated with lack of β-carotene and other carotenoids in white cassava. Previous studies on the practical inclusion of whole cassava root meal as energy feedstuff in feed for poultry (Aderemi et al., 2012; Akapo et al., 2014; Kyawt et al., 2015; Oso et al., 2014), have limited information on the use of biofortified (yellow) cassava in the feed of poultry. This study therefore seeks to investigate the effect of synthetic amino acids (methionine and lysine) and cellulase enzyme supplementation of unpeeled white and yellow cassava root meals (WCRM and YCRM respectively) on nutrient digestibility, energy metabolizablility and carcass traits of broiler chicken.

MATERIALS AND METHODS

Experimental Location

The experiment was carried out at the Poultry Unit of Ogun-Oshun River Basin Development Authority, Abeokuta (7° 12' 1.0" N, 3° 26' 13.2" E), Nigeria, West

Africa. This is in the tropical sub-savannah region with an average ambient temperature of 32.91°C and a relative humidity of 79.25 per cent. It receives a mean precipitation of 1,685 mm per annum (Ogun-Oshun River Basin Development Authority [OORBDA], 2016).

Preparation of Cassava Root Meal

Freshly harvested white cassava variety (TME 419) and yellow cassava variety (ITA/IBD/1368) were gotten from the Federal University of Agriculture, Abeokuta farm for the study. Each variety was thoroughly washed with clean water (to be free of dirt and sand) and chipped into smaller pieces as described by Oso et al. (2010). The chipped cassava tubers obtained from each variety were sun-dried separately until they reached a moisture content of approximately 10–12 per cent. The dried chips were collected, bagged, stored, and subsequently milled (2.5-mm sieve) separately to obtain the WCRM and YCRM. The processed cassava root meals were later mixed with other feed ingredients to formulate the experimental diets.

Chemical Composition of White and Yellow Cassava Root Meals

Samples of the cassava root meals were analysed to determine their chemical constituents using the method described by the Association of Official Analytical Chemists (Horwitz, 2005). The fibre fractions that include the neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) were determined according to the methods of Van Soest et al. (1991). Hemicellulose was calculated as the difference between NDF and ADF, while cellulose was calculated as the difference between ADF and ADL. Also, the cyanide content of the samples was determined following the method of Bradbury et al. (1991). Mineral content Ca, P, Cu, Mg, Mn, and Zn as well as β-carotene of the cassava root meals were determined using Horwitz (2005) and (Association of Official Analytical Chemists [AOAC], 1997), respectively (Table 1).

Table 1
Chemical composition of white (TME 419) and yellow (ITA/IBD/1368) cassava root meals

	White cassava	Yellow cassava
Proximate components (%)		
Dry matter content	90.42	91.33
Crude protein	2.20	3.56
Ether extract	0.76	0.52
Crude fibre	1.26	1.09
Ash	2.34	2.90
Nitrogen free extract (NFE)	83.77	82.98
β-carotene (µg/100 g)	15.42	349.01
Gross energy (MJ/kg)	14.80	14.46
Hydrocyanide HCN (mg/kg)	26.60	25.40
Fibre fractions (%)		
Nitrogen detergent fibre (NDF)	26.59	24.95
Acid detergent fibre (ADF)	15.58	14.06
Acid detergent lignin (ADL)	3.37	2.53
Hemicellulose	11.01	10.89
Cellulose	12.21	11.53
Mineral content (mg/g)		
Ca	3.55	3.72
P	0.80	0.90
Cu	0.28	0.32
Mg	0.40	0.46
Mn	0.14	0.22
Zn	0.11	0.10

Experimental Birds and Management

A total of 240-day-old, unsexed broiler chickens of Marshall® strain were distributed at random between 24 pens. Three pens were assigned to each of the eight-dietary treatment in three replications of 10 birds per replicate. The birds were brooded and reared intensively on a deep litter housing system with dried wood shavings as the litter material. Feed and water were offered *ad libitum.* The experiment lasted for eight weeks (0–4 weeks for the starter phase and 5 – 8 weeks for the finisher phase).

Dietary Treatments

White and yellow cassava root meals separately replaced 30 per cent of maize as the basal diet in the experimental diets, with different types of additives as follows: there was no additive in one of the diets (control) while the remaining three contained recommended levels of synthetic amino acids (15g methionine and 5g lysine), exogenous enzyme (3g cellulase), and a combination of both amino acids and enzyme. There were eight dietary treatments laid out in a 2 × 4 factorial arrangement, i.e. two varieties of cassava and four types of additives, as indicated below:

- Dietary Treatment 1: WCRM + No additive
- Dietary Treatment 2: WCRM + Synthetic amino acids
- Dietary Treatment 3: WCRM + Exogenous enzyme
- Dietary Treatment 4: WCRM + Synthetic amino acids + Exogenous enzyme
- Dietary Treatment 5: YCRM + No additive
- Dietary Treatment 6: YCRM + Synthetic amino acids
- Dietary Treatment 7: YCRM + Exogenous enzyme
- Dietary Treatment 8: YCRM + Synthetic amino acids + Exogenous enzyme

The composition of the basal diets for both starter and finisher phases are as shown in Table 2.

Nutrient Digestibility Determination

At the end of starting and finishing phases, 2 birds from each of the 3 replicates per dietary treatment (48 birds per phase) were selected at random and housed individually in clean-wired floor metabolic cages fitted with individual feed troughs and facility for separate excreta collection. The birds were acclimatized for 2 days prior to the commencement of the 3-day collection period. Birds in each treatment group were fed with the respective test diets and excreta were collected daily for 3 days. The daily feed intake and excreta voided were weighed for the 3-day period. Feed intake was measured by deducting the weight of left-over feed from the weight of feed given daily. The daily excreta voided following the feeding procedure was collected quantitatively and dried at 65°C until moisture content was < 10% and the total collection per group of birds at the expiration of 3-day digestibility trial was pooled and ground. The proximate composition of feed and dried excreta

Table 2
Gross composition of experimental diets fed to starter and finisher broilers (g/kg)

	Starter		Finisher	
Ingredients	WCRM	YCRM	WCRM	YCRM
Maize	320	320	378	320
White cassava	136	–	162	–
Yellow cassava	–	136	–	136
Soya bean meal	290	290	204	290
Fish meal (70%)	10	10	–	–
Groundnut cake	90	90	122	122
Wheat offal	100	100	80	80
Palm oil	10	10	20	20
Bone meal	20	20	17	17
Oyster shell	15	15	8	8
Methionine	2	2	2	2
Lysine	1.5	1.5	1.5	1.5
*Premix (broilers)	2.5	2.5	2.5	2.5
Common salt	3	3	3	3
Total	1,000	1,000	1,000	1,000
Determined analyses				
Metabolized energy (kcal/kg)	2,917.91	2,881.44	3,092.91	3,081.44
Crude protein (%)	22.90	22.97	20.03	20.11
Crude fibre (%)	5.56	5.54	5.77	5.89
Ether extract (%)	5.48	5.35	5.60	5.58

Note. Each 2.5 kg broiler premix contains 1.25 kg Vitamin Premix (Vit. A 10,000,000 I.U; Vit. D3 2,000,000 I.U; Vit. E 10,000 mg; Vit. K3 2,000 mg; Vit. B2 4,000 mg; Vit. B6 1,500 mg; Vit. B12 10 mg; pantothenic acid 5,000 mg; biotin 20 mg; niacin 15,000 mg; and antioxidant 125,000 mg), 1 1.25 kg Mineral Premix (copper 5,000 mg; iodine 1,200 mg; selenium 200 mg; cobalt 200 mg; iron 20,000 mg; zinc 50,000 mg; manganese 80,000 mg; and choline chloride 200 g

samples was analyzed for dry matter, crude fibre, ether extract, ash, and crude protein (N × 6.25) using standard methods of AOAC (2000).

The feed intake: The feed intake was calculated using the formula:

$$\text{Feed intake per bird (g)} = \frac{\text{Feed supplied(g)} - \text{Left over feed(g)}}{\text{Total number of Birds}}$$

Dry matter digestibility: The dry matter digestibility was calculated using the formula:

$$\text{Dry matter digestibility (\%)} = \frac{\text{Weight of feed intake (g/D M)} - \text{Weight of feed dropping (g/D M)} \times 100}{\text{Weight of feed intake (g/D M)}}$$

From the results of the proximate composition of both the feed and excreta samples, the digestible crude protein was calculated as:

$$\text{Digestibility Crude Protein (\%)} = \frac{(\text{Weight of feed intake (DM)} \times \%\text{CP in diet}) - (\text{Weight of dropping (DM)} \times \%\text{CP in dropping}) \times 100}{(\text{Weight of feed intake (DM)} \times \%\text{CP in diet})}$$

The same method was used to calculate the digestibility of fat, crude fibre, ash and NFE.

Apparent and True Metabolizable Energy

At the end of the digestibility trials at both starter and finisher phases of the experiment, the birds in the metabolic cages were starved of diets and given unrestricted access to clean water for 24 hours during which the excreta voided was discarded. After the expiration of the 24-hour starvation, each bird was dosed with 50ml of warm glucose solution to reduce stress. They were then deprived of feed for another 24 hours, making a total of 48 hours starvation period. Total excreta voided per bird during the last (24h) phase of feed starvation was collected, weighed and used for the estimation of endogenous losses. The excreta sample per bird was oven dried at 60°C until the weight was consistent; the samples were then pooled together by group and ground to pass through 0.1 mm sieve. Excreta samples (from fed and starved birds) were assayed for gross energy according to Sibbald (1980).

The following equations were used to calculate apparent metabolizable energy (AME), nitrogen corrected apparent metabolizable energy (AMEn), true metabolizable energy (TME), and nitrogen corrected true metabolizable energy (TMEn) of test samples.

$$\text{AM E/g of feed} = \frac{[(\text{Fi} \times \text{GEf}) - (\text{E} \times \text{GEe})]}{\text{Fi}}$$

where: Fi is the feed intake (g on dry matter basis), E is quantity of excreta output (g on dry matter basis), GEf is the gross energy (MJ/kg) of feed and GEe the gross energy (MJ/kg) of excreta.

$$\text{AM E/g of feed} = \frac{\left\{\begin{matrix}[(\text{Fi} \times \text{GEf}) - (\text{E} \times \text{GEe})] \\ -(\text{NR} \times 36.5)\end{matrix}\right\}}{\text{Fi}}$$

where: nitrogen retention (NR) = (Fi × Nf) − (E × Ne). Nf is the nitrogen content (g/kg) of feed, Ne is the nitrogen content (g/kg) of excreta.

$$\text{TM E/g of feed} = \frac{\left\{\begin{matrix}[(\text{Fi} \times \text{GEf}) - (\text{E} \times \text{GEe})] \\ +(\text{FEm} + \text{UEe})\end{matrix}\right\}}{\text{Fi}}$$

where: FEm is metabolic faecal energy (kJ) (calculated from gross energy of excreta from endogenous loss), and UEe is endogenous urinary energy (kJ) (This is assumed zero since urine and faeces are passed together).

$$\text{TME n/g of feed} = \frac{\{[(\text{Fi GEf}) - (\text{E} \times \text{GEe})] - (\text{NR} \times \text{K})\} + \{(\text{FEm} + \text{UEe}) + (\text{NRo} \times 36.5)\}}{\text{Fi}}$$

where: NR and NRo are estimates of nitrogen retention for fed and starved birds, respectively.

Carcass Measurements

At 8th week, six experimental birds per treatment (two per replicate) were selected and weighed for carcass measurements. Prior to slaughtering, the birds were starved overnight to empty their crops. They were then slaughtered by neck slitting, allowed to bleed, scalded in warm water and de-feathered. Dressed weights and weights of the cut parts and organs were thereafter taken. Weights of the cut parts and organs were expressed as percentage of live weights while the dressed percentage was calculated using the formula:

$$\text{Dressed Percentage}(\%) = \frac{\text{Dressed weight(g)}}{\text{Live weight(g)}} \times 100$$

Statistical Analysis

Data generated were analysed by the analysis of variance technique using the Statistical Analysis System computer package (Statistical Analysis System Institute [SAS Institute], 1999) to separate the main effects of using different varieties of cassava and different additives. The interaction effect between the white or yellow cassava varieties and the type of additive (no additive, amino acid supplementation, exogenous enzyme, or combination of amino acid and enzyme) was also determined. Differences between significant mean values were separated using Duncan's multiple range test (Duncan, 1955).

Statistical Model:

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + E_{ijk}$$

where:

Y_{ijk} = observed values of dependent variable

μ = population mean

A_i = main effect of cassava (White and Yellow)

B_j = main effect of additive (Non, Amino acid, Enzyme, Amino acid + Enzyme)

$(AB)_{ij}$ = interaction effect of cassava varieties and additives

E_{ij} = random residual error

RESULTS

The chemical composition of white cassava (WCRM) and yellow cassava root meal (YCRM) (average of four determinations) as shown in Table 1 revealed that the dry matter content of the two cassava varieties used in this study differed, with values of 90.42% and 91.33% for WCRM and YCRM, respectively. White cassava root meal recorded higher values for crude fat and crude fibre content while 3.56% crude protein in YCRM was higher than 2.20% crude protein recorded for WCRM. The ash and β-carotene content (2.90% and 349.01 μg/100 g, respectively) obtained for YCRM were higher than the values obtained for ash and β-carotene content in WCRM. The NFE value recorded for WCRM (83.77%) was higher than 82.98% NFE recorded for YCRM. White cassava root meal showed higher values for NDF (26.59%), ADF (15.58%) and ADL (3.37%). It also had 2.66 mg/kg HCN content while the HCN content of YCRM was 2.54 mg/kg. Values of the minerals Ca, P, Cu, Mg, and Mn measured in YCRM were 3.55, 0.80, 0.28, 0.40, and 0.140, respectively, which were higher than the mineral contents recorded in WCRM except for the value of Zn which was the same as that obtained in YCRM. The gross energy value obtained for WCRM (3537.10 kcal/kg) was higher than the gross energy recorded for YCRM.

Main Effect of Cassava Varieties and Additives on Nutrient Digestibility of Starter and Finisher Broilers

The result of the main effects of cassava varieties and additives on nutrient digestibility of starter and finisher broilers as shown in Table 3 revealed that the two cassava varieties had no significant ($p>0.05$) effect on dry matter digestibility (DMD), crude protein retention (CPR), ether extract digestibility (EED), crude fibre digestibility (CFD), ash digestibility (ASHD), and nitrogen free extract digestibility (NFED) of the starter broilers. The various additives also had no significant ($p>0.05$) effect on dry matter digestibility (DMD), crude protein retention (CPR), ether extract digestibility (EED), crude fibre digestibility (CFD), ash digestibility (ASHD), and nitrogen free extract digestibility (NFED) of the broilers at the starter phase.

The result of main effects of cassava varieties and additives on nutrient digestibility of finisher broilers showed that birds fed white cassava variety had higher ($p<0.05$) DMD (73.89%), CPR (78.71%), EED (67.96%), CFD (64.25%), ASHD (69.89%) and NFED (67.04%) values. Main effect of additives showed that finisher broilers fed cassava diets + amino acids + enzyme had the least values ($p<0.05$) for DMD, EED, CFD, ASHD and NFED (71.96%, 64.74%, 59.66%, 63.85% and 65.25%). DMD, EED and CFD values obtained for finisher broilers fed cassava diets with no additive, those fed cassava diets with amino acid, and those fed cassava diets with enzyme were not significantly different ($p>0.05$).

Interaction Effect of Cassava Varieties and Additives on Nutrient Digestibility of Starter and Finisher Broilers

The result of the interaction effects of cassava varieties and additives on nutrient digestibility of starter and finisher broilers

Table 3
Main effects of cassava varieties and additives on nutrient digestibility of starter and finisher broilers

Parameters (%)	Varieties				Additives					
	White	Yellow	SEM	P-value	Control	A.A	Enzyme	A.A + Enz	SEM	P-value
Starter Phase										
Dry matter digestibility	74.34	74.97	0.30	0.413	74.51	74.93	74.35	74.83	0.41	0.813
Crude protein digestibility	76.36	76.76	0.20	0.357	76.49	76.73	76.15	76.88	0.25	0.638
Ether extract digestibility	72.77	72.49	0.38	0.572	72.71	72.57	71.94	73.29	0.52	0.678
Crude fibre digestibility	58.22	61.01	1.35	0.218	58.59	60.17	60.50	59.19	1.92	0.543
Ash digestibility	71.38	73.23	1.11	0.511	70.59	73.69	72.67	72.26	1.46	0.711
Nitrogen free extract digestibility	66.23	66.71	0.19	0.543	66.28	66.68	66.36	66.56	0.26	0.588
Average feed intake/bird (g)	1367.50	1358.52	31.30	0.812	1278.79^{b}	1338.18^{b}	1460.07^{a}	1375.00^{ab}	35.99	0.020
Finisher Phase										
Dry matter digestibility	73.89^{a}	72.63^{b}	0.29	0.026	73.04^{b}	74.03^{a}	74.03^{a}	71.96^{c}	0.34	0.000
Crude protein digestibility	78.71^{a}	77.51^{b}	0.13	0.021	78.31^{a}	78.02^{b}	78.16^{ab}	77.94^{b}	0.27	0.024
Ether extract digestibility	67.96^{a}	65.86^{b}	0.46	0.031	67.28^{a}	67.66^{a}	67.96^{a}	64.74^{b}	0.59	0.001
Crude fibre digestibility	64.25^{a}	61.86^{b}	0.82	0.012	63.04^{a}	64.98^{a}	64.54^{a}	59.66^{b}	0.94	0.017
Ash digestibility	69.89^{a}	65.75^{b}	0.95	0.035	66.58^{b}	70.94^{a}	69.92^{a}	63.85^{c}	1.03	0.000
Nitrogen free extract digestibility	67.04^{a}	65.58^{b}	0.28	0.034	65.97^{b}	66.44^{b}	67.59^{a}	65.25^{c}	0.35	0.000
Average feed Intake/bird (g)	3180.06	3124.23	33.87	0.250	3217.62	3081.58	3167.33	3142.05	46.75	0.263

Note. All values within rows having the same or no superscripts are not significantly different ($p>0.05$)
A.A = Amino acids (Methionine and Lysine), Enzyme = Cellulase, A.A + Enz = (Methionine and Lysine + Cellulase)

is shown in Table 4. Starter broilers fed yellow cassava diet with amino acids + enzyme, recorded higher ($p<0.05$) values for DMD, CPR, EED, CFD, ASHD, and NFED (76.31%, 77.82%, 74.40%, 65.85%, 77.42% and 67.52% in that order) while starter broilers fed white cassava diet with amino acids + enzyme had lower values except for EED.

The result of the interaction effects of cassava varieties and additives on nutrient digestibility of finisher broilers revealed that finisher broilers fed yellow cassava diet with amino acids + enzyme had lower values ($p<0.05$) of DMD, CPR, EED, ASHD, CFD, and NFED. Finisher broilers fed white cassava supplemented with amino acids had higher values ($p<0.05$) of DMD (74.73%), EED (69.09%) and ASHD (73.14%) while finisher broilers fed white cassava with no additive had higher ($p<0.05$) CPR (78.88%) value. NFED (68.77%) value was highest ($p<0.05$) for birds fed white cassava diets with enzyme.

Main Effect of Cassava Varieties and Additives on Metabolizable Energy of Starter and Finisher Broilers

The result of main effects of cassava varieties and additives on the metabolizable energy of starter and finisher broilers is presented in Table 5. The result showed that birds that were fed with white cassava root meal at the starter phase had higher ($p<0.05$) AME, AMEn, TME, and TMEn (13.11 MJ/kg, 11.67 MJ/kg, 13.22 MJ/kg and 11.78 MJ/kg respectively) values than the birds that were fed the yellow variety. The Starter broilers fed cassava diets with enzyme recorded highest ($p<0.05$) values for AME (13.69 MJ/kg), AMEn (12.24 MJ/kg), TME (13.80 MJ/kg), and TMEn (12.35 MJ/kg) while the other birds fed cassava diets with other additives had lower values of AME, AMEn, TME, and TMEn.

The result of main effects of cassava varieties and additives on the metabolizable energy of finisher broilers showed that no significant ($p>0.05$) effect was observed with the use of white and yellow cassava root meals on AME, AMEn, TME, and TMEn values for the birds. Finisher broilers fed cassava diets with amino acids recorded the highest ($p<0.05$) values for AME (13.64 MJ/kg), AMEn (12.57 MJ/kg), TME (13.75 MJ/kg), and TMEn (12.68 MJ/kg) while birds fed cassava diets with amino acids + enzyme had the least AME, AMEn, TME, and TMEn values.

Interaction Effect of Cassava Varieties and Additives on Metabolizable Energy of Starter and Finisher Broilers

The result of the interaction effects of cassava varieties and additives on the metabolizable energy of starter and finisher broilers is shown in Table 6. At the starter phase, birds fed white cassava with enzyme recorded highest ($p<0.05$) values for AME, AMEn, TME, and TMEn (14.72 MJ/kg, 13.28 MJ/kg, 14.83 MJ/kg and 13.38 MJ/kg respectively), while lowest values of AME, AMEn, TME, and TMEn were recorded with birds fed yellow cassava with no additive.

Table 4
Interaction effects of cassava varieties and additives on nutrient digestibility of starter and finisher broilers

Parameters (%)	White cassava				Yellow cassava					
	Control	A.A	Enzyme	A.A + Enz	Control	A.A	Enzyme	A.A + Enz	SEM	P-value
Starter Phase										
Dry matter digestibility	74.46^{bc}	75.26^{ab}	74.27^{bc}	73.34^{c}	74.56^{bc}	74.59^{bc}	74.43^{bc}	76.31^{a}	0.22	0.043
Crude protein digestibility	76.47^{bc}	76.95^{ab}	76.10^{bc}	75.93^{c}	76.50^{bc}	76.50^{bc}	76.20^{bc}	77.82^{a}	0.15	0.044
Ether extract digestibility	73.19^{ab}	73.22^{ab}	72.49^{ab}	72.17^{ab}	72.23^{ab}	71.92^{b}	71.39^{b}	74.40^{a}	0.27	0.019
Crude fibre digestibility	59.92^{ab}	60.18^{ab}	60.25^{ab}	52.53^{c}	57.26^{bc}	60.16^{ab}	60.76^{ab}	65.85^{a}	0.98	0.038
Ash digestibility	70.12^{cd}	75.84^{ab}	72.44^{abcd}	67.10^{d}	71.06^{bcd}	71.53^{bcd}	72.90^{abc}	77.42^{a}	0.79	0.048
Nitrogen free extract digestibility	66.19^{bc}	66.83^{ab}	66.31^{bc}	65.60^{c}	66.36^{bc}	66.52^{bc}	66.41^{bc}	67.52^{a}	0.14	0.043
Average feed Intake/bird (g)	1302.73^{bc}	1405.15^{ab}	1463.47^{a}	1298.64^{bc}	1254.85^{c}	1271.21^{bc}	1456.67^{a}	1451.36^{a}	21.80	0.009
Finisher Phase										
Dry matter digestibility	73.70^{bc}	74.73^{a}	74.33^{ab}	72.82^{cd}	73.38^{d}	73.34^{c}	73.74^{bc}	71.09^{e}	0.24	0.032
Crude protein digestibility	78.88^{a}	78.76^{ab}	78.62^{b}	78.57^{b}	77.75^{c}	77.28^{d}	77.70^{c}	77.31^{d}	0.13	0.001
Ether extract digestibility	67.89^{abc}	69.09^{a}	68.46^{ab}	66.38^{c}	66.66^{bc}	66.22^{c}	67.45^{abc}	63.09^{d}	0.40	0.041
Crude fibre digestibility	63.85^{a}	65.45^{a}	65.83^{a}	61.85^{a}	62.22^{a}	64.51^{a}	63.26^{a}	57.46^{b}	0.63	0.000
Ash digestibility	69.82^{b}	73.14^{a}	70.77^{ab}	65.87^{c}	63.33^{d}	68.75^{b}	69.07^{b}	61.83^{d}	0.79	0.015
Nitrogen free extract digestibility	66.48^{bc}	66.88^{b}	68.77^{a}	66.04^{c}	65.47^{d}	65.99^{cd}	66.41^{bc}	64.47^{e}	0.25	0.003
Average feed Intake/bird (g)	3195.64	3143.33	3232.33	3148.94	3239.61	3019.82	3102.33	3135.15	24.46	0.395

^{a,b,c,d} means with the same superscripts along the rows are not significantly different ($p<0.05$)
A.A = Amino acids (Methionine and Lysine), Enzyme = Cellulase, A.A + Enz = (Methionine and Lysine + Cellulase)

Table 5
Main effects of cassava varieties and additives on the metabolizable energy of starter and finisher broilers

Parameters (MJ/Kg)	Varieties				Additives					
	White	Yellow	SEM	P-value	Control	A.A	Enzyme	A.A + Enz	SEM	P-value
Starter Phase										
AME	13.11^{a}	12.56^{b}	0.16	0.033	12.52^{b}	12.55^{b}	13.69^{a}	12.58^{b}	0.14	0.000
AME_n	11.67^{a}	11.11^{b}	0.16	0.025	11.07^{b}	13.11^{b}	12.24^{a}	11.13^{b}	0.14	0.000
TME	13.22^{a}	12.67^{b}	0.16	0.019	12.63^{b}	12.67^{b}	13.80^{a}	12.69^{b}	0.14	0.000
TME_n	11.78^{a}	11.22^{b}	0.16	0.021	11.18^{b}	11.22^{b}	12.35^{a}	11.25^{b}	0.14	0.000
Finisher Phase										
AME	13.56	13.55	0.02	0.185	13.55^{b}	13.64^{a}	13.56^{b}	13.48^{c}	0.01	0.000
AMEn	12.46	12.47	0.02	0.319	12.46^{b}	12.57^{a}	12.45^{b}	12.38^{c}	0.02	0.000
TME	13.67	13.66	0.02	0.526	13.66^{b}	13.75^{a}	13.67^{b}	13.59^{c}	0.01	0.000
TMEn	12.57	12.58	0.02	0.811	12.57^{b}	12.68^{a}	12.57^{b}	12.49^{c}	0.02	0.000

^{a,b} means with the same superscripts along the rows are not significantly different ($p<0.05$)
AME = Apparent Metabolizable Energy; AME_n = Apparent Metabolizable Energy corrected for Nitrogen Retention; TME = True Metabolizable Energy; TME_n= True Metabolizable Energy corrected for Nitrogen Retention

Table 6
Interaction effects of cassava varieties and additives on the metabolizable energy of starter and finisher broilers

Parameters (MJ/Kg)	WCRM				YCRM					
	Control	A.A	Enzyme	A.A + Enz	Control	A.A	Enzyme	A.A + Enz	SEM	P-value
Starter Phase										
AME	12.67^{b}	12.49^{e}	14.72^{a}	12.57^{d}	12.36^{f}	12.62^{c}	12.66^{bc}	12.58^{d}	0.15	0.024
AME_n	11.22^{b}	11.05^{e}	13.28^{a}	11.12^{d}	10.92^{f}	11.17^{c}	11.21^{b}	11.14^{cd}	0.15	0.026
TME	12.78^{b}	12.60^{e}	14.83^{a}	12.68^{d}	12.47^{f}	12.74^{c}	12.78^{b}	12.70^{d}	0.15	0.013
TME_n	11.33^{b}	11.16^{e}	13.38^{a}	11.23^{d}	11.03^{f}	11.28^{c}	11.32^{b}	11.26^{cd}	0.15	0.018
Finisher Phase										
AME	13.54^{c}	13.69^{a}	13.54^{c}	13.47^{e}	13.55^{c}	13.59^{b}	13.58^{b}	13.49^{d}	0.01	0.001
AMEn	12.44^{d}	12.62^{a}	12.43^{de}	12.35^{f}	12.48^{c}	12.51^{b}	12.48^{b}	12.41^{e}	0.02	0.001
TME	13.65^{d}	13.80^{a}	13.66^{cd}	13.57^{f}	13.66^{cd}	13.70^{b}	13.69^{bc}	13.60^{e}	0.01	0.003
TMEn	12.56^{d}	12.73^{a}	12.55^{d}	12.46^{f}	12.59^{c}	12.62^{b}	12.59^{c}	12.51^{e}	0.02	0.000

^{a,b,c,d,e,f} means with the same superscripts along the rows are not significantly different ($p<0.05$)
AME = Apparent Metabolizable Energy; AME_n = Apparent Metabolizable Energy corrected for Nitrogen Retention; TME = True Metabolizable Energy; TME_n= True Metabolizable Energy corrected for Nitrogen Retention

Finisher broilers fed white cassava with amino acid recorded the highest ($p<0.05$) values for AME, AMEn, TME, and TMEn while finisher broilers fed white cassava with amino acids + enzyme had the least AME, AMEn, TME, and TMEn values (13.49 MJ/kg, 12.41 MJ/kg, 13.60 MJ/kg, and 12.51 MJ/kg respectively).

Main Effect of Cassava Varieties and Additives on Carcass Yield and Cut Parts of Broilers

Table 7 shows the result of main effects of cassava varieties and additives on the carcass yield and cut parts of broilers. It was observed that white and yellow varieties of cassava had no significant ($p>0.05$) effect on live weight, plucked weight, eviscerated weight, dressed weight, dressed percentage, breast, back, drumstick, thigh, neck, wings, head and shanks of the birds across the treatments. The main effect of additive was also not significant ($p>0.05$) on live weight, plucked weight, eviscerated weight, dressed weight, dressed percentage, breast, back, drumstick, thigh, neck, wings, head, and shanks of the experimental birds.

Interaction Effect of Cassava Varieties and Additives on Carcass Yield and Cut Parts of Broilers

The result of the interaction effects of cassava varieties and additives on the carcass yield and cut parts of broilers (8 weeks) are as presented in Table 8. The interaction between cassava variety and inclusion of additives were not significant ($p>0.05$) for plucked weight, eviscerated weight, dressed weight, dressed percentage, breast, back, drumstick, thigh, neck, wings, and shanks of the birds. Broilers fed white cassava diet with amino acids had higher ($p<0.05$) live weight value (1946.33g) while the broilers fed white cassava with no additive recorded lower live weight value (1878.33g).

DISCUSSION

Main Effect of Cassava Varieties and Additives on Nutrient Digestibility and Metabolizable Energy of Starter and Finisher Broilers

Yellow cassava varieties investigated in this study showed poor nutrient digestibilities when compared to the white variety. This implies that it did not contribute any digestible benefit to the birds. The findings on the main effect of additives showed that dietary supplementation with either amino acids or enzyme significantly improved nutrient digestibility at the finisher phase. Amino acid supplementation in turkeys has been reported by Oso et al. (2017) to improve nutrient digestibility. Amino acids added make-up for the shortages of Sulphur amino acids depleted during thiocyanate detoxification. Enzyme supplementation has been reported to break down fibrous component in cassava thereby improving its digestibility (Belewu & Banjo, 1999).

White cassava variety recorded higher metabolizable energy values when compared with the yellow variety at the starter phase. The fact that there was no difference in the metabolizable energy values of finishing broilers fed either white or yellow cassava implied that both yielded similar energy values.

Table 7
Main effects of cassava varieties and additives on the carcass yield and cut parts of broilers (8 weeks)

Parameters	Varieties				Additives					
	White	Yellow	SEM	P-value	Control	A.A	Enzyme	A.A + Enz	SEM	P-value
Live weight (g)	1923.84	1906.42	36.16	0.170	1889.50	1921.33	1930.17	1919.50	50.30	0.061
Plucked weight (g)	1798.65	1798.00	39.46	0.251	1780.24	1800.38	1809.21	1803.49	55.70	0.058
Eviscerated weight (g)	1554.42	1562.21	33.86	0.091	1544.26	1567.24	1555.99	1565.77	50.60	0.112
Dressed weight (g)	1190.78	1217.91	27.27	0.359	1197.60	1199.23	1217.25	1203.3	41.30	0.073
Dressed %	64.99	67.25	1.02	0.600	66.51	65.78	66.39	65.81	1.56	0.253
Cut Parts										
(% live weight)										
Breast	17.33	18.19	0.48	0.580	18.23	17.64	17.38	17.79	0.69	0.395
Back	13.90	14.11	0.47	0.701	14.24	13.62	14.38	13.77	0.69	0.721
Drumstick	9.50	10.00	0.22	0.630	9.47	10.09	9.76	9.66	0.33	0.819
Thigh	10.02	10.20	0.27	0.419	10.10	9.81	10.38	10.14	0.35	0.703
Neck	3.81	3.59	0.10	0.725	3.61	3.88	3.52	3.79	0.14	0.634
Wings	7.50	7.83	0.14	0.182	7.74	7.72	7.65	7.55	0.21	0.659
Head	2.50	2.52	0.08	0.360	2.41	2.57	2.66	2.38	0.10	0.710
Shank	4.21	4.36	0.17	0.714	3.99	4.52	4.62	4.01	0.21	0.439

Table 8
Interaction effects of cassava varieties and additives on the carcass yield and cut parts of broilers (8 weeks)

Parameters	WCRM				YCRM					
	Control	A.A	Enzyme	A.A + Enz	Control	A.A	Enzyme	A.A + Enz	SEM	P-value
Live weight (g)	1900.67^{c}	1946.33^{a}	1936.67^{ab}	1911.67^{abc}	1878.33^{abc}	1896.33^{bc}	1923.67^{bc}	1927.33^{ab}	26.10	0.000
Plucked weight (g)	1785.90	1801.08	1818.43	1789.19	1774.57	1799.68	1799.18	1817.78	27.50	0.072
Eviscerated weight(g)	1548.90	1588.04	1535.00	1545.78	1539.66	1546.43	1576.98	1585.76	24.80	0.601
Dressed weight(g)	1178.60	1166.59	1187.37	1230.54	1216.59	1231.86	1247.12	1176.06	20.00	0.781
Dressed %	64.94	63.35	64.54	67.65	68.08	68.22	68.24	64.45	0.74	0.912
Cut Parts										
(% live weight)										
Breast	17.48	17.03	16.47	18.36	18.98	18.26	18.28	17.21	0.34	0.548
Back	14.18	12.62	14.22	14.57	14.30	14.61	14.54	12.96	0.33	0.587
Drumstick	9.03	9.95	9.63	9.37	9.91	10.23	9.90	9.96	0.17	0.631
Thigh	9.96	9.73	9.84	10.55	10.24	9.89	10.93	9.72	0.19	0.712
Neck	3.81	3.89	3.52	4.03	3.41	3.87	3.51	3.55	0.07	0.635
Wings	7.55	7.34	7.62	7.49	7.93	8.10	7.67	7.62	0.10	0.583
Head	2.29^{b}	2.61^{ab}	2.83^{a}	2.27^{b}	2.53^{ab}	2.53^{ab}	2.50^{ab}	2.50^{ab}	0.05	0.023
Shank	4.06	4.30	4.63	3.85	3.91	4.73	4.62	4.18	0.12	0.659

^{a,b,c} means with the same superscripts along the rows are not significantly different ($p<0.05$)

Interaction Effect of Cassava Varieties and Additives on Nutrient Digestibility and Metabolizable Energy of Starter and Finisher Broilers

Starting broilers fed diet containing yellow cassava root meal (YCRM) supplemented with A.A + Enz recorded improved nutrient digestibility. Obviously, the amino acid supplementation and enzyme inclusion would have improved utilization of protein at this stage. The improvement could also be attributed to cassava variety used. Yellow cassava root meal has lower fibre content that could lead to improved digestibility and nutrient utilization compared to white variety of cassava (Isikwenu et al., 2000). In comparison with white cassava variety, yellow cassava contains higher quantity of β-carotene which may be indicative of its higher potential antioxidant roles, enhanced immune system (Navara & Hills, 2003) and reduced risk of degenerative diseases (Cooper et al., 1999). All these can also contribute to improved nutrient digestibility of the yellow cassava variety. At the finishing phase, the broilers fed white cassava root meal (WCRM) supplemented with amino acids recorded better digestibility of dry matter, fat, ash and crude fibre. Supplementing the diet with amino acids could have improved the normal functioning of the digestive system of the birds thereby enhancing improved nutrient utilization. The superiority of YCRM at the starting phase was not sustained at the finishing phase because the younger birds at the starting phase required better mix of nutrient reported to be present in YCRM, whereas at the finishing phase, the need for this nutrient would have reduced. Coupled with the stronger digestive system of the birds at the finishing phase, addition of amino acids to white cassava would have improved the digestibility and absorption of white cassava at this phase. Oso et al. (2017) hinted that amino acids supplementation improved nutrient digestibility and absorption in grower and finisher turkeys.

Improved metabolizable energy values of starter broilers fed WCRM diet supplemented with enzyme when compared with other treatments could be due to higher energy [Gross energy (GE)] content of white cassava variety and exogenous enzyme added. White cassava root meal in this study has been assayed to have more energy (GE) than YCRM. With appropriate enzyme supplementation of WCRM, more energy is released when compared to YCRM. Cellulase enzymes used in this study has been reported to degrade the fibre component of cassava product, thereby making more energy available to monogastric (Belewu & Banjo, 1999; Raji & Okeniyi, 1998). Previous studies also confirmed significant improvements in energy metabolizability of feed ingredient following enzyme supplementation (Adeola & Bedford, 2004; Meng & Slominski, 2005; Slominski, 2011).

Supplementation of WCRM with amino acids only at the finisher phase, resulted in improved metabolizable energy values as opposed to starter broilers which needed enzyme supplementation of WCRM to elicit best energy metabolizability. As the birds grew older, their gastro-intestinal tract (GIT) became more mature to handle fibrous components of the feed which the starting birds could not handle because of their immature digestive system. Improved metabolizable energy values of WCRM following limiting amino acid supplementation at the finishing phase could also be due to the high energy (GE) content of WCRM and amino acid supplementation which made up for the shortage of protein content and poor amino acid profile in cassava. The mechanism through which limiting amino acid supplementation improves energy metabolizability could be attributed to some biochemical reactions which occurred during cassava processing. Cyanide contained in cassava root is converted to a less toxic thiocyanate during processing using the enzyme rhodnase. This biochemical conversion to thiocyanate utilizes the constituent sulphur containing amino acid as sulfur donor (Cardoso et al., 2005) thus making sulphur amino acid to be grossly deficient in cassava-based diets. Hence, supplemental amino acid used in this study greatly made allowance for the shortage that would have been created, thereby harnessing the rich energy potential of WCRM maximally. Improved energy metabolizability of cassava root meal for meat-type cockerels had also been reported by Oso et al. (2015) following amino acid supplementation and solid-state fermentation.

Main and Interaction Effects of Cassava Varieties and Additives on The Carcass Yield and Cut Parts of Broilers

According to Adeyemi et al. (2008) and Agunbiade et al. (2002), the breast meat, drumstick and thigh are the most expensive commercial cuts of the chicken, which give a picture of the carcass meatiness and eventually revenue yield. Cassava varieties and additives used in this study showed no influence on plucked weight, eviscerated weight, dressed weight, dressed percentage, breast, back, drumstick, thigh and wings of the birds. This is at variance with the report that dressed weight, thigh and drumstick weight were influenced by dietary treatments (Adeyemi et al., 2012) but agrees with the observations of Eruvbetine et al. (2003) and George and Sese (2012) that dietary treatments had no influence on carcass quality characteristics. Rahmatnejad et al. (2011) reported that addition of commercial multi-enzyme did not improve dressed percentage, yield of breast, thigh and wing components.

The insignificant effect of diets on heart, kidney, spleen, bile, whole gizzard, empty gizzard, and whole intestine values of the broilers across the dietary treatments indicated that there were no abnormalities or pathological lesions in these organs. This aligns with the report of Omojola and Adesehinwa (2007) that the inclusion of exogenous enzyme in broilers fed cassava meal diets showed no effect on the relative weights of kidney, gizzard and heart. The use of protein concentrates with a good balance of amino acids in broiler diets containing cassava meal showed no significant effect on the weights of the internal organs like liver, kidney, heart and spleen (Adeyemi et al., 2012).

CONCLUSION

It was concluded from this study that WCRM favoured improved nutrient utilization and digestibility than YCRM. Further supplementation of YCRM with both amino acids + enzyme at starter phase and WCRM with amino acids at finisher phase improved nutrient digestibility of broilers. Amino acid supplementation of cassava diets (WCRM, YCRM) augmented the constituent poor amino acid profile in cassava root and hence improved the nutrient utilization and digestibility. Meanwhile, for optimal utilization of YCRM, both amino acids and enzyme need to be supplemented. Enzyme and amino acid supplementation of WCRM at the starter and finisher phases respectively of broilers resulted in improved metabolizable energy values than in YCRM. Supplementing diet containing WCRM with enzyme assisted in the breakdown of the constituent fibre, increased available energy, thus yielding improved energy metabolizability. Supplementing diet containing WCRM with amino acid made allowance for the shortage of protein content and poor amino acid profile in cassava and harnessed the rich energy potential of WCRM maximally. This resulted in improved metabolizable energy values.

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REFERENCES

Abdulrashid, M., Agwuobi, L. N., Jokthan, G. E., & Abdul, S. B. (2007). Carcass quality characteristics of broiler finisher fed taro (*Colocasia esculanta*) cocoyam meal. In *Proceedings of 32nd Annual Conference of Nigerian Society for Animal Production* (pp. 457-460). Calabar, Nigeria: University of Calabar.

Adeola, O., & Bredford, M. R. (2004). Exogenous dietary xylanase ameliorates viscosity-induced anti-nutritional effects in wheat-based diets for White Pekin ducks (*Anas platyrinchos domesticus*). *British Journal of Nutrition*, *92*(1), 87-94.

Aderemi, F. A, Adenowo, T. K., & Oguntunji, A. O. (2012). Effect of whole cassava meal on performance and egg quality characteristics of layers. *Nigerian Journal of Animal Science*, *5*(2), 95-200.

Adeyemi, O. A., Adekoya, J. A., & Sobayo, R. A. (2012). Performance of broiler chickens fed diets containing cassava leaf blood meal mix as replacement for soybean meal. *Revista Científica UDO Agrícola*, *12*(1), 213-220.

Adeyemi, O. A., Eruvbetine, D., Oguntona, T. O., Dipeolu, M. A., & Agunbiade, J. A. (2008). Feeding broiler chickens with diet containing whole cassava root meal fermented with rumen filtrate. *Archives Zootecnia*, *57*(218), 247-258.

Agunbiade, J. A., Adeyemi, O. A., Adepoju, O. A., & Lawal, O. A. (2002). The use of whole cassava meal and leaf meal in broiler diets. *Nigerian Journal of Animal Science*, *5*(1), 161-173.

Akapo, A. O., Oso, A. O., Bamgbose, A. M., Sanwo, K. A., Jegede, A. V., Sobayo, R. A., … Olorunsola, R. A. (2014). Effects of feeding cassava (*Manihot esculenta* Crantz) root meal on growth performance, hydrocyanide intake and haematological parameters of broiler chicks. *Journal of Tropical Animal Health Production*, *46*(7), 1167–1172.

Association of Official Analytical Chemists. (1997). *Official methods of analysis* (16th ed.). Rockville, USA: AOAC International.

Association of Official Analytical Chemists. (2000). *Official methods of analysis* (17th ed.). Rockville, USA: AOAC International.

Banea-Mayambu, J. P., Tylleskar, T., Gitebo, N., Matadi, N., Gebre-Medhin, M., & Rosling, H. (1997). Geographical and seasonal association between linamarin and cyanide exposure from cassava and the upper motor neuron disease konzo in former Zaire. *Tropical Medicine and International Health*, *2*(12), 1143–1151.

Belewu, G. I., & Banjo, N. O. (1999). Biodegradation of rice husk and sorghum stover by edible mushroom (*Pleurotus sajo-caju*). *Tropical Journal Animal Science*, *2*, 137-142.

Bradbury, J. H., Egan, S. V., & Lynch, M. J. (1991). Analysis of cyanide in cassava using acid hydrolysis of cyanogenic glucosides. *Journal of Science, Food and Agriculture*, *55*(2), 277-290.

Cardoso, A. P., Estevao, M., Mario, E., Fernando, M., Julie, C., Haque, M. R., & Bradbury, J. H. (2005). Processing of cassava roots to remove cyanogens. *Journal of Food Composition and Analysis*, *18*(5), 451-460.

Cooper, D. A., Eldridge, A. L., & Peters, J. C. (1999). Dietary carotenoids and certain cancers, heart disease, and age-related macular degeneration: A review of recent research. *Nutrition Reviews*, *57*(7), 201-214. doi: 10.1111/j.1753-4887.1999.tb06944.x

Duncan, D. B. (1955). Multiple range and multiple F tests. *Biometrics*, *11*(1), 1–42.

El-Sharkawy, M. (2012). Stress-tolerant cassava: The role of integrative ecophysiology-breeding research in crop improvement. *Journal of Soil Science*, *2*(2), 162-186.

Eruvbetine, D., Tajudeen, I. D., Adeosun, A. T., & Olojede, A. A. (2003). Cassava (*Manihot esculenta*) leaf and tuber concentrate in diets for broiler chickens. *Bioresource Technology*, *86*(3), 277–281.

George, O. S., & Sese, B. T. (2012). The effects of whole cassava meal on broiler carcass weight and the optimal inclusion rate of whole cassava meal in broiler production. *Advances in Agriculture, Science and Engineering Research*, *2*(6), 184-189.

Horwitz, W. (Ed.). (2005). *Official methods of analysis* (17^{th} ed.). Rockville, USA: Association of Official Analytical Chemists.

Isikwenu, J. O., Akpodiete, O. J., Emegha, I. O., & Bratter, L. (2000). Effects of dietary fibre (maize cob) levels on growth performance of broiler. In S. N. Ukachukwu (Ed.), *Proceedings of the 25th Annual Conference of Nigerian Society for Animal Production* (p. 278). Umudike, Nigeria: Michael Okpara University of Agriculture.

Kayode, R. M. (2009). *Suitability of mango (*Mangifera indica*) fermented kernel as animal feed supplement* (Unpublished Doctoral thesis), University of Ilorin, Nigeria.

Khajarern, S., & Khajarern, J. (2007). *Use of cassava products in poultry feeding*. Retrieved October 6, 2017, from the FAO Corporate Document Repository website: http://www.fao.org/DOCREP/003/T0554E/T0554E10.htm

Kyawt, Y., Toyama, H., Htwe, W., Thaikua, S., Imura, Y., & Kawamoto, Y. (2015). Effect of whole cassava meal as substitutes for maize in the diet on the performance characteristics and egg quality of laying eggs. *Journal of Warm Regional Society of Animal Science*, *58*(1), 19-28.

Meng, X., & Slominski, B. A. (2005). Nutritive values of corn, soybean meal, canola meal, and peas for broiler chickens as affected by a multicarbohydrase preparation of cell wall degrading enzymes. *Poultry Science*, *84*(8), 1242-1251.

Navara, K. J., & Hills, G. E. (2003). Dietary carotenoid pigments and immune function in a song bird with extensive carotenoid-based plumage coloration. *Behavioral Ecology*, *14*(6), 909-916.

Ngiki, Y. U., Igwebuike, J. U., & Moruppa, S. M. (2014). Utilization of cassava products for poultry feeding: A review. *International Journal of Science and Technology*, *2*(6), 48-59.

Ogun-Oshun River Basin Development Authority. (2016). *Means of agrometeorological observation*. Abeokuta, Nigeria: Ogun-Oshun River Basin Development Authority.

Omojola, A. B., & Adesehinwa, A. O. K. (2007). Performance and carcass characteristics of broiler chickens fed diets supplemented with graded levels of Roxazyme-G®. *International Journal of Poultry Science*, *6*(5), 335-339.

Omole, T. A. (1977). Cassava in the nutrition of layers. In B. Nestel & M. Graham (Eds.), *Proceedings of Cassava as Animal Feed Workshop* (pp. 51-55). Ottawa, Canada: International Development Research Center.

Oso, A. O., Akapo O., Sanwo K. A., & Bamgbose A. M. (2014). Utilization of unpeeled cassava (*Manihot esculenta* Crantz) root meal supplemented with or without charcoal by broiler chickens. *Journal of Animal Physiology and Animal Nutrition*, *98*(3), 431-438.

Oso, A. O., Li, L., Zhang, B., Uo, R., Fan, J. X., Wang, S., … Bamgbose, A. M. (2015). Effect of fungal fermentation with *Aspergillus niger* and enzyme supplementation on metabolizable energy values of unpeeled cassava root meal for meat-type cockerels. *Animal Feed Science and Technology*, *210*, 281-286.

Oso, A. O., Oso, O. A., Bamgbose, A. M., & Eruvbetine, D. (2010). Utilization of unpeeled cassava (*Manihotes culenta*) root meal in diets of weaner rabbits. *Livestock Production Science*, *127*(2-3), 192–196.

Oso, A. O., Williams, G. A., Oluwatosin, O. O., Bamgbose, A. M., Adebayo, A. O., Olowofeso, O., … Xin, W. (2017). Growth performance, nutrient digestibility, metabolizable energy, and intestinal morphology of growing turkeys fed diet supplemented with arginine. *Livestock Science*, *198*, 24–30.

Rahmatnejad, E., Pour, M. B., Mamuei, M., Mirzadeh, K., & Perai, A. H. (2011). The effects of dried tomato pomace and a multiple enzyme mixture supplementation (Rovabio Excel™) on performance and carcass quality of broiler chickens. *African Journal of Biotechnology*, *10*(45), 9207-9212.

Raji, A. I., & Okeniyi, S. O. (1998). Optimization of cellulase enzyme production from *Aspergillus fumigatus*-CSS36. *Spectrum Journal*, *5*, 164-168.

Sibbald, I. R. (1980). Metabolizable energy in poultry nutrition. *BioScience*, *30*(11), 736-741.

Slominski, B. A. (2011). Recent advances in research on enzymes for poultry diets. *Poultry Science*, *90*(9), 2013-2023. doi: 10.3382/ps.2011-01372

Statistical Analysis System Institute. (1999). *SAS user's guide statistics: Version 6.03 edition*. Cary, USA: SAS Institute Inc.

Van Soest, P. J., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, *74*(10), 3583-3597.