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Performance and Tibia Characteristics of Chickens Fed Cassava Chips Supplemented with Dl-Methionine

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ADO, OAO and.GOA designed the study. Authors SE and AD carried out the feeding trial. Authors SE and AD carried out the laboratory analyses. Authors ADO, OAO and GOA supervised the work. Author IOA handled the literatures and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study was carried out to investigate the effect of cassava chips and DL-methionine supplementation on performance and tibia bone characteristics of broiler chickens. Broiler chickens were randomly assigned to 20 treatments in a 4x5 factorial arrangement with 5 dietary levels of cassava chips (0, 25, 50, 75 and 100 corn replacement) and 4 dietary levels of DL-methionine supplementation (0, 0.05, 0.1 and 0.2% i.e. 0, ½ NRC, NRC and double NRC 1994 recommended levels). Data obtained were subjected to analysis of variance. At starter phase, birds on cassava chips-based diets had significantly ($P<0.05$) higher body weight gain (BWG) than the control.

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Those on 25% cassava chip-based diet compared well with the control. Methionine supplement improved BWG at both starter and finisher phases. Cassava chips supplemented with DL-methionine can replace corn 100.00% in broiler chickens diet.

Keywords: Broiler chickens; cassava-chips; DL-methionine; performance; tibia bone.

1. INTRODUCTION

The keen competition between human beings, industries and livestock for cereal grains [1] has brought about the need to replace considerably the use of cereal grains with energy sources that are cheap, available all-round the year and well distributed naturally across the country in livestock feed [2,3]. Cassava is a potential non-conventional energy source capable of overcoming this challenge. Nigeria has been described as the leading producer of cassava [4].

Previous studies had reported the replacement of corn with cassava chips [1,5]. However, Garcia and Dale [6] suggested that cassava diet for poultry should be complemented with appropriate proportion of soybean meal or fish meal. Avian species require methionine for several functions such as feather growth and protein synthesis. Cassava is high in cyanide which limits its use in livestock feeding. It had been observed that methionine could play significant role in detoxifying the residual HCN in cassava [7]. Previous studies by Ologhobo et al. [8] and Adeniji et al. [9] revealed that methionine and formic acid improved gut morphology and body weight gain of broiler chickens.

Feed cost presently makes about 70% of the total cost of production of animal products in developing countries, which necessitates the need for feed management to broiler producers, making it necessary to reduce the cost of feeds in order to have cheaper products without affecting profits. Energy source constitutes about 50% of finished feeds for monogastric animals. However, the use of unconventional feed resources in poultry nutrition is one of the ways to overcome the feed crisis in the poultry industry. Alternative feed sources have proved valuable in supporting the performance of livestock and poultry at low cost of production [10].

Cassava is relatively very available in large quantity in Nigeria and it has been investigated to serve as alternative main energy source in broiler feedstuffs [11,12]. However, the problem of hydrocyanic acid present in cassava has limited its use as feed ingredient for monogastric animals. Several processing methods have been used to ameliorate the effect of hydrocyanic acid in cassava products, which include like sun drying, fermentation, cooking, addition of palm oil and feeding of high protein supplements and/or amino acids like Methionine and Lysine [11,13]. Methionine has been observed to be involved in cassava detoxification [14]. Cyanide is detoxified to thiocyanate by the enzyme rhodanase making use of Methionine as the sulphur donor which makes this amino acid a limiting factor in cassava based-feeds. Du Thanh Hang et al. [15] reported an improvement in the production performance of pigs when diets containing 20% fresh cassava leaves (DM basis) supplemented with 0.2% synthetic DL-methionine. This study was therefore carried out to investigate the effects of methionine on growth performance and tibia characteristics of broiler chickens fed cassava chips-based diets.

2. MATERIALS AND METHODS

The experiment was undertaken at the Poultry Unit, Farmers' Partners Farm in Ibadan as approved by the Department of Animal Science, University of Ibadan, Nigeria. Six hundred 1 d old Arbor acre broiler chicks with average weight of 49.00±1.00 g were used for the experiment. Brooding of birds was done at 32°C and Relative Humidity of 64.05%. This condition was maintained for the first week with a decreasing increment of 2.4°C for successive weeks. Birds were fed with fresh feed and drinking water *ad libitum*, while adequate vaccination programmes were administered. The feeding trial lasted for 56 d. Broiler chickens were randomly assigned to 20 treatments in a 4x5 factorial arrangement with 5 dietary levels of cassava chips (0, 25, 50, 75 and 100 corn replacement) and 4 dietary levels of DL-methionine supplementation (0, 0.05, 0.1 and 0.2% i.e. 0, ½ NRC, NRC and double NRC 1994 recommended levels) (Table 1). Weekly voluntary feed intake (FI) and body weight gain (BWG) were recorded while feed conversion (FCR) was calculated from FI and BWG. At the end of the study, tibias of selected birds were treated as described by Ogunwole [16]. The bone weight/length index was obtained for each group. Robusticity index was determined according to the procedure described by Adebiyi et al. [17]. Phosphorous and calcium were determined with atomic absorption spectrophotometer [18]. The percentage ash was determined relative to dry weight of tibia. Data obtained were analysed within the framework of linear model of analysis of variance procedure of SAS [19]. Differences among treatments means were analysed using Duncan's multiple range test.

3. RESULTS AND DISCUSSION

3.1 Performance Characteristics

Effect of graded levels of DL-methionine on performance of broiler chickens, effect of graded levels of cassava chips on performance of broiler chickens, interaction effect of graded levels of cassava chips and DL-methionine on performance of broiler chickens at the starter phase and interaction effect of graded levels of cassava chips and DL-methionine on performance of broiler chickens at the finisher phase are presented in Tables 2, 3, 4 and 5 respectively. The FI for experimental diets were statistically similar to the control (Table 2). Birds on 50% cassava chip supplemented diet (797.99±29.51 g), 75% cassava chip supplemented diet (645.49±23.55 g) and 100% cassava chip supplemented diet (638.19±29.07 g) had significantly ($P<0.05$) decreased BWG than the control (799.66±26.48 g) at the starter phase, while those on 25% cassava chip supplemented diet (753.49±23.55 g) are statistically similar to the control. The FCRs were significantly ($P<0.05$) higher for birds on 50% cassava chip supplemented diet (1.94±0.32), 75% cassava chip supplemented diet (2.14±0.46) and 100% cassava chip supplemented diet (2.13±0.33) than the control (1.69±0.19). Those on 25% cassava chip supplemented diet (1.79±0.15) were statistically similar to the control and 50% cassava chip supplemented diet. The BWG were lower for the experimental diets at the finisher phase. The FI was not significantly different across treatments. For FCR, only birds on 100% cassava chips (2.84±0.83) had higher value than the control (2.50±0.23).

Methionine did not influence FI across the treatments at the starter phase (Table 3). The FCR were significantly ($P<0.05$) lower for NRC (1.76±0.11), and 2NRC (1.91±0.47) than the control (2.13±0.03), while 1/2NRC (1.95±0.33) was similar to the control at the starter phase. The BWG were significantly ($P<0.05$) higher for the experimental diets for both starter and finisher phases. The FI for the experimental diets during the finisher phase were statistically similar to the control, while FCR recorded lower values for the experimental diets.

3.2 Bone Characteristics

The main effect of graded levels of cassava and DL-methionine on bone characteristics, interaction effect of graded levels of cassava and DL-methionine on bone and interaction effect of graded levels of cassava and DL-methionine on bone characteristics are presented in Tables 6, 7 and 8. Cassava chips and methionine did not influence tibia length, diaphysis diameter, lateral wall thickness, medullary diameter, robusticity index, phosphorus and calcium (Table 6). Media wall thickness was not influenced by methionine supplementation, but birds on 75% cassava chips (0.16 mm) and 100% (0.15 mm) had significantly ($P<0.05$) higher values than the control (0.13 mm), which is statistically similar to those on 50% (0.14 mm). Cassava chips did not influence weight/length index (MLI) and bone weight (BW). Birds on NRC and 2NRC (1.04 g/cm) had significantly ($P<0.05$) higher MLI than those on control (0.91 g/cm) which was similar to those on 1/2NRC (0.99 g/cm). Birds on 1/2NRC, NRC and 2NRC recorded BW values which were statistically similar to the control. Ash content was significantly ($P<0.05$) higher for 1/2NRC, NRC and 2NRC than the control.

Table 1. Percentage composition of experimental diets

Feed ingredients (%)	Starter phase	Finisher phase
Maize	59.00	59.00
Cassava chips	0.00	0.00
Soya bean cake (45%)	36.00	30.00
Wheat bran	2.00	7.00
$CaCo_3$	1.00	1.00
Salt	0.25	0.25
Di-calcium phosphate	1.50	1.50
Vitamin-mineral premix	0.25	0.25
Methionine	0.00	0.00
Toxin binder	1.00	1.00
Total (kg)	100.00	100.00
Calculated values		
Crude protein	22.44	20.59
Metabolic energy (Kcal/kg)	3032.06	3000
Crude fiber	3.00	3.00
Methionine	0.38	0.34

Methionine improved body weight gain of the birds across the treatments while NRC gave the best FC and body weight gain at the starter phase and highest body weight gain at the finisher phase. This implies that NRC recommendation is adequate to ensure normal productivity and broiler production. Ologhobo et al. [12] earlier reported that methionine enhanced body weight gain in broiler chickens. The authors also reported lower body weight gain for chickens fed cassava chips. The result of the present study indicated that higher inclusion level of cassava chips resulted in lower body weight gain which may be attributed to hydrocyanic acid present in cassava. The reduction in weight gain in diets containing progressively larger amounts of cassava is similar to the reports of other authors [20,21]. Wyllie et al. [22] suggested feed efficiency decrease as the proportion of cassava in the diet increased. The reasons for the reduced performance may be due to several reasons like the presence of cyanoglucosidases in cassava; differences in energy content between cassava and maize; palatability differences and the presence of aflatoxins in the cassava meal. Methionine enhanced ash content of the bone of the chickens, improving the mineralization of the chickens. Addition of methionine over and above the recommended requirement of chickens has been shown to improve their performance in terms of body weight gain and food conversion efficiency [23], while supplementing herbal or synthetic sources of methionine improved in grower and total. Cassava is relatively very available in large quantity in Nigeria and it has been investigated to serve as alternative main energy source in broiler feedstuffs [11,12]. However, the problem of hydrocyanic acid present in cassava has limited its use as feed ingredient for monogastric animals. Several processing methods have been used to ameliorate the effect of hydrocyanic acid and other anti-nutritional factors in cassava as well as other products, which include sun drying, fermentation, cooking, addition of palm oil and feeding of high protein supplements and/or amino acids like Methionine and Lysine [11,13,24]. Methionine has been observed to be involved in cassava detoxification [14].

Table 2. Effect of graded levels of cassava chips on performance of broiler chickens

Parameters	0	25	50	75	100
			Starter phase		
FW (g)	849.66±6.48^{a}	803.47±7.67^{ab}	757.99±8.51^{bc}	695.49±8.55^{cd}	688.19±9.07^{d}
BWG (g)	799.66±26.48^{a}	753.47±27.67^{ab}	707.99±29.51^{bc}	645.49±23.55^{cd}	638.19±29.07^{d}
FI (g)	1337.26±8.54^{ab}	1344.14±10.22^{a}	1342.58±14.86^{ab}	1325.14±28.1^{b}	1330.45±18.86^{ab}
FCR	1.69±0.19^{c}	1.79±0.15^{bc}	1.94±0.32^{ab}	2.14±0.46^{a}	2.13±0.33^{a}
Liv. (%)	100.00	96.25	100.00	98.75	98.75
			Finisher phase		
FW (g)	2104.27±13.48^{a}	2026.1±21.91^{b}	1945.01±19.95^{c}	1880.85±17.40^{c}	1827.77±16.39^{c}
BWG (g)	1254.61±15.64^{a}	1222.62±14.12^{b}	1187.02±12.46^{c}	1185.36±20.69^{c}	1139.58±28.82^{d}
FI (g)	3126.77±27.50	3130.66±270.6	2998.47±12.91	2957.5±14.63	3080.83±12.34
FCR	2.50±0.23^{b}	2.63±0.47^{b}	2.60±0.51^{b}	2.62±0.63^{b}	2.84±0.63^{a}
Liv. (%)	93.75	96.10	98.75	98.73	100.00

Means with the same superscripts in a row are not significantly (P>0.05) different. FW = final weight, BWG = body weight gain, FI = feed intake, FCR = feed conversion ratio, Liv. = livability

Table 3. Effect of graded levels of DL-methionine on performance of broiler chickens

Parameters	0	1/2NRC	NRC	2NRC
		Starter phase		
FW (g)	684.72±99.21^{c}	751.12±116.02^{b}	816.11±47.46^{a}	783.89±146.14^{ab}
BWG (g)	634.72±99.21^{c}	701.12±116.02^{b}	766.11±47.46^{a}	733.89±146.14^{ab}
FI (g)	1328.15±24.92	1335.85±17.49	1340.05±9.6	1339.6±17.64
FCR	2.13±0.30^{a}	1.95±0.33^{ab}	1.76±0.11^{c}	1.91±0.47^{bc}
Liv. (%)	100.00	100.00	98.00	97.00
		Finisher phase		
FW (g)	1635.70±230.76^{c}	1888.32±155.94^{b}	2175.14±135.28^{a}	2128.04±229.70^{a}
BWG (g)	950.98±41.26^{c}	1137.20±79.11^{b}	1359.03±138.26^{a}	1344.15±158.32^{a}
FI (g)	3015.56±138.2^{ab}	3056.67±160.30^{ab}	3170.28±304.19^{a}	2992.89±104^{b}
FCR	3.22±0.41^{a}	2.70±0.22^{b}	2.36±0.39^{b}	2.26±0.3^{b}
Liv. (%)	98.00	95.00	95.00	99.00

Means with the same superscripts in a row are not significantly (P>0.05) different. 1/2NRC, NRC, 2NRC = ½, 1 and 2 NRC recommendations, FW = final weight, BWG = body weight gain, FI = feed intake, FCR = feed conversion ratio, Liv. = livability

Table 4. Interaction effect of graded levels of cassava chips and DL-methionine on performance of broiler chickens at the starter phase

Treatment	Cassava	DL-methionine	FW (g)	BWG (g)	FI (g)	FCR	%Liv
1	0	0	845.84^{abcd}	795.84^{abcd}	1342.7^{ab}	1.69^{ef}	95.00
6		1/2NRC	815.3^{abcd}	765.3^{abcd}	1334.45^{abc}	1.8d^{ef}	100.00
11		NRC	854.17abc	804.17^{abc}	1337.95^{ab}	1.66^{ef}	85.00
16		2NRC	883.33^{ab}	833.33^{ab}	1333.95^{abc}	1.6^{f}	95.00
2	25	0	719.44^{defg}	669.44^{defgh}	1350.45^{ab}	2.02^{bcde}	100.00
7		1/2NRC	843.06^{abcd}	793.06^{abcd}	1340.2^{ab}	1.69^{ef}	95.00
12		NRC	831.95^{abcd}	781.95^{abcd}	1343.95^{ab}	1.72^{ef}	90.00
17		2NRC	819.45^{abcd}	769.45^{abcd}	1341.95^{ab}	1.74^{def}	90.00
3	50	0	604.17^{ghi}	554.17^{ghi}	1325.2^{abc}	2.39^{ab}	95.00
8		1/2NRC	734.73^{cdefg}	684.73^{cdef}	1345.7^{ab}	1.97^{cdef}	100.00
13		NRC	783.34^{abcde}	733.34^{abcde}	1344.95^{ab}	1.83^{def}	100.00
18		2NRC	909.72^{a}	859.72^{a}	1354.45^{a}	1.58^{f}	100.00
4	75	0	656.95^{efghi}	606.95^{efghi}	1301.95^{c}	2.15^{bcd}	100.0
9		1/2NRC	740.28^{cdef}	690.28^{cdef}	1337.7^{abc}	1.97^{cdef}	95.00
14		NRC	852.78^{abcd}	802.78^{abcd}	1345.45^{ab}	1.68^{ef}	100.00
19		2NRC	531.95^{i}	481.95^{i}	1315.45^{bc}	2.75^{a}	95.00
5	100	0	597.22^{hi}	547.22^{hi}	1320.45^{abc}	2.42^{ab}	100.00
10		1/2NRC	622.22^{fghi}	572.22^{fghi}	1321.2^{abc}	2.34^{bc}	85.00
15		NRC	758.34^{bcde}	708.34^{bcde}	1327.95^{abc}	1.88^{def}	95.00
20		2NRC	775^{bcde}	725^{bcde}	1352.2^{a}	1.88^{def}	100.00
		SEM	18.20	18.20	2.87	0.05	-

Means with the same superscripts in a column are not significantly (P>0.05) different. 1/2NRC, NRC, 2NRC = ½, 1 and 2 NRC recommendations, FW = final weight, BWG = body weight gain, FI = feed intake, FCR = feed conversion ratio, Liv. = livability

Table 5. Interaction effect of graded levels of cassava chips and Dl-mtethionine on performance of broiler chickens at the finisher phase

Treatment	Cassava	DL-methionine	FW (g)	BWG (g)	FI (g)	FCR	%Liv
1	0	0	2030.09^{cd}	1184.26^{g}	3113.89^{bc}	2.63^{efgh}	95.00
6		1/2NRC	2067.58^{bcd}	1252.28^{ef}	2950.00^{c}	2.36^{hij}	100.00
11		NRC	2146.29^{bc}	1292.12^{e}	3318.75^{ab}	2.57^{fgh}	90.00
16		2NRC	2173.13^{b}	1289.8^{e}	3124.44^{abc}	2.42^{ghi}	95.00
2	25	0	1688.78^{g}	969.34^{j}	2950.00^{c}	3.05^{dc}	100.00
7		1/2NRC	2021.29^{d}	1178.24^{g}	3124.44^{abc}	2.65^{efgh}	95.00
12		NRC	2047.63^{cd}	1215.68^{fg}	3488.19^{a}	2.87^{def}	90.00
17		2NRC	2346.69^{a}	1527.24^{ab}	2960.00^{bc}	1.94^{k}	100.00
3	50	0	1547.65^{h}	943.48^{j}	3113.89^{bc}	3.3^{bc}	95.00
8		1/2NRC	1828.25^{fe}	1093.52^{h}	2960^{bc}	2.71^{defg}	100.00
13		NRC	2038.86^{cd}	1255.52^{ef}	2960.00^{bc}	2.36^{hij}	100.00
18		2NRC	2365.28^{a}	1455.56^{c}	2960.00^{bc}	2.03^{k}	100.00
4	75	0	1512.95^{hi}	856.01^{k}	2950.00^{c}	3.45^{ab}	100.00
9		1/2NRC	1776.28^{feg}	1036^{i}	2960^{bc}	2.86^{def}	95.00
14		NRC	2345.74^{a}	1492.96^{bc}	2960.00^{bc}	1.98^{k}	100.00
19		2NRC	1888.43^{e}	1356.48^{d}	2960.00^{bc}	2.18^{ijk}	100.00
5	100	0	1399.02^{i}	801.8^{l}	2950.00^{c}	3.68^{a}	100.00
10		1/2NRC	1748.18^{fg}	1125.96^{h}	3288.89^{abc}	2.92^{de}	85.00
15		NRC	2297.22^{a}	1538.88^{a}	3124.44^{abc}	2.03^{k}	100.00
20		2NRC	1866.66^{fe}	1091.66^{h}	2960.00^{bc}	2.71^{ijk}	100.00
		SEM	45.19	33.53	31.21	0.08	

Means with the same superscripts in a column are not significantly (P>0.05) different. 1/2NRC, NRC, 2NRC = ½, 1 and 2 NRC recommendations, FW = final weight, BWG = body weight gain, FI = feed intake, FCR = feed conversion ratio, Liv. = livability

Table 6. Main effect of graded levels of cassava and DL-methionine on bone characteristics

	Cassava effect					DL-methionine effect				
	0%	25%	50%	75%	100%	0	1/2NRC	NRC	2NRC	SEM
TL (cm)	8.95	9.00	8.91	8.82	8.74	8.65	8.86	9.01	9.01	0.06
DD (mm)	7.30	7.00	7.28	7.41	6.96	6.94	6.99	7.37	7.47	0.11
LWT (mm)	0.18	0.18	0.28	0.19	0.19	0.20	0.19	0.18	0.25	0.02
MWT (mm)	0.13^{b}	0.14^{ab}	0.14^{ab}	0.16^{a}	0.15^{a}	0.15	0.14	0.14	0.14	0.00
MD (mm)	6.98	6.67	6.85	7.06	6.63	6.59	6.65	7.04	7.07	0.11
BW (g)	9.42	9.11	8.74	8.68	8.34	7.85^{a}	8.78^{ab}	9.38^{a}	9.42^{a}	0.23
WLI (g/cm)	1.05	1.01	0.98	0.98	0.95	0.91^{b}	0.99^{ab}	1.04^{a}	1.04^{a}	0.02
RI (mm/mg^3)	4.25	4.32	4.35	4.34	4.33	4.37	4.32	4.29	4.30	0.02
Ash (%)	41.05	42.51	41.73	39.4	41.11	37.74^{c}	43.84^{a}	42.73^{ab}	40.32^{ab}	0.84
Phos. (%)	5.69	5.46	5.26	6.23	6.48	5.41	6.33	6.21	5.35	0.29
Calcium (%)	20.34	21.12	17.76	19.79	17.16	19.1	18.21	20.54	19.09	0.68

Means with same superscripts in a row are not significantly (P>0.05) different. TL= Tibia length, DD = Diaphysis diameter, LWT = Lateral Wall Thickness, MWT = Media Wall Thickness, MD = Medullary Diameter, BW = Bone Weight, WLI = Weight/Length Index, RI= Robusticity Index, Phos. = Phosphorous, 1/2NRC, NRC and 2NRC = 1/2NRC, NRC and 2NRC recommended DL-methionine supplementation level

Table 7. Interaction effect of graded levels of cassava and DL-methionine on bone characteristics

Treatment	Cassava (%)	Dl-methionine	TL (cm)	DD (mm)	LWT (mm)	MWT (mm)	MD (mm)
1	0	0	8.64	7.94^{ab}	0.23	0.12^{d}	7.59^{ab}
6		1/2NRC	9.02	7.23^{abc}	0.19	0.14^{bcd}	6.91^{abcd}
11		NRC	9.03	7.5^{abc}	0.15	0.12^{d}	7.24^{abcd}
16		2NRC	9.13	6.52^{c}	0.17	0.15^{abcd}	6.2^{cd}
2	25	0	8.69	7.03^{abc}	0.19	0.16^{abc}	6.69^{abcd}
7		1/2NRC	9.33	6.64^{bc}	0.18	0.14^{bcd}	6.33^{bcd}
12		NRC	9.09	7.05^{abc}	0.20	0.16^{abc}	6.69^{abcd}
17		2NRC	8.91	7.29^{abc}	0.17	0.13^{cd}	7^{abcd}
3	50	0	8.70	6.45^{c}	0.21	0.14^{bcd}	6.11^{cd}
8		1/2NRC	8.67	7.17^{abc}	0.19	0.15^{abcd}	6.83^{abcd}
13		NRC	8.94	7.48^{abc}	0.19	0.15^{abcd}	7.15^{abcd}
18		2NRC	9.33	8.02^{ab}	0.54^{a}	0.14^{bcd}	7.34^{abc}
4	75	0	8.76	6.92^{bc}	0.19	0.18^{a}	6.56^{bcd}
9		1/2NRC	8.72	6.78^{bc}	0.21	0.14^{bcd}	6.43^{bcd}
14		NRC	8.99	7.64^{abc}	0.19	0.15^{abcd}	7.31^{abcd}
19		2NRC	8.82	8.32^{a}	0.19	0.17^{ab}	7.97^{a}
5	100	0	8.5	6.35^{c}	0.18	0.16^{abc}	6.02^{d}
10		1/2NRC	8.6	7.13^{abc}	0.20	0.15^{abcd}	6.79^{abcd}
15		NRC	9.02	7.18^{abc}	0.20	0.16^{ab}	6.82^{abcd}
20		2NRC	8.86	7.2^{abc}	0.18	0.15^{abcd}	6.88^{abcd}
		SEM	0.06	0.11	0.02	0	0.11

Means with same superscripts in a column are not significantly (P>0.05) different. TL= Tibia length, DD = Diaphysis diameter, LWT = Lateral Wall Thickness, MWT = Media Wall Thickness, MD = Medullary Diameter, 1/2NRC, NRC and 2NRC = 1/2NRC. NRC and 2NRC recommended DL-methionine supplementation level

Table 8. Interaction effect of graded levels of cassava and DL-methionine on bone characteristics

Treatment	Cassava (%)	Dl-methionine	BW (g)	WLI (g/cm)	RI	Ash (%)	Phos (%)	Calcium (%)
1	0	0	9.03	1.05	4.16^{c}	38.09^{cdefg}	4.34^{ab}	15.66^{ab}
6		1/2NRC	9.63	1.06	4.26^{ab}	39.74^{cdefg}	5.05^{ab}	19.66^{ab}
11		NRC	9.74	1.08	4.23^{ab}	42.15^{bcdefg}	6.15^{ab}	24.44^{a}
16		2NRC	9.29	1.02	4.35^{ab}	44.21^{bc}	7.24^{ab}	21.59^{ab}
2	25	0	8.27	0.95	4.30^{ab}	35.71^{efg}	6.45^{ab}	19.26^{ab}
7		1/2NRC	9.92	1.06	4.35^{ab}	42.48^{bcde}	5.53^{ab}	21.8^{ab}
12		NRC	9.3	1.02	4.33^{ab}	48.36^{ab}	5.39^{ab}	23.4^{ab}
17		2NRC	8.9	1.00	4.30^{ab}	43.48^{bcd}	4.49^{ab}	20.03^{ab}
3	50	0	7.51	0.86	4.44^{ab}	34.41^{g}	3.79^{ab}	19.07^{ab}
8		1/2NRC	8.17	0.94	4.33^{ab}	53.06^{a}	6.87^{ab}	17.61^{ab}
13		NRC	8.88	0.99	4.32^{ab}	44.34^{bc}	5.6^{ab}	18.6^{ab}
18		2NRC	10.4	1.11	4.28^{ab}	35.11^{fg}	4.79^{ab}	15.75^{ab}
4	75	0	7.24	0.82	4.53^{a}	36.53^{defg}	6.22^{ab}	21.16^{ab}
9		1/2NRC	8.13	0.93	4.35^{ab}	44.84^{ab}	8.2^{a}	17.7^{ab}
14		NRC	9.7	1.08	4.24^{ab}	40.18^{cdefg}	6.35^{ab}	21.41^{ab}
19		2NRC	9.67	1.11	4.24^{ab}	36.05^{efg}	4.17^{ab}	18.87^{ab}
5	100	0	7.22	0.85	4.40^{a}	43.95^{bc}	6.28^{ab}	20.35^{ab}
10		1/2NRC	8.05	0.93	4.29^{ab}	39.09^{cdef}	5.99^{ab}	14.26^{b}
15		NRC	9.26	1.02	4.32^{ab}	38.61^{cdefg}	7.56^{ab}	14.85^{ab}
20		2NRC	8.85	0.99	4.30^{ab}	42.74^{bcde}	6.07^{ab}	19.19^{ab}
		SEM	0.23	0.02	0.02	0.84	0.29	0.68

Means with same superscripts are not significantly (P>0.05) different. BW = Bone Weight, WLI = Weight/Length Index, RI= Robusticity Index, Phos. = Phosphorous, 1/2NRC, NRC and 2NRC = 1/2NRC, NRC and 2NRC recommended DL-methionine supplementation level

4. CONCLUSION

Feeding cassava chips in a pelletised final feed supplemented with methionine could enhance its nutritive value, resulting in increased body weight and bone mineralization of broiler chickens.

ETHICAL APPROVAL

All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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