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# Performance and economic benefits of meat-type chicken fed diets containing white and yellow cassava supplemented with different additives

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**Abstract:** *Two hundred and forty unsexed day-old broiler chickens were allotted to eight dietary treatments arranged in a 4 × 2 factorial arrangement of two cassava varieties (white and yellow cassava) supplemented with no additive (control), synthetic amino acid, cellulase enzyme and a combination of amino acid and cellulase enzyme for the starter (0–4 weeks) and finisher (4–8 weeks) phases. Data was collected on growth performance, feed conversion ratio (FCR), cost of feed consumed per kilogram and analysed using ANOVA. Starting broilers fed a diet containing yellow cassava supplemented with amino acids had the most superior ($p < 0.05$) final weight (709.09 g/bird), weight gain (657.27 g/bird), best FCR (1.93), and the cheapest ($p < 0.05$) cost per kilogram weight gain (₦200.15/kg [US$0.56]). Finishing broilers fed a diet containing white cassava supplemented with amino acid also recorded the best ($p < 0.05$) FCR (2.43) and cheapest cost of feed consumed per kilogram weight gain (₦226.71/kg [$0.63]). The study concluded that dietary supplementation with amino acid when white or yellow cassava root is to be used in the nutrition of broilers is essential for improved growth performance and economic benefits to broiler farmers.*

**Keywords:** performance, meat-type chickens, cassava root, additives

There is the need to provide solutions to the present challenges of shortage and high cost of conventional feed ingredients such as maize. Over the years, maize has been the ingredient of choice for the supply of energy in monogastric animal nutrition because of its high-energy content and low anti-nutritional factors (Donkoh and Attoh-Kotoku, 2009). In recent years, maize price has increased considerably due to keen competition by livestock, food industries, increased

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production of biofuel, direct human consumption, and droughts in some parts of Africa (Nigeria, Ghana, and Benin Republic). This scenario justified the need to explore alternative feed resources that can partially or fully replace maize at a low cost for poultry production. Cassava is a cheaper, high energy ingredient and can potentially replace maize as an energy source in poultry diets without adverse effects on birds' performance.

The use of cassava as replacement for other conventional cereal grains (maize, sorghum, wheat, etc.) in poultry feed is limited by a few factors, including its low protein quality and quantity, with very low essential amino acid contents (Adeyemi et al., 2008; Olugbemi et al., 2010). Diets containing cassava therefore need to be supplemented with synthetic amino acid to make up for the protein deficiency. The high fibrous content of cassava peel and the presence of cyanogenic glucosides, linamarin and lotaustralin, which yield hydrocyanide (HCN) upon hydrolysis, is also a demerit (Udedibie et al., 2008). Inclusion of feed additives like enzymes is known to improve utilization of fibrous feed (Abdulrashid et al., 2007). The conventional white cassava roots and products are known to be deficient in β-carotene and other carotenoids (Omole, 1977; Khajarern and Khajarern, 2007) which could consequently lead to nutritional deficiencies and cause *in vivo* oxidative stress with the attendant effects on animal products (Ngiki et al., 2014).

Previous studies exist on the practical inclusion of whole cassava root meal (white) as energy feedstuff in feed for poultry (Aderemi et al., 2012; Oso et al., 2014; Akapo et al., 2014) but there is limited information on the use of biofortified (yellow) cassava in the feed of poultry. Understanding of the nutritional importance of yellow cassava varieties will encourage or boost its production by farmers, and improve the economic status and livelihood of rural farmers. Yellow cassava varieties are known to have lower HCN content than white cultivars with added carotene content. This is an improvement over the white cultivars. Further nutritional enhancement of the yellow cassava cultivars (such as solid state or fungal fermentation) in future research could reduce the concentration of amino acid employed to improve cassava utilization with attendant reduction in feed cost. This study will therefore focus on the comparative utilization of unpeeled white and yellow cassava root meals (WCRM and YCRM respectively) supplemented with synthetic amino acids and cellulase enzyme by meat-type chickens.

## Materials and methods

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, 2016).

Freshly harvested white cassava variety (TME 419) and yellow cassava variety (ITA/IBD/1368) were purchased at the Institute of Food Security and Environmental Research Agency (IFSERA) and used for the study. Each variety was thoroughly washed with clean water (to be free of dirt and sand) and manually chipped into smaller pieces (about 0.5 cm thick, without prior peeling) as described by Oso et al. (2010). The chipped cassava tubers obtained from each variety were sun-dried separately on a concrete floor for about 5–6 days and turned occasionally for effective drying 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 such as Ca, P, Cu, Mg, Mn, and Zn as well as β-carotene of the cassava root meals were determined using Horwitz (2005) and AOAC (1997), respectively (Table 1).

**Table 1** Chemical composition of white and yellow cassava root meals

| | *White cassava* | *Yellow cassava* |
|---|---|---|
| Proximate components (%) | | |
| Moisture content | 9.58 | 8.67 |
| 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 (kcal/kg) or MJ/kg | (3537.1) 14.80 | (3457.1) 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 |

*(continued)*

| | *White cassava* | *Yellow cassava* |
|---|---|---|
| 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 treatment and each pen contained 10 birds. 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 4–8 weeks for the finisher phase).

### *Dietary treatments*

White cassava root meal replaced 30 per cent of maize as the basal diet in the experimental diets, with varying levels 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, exogenous enzyme, and a combination of both amino acids and enzyme. This was done for each cassava variety. There were eight dietary treatments laid out in a 2 × 4 factorial arrangement, i.e. two varieties of cassava and four types of additives. The composition of the experimental diets for both starter and finisher phases are as shown in Tables 2 and 3, respectively.

**Table 2** Gross composition of experimental diets fed to starting broilers (g/kg)

| *Ingredients* | *White cassava* | | | | *Yellow cassava* | | | |
|---|---|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
| Maize | 320 | 320 | 320 | 320 | 320 | 320 | 320 | 320 |
| White cassava | 136 | 136 | 136 | 136 | – | – | – | – |
| Yellow cassava | – | – | – | – | 136 | 136 | 136 | 136 |
| Soya bean meal | 290 | 290 | 290 | 290 | 290 | 290 | 290 | 290 |
| Fish meal (70%) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Groundnut cake | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| Wheat offal | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Palm oil | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Bone meal | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| Oyster shell | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Methionine | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Lysine | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Premix (broilers) | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Common salt | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Amino acid | – | * | – | – | – | * | – | – |
| Cellulase enzyme | – | – | ** | – | – | – | ** | – |
| Amino acid + enzyme | – | – | – | *** | – | – | – | *** |
| Total | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| **Determined analyses** | | | | | | | | |
| Metabolized energy (kcal/kg) | 2,891.46 | 2,890.75 | 2,993.10 | 2,896.34 | 2,879.89 | 2,879.65 | 2,881.75 | 2,884.45 |
| Crude protein (%) | 22.82 | 22.85 | 22.90 | 23.03 | 22.88 | 22.93 | 22.96 | 23.12 |
| Crude fibre (%) | 5.56 | 5.57 | 5.52 | 5.50 | 5.54 | 5.55 | 5.54 | 5.51 |
| Ether extract (%) | 5.56 | 5.28 | 5.55 | 5.54 | 5.31 | 5.47 | 5.42 | 5.20 |

Note: Each 2.5 kg of the 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), 1.25 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)

**Table 3** Gross composition of experimental diets fed to finishing broilers (g/kg)

| *Ingredients* | *White cassava* | | | | *Yellow cassava* | | | |
|---|---|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
| Maize | 378 | 378 | 378 | 378 | 378 | 378 | 378 | 378 |
| White cassava | 162 | 162 | 162 | 162 | – | – | – | – |
| Yellow cassava | – | – | – | – | 162 | 162 | 162 | 162 |
| Soya bean meal | 204 | 204 | 204 | 204 | 204 | 204 | 204 | 204 |
| Groundnut cake | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 |
| Wheat offal | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| Palm oil | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| Bone meal | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| Oyster shell | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Methionine | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Lysine | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Premix (broilers) | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Common salt | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Amino acid | – | * | – | – | – | * | – | – |
| Cellulase enzyme | – | – | ** | – | – | – | ** | – |
| Amino acid + enzyme | – | – | – | *** | – | – | – | *** |
| Total | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| **Determined analyses** | | | | | | | | |
| Metabolized energy (kcal/kg) | 3,091.46 | 3,090.75 | 3,093.10 | 3,096.34 | 3,079.89 | 3,079.65 | 3,081.75 | 3,084.45 |
| Crude protein (%) | 19.64 | 20.15 | 19.88 | 20.44 | 19.74 | 20.23 | 19.93 | 20.53 |
| Crude fibre (%) | 5.86 | 5.43 | 5.95 | 5.83 | 5.90 | 5.88 | 5.85 | 5.94 |
| Ether extract (%) | 5.66 | 5.60 | 5.54 | 5.61 | 5.66 | 5.56 | 5.52 | 5.57 |

Note: Each 2.5 kg of the 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 1500 mg; Vit. B12 10 mg; pantothenic acid 5,000 mg; biotin 20 mg; niacin 15,000 mg; and antioxidant 125,000 mg), 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)

## Data measurement

The body weight of birds in each replicate group was measured at the beginning of the experiment and weekly thereafter. Weight gain for each week was obtained by the difference in the body weights of two consecutive weighings for each replicate group. Feed intake was calculated as the difference between the feed offered and left over. Feed conversion ratio was computed as the ratio of feed consumed to weight gain.

The cost of feed ingredients at the time of the study was noted and used to calculate the cost of the dietary treatments per kg (naira), total cost of feed consumed per bird (naira) and cost of feed consumed to produce a kilogram of weight gain using the procedure of Sonaiya et al. (1996).

a. Total cost of feed consumed TCFC (₦) = Total feed consumed × Cost per kilogram of feed

b. $$\text{Cost of feed per kilogram diet (₦/kg)} = \frac{\text{Cost of feed consumed (₦)}}{\text{Total feed consumed (kg)}}$$

c. $$\text{Cost of feed per kilogram weight gain (₦/kg)} = \frac{\text{Cost of feed consumed (₦)}}{\text{Weight gain (kg)}}$$

## Statistical analysis

Data generated were analysed by the analysis of variance technique using the SAS computer package (SAS Institute, 1999) to separate the main effects of using different varieties of cassava. 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).

## Results

The chemical composition of WCRM and YCRM (average of four determinations) as shown in Table 1 revealed that the moisture content of the two cassava varieties used in this study differ, with values of 9.55 per cent and 8.67 per cent for WCRM and YCRM, respectively. White cassava root meal recorded higher values for crude fat and crude fibre content, while 3.56 per cent crude protein in YCRM is higher than 2.20 per cent crude protein recorded for WCRM. The ash and β-carotene content (2.90 per cent 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 per cent) is higher than 82.98 per cent NFE recorded for YCRM. White cassava root meal showed higher values for NDF (26.59 per cent), ADF (15.58 per cent) and ADL (3.37 per cent). 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 is the same as that obtained in YCRM. The gross energy value obtained for WCRM (3537.10 kcal/kg) is higher than the gross energy recorded for YCRM.

The results of the main effects of cassava varieties and use of additives on the performance of starting broilers presented in Table 4 showed that birds fed diets containing yellow cassava had significantly higher ($p < 0.05$) final live weight and weight gain values (692.95 g and 638.95 g, respectively) than those fed diet containing white cassava. Birds fed with white cassava diets, however, had significantly higher ($p < 0.05$) feed conversion ratio (FCR) (2.34) and cost of feed per kg weight gain (₦246.76/kg [$0.69]). Cassava varieties had no significant effect ($p > 0.05$) on the feed intake and total cost of feed consumed.

The main effect of additives was not significant ($p > 0.05$) on values recorded for final live weight and weight gain. Birds fed a diet containing cassava with enzyme had significantly higher ($p < 0.05$) feed intake (1,460.07 g), FCR (2.35) and cost of feed per kg weight gain (₦252.17 /kg [$0.70]) values, while the birds fed diets containing cassava with no additives showed lower FCR value (2.09). Birds fed diets containing cassava with amino acids + enzyme recorded significantly higher ($p < 0.05$) value of total cost of feed consumed (₦156.59 [$0.44]) than birds fed diets containing cassava with no additive. The cost of feed per kg diet was highest ($p < 0.05$) for diets containing cassava with amino acids + enzyme (₦108.90 [$0.30]) and lowest for diets containing cassava with no additive (₦101.90 [$0.28]).

In Table 5, the result of the interaction effects of cassava varieties and use of additives on the performance of starting broilers showed that broilers fed a diet containing white cassava with amino acids had significantly lower ($p < 0.05$) values for final live weight and weight gain (602.12 g and 548.57 g, respectively). Those that were fed a diet containing yellow cassava with amino acids + enzyme recorded higher ($p < 0.05$) final live weight and weight gain values (714.55 g and 659.94 g). The broilers fed a diet containing white and yellow cassava with enzyme and those fed a diet containing yellow cassava with amino acids + enzyme recorded significantly higher ($p < 0.05$) values for feed intake and total cost of feed consumed, while those fed a diet containing yellow cassava with no additive had lower values for feed intake and total cost of feed consumed. The highest significant ($p < 0.05$) value for FCR (2.56) was recorded with birds fed a white cassava diet with amino acids while birds fed a yellow cassava diet with amino acids had the lowest value for FCR (1.93). Cost of feed per kg diet was highest ($p < 0.05$) for diets containing white and yellow cassava with amino acids + enzyme, while diets containing white and yellow cassava with no additive recorded the lowest cost of feed per kg diet. Broilers fed a diet containing white cassava with amino acids recorded a significantly higher ($p < 0.05$) value for cost of feed per kg weight gain (₦265.22 [$0.74]) and those fed a diet containing yellow cassava with amino acids recorded lower values (₦200.15 [$0.56]).

Results of the main effects of cassava varieties and use of additives on the performance of finishing broilers is shown in Table 6. It is observed from

**Table 4** Main effects of cassava varieties and additives on the performance of starting broilers (0–4 weeks)

| Parameters | Varieties | | | | Additives | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *White* | *Yellow* | *SEM* | *P-value* | *Control* | *Amino acid* | *Enzyme* | *Amino acid + enzyme* | *SEM* | *P-value* |
| Initial live weight/bird (g) | 54.83 | 54.00 | 0.93 | 0.536 | 54.8 | 52.68 | 56.26 | 53.92 | 1.24 | 0.294 |
| Final live weight/bird (g) | $640.12^{b}$ | $692.95^{a}$ | 12.26 | 0.009 | 668.03 | 655.61 | 677.05 | 665.45 | 20.56 | 0.873 |
| Total weight gain/bird (g) | $585.29^{b}$ | $638.95^{a}$ | 11.68 | 0.007 | 613.23 | 602.92 | 620.8 | 611.54 | 19.88 | 0.912 |
| Daily weight gain/bird (g) | $20.90^{b}$ | $22.82^{a}$ | 0.42 | 0.007 | 21.90 | 21.53 | 22.17 | 21.84 | 0.71 | 0.912 |
| Feed intake/bird (g) | 1,367.5 | 1,358.52 | 31.30 | 0.812 | $1{,}278.79^{b}$ | $1{,}338.18^{b}$ | $1{,}460.07^{a}$ | $1{,}375.00^{ab}$ | 35.99 | 0.020 |
| Daily feed intake (g/bird/day) | 48.84 | 48.52 | 1.12 | 0.812 | $45.67^{b}$ | $47.79^{b}$ | $52.15^{a}$ | $49.11^{ab}$ | 1.29 | 0.020 |
| Feed conversion ratio | $2.34^{a}$ | $2.13^{b}$ | 0.05 | 0.006 | $2.09^{b}$ | $2.25^{ab}$ | $2.35^{a}$ | $2.25^{ab}$ | 0.07 | 0.007 |
| Cost of feed/kg diet (₦) | 105.40 | 105.40 | 0.85 | 0.000 | $101.90^{d}$ | $103.50^{c}$ | $107.30^{b}$ | $108.90^{a}$ | 0.00 | 0.000 |
| Cost of feed/kg weight gain (₦) | $246.76^{a}$ | $224.91^{b}$ | 6.39 | 0.006 | $212.84^{b}$ | $232.67^{ab}$ | $252.17^{a}$ | $245.65^{a}$ | 6.92 | 0.005 |
| Total cost of feed consumed/ bird (₦) | 144.12 | 143.41 | 3.95 | 0.860 | $130.25^{c}$ | $138.49^{bc}$ | $149.72^{ab}$ | $156.59^{a}$ | 3.80 | 0.001 |

Note: $^{a,b,c,d}$ means those figures with the same superscripts along the rows are not significantly different ($p < 0.05$); US$1.00 = ₦359.79 as of September 2018

**Table 5** Interaction effects of cassava varieties and additives on the performance of starting broilers (0–4 weeks)

| *Parameters* | *White cassava* | | | | *Yellow cassava* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Control* | *Amino acid* | *Enzyme* | *Amino acid + enzyme* | *Control* | *Amino acid* | *Enzyme* | *Amino acid + enzyme* | *SEM* | *P-value* |
| Initial live weight/bird (g) | 54.8 | 53.55 | 53.72 | 53.24 | 54.8 | 51.82 | 54.8 | 54.6 | 0.66 | 0.612 |
| Final live weight/bird (g) | 658.48$^{abc}$ | 602.12$^{c}$ | 679.50$^{ab}$ | 616.36$^{bc}$ | 677.58$^{ab}$ | 709.09$^{a}$ | 670.61$^{abc}$ | 714.55$^{a}$ | 10.12 | 0.020 |
| Total weight gain/ bird (g) | 603.69$^{abc}$ | 548.57$^{c}$ | 625.78$^{ab}$ | 563.13$^{bc}$ | 622.78$^{ab}$ | 657.27$^{a}$ | 615.81$^{ab}$ | 659.94$^{a}$ | 9.83 | 0.012 |
| Daily weight gain/bird (g) | 21.56$^{abc}$ | 19.59$^{c}$ | 22.35$^{ab}$ | 20.11$^{bc}$ | 22.24$^{ab}$ | 23.47$^{a}$ | 21.99$^{ab}$ | 23.57$^{a}$ | 0.35 | 0.012 |
| Total feed intake/ bird (g) | 1,302.73$^{bc}$ | 1,405.15$^{ab}$ | 1,463.47$^{a}$ | 1,298.64$^{bc}$ | 1,254.85$^{c}$ | 1,271.21$^{bc}$ | 1,456.67$^{a}$ | 1,451.36$^{a}$ | 21.8 | 0.009 |
| Daily feed intake (g/bird/day) | 46.53$^{bc}$ | 50.18$^{ab}$ | 52.27$^{a}$ | 46.38$^{bc}$ | 44.82$^{c}$ | 45.40$^{bc}$ | 52.02$^{a}$ | 51.83$^{a}$ | 0.78 | 0.009 |
| Feed conversion ratio | 2.16$^{cd}$ | 2.56$^{a}$ | 2.34$^{bc}$ | 2.31$^{bc}$ | 2.02$^{de}$ | 1.93$^{e}$ | 2.36$^{b}$ | 2.21$^{bc}$ | 0.04 | 0.000 |
| Cost of feed/kg diet (₦) | 101.85$^{d}$ | 103.49$^{c}$ | 107.25$^{b}$ | 108.89$^{a}$ | 101.85$^{d}$ | 103.49$^{c}$ | 107.25$^{b}$ | 108.89$^{a}$ | 0.59 | 0.000 |
| Cost of feed/kg weight gain (₦) | 219.91$^{c}$ | 265.22$^{a}$ | 250.76$^{ab}$ | 251.13$^{ab}$ | 205.77$^{cd}$ | 200.15$^{d}$ | 253.58$^{ab}$ | 240.16$^{b}$ | 5.02 | 0.000 |
| Total cost of feed consumed/ bird (₦) | 132.68$^{bc}$ | 145.42$^{ab}$ | 156.96$^{a}$ | 141.41$^{bc}$ | 127.81$^{c}$ | 131.56$^{bc}$ | 156.23$^{a}$ | 158.04$^{a}$ | 2.77 | 0.006 |

Note: $^{a,b,c,d,e}$ means those figures with the same superscripts along the rows are not significantly different ($p < 0.05$); US\$1.00 = ₦359.79 as of September 2018

**Table 6** Main effects of cassava varieties and additives on the performance of finishing broilers (4–8 weeks)

| *Parameters* | *Varieties* | | | | *Additives* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *White* | *Yellow* | *SEM* | *P-value* | *Control* | *Amino acid* | *Enzyme* | *Amino acid + enzyme* | *SEM* | *P-value* |
| Initial live weight/bird (g) | 645.04 | 698.6 | 13.25 | 0.212 | 690.23 | 667.05 | 675.83 | 654.17 | 21.5 | 0.613 |
| Final live weight/bird (g) | 1,903.11 | 1,872.65 | 20.62 | 0.324 | 1,862.88 | 1,879.55 | 1,918.64 | 1,890.45 | 29.89 | 0.619 |
| Total weight gain/bird (g) | $1,258.07^{a}$ | $1,174.05^{b}$ | 24.74 | 0.029 | 1,172.65 | 1,212.5 | 1,242.8 | 1,236.29 | 38.15 | 0.511 |
| Daily weight gain/bird (g) | $44.93^{a}$ | $41.93^{b}$ | 0.88 | 0.029 | 41.88 | 43.30 | 44.39 | 44.15 | 1.36 | 0.511 |
| Total feed intake/bird (g) | 3,180.06 | 3,124.23 | 33.87 | 0.25 | 3,217.62 | 3,081.58 | 3,167.33 | 3,142.05 | 46.75 | 0.263 |
| Daily feed intake (g/bird/day) | 113.57 | 111.58 | 1.21 | 0.25 | 114.92 | 110.06 | 113.12 | 112.22 | 1.67 | 0.263 |
| Feed conversion ratio | $2.54^{b}$ | $2.67^{a}$ | 0.05 | 0.042 | $2.75^{a}$ | $2.56^{b}$ | $2.56^{b}$ | $2.55^{b}$ | 0.07 | 0.040 |
| Cost of feed/kg diet (₦) | 95.09 | 95.09 | 0.85 | 0.000 | $91.57^{d}$ | $93.21^{c}$ | $96.97^{b}$ | $98.61^{a}$ | 0.00 | 0.000 |
| Cost of feed/kg weight gain (₦) | $241.08^{b}$ | $253.70^{a}$ | 4.17 | 0.045 | 251.8 | 238.24 | 248.45 | 251.07 | 6.21 | 0.357 |
| Total cost of feed consumed/ bird (₦) | 302.39 | 297.03 | 4.04 | 0.245 | $294.64^{bc}$ | $287.23^{c}$ | $307.14^{ab}$ | $309.84^{a}$ | 4.44 | 0.006 |

Note: $^{a,b,c,d}$ means those figures with the same superscripts along the rows are not significantly different ($p < 0.05$); US$1.00 = ₦359.79 as of September 2018

the results that cassava varieties had no significant effect ($p > 0.05$) on the final live weight, feed intake, and total cost of feed consumed. Finishing broilers fed a diet containing yellow cassava variety showed significantly higher ($p < 0.05$) values for FCR (2.67) and cost of feed per kg weight gain (₦253.70 [$0.70]) while birds fed a diet containing white cassava variety showed a higher value ($p < 0.05$) for weight gain (1,258.07 g).

There was no significant effect of additives ($p > 0.05$) on final live weight, weight gain, feed intake, and cost of feed per kg weight gain. Birds fed diets containing cassava with no additives showed a significantly higher value of 2.75 for FCR. Birds fed a diet containing cassava with amino acids + enzyme had the highest significant ($p < 0.05$) total cost of feed consumed (₦309.84 [$0.86]) and the birds fed a diet containing cassava with amino acids recorded the lowest value (₦287.23 [$0.80]) for total cost of feed consumed. Cost of feed per kg diet was lowest (₦91.57 [$0.25]) for diets containing cassava with no additive and highest for the diet containing cassava with amino acids + enzyme (₦98.61 [$0.27]).

Table 7 shows the results of interaction effects of cassava varieties and use of additives on the performance of finishing broilers. It is observed that there was no significant effect ($p > 0.05$) on the final live weight, weight gain, and feed intake. Finishing broilers fed a diet containing yellow cassava with no additive had higher ($p < 0.05$) FCR (2.84) and those fed a diet containing white cassava with amino acids and amino acids + enzyme (2.43 and 2.49, respectively) recorded lower values. Finishing broilers fed a diet containing yellow cassava with no additive and those fed a diet containing yellow cassava with amino acids + enzyme showed significantly higher ($p < 0.05$) values for cost of feed per kg weight gain, while a lower value (₦226.71 [$0.63]) was recorded for those fed a diet containing white cassava with amino acids. The finishing broilers fed a diet containing yellow cassava with amino acids showed a significantly lower ($p > 0.05$) value for total cost of feed consumed (₦281.48 [$0.78]) but higher values of total cost of feed consumed were recorded for those fed a diet containing white and yellow cassava diets with amino acids + enzyme. The same result was found for those fed a diet containing white cassava with enzyme. Cost of feed per kg diet was highest for diets containing both white and yellow cassava with amino acids + enzyme and lowest for white and yellow cassava diets with no additive.

## Discussion

Broiler starters fed a diet containing YCRM supplemented with enzyme, amino acids + enzyme, and those fed a diet containing WCRM supplemented with enzyme showed improved feed intake although with higher feed cost than those fed YCRM or WCRM without additive. The improved feed intake obtained could be attributed to the effect of enzyme and amino acid supplemented in the feed. This agrees with the findings of Abdulrashid et al. (2007) that enzymes are needed to degrade fibre structures and increase the feeding value of feed materials. It also corroborates the findings of Midau et al. (2011) that improved feed utilization due to enzyme supplementation was responsible for the increased feed intake and live weight gain in

**Table 7** Interaction effects of cassava varieties and additives on the performance of finishing broilers (4–8 weeks)

| *Parameters* | *White cassava* | | | | *Yellow cassava* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Control* | *Amino acid* | *Enzyme* | *Amino acid + enzyme* | *Control* | *Amino acid* | *Enzyme* | *Amino acid + enzyme* | *SEM* | *P-value* |
| Initial live weight/bird (g) | 680.3 | 602.42 | 680 | 617.42 | 700.15 | 731.67 | 671.67 | 690.91 | 10.75 | 0.021 |
| Final live weight/bird (g) | 1,881.21 | 1,900.61 | 1,946.67 | 1,883.94 | 1,844.55 | 1,858.48 | 1,890.61 | 1,896.97 | 14.67 | 0.856 |
| Total weight gain/bird (g) | 1,200.91 | 1,298.18 | 1,266.67 | 1,266.52 | 1,144.39 | 1,126.82 | 1,218.94 | 1,206.06 | 19.26 | 0.293 |
| Daily weight gain/bird (g) | 42.89 | 46.36 | 45.24 | 45.23 | 40.87 | 40.24 | 43.53 | 43.07 | 0.68 | 0.293 |
| Total feed intake/bird (g) | 3,195.64 | 3,143.33 | 3,232.33 | 3,148.94 | 3,239.61 | 3,019.82 | 3,102.33 | 3,135.15 | 24.46 | 0.395 |
| Daily feed intake (g/bird/day) | 114.13 | 112.26 | 115.44 | 112.46 | 115.70 | 107.85 | 110.80 | 111.97 | 0.87 | 0.395 |
| Feed conversion ratio | $2.66^{ab}$ | $2.43^{b}$ | $2.56^{ab}$ | $2.49^{b}$ | $2.84^{a}$ | $2.68^{ab}$ | $2.56^{ab}$ | $2.60^{ab}$ | 0.03 | 0.012 |
| Cost of feed/kg diet (₦) | $91.57^{d}$ | $93.21^{c}$ | $96.97^{b}$ | $98.61^{a}$ | $91.57^{d}$ | $93.21^{c}$ | $96.97^{b}$ | $98.61^{a}$ | 0.59 | 0.000 |
| Cost of feed/kg weight gain (₦) | $243.87^{ab}$ | $226.71^{b}$ | $248.23^{ab}$ | $245.51^{ab}$ | $259.73^{a}$ | $249.77^{ab}$ | $248.67^{ab}$ | $256.64^{a}$ | 3.18 | 0.029 |
| Total cost of feed consumed/ bird (₦) | $292.62^{ab}$ | $292.99^{ab}$ | $313.44^{a}$ | $310.52^{a}$ | $296.65^{ab}$ | $281.48^{b}$ | $300.83^{ab}$ | $308.16^{a}$ | 2.85 | 0.038 |

Note: $^{a,b,c,d}$ means those figures with the same superscripts along the rows are not significantly different ($p < 0.05$); US$1.00 = ₦359.79 as of September 2018

broilers on similar levels of dietary nutrient concentration. Uni and Ferket (2003) reported that amino acid supplementation had the potential to improve the normal functioning of the digestive system in birds thereby enhancing improved nutrient utilization and increased final body weight gain of broilers.

The improved growth performance obtained with starter broilers fed a diet containing YCRM supplemented with amino acids could be attributed to the variety of the cassava root used in this study. Yellow cassava root meal showed higher crude protein, carotene, and reduced cyanide levels than the white variety which could have a cumulative effect and contribute to the improved performance noticed at the starter phase when compared with broilers on WCRM. Beta-carotene is an antioxidant which could be used to fight against damaging free radicals in the body (Tanumihardjo, 2008). Another reason for improved growth performance obtained at the starter phase with broilers fed with YCRM supplemented with amino acids could be the limiting amino acid (methionine and lysine) supplemented in the diet. Limiting amino acid supplementation has been reported to interact with HCN to ameliorate its effect in poultry nutrition (Tewe and Egbunike, 1992). Improved utilization of cassava meal and reduced cyanide effect have been reported in literatures following amino acid supplementation (Oboh and Kindahunsi, 2005; Zanu and Dei, 2011). Hence, improved growth response of starter broilers fed YCRM supplemented with amino acids could be attributed to the cumulative effect of higher crude protein, carotene, reduced cyanide levels, and supplemental amino acid. Feeding starting broilers with a diet containing YCRM supplemented with amino acids makes the best economic sense since it yields the least cost per kilogram weight gain. This implied that, despite the added cost of amino acid supplemented, it is still more cost effective. This trend reported for cost corroborated the observations in growth performance.

At the finisher phase, there were no statistical differences on growth parameters (except feed conversion ratio) following dietary treatments. This implied that either WCRM or YCRM inclusion, supplemented with or without additives, showed no effect on these parameters. This agrees with the report of Hassan et al. (2012) that using 30 per cent of cassava meal in place of maize had no adverse effects on the performance of finisher broilers. All the treatments showed improved FCR except for finishing broilers fed YCRM without amino acids which exhibited poor FCR. This observation underscores the need to improve protein level and reduce the cyanide content of cassava meal to promote its utilization by amino acid supplementation (Zanu and Dei, 2011). The cheapest diet to yield a kilogram weight of finisher broilers was the diet containing WCRM supplemented with amino acids. This implied that it is cheaper to produce a kilogram weight of finisher broiler when fed with WCRM supplemented with amino acids.

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