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# Carcass trait, meat lipid profile and meat quality of broiler chickens fed diets containing high inclusion level of high quality cassava (*Manihot esculenta*) peel meal

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**Abstract**

The current hike in price of conventional energy feedstuff warrants an intensified effort for a sustainable alternative that would not compromise performance and meat quality of poultry birds. The study evaluated the carcass trait and meat quality of finisher broiler chickens fed diets containing highly processed cassava peel meal at 50 % inclusion level in replacement of maize. Three hundred and twenty Cobb500 broiler chickens were allocated to 4 dietary treatments on a weight equalisation basis. Diet 1 = control diet (corn-soybean meal based diet) containing 4.0 g $kg^{-1}$ digestible methionine (MET), 0.96 g $kg^{-1}$ digestible lysine, diet 2 = diet containing 50 % replacement of maize in diet 1 with high quality cassava peel meal and containing 4.0 g $kg^{-1}$ digestible MET, 0.96 g $kg^{-1}$ digestible lysine, diets 3 and 4 are similar to diet 2 except with higher MET and lysine concentrations. Diet 3 contains 4.4 g $kg^{-1}$ digestible MET, 1.02 g $kg^{-1}$ digestible lysine, and diet 4 contains 4.8 g $kg^{-1}$ digestible MET, 1.08 g $kg^{-1}$ digestible lysine. The study lasted for 3 weeks (finisher phase). The highest slaughtered, carcass, and small intestinal weight were recorded in birds fed diet 2 while the birds fed diet 3 had the least abdominal fat value ($p < 0.05$). The water holding capacity and cooking loss percentage was highest in the meat of the chickens fed diet 4. The meat colour (redness, yellowness, and lightness) of chickens fed diet 4 recorded the highest value. The very low density of lipoprotein and triglyceride concentrations were least in the meat of chickens fed diet 2 ($p < 0.05$). It can be concluded that supplementation of methionine/lysine to high quality cassava peel meal improved the carcass trait and meat quality of the broiler chickens.

*Keywords:* cassava peel, methionine, lysine, abdominal fat, internal organs, meat colour

## 1 Introduction

The production of animal feeds that meet the nutritional needs of monogastric animals is a considerable challenge due to the high cost of protein and energy feed components. As a result, there has been an increase in the cost of producing animal feeds, which has led to an increase in the overall cost of animal production and related products, including chicken meat (Choi *et al.*, 2023). This occurrence has led the investigation of alternative feed components in order to reduce production costs while retaining optimal animal performance and not compromising meat quality.

Consequently, the use of agro-industrial by-products in chicken production has been recognized (Yafetto *et al.*, 2023). Cassava peels, which constitute around 5-15 % of the total weight of the tuber, are a significant by-product of cassava. Cassava ranks as the third most significant provider of dietary carbohydrate for human consumption globally (Morgan & Choct, 2016). Upon undergoing appropriate processing, cassava peels have the potential to serve as a viable substitute for corn or wheat in animal production (Apeh Akwu *et al.*, 2017). Nevertheless, the utilisation of this agro-waste in the diets of monogastric animals is constrained due to the elevated presence of carbohydrates that are structurally indigestible, such as cellulose, hemicellulose, pectin, and lignin, as well as the substantial amounts of antinutrients including hydrogen cyanide, tannin, and phytate. Additionally, the protein and amino acid (specifically methionine) content is very low (Oloruntola *et al.*, 2019). The nutritional constraints associated with cassava peel contribute to sub-

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optimal feed intake and compromised digestion, ultimately resulting in diminished performance within broiler chicken feeding regimes. Tewe (1992) and Nourani *et al.* (2021) reported the manifestation of cytotoxic hypoxia, which occurs when phosphorylation is hampered due to the suppression of cytochrome C oxidase, the terminal enzyme of the respiratory chain, by cyanide. The consumption of cassava peel-based diets has been found to result in reduced nutritional digestion and absorption in animals (Lukuyu *et al.*, 2014). The metabolic aberration found in animals consuming diets high in cyanide, such as cassava peels, can be attributed to a mechanism of action that includes the continuing depletion of sulfur-containing amino acids, specifically methionine, in the circulatory system. Therefore, in order to enhance the utilisation of cassava peels in monogastric diet, it is imperative to ensure a balanced amino acid concentration and minimize the cyanide content present in the peels. The involvement of methionine, an amino acid containing sulfur, in the detoxification of cassava has been proposed for a considerable period of time (Ayenor, 1985). According to Waldroup (2006), it has been observed that an increase in methionine need and supplementation necessitates modifications in the level of dietary lysine consumption. The significance of lysine in cassava or cassava by-product based diets is frequently underestimated, mostly due to its status as the second limiting amino acid. The impact of the second limiting amino acid may not be readily apparent until the dietary need for the first limiting amino acid is met (Cafe & Waldroup, 2006). In a study conducted by Baker & Han (1994), it was found that the concentration of lysine in a diet can have an impact on the sensitivity of birds to methionine. Hence, the augmentation of methionine levels in a diet mostly composed of cassava peel meal, which inherently lacks sufficient methionine, may necessitate the inclusion of supplementary lysine. Therefore, it is hypothesized that higher methionine and lysine supplementation to cassava peel meal-based diet is important for improved carcass trait and meat quality of broiler chickens. The objective of this study is to assess the impact of processed cassava peel meal (at a high inclusion level of 50 % replacement for corn), with added methionine and lysine, on meat lipid composition, carcass trait, and meat quality of finisher broiler chickens.

## 2 Materials and methods

This study was conducted at the Federal University of Agriculture, Abeokuta, Nigeria and all procedures followed in the study were approved by the Animal Care and Use Committee of the University. Feed grade methionine and lysine (Evonik Nutrition & Care GmbH) were purchased from reputable feed additive store in Oyo State, Nigeria.

**Table 1:** *Ingredient composition of experimental finisher diets.*

| *Ingredients (%)* | *Diet 1* | *Diet 2* | *Diet 3* | *Diet 4* |
|---|---|---|---|---|
| Maize | 61.00 | 30.50 | 30.50 | 30.50 |
| CPM | 0.0 | 30.50 | 30.50 | 30.50 |
| Soyabean meal | 30.00 | 31.50 | 31.50 | 31.50 |
| Palm oil | 3.00 | 3.20 | 3.20 | 3.20 |
| Bone meal | 4.50 | 3.0 | 3.0 | 3.0 |
| Limestone | 0.60 | 0.40 | 0.40 | 0.40 |
| Methionine | 0.20 | 0.20 | 0.25 | 0.28 |
| Lysine | 0.10 | 0.10 | 0.12 | 0.14 |
| Broiler premix* | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.35 | 0.35 | 0.35 | 0.35 |
| *Nutrients (%)* | | | | |
| ME (kcal/kg) | 3100.00 | 3080.02 | 3090.00 | 3090.00 |
| Crude protein | 19.55 | 19.54 | 19.56 | 19.58 |
| Crude fibre | 4.05 | 4.05 | 4.05 | 4.05 |
| Ether extract | 4.92 | 4.92 | 4.92 | 4.92 |
| Calcium | 0.83 | 0.86 | 0.86 | 0.83 |
| Phosphorus | 0.63 | 0.64 | 0.63 | 0.63 |
| Methionine | 0.40 | 0.40 | 0.44 | 0.48 |
| Lysine | 0.96 | 0.96 | 1.02 | 1.08 |
| Energy protein† | 158.56 | 157.78 | 157.97 | 157.81 |
| Meth. + Cyst.‡ | 0.77 | 0.78 | 0.81 | 0.83 |

*Vitamin-mineral premix per kilogram of diet: 1200 IU vitamin A; 300 IU vitamin D3; 4.2 mg vitamin E; 0.2 mg vitamin K3; 0.2 mg vitamin B1; 0.66 mg vitamin B3; 0.5 mg vitamin B6; 2 $\mu$g vitamin B12; 0.1 mg folic acid; 0.02 mg biotin; 1.5 mg Ca pantothenate, 0.07 g choline chloride; 12 mg antioxidant (butylhydroxytoluene); 0.23 g Ca; 0.5 mg Cu; 5.1 mg Zn; 6 mg Fe; 7.1 mg Mn; 0.06 mg I; and 0.02 mg Se.
†Energy protein ratio; ‡Methionine + Cysteine.
Diet 1 = Control Diet (Corn-soyabean meal based diet) containing 4.0 g $kg^{-1}$ digestible MET, 0.96 g $kg^{-1}$ digestible lysine, Diet 2 = A diet containing 50 % replacement of maize in Diet 1 with high quality cassava peel meal and containing 4.0 g $kg^{-1}$ digestible MET, 0.96 g $kg^{-1}$ digestible lysine, Diet 3 = A diet containing 50 % replacement of maize in Diet 1 with high quality cassava peel meal and containing 4.4 g $kg^{-1}$ digestible MET, 1.02 g $kg^{-1}$ digestible lysine, Diet 4 = A diet containing 50 % replacement of maize in Diet 1 with high quality cassava peel meal and containing 4.8 g $kg^{-1}$ digestible MET, 1.08 g $kg^{-1}$ digestible lysine, CPM = Processed Cassava Peel Meal (high quality cassava peel meal).

### 2.1 Experimental design

A total of 350, 1-day-old male Cobb-500 broiler chickens were purchased from a commercial hatchery. The experimental period of the study lasted for 3 weeks under a deep litter housing system. A total of 320 birds were selected on weight equalisation basis after the pre-experimental period (starter phase, 3 weeks). Broiler chickens were provided with commercial diets based on maize-soybean meal during the pre-experimental period (metabolisable energy (ME) = 2900 kcal kg-1, crude protein (CP)

= 220 g kg$^{-1}$), which met the nutritional requirements of the chicks at the starter phase. A control diet based on corn and soybean meal was formulated to meet the recommended digestible methionine and lysine specification of 4.0 g kg$^{-1}$ and 0.96 g kg$^{-1}$, respectively (VenCobb 500 Broiler Management Guide, 2022) for the finisher phase. Three other diets were formulated to have 100 %, 112.5 % and 125 % of the recommended digestible methionine and 100 %, 106.25 % and 112.5 % of the recommended digestible lysine while 50 % of the corn in the control diet was replaced with high quality cassava peel meal in these diets, yielding 4.0 g kg$^{-1}$, 4.4 g kg$^{-1}$, and 4.8 g kg$^{-1}$ digestible methionine, respectively, and 0.96 g kg$^{-1}$, 1.02 g kg$^{-1}$, and 1.08 g kg$^{-1}$ digestible lysine, respectively (VenCobb 500 Broiler Management Guide, 2022) for the finisher phase (Table 1). Each dietary treatment consisted of eight replicates with ten birds in each replicate. All diets were formulated to be isonitrogeneous and iso-calorific.

### 2.2 *High quality cassava peel meal (HQCPM)*

The HQCPM was obtained from International Livestock Research Institute (ILRI) in Ibadan. The detailed methods for the production has been documented by Amole *et al.* (2019). The freshly harvested cassava was peeled and grated. The grated peels were then dewatered for 24 hrs (placed in woven bags) using an hydraulic press. Then, pulverized and sieved to pass through a 3 mm mesh (separation of coarse fraction), the resultant material was dried locally in the sun and stored in plastic woven bags.

### 2.3 *Chemical analysis*

The concentration of moisture (method no. 934.01), protein (method no. 996.11), and crude fibre (method no. 978.01) in the high quality cassava peel and feed were determined following the established protocol (AOAC 2000). Neutral detergent fibreer and acid detergent fibre were determined using Van Soest method (Goering & Van Soest 1970). The silver nitrate method was used to determine the cyanide content of the peels and the organic matter and gross energy was determined following Weiss & Tebbe (2019). Technicon Sequential Multi-sample (TSM) Amino Acid Analyser was used to determine the methionine, cysteine and lysine content of the test ingredient and the experimental feed in triplicates according to the method of (Spackman *et al.*, 1958)

### 2.4 *Carcass characteristics*

On the last day of the finisher phase, five broiler chickens per replicate (40 per treatment) were selected at random, slaughtered in accordance to the standards of Ministry of Agriculture, Nigeria, defeathered, and eviscerated following standard commercial procedures (Uijttenboogaart & Gerrits, 1982). The body weight (BW) and dressed weights were measured digital scale balance (Nihon Kohden, A-12), while the dressing percentage was calculated. The cut parts, which include breast, thighs, and drumsticks were weighed and recorded as relative weights (percentage of BW). The organs, which include kidney, liver, and the spleen were collected, weighed, and calculated as percentages of respective body weight.

**Table 2:** *Analysed chemical composition of high quality cassava peel.*

| *Parameters* | *Composition (%)* |
|---|---|
| Crude protein | 4.63 |
| Crude fibre | 8.20 |
| NDF | 35.17 |
| ADF | 22.56 |
| Ether extract | 1.22 |
| Gross energy (MJ kg)$^{-1}$ | 18.01 |
| Methionine | 0.05 |
| Cysteine | 0.02 |
| Lysine | 0.03 |
| Hydrocyanide content (ppm) | 7.48 |

NDF: neutral detergent fibre; ADF: acid detergent fibre.

### 2.5 *Meat quality and colour analysis*

The surface colour of breast meat was determined using a colorimeter (Minolta Chroma Meter CR-400, Minolta Italia S.p.A.). The instrument was calibrated against white reference tiles prior to use. L* (lightness), a* (redness), and b* (yellowness) values were recorded as reported by Zhuang & Savage (2010).

The hydrogen index of the breast muscle was evaluated with a digital tipped meat pH probe (Meat pH Tester, Hanna, USA) which was inserted into the cranial left side of the muscle to measure the meat pH. For each carcass, two measurements were taken and the mean pH value was calculated. The water-holding capacity (WHC) was evaluated using the centrifugal method as described by Zhang *et al.* (2011). A total of 15 g of ground breast samples from each replicate were weighed in a centrifuge tube and centrifuged at 7,000 × g at 4 °C for 15 min (Sorvall RC-5B, Du Pont Instruments, Wilmington, DE). Subsequently, the supernatant was carefully removed, and the remaining solid portion was weighed. WHC was expressed as the percentage of water loss using the equation below:

$$\text{WHC}\ (\%) = \frac{\text{initial SW} - \text{SW after centrifugation}}{\text{initial SW}} \times 100$$

Where SW = sample weight.

The cranial portion of the pectoralis muscle was divided, weighed (about 100 g), placed in separate zip-lock bags, and refrigerated at 4 °C for 48 hours. A dried paper towel was used to dry the samples before the initial weights were taken. The samples were individually drained, and reweighed after storage. Drip loss was calculated as the difference between final and initial weights and expressed as a percentage of the initial weight. The cranial section of breast meat was cut, weighed at approximately 90 g, and packaged in a zip-lock bag. The sample was cooked in a boiling water bath until the internal temperature reached 75 °C. Cooked samples were cooled for 1h in a refrigerator at 4 °C to allow the temperature to equilibrate prior to weighing. Excess liquid was removed from the meat by patting with a paper towel. Subsequently, the cooked sample was weighed. Cooking yield is calculated as the ratio of cooked weight to raw weight and expressed as a percentage (Hussnain *et al.*, 2020). Weight of sample before freezing minus sample weight after thawing] × 100/weight of sample before freezing was used to compute the percentage thaw loss (Henrikson *et al.*, 2018).

### 2.6 Meat lipid analysis

Total lipid in the muscle samples was extracted following the method of Elkin & Rogler (1990). About 1 g each of muscle samples from each replicate was homogenised with 12 mL of chloroform-methanol 2 : 1 (v/v) and filtered directly into a 50-mL volumetric flask using a glass microfiber filter. After rehomogenisation and refiltration, the muscle filtrates were diluted to a final volume of 50 mL with chloroform-methanol 2 : 1 (v/v) . In addition to increase the concentration of lipid extract of the muscle samples, the chloroform-methanol was removed by rotary evaporator (Virtis, Gardiner, NY, USA) following centrifugation (1000 g for 10 min) and filtration, and finally the dried extract was dissolved in 5 mL of chloroform-methanol 2 : 1 (v/v). Cholesterol, low density lipoprotein, very low density lipoprotein, high density lipoprotein, and triglyceride concentrations in the total lipid extracts were determined using commercial analytical kits (Randox diagnostic kit; GPO-PAP Method; Antrim, orthern Ireland) and automatic blood biochemical analyser was used (Roche Cobas Miras, Basel, Switzerland)

## 3 Results

### 3.1 Carcass trait of broiler chickens

The results showed in Table 3 suggest that the highest slaughter and carcass weight was recorded in birds fed Diet 2, while the birds fed the control diet (CON) showed the lowest slaughter weight among the treatments ($p < 0.05$). The breast meat of the finisher broiler chickens fed Diet 3 had the highest weight while the birds fed Diet 4 had the least breast meat weight ($p < 0.05$). The thigh weight was least in the birds fed the control diet and highest in the birds fed Diet 2. The abdominal fat was least in birds fed Diet 3 and highest in birds fed the control diet and Diet 1.

### 3.2 Internal organs of finisher broiler chickens

Dietary treatments had no significant effect on the liver, empty gizzard, full gizzard, heart and spleen weight of finisher broiler chickens fed the different dietary treatments ($p < 0.05$). However, the dietary treatments seem to affect the small intestinal weight (Table 4). The birds fed Diet 2 had the highest small intestinal weight while the small intestinal weight of birds fed Diet 1 was observed to be lowest ($p < 0.05$).

**Table 3:** *Effect of dietary treatments on carcass traits of broiler chickens (in g).*

| *Item* | *Diet 1* | *Diet 2* | *Diet 3* | *Diet 4* | *SEM* | *$p < 0.05$* |
|---|---|---|---|---|---|---|
| Slaughter weight | $1900.0^{c}$ | $2130.0^{a}$ | $2070.0^{a}$ | $2030.0^{b}$ | 25.00 | 0.03 |
| Carcass weight | $1600.0^{a}$ | $1630.0^{a}$ | $1600.0^{a}$ | $1580.0^{c}$ | 20.88 | 0.03 |
| Breast | $518.47^{b}$ | $583.61^{b}$ | $617.03^{a}$ | $451.79^{c}$ | 25.45 | 0.02 |
| Thigh | $83.02^{c}$ | $101.08^{a}$ | $98.30^{b}$ | $94.33^{b}$ | 10.89 | 0.04 |
| Drumstick | $220.85^{b}$ | $231.87^{a}$ | $220.55^{b}$ | $212.95^{c}$ | 5.07 | 0.04 |
| Heart | 10.11 | 10.03 | 11.98 | 9.40 | 2.09 | 0.07 |
| Abdominal fat | $21.39^{a}$ | $23.12^{a}$ | $13.68^{c}$ | $16.31^{b}$ | 1.96 | 0.02 |

See table 1 for diet description; $^{a-c}$ = means in the same row without common superscript differ at $p < 0.05$; SEM= standard error of mean.

**Table 4:** *Effect of dietary treatments on internal organs of broiler chickens (in g).*

| *Item* | *Diet 1* | *Diet 2* | *Diet 3* | *Diet 4* | *SEM* | *$p < 0.05$* |
|---|---|---|---|---|---|---|
| Small intestine | $73.08^c$ | $95.93^a$ | $78.89^b$ | $80.31^b$ | 5.65 | 0.01 |
| Liver | 36.73 | 36.14 | 32.13 | 32.04 | 5.67 | 0.18 |
| Empty Gizzard | 41.73 | 39.75 | 43.08 | 48.21 | 10.06 | 0.30 |
| Full Gizzard | 50.35 | 50.73 | 56.12 | 68.54 | 10.34 | 0.09 |
| Heart | 10.11 | 10.03 | 11.98 | 9.40 | 3.23 | 0.12 |
| Spleen | 2.45 | 2.43 | 2.14 | 1.76 | 1.49 | 0.68 |

See table 1 for diet description; $^{a-c}$ = means in the same row without common superscript differ at $p < 0.05$; SEM= standard error of mean.

**Table 5:** *Effect of dietary treatments on meat quality of broiler chickens.*

| *Item* | *Diet 1* | *Diet 2* | *Diet 3* | *Diet 4* | *SEM* | *$p < 0.05$* |
|---|---|---|---|---|---|---|
| Water holding capacity (%) | $30.25^c$ | $31.31^b$ | $32.35^b$ | $37.24^a$ | 2.23 | 0.04 |
| Cooking loss (%) | $38.73^b$ | $37.90^b$ | $25.37^c$ | $41.12^a$ | 5.78 | 0.03 |
| Refrigeration loss (%) | 1.55 | 1.47 | 0.90 | 1.98 | 0.89 | 0.05 |
| Water absorption capacity (%) | 1.49 | 0.86 | 1.43 | 1.12 | 0.78 | 0.06 |

See table 1 for diet description; $^{a-c}$ = means in the same row without common superscript differ at $p < 0.05$; SEM= standard error of mean.

### 3.3 Meat quality of finisher broiler chickens

Table 5 shows that there are significant dietary effects on the meat quality with the exception of water absorption capacity and refrigeration loss. The meat of broiler chicken fed the control diet (CON) had the least water holding capacity while the broiler chickens fed Diet 4 had the highest water holding capacity. The meat cooking loss of chickens fed Diet 4 was highest while the lowest cooking loss was recorded in meat of broiler chickens fed Diet 3.

### 3.4 Meat colour

The effect of dietary treatments on meat colour are provided in Table 6. The breast meat of chickens fed Diet 3 had the highest lightness ($L^*$) and redness ($a^*$) while the meat of the chickens fed the control diet had the least lightness ($L^*$) and redness ($a^*$) ($p < 0.05$). Diet 3 had the highest impact on the lightness (L) and redness (a) of the broiler chicken meat while the chickens fed the control diet showed the lowest meat lightness (L) and redness (a) ($p < 0.05$). The Yellowness (b*) of the finisher broiler's meat was not statistically different among the treatments ($p > 0.05$).

### 3.5 Breast meat lipid profile

The control diet fed broiler chickens had meat containing the highest cholesterol, low density lipoprotein (LDL), High density lipoprotein (HDL ), Very low density lipoprotein (VLDL) and triglyceride concentration ($p < 0.05$) while the meat of broiler chickens fed Diet 2 (diet without additional methionine and lysine supplementation) had the lowest cholesterol, triglyceride, LDL and VLDL concentration ($p < 0.05$). The lowest HDL concentration was observed in the meat of broiler chickens fed Diet 3 (Table 7).

**Table 6:** *Effect of dietary treatments on meat colour of broiler chickens.*

| *Item* | *Diet 1* | *Diet 2* | *Diet 3* | *Diet 4* | *SEM* | *$p < 0.05$* |
|---|---|---|---|---|---|---|
| Lightness (L) | $40.26^c$ | $41.92^b$ | $43.79^a$ | $42.78^a$ | 1.22 | 0.03 |
| Redness(a) | $4.95^c$ | $5.80^b$ | $7.91^a$ | $5.31^b$ | 1.34 | 0.03 |
| Yellowness(b) | 5.30b | $6.41^a$ | $6.04^a$ | $5.17^b$ | 1.55 | 0.04 |
| Lightness($L^*$) | $47.25^b$ | $48.63^b$ | $50.89^a$ | $49.86^a$ | 1.33 | 0.04 |
| Redness($a^*$) | 6.23c | $7.21^b$ | $9.61^a$ | $6.57^c$ | 2.01 | 0.04 |
| Yellowness($b^*$) | $7.32^b$ | $8.87^a$ | $8.14^a$ | $6.95^b$ | 1.88 | 0.05 |

See table 1 for diet description; $^{a-c}$ = means in the same row without common superscript differ at $p < 0.05$; SEM= standard error of mean.

**Table 7:** *Effect of dietary treatments on breast meat lipid profile of broiler chickens.*

| *Item* | *Diet 1* | *Diet 2* | *Diet 3* | *Diet 4* | *SEM* | *p < 0.05* |
|---|---|---|---|---|---|---|
| Cholesterol | $134.40^a$ | $97.80^c$ | $106.50^c$ | $119.40^b$ | 9.02 | 0.02 |
| HDL | $59.00^a$ | $46.10^c$ | $44.90^c$ | $55.40^b$ | 5.80 | 0.04 |
| LDL | $45.70^a$ | $30.40^c$ | $34.10^c$ | $41.30^b$ | 5.23 | 0.03 |
| VLDL | $29.70^a$ | $21.40^c$ | $27.40^b$ | $22.60^c$ | 4.04 | 0.04 |
| Triglyceride | $148.70^a$ | $106.80^c$ | $137.20^b$ | $113.10^c$ | 10.34 | 0.03 |

See table 1 for diet description; $^{a-d}$ = means in the same row without common superscript differ at $p < 0.05$; SEM= standard error of mean.

## 4 Discussion

The current high cost of feed materials has prompted an increased search for sustainable alternative feedstuffs for poultry nutrition. Cassava peels have been reported to have potentials to substitute for maize in the feeding program of broiler chickens (Chang'a *et al.*, 2020), however, the impact of the agro-waste on carcass trait, internal organs and meat quality of food animals should be assessed. This study observed that carcass trait was not compromised in birds fed cassava peel meal-based diet. The improved slaughtered weight, carcass weight, breast meat weight, thigh meat weight, drumstick weight and abdominal fat content of birds fed diets containing high quality cassava peel as compared to the control-fed birds suggests that high quality cassava peel meal could be a viable and sustainable energy feedstuff for finisher broiler chickens. Oladimeji *et al.* (2020) reported that feeding up to 60 % cassava peel products in broiler chicken diets had similar effects on carcass yield, but breast meat yield was higher in maize-based diets. In this study, the additional supplementation of methionine (4.4 g $kg^{-1}$ digestible methionine) and lysine (1.02 g $kg^{-1}$ digestible lysine) improved breast meat yield of the chickens. Khempaka *et al.* (2013) suggested that fermented cassava pulp (FCP) can be used in broiler diets up to 160 g $kg^{-1}$ feed without detrimental effects on carcass quality. The author deduced that fermentation or other improved processing methods may influence the effect of cassava byproducts on carcass quality of broiler chickens. This seems to be associated with the result obtained in this study. Choi *et al.* (2023) reported that contemporary broiler strains possess fat levels ranging from 15 % to 20 %, and more than 85 % of this fat is deemed unnecessary for physiological functions. Generally, the excessive accumulation of fat is undesirable for both producers and consumers, as it represents wasted dietary energy and a low-value byproduct (Emmanuel *et al.*, 2018). Not only does this result in a reduction in carcass yield, but it also adversely affects consumer acceptance. This study showed that the fortified high quality cassava peels with methionine and lysine above the recommended levels significantly reduced the deposition of abdominal fats in the broiler chickens. This could imply that high quality cassava peel meal may have no discernible impact on the acceptability of broiler chicken meat by consumers.

Reduced weight or length of the small intestine could lead to reduced nutrient metabolism in broiler chickens. Ogbuewu & Mbajiorgu (2023) reported that an increase in the length and weight of the various segments of the small intestine of broilers could be a strategy to handle the fibre contained in the diets. This phenomenon is likely attributed to an expansion in the absorptive surface area of the villi, contributing to improved efficiency in the digestion and absorption of nutrients (Baurhoo *et al.*, 2007). The observed increased small intestinal length of birds fed cassava peel meal based diets may suggest increased nutrient metabolism which could be related to the higher slaughtered weight and carcass weight of the birds. The gizzard is a muscular organ responsible for grinding and breaking down feed particles. In broiler chickens, the gizzard is well-developed to support efficient digestion. Large gizzard is good for better grinding of ingested feed and has economic importance as its consumer demand is high (Amerah *et al.*, 2007). The heart of a broiler chicken is relatively small compared to the overall body size. This may have consequences for the rapid development of body mass in broilers. Interestingly, the size of the heart, spleen and liver were not significantly influence by the different diets. This may suggest that dietary high inclusion level (50 % replacement for maize) of high quality cassava peel meal does not pose threat to the physical size of vital internal organs of finisher broiler chickens. The water holding capacity is a crucial attribute influencing the quality of meat. It plays a role in the visual appeal of raw meat, its behaviour while cooking, and the juiciness experienced during consumption. A high-water holding capacity in fresh meat is indicative of good firmness and a tightly structured texture. The mechanism underlying the retention of water in fresh meat is rooted in the structure of the muscle cell and in the state of key proteins associated with the myofibril (Huff-Lonergan, 2009). This study showed that cassava peel meal-based diet improved the firmness on broiler chicken meat, an indication that it does not negatively affect key proteins associated with the myofibril. However, this study did not determine the expression of key proteins (such as the myosin or actin) associated with muscle contraction in the chickens.

The heat treatment of meat induces various structural changes, including the breakdown of cell membranes, rupture of muscle fibers, and the disintegration of connective tissue proteins (Vujadinovic *et al.*, 2014). Additionally, the heat causes coagulation and gel formation of myofibrillar and sarcoplasmic proteins. These alterations in the meat's structure play a significant role in its texture, flavour, and overall palatability when cooked. The specific effects of heat treatment on meat structure contribute to the transformation of raw meat into a more palatable and digestible form during cooking. This study showed that cassava peel meal-based diet fortified with higher methionine and lysine levels significantly reduced the cooking loss of broiler chicken meat. Pokoo-Aikins *et al.* (2022) observed a similar result with increased supplementation of amino acid (methionine) in diets of broiler chickens. The study did not observe a significant difference in the refrigeration loss and water absorption capacity of the meat of the broiler chickens fed the different dietary treatments.

Health concerns arise due to the potential occurrence of diseases linked to the consumption of meats containing high levels of cholesterol (Duan *et al.*, 2022). Reports have shown that diets containing cassava peels has potentials in the metabolism of lipids and cholesterol contents of animals (Aro & Akinjokun, 2012, Abouelezz *et al.*, 2022). This was also recorded in the meat of 42 days old broiler chickens used in this study. The mechanism by which cassava peel containing diets reduce lipid content in broiler chickens may be associated with the high amylose/amylopectin ratio in cassava peels. A higher amylose/amylopectin in carbohydrates can lead to a lower glycemic index, potentially promoting better insulin sensitivity and lower fat storage. This may have implication for the overall reduction of LDL, VLDL, and triglyceride concentration in the meat of birds fed the cassava peel meal-based diets. With decreased LDL concentration in the blood circulations, high density lipoprotein concentration increases and clears cholesterol from plasma via promoting cholesterol delivery from the periphery to liver (Grummer & Carroll, 1988, Adebowale *et al.*, 2019). Surprisingly, despite the high concentrations of cholesterol in the meat of birds fed corn-soybean meal based diet, a high HDL concentration was also recorded, which was closely followed by the HDL concentration in the meat of broiler chickens fed cassava peel meal based diet containing 4.8 g kg$^{-1}$ and 1.08 g kg$^{-1}$ digestible methionine and lysine, respectively.

Consumers attach importance to the colour of meat as it helps them to judge its freshness and safety (Hussnain *et al.*, 2020). This study showed that high inclusion level of cassava peel improved the lightness, redness and yellowness of broiler chicken meat. A further improvement of the meat colour was observed when additional methionine and lysine was added to the cassava peel meal-based diets. Myoglobin, a protein with heme iron, is accountable for the colour of meat and is recognized as a beneficial source of dietary iron (Suman & Joseph, 2013). This outcome suggests that meat from birds fed a diet based on cassava peel meal may exhibit enhanced visual appeal to consumers and possess elevated iron content. Further research is suggested to explore the micronutrient composition of meat from birds fed diets rich in processed and fortified cassava waste meal.

In conclusion, high dietary inclusion of high quality cassava peel meal (at 50 % maize replacement) with or without additional supplementation of methionine and lysine did not affect carcass characteristics, meat quality and meat lipid in broiler chickens. Internal organ weight and meat colour were also not affected. However, abdominal fat deposition, redness, yellowness and lightness (visual appeal) of the meat were further improved in birds fed diets containing high quality cassava peel meal supplemented with 112.5 % and 106.25 % of the recommended digestible methionine and lysine. There is a compelling economic advantage for the use of high quality cassava peel meal in place of maize in finisher broiler diets due to lower cost, similar or better performance in terms of carcass characteristics, meat quality and meat lipid profile. It is recommended that further studies should elucidate the micronutrient and major protein composition of meat from birds fed diets based on high quality cassava peel meal.

### *Conflict of interest*

The authors have no relevant financial or non-financial interests to disclose.

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## References

Abouelezz, K. F. M., Wang, S., Xia, W. G., Chen, W., Elokil, A. A., Zhang, Y. N., Wang, S. L., Li, K. C., Huang, X. B. & Zheng, C. T. (2022). Effects of dietary inclusion of cassava starch-extraction-residue meal on egg production, egg quality, oxidative status, and yolk fatty acid profile in laying ducks. *Poultry Science,* 101, 102015.

Adebowale, T., Oso, A. O., Liu, H., Tossou, M. C. B., Chen, J., Li, H., Kang, B. & Yao, K. (2019). Effect of Dietary Niacin Supplementation on Growth Performance, Nutrient Digestibility, Hematology, and Lipoprotein Concentrations of Young Turkeys, Meleagris gallopavo. *Journal of Poultry Science*, 56, 112–119.

Amerah, A. M., Lentle, R. & Ravindran, V. (2007). Influence of Feed Form on Gizzard Morphology and Particle Size Spectra of Duodenal Digesta in Broiler Chickens. *Journal of Poultry Science - JournalPoultry Science*, 44, 175-181.

Amole, T. A., Anandan, S. & Okike, I. (2019). A guide to the production of High-Quality Cassava Peel® mash as a feed for livestock. ILRI Manual 35. Nairobi, Kenya: International Livestock Research Institute (ILRI).

AOAC (2000). *Official method of Analysis of AOAC International*, 17th edition. Association of Official Analytical Chemists Washington, DC., US.

Apeh Akwu, O., Emmanuel Uchenna, A., Ze Yuan, Z., Fidelis, F.-N. & Paul Ade, I. 2017. Improving Cassava Quality for Poultry Feeding Through Application of Biotechnology. In: Viduranga, W. (ed.). *Cassava*, p. Ch. 14, IntechOpen, Rijeka.

Aro, S. & Akinjokun, O. M. (2012). Meat and carcass characteristics of growing pigs fed microbially enhanced cassava peel diets. *Archivos De Zootecnia*, 61, 407–414.

Ayenor, G. A. (1985). Effect of retting of cassava on product yield and cyanide detoxification. *Journal of Food Technology*, 20:89–96.

Baker, D. H. & Han, Y. (1994). Ideal amino acid profile for chicks during the first three weeks posthatching. *Poultry Science*, 73, 1441–1447.

Baurhoo, B., Phillip, L. & Ruiz-Feria, C. A. (2007). Effects of Purified Lignin and Mannan Oligosaccharides on Intestinal Integrity and Microbial Populations in the Ceca and Litter of Broiler Chickens. *Poultry Science*, 86, 1070–1078.

Cafe, M. B. & Waldroup, P. W. (2006). Interactions between levels of methionine and lysine in broiler diets changed at typical industry intervals. *International Journal of Poultry Science*, 5, 1008–1015.

Chang'a, E. P., Abdallh, M. E., Ahiwe, E. U., Mbaga, S., Zhu, Z. Y., Fru-Nji, F. & Iji, P. A. (2020). Replacement value of cassava for maize in broiler chicken diets supplemented with enzymes. *Asian-Australasian Journal of Animal Science*, 33, 1126–1137.

Choi, J., Kong, B., Bowker, B. C., Zhuang, H. & Kim, W. K. (2023). Nutritional Strategies to Improve Meat Quality and Composition in the Challenging Conditions of Broiler Production: A Review. *Animals (Basel)* 13.

Duan, Y., Gong, K., Xu, S., Zhang, F., Meng, X. & Han, J. (2022). Regulation of cholesterol homeostasis in health and diseases: from mechanisms to targeted therapeutics. *Signal Transduction of Target Therapy*, 7, 265.

Emmanuel, U. A., Apeh, A. O., Medani, B. A. & Paul, A. I. 2018. Managing Dietary Energy Intake by Broiler Chickens to Reduce Production Costs and Improve Product Quality. In: Banu, Y., & Turgay, T. (eds). *Animal Husbandry and Nutrition*, p. Ch. 6, IntechOpen, Rijeka.

Grummer, R. R. & Carroll, D. J. (1988). A review of lipoprotein cholesterol metabolism: importance to ovarian function. *Journal of Animal Science*, 66, 3160–3173.

Henrikson, Z. A., Vermette, C. J., Schwean-Lardner, K. & Crowe, T. G. (2018). Effects of cold exposure on physiology, meat quality, and behavior of turkey hens and toms crated at transport density. *Poultry Science*, 97, 347–357.

Huff-Lonergan, E. (2009). Fresh meat water-holding capacity. Improving the Sensory and Nutritional Quality of Fresh Meat. *Woodhead Publishing Series in Food Science, Technology and Nutrition*, 4669, 147–160.

Hussnain, F., Mahmud, A., Mehmood, S. & Jaspal, M. H. (2020). Meat Quality and Cooking Characteristics in Broilers Influenced by Winter Transportation Distance and Crate Density. *Journal of Poultry Science*, 57, 175–182.

Khempaka, S., Thongkratok, R., Okrathok, S. & Molee, W. (2013). An Evaluation of Cassava Pulp Feedstuff Fermented with *A. oryzae*, on Growth Performance, Nutrient Digestibility and Carcass Quality of Broilers. *Journal of Poultry Science*, 51, 71–79.

Lukuyu, B., Okike, I., Duncan, A., Beveridge, M. & Blümmel, M. (2014). Use of cassava in livestock and aquaculture feeding programs. *ILRI discussion paper 25*. International Livestock Research Institute, Nairobi, Kenya.

Morgan, N. K. & Choct, M. (2016). Cassava: Nutrient composition and nutritive value in poultry diets. *Animal Nutrition*, 2, 253–261.

Nourani, M. R., Kalantari Hesari, A., Shahrooz, R. & Asadi, M. R. (2021). Effect of Sodium Cyanide-induced Tissue Hypoxia on Reproductive Capability of Male Mice and the Protective Effect of Ethyl Pyruvate. *Archives of Razi Institute*, 76, 323-333.

Ogbuewu, I. P. & Mbajiorgu, C. A. (2023). Dose-related responses of broiler chickens to black velvet tamarind (*Dialium guineense*) stem bark supplementation: carcass characteristics, organ weight and intestinal biometry. *Agroforestry Systems*, 98, 245–254.

Oladimeji, S., Ogunwole, O., Amole, T. & Oo, T. (2020). Carcass characteristics and organ weights of broiler chicken fed varying inclusion levels of cassava (*Manihot esculenta* Crantz) peel products- based diets. *Nigerian Journal of Animal Science*, 22, 147–157.

Oloruntola, O. D., Ayodele, S. O., Jimoh, O. A. & Agbede, J. O. (2019). Dietary cassava peel meal, methionine, and multi-enzyme supplementation in rabbits' nutrition: effect on growth, digestibility, and carcass traits. *The Journal of Basic and Applied Zoology*, 80, 46.

Pokoo-Aikins, A., Timmons, J. R., Min, B. R., Lee, W. R., Mwangi, S. N., McDonough, C. M. & Chen, C. (2022). Effects of Varying Levels of Dietary DL-Methionine Supplementation on Breast Meat Quality of Male and Female Broilers. *Poultry*, 1, 40-53.

Spackman, D. H., Stein, W. H. & Moore, S. (1958). Automatic Recording Apparatus for Use in Chromatography of Amino Acids. *Analytical Chemistry*, 30, 1190–1206.

Suman, S. P. & Joseph, P. (2013). Myoglobin chemistry and meat color. Annual Review of Food Science and *Technology*, 4, 79–99.

Tewe, O. O. (1992). Detoxification of cassava products and effects of residual toxins on consuming animals. Roots, tubers, plantains and bananas in animal feeding. In: Machin, D., & Nyvold, S. (eds.) *FAO Animal Production and Health Paper 95*, 81–98.

Uijttenboogaart, T. G. & Gerrits, A. R. (1982). *Method of dissection of broiler carcasses and description of parts.* Beekbergen, Centrum voor Onderzoek en Voorlichting voor de Pluimveehouderij.

Vujadinovic, D. P., Grujic, R. D., Tomović, V., Vukic, M. & Jokanović, M. (2014). Cook Loss as a Function of Meat Heat Treatment and Regime.*Quality of Life (Banja Luka) - APEIRON* 10(3-4).

Waldroup, M. B. C. a. P. W. (2006). Interactions Between Levels of Methionine and Lysine in Broiler Diets Changed at Typical Industry Intervals. *International Journal of Poultry Science*, 5, 1008–1015.

Weiss, W. P. & Tebbe, A. W. (2019). Estimating digestible energy values of feeds and diets and integrating those values into net energy systems. *Translational Animal Science*, 3, 953–961.

Yafetto, L., Odamtten, G. T. & Wiafe-Kwagyan, M. (2023). Valorization of agro-industrial wastes into animal feed through microbial fermentation: A review of the global and Ghanaian case. *Heliyon*, 9, e14814.

Zhuang, H., & Savage, E. M. (2010). Comparisons of sensory descriptive flavor and texture profiles of cooked broiler breast fillets categorized by raw meat color lightness values. *Poultry Science*, 5, 1049–1055.

Zhang, W., Xiao, S., Lee, E. J. & Ahn, D. U. (2011). Consumption of oxidized oil increases oxidative stress in broilers and affects the quality of breast meat. *Journal of Agricultural and Food Chemistry*, 59, 969–974.