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CARCASS INDICES AND MEAT QUALITY OF BROILER CHICKENS FED DIETS CONTAINING FORTIFIED FERMENTED CASSAVA STUMP

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ABSTRACT

A 56-day study was conducted to evaluate carcass and meat quality of broiler chickens fed diets containing fortified fermented cassava stump (FFCS) as a replacement for maize. Cassava stumps and leaves were fermented in the solid state at room temperature, using *Aspergillus niger* ATCC 16404 for 192 and 96 hours, respectively, and then mixed at a ratio of 19:1 to obtain the FFCS. The birds were allotted into four treatments with three replicates (n= 30). The treatments consisted of different inclusion levels of FFCS: Diet 1 containing 0% FFCS (control treatment); Diet 2 containing 20% FFCS; Diet 3 containing 40% FFCS; and Diet 4 containing 60% FFCS. Dressing and eviscerated percentages were higher ($p \leq 0.05$) in birds fed the diets with up to 40% FFCS. The carcass yield was not significantly influenced ($p > 0.05$) by the inclusion of FFCS, but values obtained were higher with up to 40%. Meat quality was significantly ($p < 0.05$) influenced by the FFCS. In addition, the degree of meat peroxidation decreased with increased FFCS levels. Diets with up to 40% FFCS inclusion resulted in improved carcass traits, oxidative stability, and meat quality. Therefore, the addition of fortified cassava stump in broiler chickens' diets could produce meat of better quality, with low peroxidation, high oxidative stability, and longer shelf-life.

Keywords: Cassava stump, cassava leaf, solid state fermentation, carcass yield, meat qualities.

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INTRODUCTION

Broiler chickens grow faster than any other meat source (Kralik et al., 2018), offering good value in terms of animal protein, which has been scientifically proved to be better than plant protein (Berrazaga et al., 2019).The meat is recognized because of its high quality nutrients, ease of preparation and delicious taste (Wahyono and Utami, 2018). In the modern intensive poultry production, feed constitutes up to 70% of the expenditure in intensive poultry enterprise (Thirumalaisamy et al., 2019). The poultry feed industry is currently facing challenges of volatility in the cost of production due to soaring bills of conventional feedstuffs, leading to the search for alternative feed ingredients. Cassava by-products are some of the alternatives to replace maize as energy resource in monogastric diets. However, their high fiber, low protein (Khempaka et al., 2009) and hydro-cyanide content have limited their use (Latif and Müller, 2015). Cassava stump, which corresponds to the trimmed ends of cassava tubers (Aro et al., 2008), is mostly considered a waste and has not been utilized in the feeding of poultry birds. Leaf meals have been reported to be good sources of protein. They also have many bioactive compounds that may be useful as alternative to antibiotic growth promoters in monogastric animals. However, these valuable feed resources are also limited by their anti-nutrients and high fiber components. Morgan and Choct (2016) described fungal solid-state fermentation (SSF) as a veritable way of improving the nutritional quality of cassava by-products. Aro (2008) and Khempaka et al. (2014) reported increased levels of protein in cassava and its by-products through SSF using *Aspergillus niger,* microbial fermentation and yeast fermentation. Sugiharto et al. (2019a) also reported on the use of enzymes and fermentation to solve the challenges of high fiber and anti–nutrient factors, thus enhancing the availability of the bioactive compound in leaf meals. In quails, SSF has also improved performance, nutrient digestibility, and carcass quality (Yasar and Gok, 2014).

The assessment of meat quality is critical because it focuses on the quality of meat components and the elements that affect palatability. It is also a metric for how long meat can be kept fresh before it starts to spoil (El Masry et al., 2012). Recently, the emphasis has been placed on quality (public health, meat safety, stakeholder competition, and consumer acceptance of production techniques), which is now considered more important than quantity and cost of beef products (Amara et al., 2018). The hydrogen index and nutrient composition are known to affect the sensory/organoleptic traits of meat (Jayasena et al., 2013).

There is little information on unfermented or fermented cassava stump in the diets of poultry. Therefore, the objective of this study was to evaluate carcass and meat quality of broiler chickens fed diets containing different levels of fortified fermented cassava stump (FFCS) as a replacement for maize.

MATERIALS AND METHODS

Experimental site

The experiment was conducted between May and July, 2019 at the Poultry Unit of the Landmark University Research Farm, Omu Aran, Irepodun local Government, Kwara State, Nigeria. Coordinates 8°08′00″N5°06′00″E.

Sources of materials

Cassava leaves and stumps were obtained from the Cassava processing Unit of Landmark University, Omu Aran, while the other feed ingredients were purchased from Ilorin, Kwara State.

The *Aspergillus niger* (ATCC 16404) was obtained from the Microbiology Laboratory of Landmark University, Omu Aran, Nigeria. The *A. niger* ATCC 16404 was maintained on Potato Dextrose Agar (PDA) medium. The microbial slants were grown at 30 °C for 72 hours and later kept at 4 °C.

Fermentation procedure

The dried cassava leaves and stumps were inoculated with *A. niger* (ATCC 16404) aseptically and fermented at room temperature for 96 and 192 hours, respectively, using the method described by Aro and Akinjokun (2012). Briefly, dried cassava leaves and stumps in batches of 2 kg were individually weighed into autoclavable nylon bags, and distilled water was added at a ratio of 1:1 (w/v). Subsequently, the samples were steam-heated at 100 °C for 30 minutes. After cooling, they were poured into fermentation plates, which were then wrapped in cellophane wrapper. Each batch was then inoculated with 40 ml of *Aspergillus niger* ATCC 16404 containing 1.07 x 10^9 CFU per ml inside the laminar flow chamber. The plates were then covered with cellophane wrapper and kept in a fermentation chamber at room temperature for 96 and 192 hours for cassava leaves and stumps, respectively. After the fermentation periods, the samples were air-dried for 5 days at 25°C and 60% relative humidity before being incorporated into the feed of the chickens.

Proximate analysis

The proximate analysis of cassava leaves and stumps were carried out before and after fermentation using the method of AOAC (2006).

Management of birds

One-day-old Ross 308 broiler chicks (numbering 120) were allocated based on their initial weight into four dietary treatments of 30 chicks per group, with ten chicks per replicates. The birds were fed a basal diet for the first one week. The type of housing used was the conventional open-ended naturally ventilated deep litter house, with 24-hour daily photoperiod. All vaccination and medication schedule, and standard management practices were in accordance with ROSS 308 management guide. Potable water and feed were provided *ad-libitum* during the whole period (56 days) of the experiment.

Experimental diets and design

FFCS meal was obtained by mixing fermented cassava stumps with fermented cassava leaves at a ratio of 19:1. The treatments consisted of 4 diets with different levels of FCCS for the starter and finisher phases: Diet 1 containing 0% FFCS (control treatment); Diet 2 containing 20% FCCS; Diet 3 containing 40% FCCS; and Diet 4 containing 60% FFCS. The composition of each diet is provided in Table 1.

Carcass evaluation

On the last day of the finisher phase, three chickens from each treatment (close to the average live weight of the treatment) were not given access to feed for twelve hours (but with access to water) prior to slaughtering. Decapitation was accomplished humanely, and the chickens were then hung upside down to allow the blood to drain out. Subsequently, the birds were defeathered and eviscerated. Carcasses were weighed to determine dressed weight and then chilled for 24 hours before primal cuts were made. Weights were obtained and recorded according to the method of Omojola et al. (2004).

Meat quality evaluation

Hydrogen index determination: The hydrogen index of the chest muscle was assessed with a digital tipped meat pH probe (Meat pH Tester HI9981O36, Hanna, USA). A sharp pointed knife was used to pierce the intact muscle to about 2.5 cm and the pH meter was immediately inserted to read the pH.

Water holding capacity (WHC): it was determined by the filter paper press method according to Kashif et al. (2014). The water released from the meat was wetting the paper, and the boundary of that wetted area was marked using a pencil; this was measured and reported in a percentage ratio of the diameter of the meat to the diameter of the water wetted paper as described by Mendiratta et al. (2008).

Cooking loss (CL): At 24-hour postmortem, 2 g samples from the breast muscles of carcass representing each of the dietary groups were taken and boiled in a water bath at 85 °C. The samples were then allowed to chill and then

Table 1. Composition (%) of broiler starter and finisher diets (on dry matter basis).

Ingredients (%)	Starter phase Diet 1	Diet 2	Diet 3	Diet 4	Finisher phase Diet 1	Diet 2	Diet 3	Diet 4
Maize	56.00	44.80	33.60	22.40	65.00	52.00	39.00	26.00
FFCS	0.00	11.20	22.40	33.60	0.00	13.00	26.00	39.00
SBM	38.01	38.01	38.01	38.01	30.00	30.00	30.00	30.00
Fish meal	2.00	2.00	2.00	2.00	1.20	1.20	1.20	1.20
Bone meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.20	0.20	0.20	0.20
Lysine	0.15	0.15	0.15	0.15	0.10	0.10	0.10	0.10
Premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Cal. Analysis								
CP (%)	23.90	23/81	23.73	23.64	20.72	20.56	20.40	20.24
ME (kcal/kg)	3036	2970	3016	3005	3073	3057	3044	3030

FFCS = Fortified fermented cassava stump; SBM = Soyabean meal; CP = Crude protein; ME = Metabolizable energy; Cal. Analysis – Calculated analysis; Diet 1 = Control diet without fortified fermented cassava stump; Diet 2 = Diet containing 20% fortified fermented cassava stump; Diet 3 = Diet containing 40% fortified fermented cassava stump; Diet 4 = Diet containing 60% fortified fermented cassava stump.

weighed again. Cooking loss (in %) was calculated as follows (Schilling et al., 2008):

$$\% \text{ CL} = \frac{\text{IW - FW}}{\text{IW}} \text{ X } 100\%$$

Where:
IW = Weight before cooking
FW = Weight after cooking

Lipid peroxidation evaluation: The concentration of TBARS (thiobarbituric acid reactive substances) was determined as described by Vashney and Kale (1990), using an assay kit (Nanjing Jiancheng Bioengineering Institute, Nanjing, and P. R. China). The values were expressed as mg of malondialdehyde (MDA) per kilogram of meat.

Statistical analysis

All data were analyzed by a One-Way Statistical Analysis of Variance (ANOVA) using SAS (2009). Subsequently, a Duncan's New Multiple Range Test was used to determine differences among the treatments at a significance level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Proximate Analysis

The results showed that the SSF using *Aspergillus niger* 16404 enhanced the nutritive values of both cassava leaf and cassava stump (Table 2), which is in agreement with Olukomaiya et al. (2019), Parmar et al. (2019), Ibarruri et al. (2021) and Shi et al. (2021).

Carcass Traits

The dressing percentage and eviscerated percentage (Table 3) of broiler chickens were statistically ($p > 0.05$) similar up to 40 % inclusion level. A similar tendency was also observed in the values of the prime cut parts. This agrees with the findings of Khempaka et al. (2014) when they evaluated the inclusion of *A. oryzae* fermented cassava pulp to the diets of broiler chickens. The reduction in the values of carcass traits at 60% inclusion level agrees with Tran et al. (2016), confirming the nutritional quality of FFCS. In the present study, dressed weights ranged from 74.15 to 86.95%, being higher than the values obtained by Ahmad et al. (2007) and Widjastuti et al. (2010), who conducted studies with fermented cassava pulp and peel-leaf mix, respectively, using *A. niger* in the solid state; and also higher that those reported by Olaifa et al. (2015), who studied the use of rumen filtrate fermented cassava peel. However, our results were within the range observed by Eyng et al. (2013) in a study on broiler chickens fed diets containing tilapia by-products. Variations in the nutrient level of the diets (Widjastuti, 2010) or the use of higher inoculum level of *A. niger* in our study can explain the differences observed in dressed weight percentage. Regardless of inclusion thresholds, the values obtained in the present study were substantially beyond the recommended range of 65.50–70.00% for meat type chickens (Adeniji, 2004). Except for the relative values of intestine and abdominal fat, the presence of FFCS did not influence ($P>0.05$) relative organ size, which is in agreement with Khempaka et al. (2014). The higher intestinal values found could be attributed to the bulk nature of the FFCS-containing meals. Adeyemi et al. (2008) also had similar results in broiler chickens that were fed diets containing 25% cassava root meal fermented with rumen filtrate. The drop in belly fat with an increased level of FFCS agrees with the results obtained by Khempaka et al. (2009), who found that the use of high level of cassava by-products in broiler chickens resulted in reduced abdominal panniculus but increased gizzard weight. Lower levels of belly fat may also suggest that the use of fungal solid-state fermentation results in reduced fat deposits, thus leading to the production of lean broiler meat, whose consumption is associated with a lower risk of heart diseases. The highest fat contents of breast and drumstick

Table 2. Proximate composition of unfermented and fermented cassava by-products.

Parameters (%)	UCL	FCL	UCS	FCS
Moisture	11.00	4.58	12.00	7.51
Crude protein (CP)	27.49	34.49	2.52	7.45
Ether extract (EE)	8.15	13.50	5.70	8.55
Crude fiber (CF)	15.50	9.05	10.00	7.51
Ash	9.50	13.95	3.00	6.55
Nitrogen free extract (NFE)	28.36	25.43	66.78	62.43

UCL = Unfermented cassava leaf; UCS = unfermented cassava stump; FCL = Fermented cassava leaf; FCS = Fermented cassava stump.

Table 3. Carcass parameters of broiler chickens fed diets containing fermented cassava by-products.

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	± SEM
Live weight (g)	2545.78a	2549.78a	2555.78a	2458.03b	1.55
Dressing %	84.20a	86.04a	86.95a	79.15b	0.58
EW (%)	76.81a	77.42a	77.20a	70.20b	0.50
Carcass cut up parts (% live weight)					
Breast	27.00	27.22	27.35	26.66	1.25
Thighs	21.02	21.08	21.68	20.90	1.25
Drum sticks	19.38	19.50	19.58	19.05	0.85
Organ weights (% live weight)					
Intestine	4.72b	4.88ab	5.13a	5.21a	1.57
Heart	0.56	0.54	0.61	0.54	0.10
Lung	0.58	0.59	0.62	0.61	0.64
Liver	2.35	2.34	2.39	2.30	1.10
Gizzard	1.65	1.67	1.70	1.74	0.55
Belly fat	139a	1.27a	1.07b	1.04b	0.24

a, b = Means in the same row with different superscripts are statistically significant ($P \leq 0.05$).
SEM = Standard error of mean; Diet 1 = Control diet without fortified fermented cassava stump; Diet 2 = Diet containing 20% fortified fermented cassava stump; Diet 3 = Diet containing 40% fortified fermented cassava stump; Diet 4 = Diet containing 60% fortified fermented cassava stump; EW = Eviscerated weight

were recorded in the broilers fed diets with 40% of FFCS. This may suggest that tissue formation for those parts were optimal at this inclusion level. The trend observed for abdominal fat in this study is similar to the effect of antibiotic growth promoters (Mokhtari et al., 2010).

Meat Quality

The meat became acidic with increased levels of FFCS (Table 4), which is in agreement with Surgiharto et al. (2017). pH is one of the key selection criteria (Le Bihan-Duval et al., 2008), because it has a big impact on meat appearance, WHC and texture. However, the relationship between pH and WHC cannot fully explain the differences in pH level (Funaro et al., 2014). The pH of the breast meat of small size carcasses is more acidic than those of heavy carcasses (Bihanchi et al., 2007).

WHC decreased as FFCS inclusion increased. This differed from the findings of Sang-Oh et al. (2013), probably explained by the effect of fermentation in our study. Navid et al. (2010) has stated that reduced WHC results in meat of better quality. Therefore, the reduction in WHC of meat with increased levels of FFCS may have positive effects on meat quality.

Cooking loss (CL) decreased with increased levels of FFCS. CL is the level of reduction of meat during cooking. The total loss represents the dripping loss as well as the volatile loss (evaporation of water). Diet 4 had the lowest percentage of cooking loss, which could indicate that it has the finest meat quality due to reduced protein loss into the water after boiling (Oko et al., 2012).

The degree of meat peroxidation as indicated by the level of MDA decreased with increased levels of FFCS. MDA recorded the highest value in Diet 1 containing 0% FFCS (control), which is in agreement with previous studies conducted by Sang-Oh et al. (2011) and Adesua and Onibi (2014). The lower MDA values in the FFCS diets shows that fermentation reduced fat accumulation in the meat, reduced peroxidation, and increased meat stability (Adesua and Onibi, 2014). It can also be inferred that oxidative stability of broiler chicken meat was improved by the fermentation of FFCS in the diets, being better at higher levels of supplementation (Onibi et al., 2009). Synthetic antioxidant supplements like sodium tripolyphosphate, propyl gallate, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and sodium erythorbate are being used to improve the oxidative stability of meat processing, but this has raised consumers' concern about food safety (Saleh et al., 2017). Accordingly, natural antioxidants found in leaves of species like cassava can be better alternatives. In fact, cassava leaf is recognized as a rich source of protein, vitamins, minerals and antioxidants (Latif and Müller,

Table 4. Meat Quality of broiler chickens fed diets containing fermented cassava by-products.

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	± SEM
Hydrogen index (pH)	7.77a	7.53b	7.46b	7.42b	0.18
Water Holding Capacity (%)	33.39a	34.44a	30.87b	30.43b	0.35
Cooking Loss (%)	34.53a	36.77a	29.51b	26.10b	0.41
MDA (mg/kg.)	1.26a	0.34b	0.25b	0.21b	0.20

a, b = Means in the same row with different superscripts are statistically significant (P < 0.05).
SEM = Standard error of mean; MDA = Malondialdehyde (mg/kg of meat); Diet 1 = Control diet without fortified containing 40% fortified fermented cassava stump; Diet 4 = Diet containing 60% fortified fermented cassava stump.

2015; Mahfuz and Piao, 2019), and this could have modified and improved the antioxidant status of the meat. Niu et al. (2019) also reported the improvement of oxidative stability by fermented feed, thus reducing MDA production (Hu et al., 2016), and in turn preventing the damaging consequence of tissue lipid peroxidation in meat (Wang et al., 2017; Surgiharto et al., 2019b). The antioxidant enzymes produced during the solid-state fermentation are probably responsible for improved oxidative stability (Liu et al., 2018). In this sense, Hossain et al. (2012) indicated that the anti-oxidative elements in fermented diets can hinder oxidants, thus preventing the oxidative reaction in meat. The fungus *A. niger* ATCC 16404 appears to be actively involved in the increased size of the visceral organs and reduced peroxidation of breast muscle of broiler chicks. Min and Ahn (2005) argued that lipid oxidation is a vital process in quality decline and reduction of shelf life of meat. Therefore, the inclusion of FFCS can preserve the quality and lengthen shelf life of broiler meat.

CONCLUSIONS

Fortified fermented cassava stump, composed of cassava stump (95%) and leaf (5%) fermented using *A. niger* ATCC 16404, can serve as a good dietary resource for broiler production. For optimal results, 40% of fortified cassava stump meal could be incorporated into the diet of broiler chickens with no risk of negative effects on carcass traits and meat quality. Further studies are required to evaluate the impact of cassava stump-based diets, fermented using bacteria, other fungi or consortium of microorganisms, on chicken production.

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