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Impact of solid state fermented cassava stump and leaves on the production and egg quality of laying chickens

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Abstract

A 12-week experiment was conducted to assess the effects of replacing maize with graded levels of enhanced cassava stump (ECS) on the egg productivity and quality of chickens. Cassava leaves and stumps were fermented with the aid of Aspergillus niger (ATCC 16404) in solid state at room temperature (28.5^{o}C) for 96 and 192 hours, respectively. Thereafter the fermented cassava stump was fortified with 5% fermented cassava leaves to make ECS. Four layer diets were formulated by replacing maize with ECS at 0, 20, 40 and 60% levels. The result showed that the proximate values of the cassava stump were enhanced by fermentation with 195.63, 59.17 and 118.33% increment in crude protein, ether extract and ash respectively. The egg production and quality were influenced (P < 0.05) by the replacement of maize by the ECS. The highest (P<0.05) aggregate egg production were obtained in the control diet (Diet 1) and Diet 2 (20% ECS), while the hen-day egg production, egg weight, mass and feed conversion ratio were similar (P > 0.05) in the control group and diet that contained 40% ECS. The cost of feed decreased as the ECS increased in the diets. The eggshell index improved as ECS level increased in the diets, while the highest Haugh unit (HU) was observed in the diet containing 60% ECS. It was concluded that though the replacement of maize up to 60% by ECS gave better egg quality and economic benefit but for optimum performance, 40% ECS is recommended.

Keywords: Agro-industrial by-products, Alternative feed resources, *Aspergillus niger,* Performance, Solid-state fermentation.

Running tittle: Fermented cassava stump in laying chickens production

Impact des souches et des feuilles de manioc fermentées à l'état solide sur la production et la qualité des œufs des poules pondeuses

Résumé

Une expérience de 12 semaines a été menée pour évaluer les effets du remplacement du maïs par des niveaux progressifs de souche de manioc améliorée (SMA) sur la productivité des œufs et la qualité des poulets. Les feuilles et les souches de manioc ont été fermentées à l'aide d'Aspergillus niger (ATCC 16404) à l'état solide à température ambiante (28,5°C) pendant 96 et 192 heures, respectivement. Par la suite, la souche de manioc fermentée a été enrichie avec 5 % de feuilles de manioc fermentées pour fabriquer de le SMA. Des régimes pour quatre pondeuses ont été formulés en remplaçant le maïs par de le SMA à des niveaux de 0, 20, 40 et 60 %. Le résultat a montré que les valeurs immédiates de la souche de manioc ont été améliorées par la fermentation avec une augmentation de 195,63, 59,17 et 118,33 % respectivement en protéines brutes, en extrait d'éther et en cendres. La production et la qualité des œufs ont été influencées (P < 0,05) par le remplacement du maïs par le SMA. La production globale d'œufs la plus élevée (P <0,05) a été obtenue dans le régime témoin (régime 1) et le régime 2 (20% SMA), tandis que la production quotidienne d'œufs de poule, le poids des œufs, la masse et le taux de conversion alimentaire étaient similaires (P > 0,05) dans le groupe témoin et le régime contenant 40 % de SMA. Le coût de l'alimentation diminuait à mesure que le SMA augmentait dans les régimes. L'indice de coquille d'œuf s'est amélioré à mesure que le niveau de SMA augmentait dans les régimes, tandis que l'unité de Haugh (HU) la plus élevée a été observée dans le régime contenant 60 % de SMA. Il a été conclu que même si le remplacement du maïs jusqu'à 60 % par l'ECS donnait une meilleure qualité des œufs et un meilleur bénéfice économique, mais pour des performances optimales, 40 % de SMA sont recommandés.

Mots-clés: Sous-produits agro-industriels, Ressources alimentaires alternatives, Aspergillus niger, Performance, Fermentation solide.

Introduction

The inability of most developing nations to sufficiently feed their rapidly expanding populations with the ideal ratio of calories to protein is one of their biggest developmental concerns (Dipasquale, 2020). Africa consumes very little animal protein, which has led to poor, stunted growth, increase in the spread of diseases, and ultimately, death (Azevedo et al., 2017). It has been noted that the growth of the poultry business is the solution to the shortage of animal protein in developing nations (Anosike *et al*., 2018). The biggest obstacles to achieving this are the high cost of feed and scarcity of feed ingredients; as a result, efforts are being made to find substitute feed sources that are affordable, easily accessible, and do not negatively impact the productivity and health of the hens (Shittu *et al*, 2016).

The agro-industries produce lots of by-products with a range of properties. Over two billion tonnes of agricultural wastes are generated from them globally (*Karigidi, 2021*). It is crucial to determine how these can be applied to animal production in order to turn wastes into wealth and valuable commodities (Singh *et al.,* 2021). The inclusion of agro-industrial residues as raw materials can help to alleviate the production cost (Sadh *et al*., 2018)

especially maize which constitutes the greatest proportion of feed. Cassava stump is the end trims obtained from cassava root processing. Due to its woody, highly fibrotic nature, and low nutritional value, these by-products is regarded as waste. According to (Nkhata *et al.,* 2018), fermentation enhances the value of the protein and the digestibility of the fiber, increases the availability of micronutrients for use, and helps to degrade anti-nutritional components. Fungal fermentation in solid state has also been reported to accomplish this effectively and bring about value added products (Soccol *et al*., 2017).
Given the rapid increase in egg consumption by the populace over the past forty years, it is anticipated that consumer expectations for egg quality would also rise. The egg is considered as a complete food for humans as a result of its large amounts of essential nutrients. Moderate consumption of eggs improves human lipid profile, and brings about reduction in the risk of cardiovascular disease and incidence of metabolic syndrome (Fallah-Moshkani *et al.*, 2017).
The aim of this experiment therefore, was to appraise the performance indices and egg quality of chickens fed diets containing varying levels of ECS cassava stumps substituted for maize.

Materials and methods

Experimental site and sources of materials

The research was conducted in the Poultry Unit, Teaching and Research Farm, Landmark University, Omu-Aran, Irepodun Local Government, Kwara State, Nigeria.latitude 8° 08′ 00″N, and longitude 5° 06′ 00″E
Cassava leaves and stumps were obtained from cassava processing factory of the University, while other feed ingredients used for the formulation of the experimental diets were purchased from Ilorin, Kwara State, Nigeria.

Candidate organism for solid state fermentation

Aspergillus niger (ATCC 16404) was obtained from the Microbiology Laboratory of Landmark University, Omu Aran, Nigeria.

Chemical Analyses of Maize and Cassava By-Products

The AOAC (2010) approach was used to conduct a baseline assessment of the proximate values of cassava stumps and leaves. The metabolizable energy (ME) was calculated from Pauzenga (1985) formula as follows:

ME (kcal/kg DM) = (37 x % CP) + (81.8 x % EE) + (35.5 x % NFE).

Solid-state fermentation (SSF) protocol

Using the technique outlined by (Aro and Akinkokun, 2012), each batch of dried cassava leaves (CSL) and stumps (CSS), weighing 2 kg each, was placed into polythene bags. Distilled water was added to the samples at a 1:1 (w:v) ratio. All samples were then autoclaved for 15 minutes at a pressure of 103.421 kPa and a temperature of 121°C. After cooling, the samples were spread into previously sterilized fermentation trays measuring 54 x 38 x 4 cm (Aro, 2010). These trays were lined with transparent cellophane sheets, which also served as covers for the waste materials. The samples were inoculated with 40 ml of *A. niger*, containing 1.07 x 10^9 spores per ml, in a laminar flow chamber. Subsequently, all the samples were carefully covered and placed in fermentation chambers at ambient temperature. The fermentation process was terminated at 96 hours for CSL and 192 hours for CSS. The fermented samples were then sun-dried and stored in cellophane bags for later incorporation into feed. Thereafter, the proximate analyses of the fermented cassava stumps and cassava leaves were conducted using the AOAC (2010) method.

Experimental diets

The ECS was produced by fortifying fermented cassava stumps with 5% fermented cassava leaves. Subsequently, four experimental layers′ diets were formulated, incorporating different proportions of ECS as a substitute for maize on a weight-for-weight (w/w) basis. The diets were developed by replacing maize with graded levels of ECS, ranging from 0% to 60%. Diet 1 served as the control, while diets 2, 3, and 4 included 20%, 40%, and 60% ECS, respectively. The crude protein content of the diets ranged from 17.50% to 17.80%, and the metabolizable energy content varied from 2747 KCal/kg to 2780 KCal/kg. The composition of the experimental diets is detailed in Table 1, while Table 2 presents the values for crude protein (CP) and metabolizable energy (ME) for ECS.

Table 1. Gross composition (%) of experimental layers' diets

Ingredients (%)	**Enhanced cassava stump Inclusion levels (%)**			
	0	**20**	**40**	**60**
Maize	50.00	40.00	30.00	20.00
Enhanced cassava stump	0.00	10.00	20.00	30.00
Wheat offal	20.00	20.00	20.00	20.00
Soya bean meal	25.00	25.00	25.00	25.00
Bone meal	4.10	4.10	4.10	4.10
Methionine	0.20	0.20	0.20	0.20
Lysine	0.10	0.10	0.10	0.10
Premix	0.30	0.30	0.30	0.30
Common salt	0.30	0.30	0.30	0.30
Total Ingredients (%)	100.00	100.00	100.00	100.00
Calculated Analysis:				
Crude Protein (%)	17.80	17.70	17.60	17.50
ME (Kcal/kg)	2780	2769	2758	2747

ECS = Fortified fermented cassava stump, ME = Metabolizable energy;

Experimental design and management of birds

A total of 120 Isa Brown layers 25 weeks of age were used for this study. Thirty laying birds were randomly allotted based on their average initial weights to each of the four diets (1, 2, 3 and 4) in a Completely Randomized Design (CRD). Each treatment group contained three replicates of ten chickens each. The experiment took place in a deep litter compartments for 12 weeks. The house, feeders and drinkers were properly washed and disinfected; while wooding laying nest were placed in each experimental pen.

Performance indices

Hens′ weights were measured at the beginning and end of the experiment, and weight change was determined as the difference between the final and initial body weights. Feed intake was calculated as the difference between the feed offered and the remaining feed. At the end of the observation period, the total number of eggs collected and the count of live birds were recorded and compiled. Eggs collected daily were individually weighed, and the average egg weight was calculated by dividing the total egg weight by the number of eggs. Hen-day egg production (HDEP) as a percentage was determined using the method described by Hunton (1995).

% HDEP =

Egg mass was calculated as:

$$\text{Egg mass} = \frac{\%\ \text{HDEP x egg weight}}{100}$$

The feed conversion ratio per mass (FCRM) was calculated:

$$\text{FCRM} = \frac{\text{kg of feed consumed}}{\text{kg of egg produced}}$$

Egg quality

On the last three days of the experiment, eggs gathered were used for the determination of both the external and internal egg qualities. The eggs were weighed using sensitive weighing balance to determine the average egg weight per treatment. The external egg quality parameters were assessed in terms of egg weight and shape index.

$$\text{Egg shape index} = \frac{\text{Width of egg}}{\text{Length of egg}} \text{ X } 100$$

Internal egg quality

Eggs were broken on a flat glass surface to measure the quality parameters. The shell, albumen, and yolk were carefully separated and were weighed individually using a sensitive balance of 0.01 g precision. Prior to determination of the thickness and weight of the shell, the interior membrane of the shell was removed. Using a digital micrometer, the average thickness of the egg's broad, middle, and narrow ends were measured. The broken eggs' albumens and yolks were meticulously separated. The albumen height was obtained through the measurement at its thickest part using a tripod spherometer. Haugh Unit was calculated according to Haugh (1937) using the formula:

$100 \log10 (H + 7.57 - 1.7w^{0.37})$,

Where H = albumen height (mm) and w = weight of egg (g).

Yolk colour

This was determined by means of the La Roche Fan scale (DSM Yolk Colour). The yolk colour was evaluated by comparing the colour of the properly mixed yolk sample placed on a white paper with the colour strips of Roche Colour fan measurement, which consists of 1-15 strips ranging from pale to orange – yellow in colour.

Statistical analysis

All data collected were subjected to a one-way analysis of variance (ANOVA) and differences between treatment means were compared using Duncan's Multiple Range Test using the SAS (2001) package"

Results

Chemical Analyses of unfermented and fermented cassava stumps and leaves

Table 2 displays the proximate values for the fermented and unfermented cassava by-products (CBPs). The results for ash, ether extract, and crude protein were highest (P<0.05) in the fermented cassava leaves

(FCL) and lowest in the unfermented cassava stump (UCS). The unfermented cassava leaves (UCL) and unfermented cassava stump (UCL) had the highest values of crude fiber and NFE, respectively, whereas the FCS and FCL had the lowest values for these variables.

Table 2. Chemical composition of fermented and unfermented cassava stumps and leaves (dry matter basis)

Parameters (%)	UCS	UCL	FCS	FCL	±SEM
Moisture	12.00^{a}	11.00^{a}	7.51^{b}	4.58^{c}	2.55
Crude protein	2.52^{d}	27.49^{b}	7.45^{c}	34.49^{a}	4.22
ether extract	5.70^{c}	8.15^{b}	8.55^{b}	13.50^{a}	4.05
Crude fiber	10.00^{b}	15.50^{a}	7.51^{c}	9.05^{b}	2.50
Ash	3.00^{d}	9.50^{b}	6.55^{c}	13.95^{a}	1.65
Nitrogen free extract	66.78^{a}	28.36^{b}	62.43^{a}	25.43^{b}	2.25
ME (Kcal/kg)	2929.13^{b}	2690.58^{d}	3191.00^{c}	3283.00^{a}	1.45

$^{a, b, c, d}$ = Means on the same row but with different superscripts are statistically significant (P < 0.05); ME = Metabolizable energy; UCS = unfermented cassava stump; UCL = unfermented cassava leaf; FCS = fermented cassava stump; FCL = fermented cassava leaf

Performance indices

Table 3 presents the performance indices of laying chickens, showcasing the impact of the inclusion level of enhanced cassava stumps (ECS) in the diets. The average weight change and total feed intake demonstrated no statistically significant differences (P > 0.05) among the dietary groups, with values ranging from 150g to 170g and 8.33kg (control) to 8.44kg (20% ECS inclusion) for average weight change and total feed intake, respectively. Although there was a progressive reduction in total egg production (TEP) and hen day egg production (HDEP) as the ECS inclusion level increased in the diets, identical values of 2304 eggs and 91.43% were observed in both the control and the group containing 20% ECS for TEP and HDEP, respectively.

Concerning egg weight and egg mass, similar values (p > 0.05) were recorded in the control and the 40% ECS inclusion group, although the control group exhibited the highest values of 57.66g and 52.72g for egg weight and egg mass, respectively. The feed conversion ratio per mass followed the same trend as mentioned above. The feed cost per kilogram and feed cost reduction per kilogram of feed decreased as the ECS inclusion level increased in the feed. Simultaneously, the weekly gross profit increased with the elevated level of ECS in the diets, ranging from 55.72% in the control to 89.41% in the 60% ECS group.

Egg quality

Tables 4 and 5 show the results of the evaluation of the internal and external qualities of eggs from the layers fed experimental diets. The internal and external qualities of the eggs were significantly (P < 0.05) influenced by the inclusion level of ECS in the diets.

External egg quality

The eggshell weight and eggshell thickness values were found to be statistically similar (p > 0.05) across all the diets. The range for these parameters was observed from 5.66g (in the 0% ECS group) to 6.10g (in the 20% ECS group) for eggshell weight, and from 0.33mm (in the 20% ECS group) to 0.42mm (in the 40% ECS group) for eggshell thickness.

Regarding the eggshell index (ESI), the highest value of 85.65 was recorded in the diet containing 20% ECS. However, the values for ESI at 0%, 40%, and 60% ECS inclusion levels were statistically similar.

Internal egg quality

The eggs from hens fed diets containing 60% ECS displayed the highest values for yolk weight, yolk diameter, yolk height, yolk color, and Haugh's Unit, with respective values of 16.17g, 43.07mm, 20.49mm, 8.80, and 79.97. Conversely, the highest values for albumin weight and albumin height were recorded in the diet containing 20% ECS, with respective values of 43.30g and 6.06mm. Additionally, it was observed that eggs from chickens fed diets containing 0% ECS exhibited the lowest values for all yolk parameters.

Table 3. The Performance indices of laying chickens fed enhanced fermented cassava stumps in partial replacement for maize

	Inclusion levels of the enhanced cassava stumps (%)				
Parameters	**0**	**20**	**40**	**60**	**SEM ±**
Initial Body Weight (kg)	1.84	1.81	1.88	1.84	0.01
Final Body Weight (kg)	2..01	1.97	2.03	1.99	0.01
AWC (g)	170.00	160.00	150.00	150.00	0.01
Daily Feed Intake (g)	118.57	120.57	119.00	119.42	0.34
TFI (Kg/bird)	8.30	8.44	8.33	8.36	0.20
TEP	2304.00^{a}	2304.00^{a}	2286.00^{b}	2073.00^{c}	1.50
HDEP (%)	91.43^{a}	91.43^{a}	90.70^{a}	82.27^{b}	0.35
Egg Weight (g)	57.66^{a}	56.34^{b}	57.46^{a}	55.96^{bc}	0.25
Egg Mass (g)	52.72^{a}	51.51^{b}	52.12^{a}	46.04^{c}	0.40
FCRM	2.25^{c}	2.34^{b}	2.28^{c}	2.59^{a}	0.22
Feed cost/kg (₦)	132.71^{a}	123.12^{b}	113.53^{bc}	103.95^{d}	0.55
FCR/kg (₦)	0.00^{d}	9.59^{c}	19.18^{b}	28.77^{a}	1.05
Weekly cost of feed (₦)	3288.00^{a}	3117.00^{bc}	2835.00^{c}	2607.00^{d}	1.05
Weekly gross profit (₦)	1832.00^{d}	2003.00^{c}	2423.00^{a}	2331.00^{b}	1.50
% Weekly gross profit	55.72^{d}	60.51^{c}	85.47^{ab}	89.41^{a}	1.10

Note: Values with different superscripts (a, b, c, d) within the same row indicate significant differences (P < 0.05). The SEM represents the standard error of the mean.

ECS; AWC = Average weight change; FCRM = Feed conversion ratio per mass; TEP = Total egg produced; TFI = Total feed intake; FCR = Feed cost reduction; SEM = Standard error of mean.

Table 4. The external egg Quality of laying chickens fed fortified fermented cassava stumps in partial replacement for maize

Parameters	**Inclusion levels of enhanced cassava stumps (%)**				
	0	**20**	**40**	**60**	**SEM ±**
Egg Weight (g)	63.37^{b}	67.27^{a}	61.40^{c}	62.83^{b}	0.32
Egg Width (mm)	44.67^{b}	47.08^{a}	44.48^{b}	44.91^{b}	0.23
Egg Length (mm)	56.40^{a}	54.97^{b}	55.92^{a}	55.42^{ab}	0.40
Shell Weight (g)	5.66	6.10	5.78	6.04	0.18
Shell Thickness (mm)	0.40	0.33	0.42	0.36	0.01
Egg Shape Index	79.20^{b}	85.65^{a}	79.54^{b}	81.04^{b}	0.25

$^{a-c}$ = Means on the same row but with different superscript differ significantly (P < 0.05)

AWC = Average weight change; FCRM = Feed conversion ratio per mass; TEP = Total egg produced; FCR = Feed cost reduction; SEM = Standard error of mean

Table 5. The internal egg Quality of laying chickens fed fortified fermented cassava stumps in partial replacement for maize

Parameters	Inclusion levels of enhanced cassava stumps (%)				
	0	20	40	60	SEM ±
Yolk Weight (g)	15.03[b]	16.00[a]	15.97[a]	16.17[a]	0.20
Yolk Diameter (mm)	37.02[c]	41.44[b]	41.75[b]	43.07[a]	0.20
Yolk Height (mm)	14.15[c]	18.51[b]	18.12[b]	20.49[a]	0.24
Yolk Color	8.60[a]	8.20[bc]	8.55[b]	8.80[a]	8.40
Albumen Weight (g)	39.93[b]	43.30[a]	40.43[b]	38.63[c]	0.39
Albumen Height (mm)	5.69[b]	6.06[a]	5.66[b]	6.02[a]	0.15
Haugh's Unit	72.51[d]	74.74[b]	73.72[c]	79.97[a]	1.11

[a – d] = Means on the same row but with different superscript differ significantly ($P < 0.05$)

AWC = Average weight change; FCRM = Feed conversion ratio per mass; TEP = Total egg produced; FCR = Feed cost reduction; SEM = Standard error of mean

Discussion

Proximate Analyses of unfermented and fermented cassava stumps and Leaves

The FCS and FCL showed a considerable improvement in CP, which may suggest that *A. niger* can be used to improve cassava by-products (CBPs). The bioconversion of sugar into protein by microbial fermentation may be the cause of the rise in CP. Ikpesu *et al.* (2016) ascribed the rise in protein levels in fermented cassava by-products (FCBPs) to the bioconversion of carbohydrate to protein as a result of *A. niger's* assisted fermentation in solid state. This could also be responsible for the decline in NFE as fermentation progressed, as there has been evidence of a negative link between protein and carbohydrate levels (Yafetto, 2018).

Higher CF reduction of 41.61% was observed in the FCL compared to 24.90% in FCS. This CF degradation may be caused by *A. niger* activity and the evoked enzymes, which can improve the digestibility of cassava by-products, particularly the cassava stumps, in the non-ruminant gastro intestinal tracts. This discovery might also advance understanding of the use of fungi in the protein enhancement and fiber fractions degradation of agricultural industrial wastes and subsequent incorporation into non-ruminant feed to increase productivity, thereby raising human protein intake and enhancing the financial situation of livestock farmers (Yafetto, 2018).

Performance indices

The non-significant values observed for the final live weight and the weight change is an indication that the spent hens would command similar economic value (Okedere *et al*., 2020). The laying birds fed the control diet had lower feed intake; this correlated with the observation of Chang'a *et al.* (2020) who reported higher feed intake when laying chickens were fed cassava peel based meal, but Olowoyeye (2016) opined that the inclusion of cassava by-products depresses feed intake. Chickens fed the control diet and those fed diets containing ECS showed different levels of voluntary intake. This could be attributed to the different metabolizable energy (ME) of these products, as birds eat primarily to meet their energy needs, and those with higher ME are more likely to feel satisfied.

The total egg production in this study is similar to the report of Kiyawt *et al.* (2014). The total egg production was utmost in birds fed diets the control diet. This is in consistent with previous works by Osei *et al.* (1990) who found that egg production decreased linearly as the inclusion level of fermented cassava peel meal increased. In addition, the egg weights observed at all levels of inclusion of ECS were higher than values obtained by other authors that did not ferment the cassava by-products (Kiyawt *et al.,* 2014; Tesfaye *et al*., 2014). This most likely reflects the outcome of microbe-assisted solid-state fermentation, which has been shown to release some non-nitrogenous protein (NPN), single cell protein, and enzymes into the fermented products, thereby transforming them into products with additional value (Soccol et al., 2017)..The weight of the eggs produced may have also been impacted by the way the cassava by-products were processed. Higher weight of the eggs were observed in this study where cassava by-products were microbially fermented in solid state process compared to values obtained by Oladunjoye *et al.* (2010), when the products were either sundried or lye treated. Engberg *et al.* (2009) observed an increase in egg weight in birds fed fermented meal compared to unfermented mash which also supports the results of the present study. The similar HDEP and egg mass is a positive indication of including fermented cassava by-products in the diets of laying chickens. It also indicated 40% inclusion level as the optimum inclusion level for the ECS; this is a great improvement from the previous work by Tewe and Lutaladio (2004) who reported optimum 20% inclusion level of cassava peel in laying chickens and decline egg production and weight at 30 – 40% inclusion level. Similar egg weights, egg bulk, and HDEP might also be due to the FCS′s fortification with cassava leaves. This is consistent with the findings of Tesfaye *et al.* (2014), who reinforced cassava root chip with *Moringa oleifera* leaf and reported similar outcomes. The results of this study, however, differ from those reported by Okrathok *et al.* (2018), who found that laying chickens produced fewer eggs and had heavier eggs when fermented cassava pulp was included at higher levels in their diets; the difference could be as a result of the different candidate organisms employed.

In laying chicken given 40% ECS, the feed conversion ratio per mass of egg (FCRM) was comparable to that of the control diet. This suggests that the laying birds were able to effectively use and transform the ECS into eggs. According to Onyia *et al*. (2015), adopting alternative feed ingredients can lower production costs; this assertion was validated in this study as the production costs decreased as the inclusion level increased, and this had no negative effects on the chickens′ laying parameter indices.

The external egg quality

The values for egg weight, width, and eggshell weight obtained at a 20 percent ECS inclusion are quantitatively superior to those obtained in the control diet, demonstrating the fermented cassava stump′s inherent nutritional potentials. Eggshell thickening is one of the symptoms of cassava toxicity, but in the current study, the maximum values for egg thickness were comparable to the control and at 60 percent ECS inclusion, the value was lower. Therefore, even at the 60 percent inclusion level, there would be no need for concern about toxicity. In a previous study, Aderemi *et al*. (2012) found that cassava meal containing dried root, leaves, and stem at a concentration of over 25% had no effect on egg weight or shell thickness. Using the fungi assisted solid-state fermentation in the present study, it was possible to include up to 60% ECS in the diets of laying chickens without any adverse effect on the quality of the eggs. This contradicts the report of Obioha *et al*. (1984) that cassava peel at inclusion level above 30% reduced egg quality. This is further supported by the report of Morgan and Choct (2016) who recommended enhancement of cassava and its by-products by *A. niger* assisted fermentation.

The main factor affecting an egg′s outward appearance and quality is the egg shape index (ESI). The ESIs in the current study were greater than those of Ogunwole *et al*. (2017), but within the same range with the values reported for laying chickens by Türker and Alkan (2019). This may be due to the effects of the fermentation process.

The Internal quality of egg

All internal quality indices in the eggs of chickens fed ECS-containing diets had better values; this finding provides evidence of the ECS′s inherent potential.

The values obtained for yolk weights, albumen weights and Haugh′s unit in this present study were higher than those obtained by Oladunjoye *et al*. (2010) who compared the egg quality of chickens fed diets containing 60% lye - treated and sun - dried cassava peels. This may also point to the advantage of fermentation process in enhancing the nutritive value of cassava by-products.

One of the key elements influencing customer preference, selection, and demand is yolk color. With an increase in ECS inclusion level, the yolk color in this study rose. Carotene and most carotenoids are typically lacking in cassava and its byproducts, although it has been observed that supplementing with cassava leaves can make up for this shortfall (Anaeto and Adighibe, 2011). The levels of the albumen parameters in the eggs from birds fed ECS-containing diets were higher than those fed the control diet.

The **Haugh's unit** is a measure of the internal quality of an egg. It is a measure of egg freshness and protein quality based on the height of its albumen. The higher the number, the better the quality of the egg. The HU is also the accepted tool used to grade eggs (Li-Chan *et al*., 2017). The values of yolk weights in the earlier study by Okrathok *et al.* (2018), who fed laying chickens meals containing fermented cassava pulp (using *A. niger*), were comparable with those from birds fed diets containing ECS in the current investigation. In addition, the albumen weights reported by Okrathok *et al.* (2018) were lower than those from chickens fed diets containing ECS. The HU in this study were generally lower than the report of Okrathok *et al.* (2018); the variations may due to the storage time of the eggs and the substrates (cassava by-products) used. In addition, there was improvement in the yolk colour with increased inclusion level of ECS in this study, which contradicted the report of Okrathok *et al.* (2018). The enhancement of fermented cassava stump with fermented cassava leaves in this study can be used to explain this variation. However, a similar trend was observed in this study and those of Okrathok *et al*. (2018) as the Haugh Unit (HU) increased with the inclusion level of fermented cassava by-products in the diets. In the present study, all the HU values were within the AA class (HU > 72) (USDA-MIS, 2000). Additionally, the values of HU in the chickens fed diets containing ECS were better than those fed the control diet, and the values increased with the elevated levels of ECS. This indicates that the inclusion of ECS in the diet of laying chickens will enhance the quality of the eggs.

Conclusion

In conclusion, the study demonstrated that the replacement of maize with enhanced cassava stump (ECS) in laying chicken diets had significant effects on egg productivity and quality. The solid-state fermentation of cassava stumps with *Aspergillus niger* resulted in a substantial improvement in the proximate. The replacement of maize with ECS at different levels influenced egg production and quality, with the 40% ECS inclusion level showing similar performance to the control diet. The eggshell index improved with increasing ECS levels, and the highest Haugh unit (HU) was observed in the diet containing 60% ECS.

The economic analysis revealed that as the inclusion level of ECS increased in the diets, the cost of feed decreased, and there was a corresponding improvement in economic benefits, with the highest weekly gross profit observed in the 60% ECS group. However, the study suggests that for optimum performance, a 40% inclusion level of ECS is recommended.

This finding is significant for addressing the challenges of high feed costs and scarcity of feed ingredients in poultry production, particularly in developing nations. The study adds to the growing body of research on the utilization of agro-industrial by-products as alternative and cost-effective feed resources for improved poultry production.

References

Aderemi, F. A., Adenowo, T. K., and Oguntunji, A. O. 2012. Effect of whole cassava meal on performance and egg quality characteristics of layers. *Journal of Agricultural Science*, *4*(2), 195-200. DOI: 10.5539/jas.v4n2p195

Anaeto, M., and Adighibe, L. C. 2011. Cassava root meal as substitute for maize in layers ration. *Brazilian Journal of Poultry Science*, *13*, 153-156.https://doi.org/10.1590/S1516-635X2011000200010

Anosike, F. U., Rekwot, G. Z., Owoshagba, O. B., Ahmed, S., and Atiku, J. A. 2018. Challenges of poultry production in Nigeria: A review. *Nigerian Journal of Animal Production*, *45*(1), 252-258. DOI: 10.51791/njap.v45i1.335

AOAC. 2010. Official methods of analysis. 19th ed. Assoiation. Official Analytical Chemistry Washington, DC

Aro, S. O., and Akinjokun, O. M. 2012. Meat and carcass characteristics of growing pigs fed microbially enhanced cassava peel diets. *Archivos de zootecnia*, *61*(235), 407-414.

Azevedo, M. J., and Azevedo, M. J. 2017. The state of health system (s) in Africa: challenges and opportunities. *Historical perspectives on the state of health and health systems in Africa, volume II**: the modern era***, 1-73.**

Chang'a, E. P., Abdallh, M. E., Ahiwe, E. U., Mbaga, S., Zhu, Z. Y., Fru-Nji, F., and de Iji, P. A. 2020. Replacement value of cassava for maize in broiler chicken diets supplemented with enzymes. *Asian-Australasian Journal of Animal Sciences*, *33*(7), 1126.

Dipasquale, V., Cucinotta, U., and Romano, C. 2020. Acute malnutrition in children: pathophysiology, clinical effects and treatment. *Nutrients*, *12*(8), 2413. doi: 10.3390/nu12082413

Engberg, R. M., Hammersh J. M., Johansen, N. F., Abousekken, M. S., Steenfeldt, S., and Jensen, B. B. 2009. Fermented feed for laying hens: effects on egg production, egg quality, plumage condition and composition and activity of the intestinal microflora. *British Poultry Science*, *50*(2), 228-239. **doi.org/10.1080/00071660902736722**

Fallah-Moshkani, R., Saadatnia, M., Shakeri, F., Keshteli, A. H., Saneei, P., Larijani, B., and Esmaillzadeh, A. 2017. A case–control study on egg consumption and risk of stroke among Iranian population. *Journal of Health, Population and Nutrition*, *36*, 1-7.

Franco, D., Rois, D., Arias, A., Justo, J. R., Marti-Quijal, F. J., Khubber, S., Barba, F. J, López-Pedrouso, M, and Manuel Lorenzo, J. 2020. Effect of breed and diet type on the freshness and quality of the eggs: A comparison between Mos (indigenous Galician breed) and Isa brown hens. *Foods*, *9*(3), 342.

Haugh, R. R. 1937. The Haugh unit for measuring egg quality. *United States Egg Poultry Magazine*, *43*, 552-555.

Hunton, P. 1995. Egg production, processing and marketing. *World Poultry Science, Elsevier, Tokyo*, 457-480.

Ikpesu, T. O., Ariyo, A. B., and Ogbomida, E. T. 2016. Optimization of Crude Protein Production and Reduction in Cyanide Content of Cassava Peels by Pretreatment with *Aspergillus niger* Anl301. *Journal of Industrial Pollution Control*, *32*(2), 633-637.

***Karigidi M. 2021.* How to ensure sustainable management of agricultural wastes. Financial Nigeria, 11 Nov 2021. https://www.financialnigeria.com/how-to-ensure-sustainable-management-of-agricultural-wastes-sustainable-1498.html**

Kyawt, Y. Y., Toyama, H., Htwe, W. M., Thaikua, S., Imura, Y., and Kawamoto, Y. 2014. Effects of cassava substitute for maize based diets on performance characteristics and egg quality of laying hens. *International Journal of Poultry Science*, *13*(9), 518.

Li-Chan, E. C., Powrie, W. D., and Nakai, S. 2017. The chemistry of eggs and egg products. In *Egg science and technology* (pp. 105-175). CRC Press.

Morgan, N. K., and Choct, M. 2016. Cassava: Nutrient composition and nutritive value in poultry diets. *Animal Nutrition*, *2*(4), 253-261. https://doi.org/10.1016/j.aninu.2016.08.010

Nkhata, S. G., Ayua, E., Kamau, E. H., and Shingiro, J. B. 2018. Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food science & nutrition*, *6*(8), 2446-2458. DOI: 10.1002/fsn3.846

Obioha, F. C., Azubuike, G. O., ENE, L. O., Okereke, H. E., and Okoli, O. O. 1984. The effect of partial replacement of maize with cassava peel meal on layer performance. *Nutrition Reports International*, *30* (6), 1423-1429.

Ogunwole, O. A., Adesope, A. I., Raji, A. A., and Oshibanjo, O. D. 2017. Effect of partial replacement of dietary maize with cassava peel meal on egg quality characteristics of chicken during storage. *Nigerian Journal of Animal Science*, *19*(2), 140-152.

Okedere, D. A., Ademola, P. Q., and Asiwaju, P. M. 2020. Performance and cost-benefit analysis of Isa Brown layers on different management systems. *Bulletin of the National Research Centre*, *44*(1), 1-7. https://doi.org/10.1186/s42269-020-00332-w

Okrathok, S., Pasri, P., Thongkratok, R., Molee, W., and Khempaka, S. 2018. Effects of cassava pulp fermented with *Aspergillus oryzae* as a feed ingredient substitution in laying hen diets. *Journal of Applied Poultry Research*, *27*(2), 188-197. https://doi.org/10.3382/japr/pfx057

Oladunjoye, I. O., Ojebiyi, O., and Amao, O. A. 2010. Effect of feeding processed cassava (*Manihot esculenta* Crantz) peel meal based diet on the performance characteristics, egg quality and blood profile of laying chicken. *Agricultura Tropica et Subtropica*, *43*(2), 119-126.

Olowoyeye, J. C. 2016. Growth Performance of Broiler-Chickens Fed Cassava Starch residue Leaf meal as a Replacement for maize diet. *Journal of Environmental Issues and Agriculture in Developing Countries*, *8*(1), 22.

Onyia, L. U., Kama, N., Michael, K. S., and Adewuyi, A. K. 2015. Growth performance and cost benefit analysis of *Clarias gariepinus* fed with different commercial and compounded feeds. *Discourse Journal of Agriculture and Food Sciences*, *3*(1), 1-6.

Osei, S. A., Asiamah, M., and Atuahene, C. C. 1990. Effects of fermented cassava peel meal on the performance of layers. *Animal FeedSscience and Technology*, *29* (3-4), 295-301.

Sadh, P. K., Duhan, S., and Duhan, J. S. 2018. Agro-industrial wastes and their utilization using solid-state fermentation: a review. *Bioresources and Bioprocessing*, *5*(1), 1-15. https://doi.org/10.1186/s40643-017-0187-z

SAS (2001). SAS/STAT Guide for Personal Computers, Version and Edition, Cary, North Carolina SAS Institute**Shittu, M. D., Ojebiyi, O. O., Ademola, S. G., and Ojediran, T. K. 2016**. Replacement value of biscuit dough for maize on performance and nutrient utilization of broiler chickens. *International Journal of Science, Environment and Technology*, *5*(3), 1057-1065.**Singh, R., Das, R., Sangwan, S., Rohatgi, B., Khanam, R., Peera, S. P. G., ... and Misra, S. 2021.** Utilisation of agro-industrial waste for sustainable green production: a review. *Environmental Sustainability*, *4*(4), 619-636. https://doi.org/10.1007/s42398-021-00200-x

Soccol, C. R., Da Costa, E. S. F., Letti, L. A. J., Karp, S. G., Woiciechowski, A. L., and de Souza Vandenberghe, L. P. 2017. Recent developments and innovations in solid state fermentation. *Biotechnology Research and Innovation*, *1*(1), 52-71. https://doi.org/10.1016/j.biori.2017.01.002

Tesfaye, E. B., Animut, G. M., Urge, M. L., and Dessie, T. A. 2014. Cassava root chips and Moringa oleifera leaf meal as alternative feed ingredients in the layer ration. *Journal of Applied Poultry Research*, *23*(4), 614-624. http://dx.doi.org/10.3382/japr.2013-00920

Tewe, O. O., and Lutaladio, N. 2004. Cassava for livestock feed in sub-Saharan Africa.

Türker, İ., and Alkan, S. 2019. Comparisons of physical and chemical characteristics of eggs obtained using hens reared in deep litter and free-range systems. *Journal of Agricultural Sciences*, *25*(2), 181-188.

USDA – MIS 2000. United State Department of Agricultural Marketing Service (USDA - MIS). Egg Grading Manual: Agricultural Handbook No. 75. Available at www.ams.usd.gov/poultry/pdfs/EggGrading%20manual pdf

Yafetto, L. 2018. Protein enrichment of cassava pulp by solid-state fermentation using *Aspergillus niger*. *Studies in Fungi*, *3*(1), 7-18. .Doi 10.5943/sif/3/1/2

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