

Effects of feeding *Aspergillus niger* fermented shea butter cake-based diets on the performance and haemato-biochemical profile of rabbits

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Abstract

Shea butter cake is an agro-industrial by-product obtained after the extraction of fat from the seed of the Shea butter tree (*Vitellaria paradoxa*, Gaertn). The cake was subjected to solid state fermentation for different days; 0, 3, 6, 9 and 12 days, after inoculated with *Aspergillus niger*. At the end of the fermentation period, it was dried in the oven at 100°C for five hours, and packaged in plastic containers, as fermented Shea butter cake (SBC) until needed. Six experimental diets were compounded thus: T1- T6 in which SBC fermented for 0, 3, 6, 9 and 12 days, replaced 10% of groundnut cake, respectively. However, T2 does not undergo any fermentation process (+ve control) A total of 72 crossbred weaner rabbits, aged 5-6 weeks of mixed sexes were used for the study and allotted to the six treatments, with two rabbits per replicate of six replicates per treatment. The feeding trial was conducted for 12 weeks, and digestibility trial carried out at the end of the 11th week. Results showed that final body weight, total body weight gain, average daily body weight gain and feed conversion ratio were significantly ($P < 0.05$) better for rabbits fed diets containing SBC fermented for 9 and 12 days (Diets 5 and 6), though not significantly ($P > 0.05$) different from rabbits fed the Control Diets (-ve control). Similarly, the total digestible nutrient (TDN) was significantly higher for T3 (94.31 %); followed by T2 (91.23 %), T4 (91.87 %) and T5 (91.03 %) which were not significantly ($P > 0.05$) different from that of the Control Diet (T1, 90.76 %). Blood profile analyses revealed that PCV and MCHC of T5 had superior values of 30.6 % and 29.33 % respectively. Hence, it can be concluded that fermenting SBC for 9 days gave optimum growth performance, apparent nutrients digestibility and haematological profile of weaner rabbits.

Key words: *Aspergillus niger* fermented shea butter cake, performance, haema-biochemical profile, rabbits.

Effets d'une alimentation à base de tourteau de beurre de karité fermenté par *Aspergillus niger* sur les performances et le profil héματο-biochimique des lapins



Résumé

Le tourteau de beurre de karité est un sous-produit agro-industriel obtenu après extraction de la graisse des graines de l'arbre à beurre de karité (*Vitellaria paradoxa*, Gaertn). Le tourteau a été soumis à une fermentation à l'état solide pendant différents nombres de jours (0, 3, 6, 9 et 12 jours) après avoir été inoculé avec *Aspergillus niger*. À la fin de la période de fermentation, il a été séché au four à 100 °C pendant cinq heures, puis conditionné dans des récipients en plastique, sous forme de tourteau de karité fermenté (SBC), jusqu'à utilisation. Six régimes alimentaires expérimentaux ont ainsi été composés : T1-T6, dans lesquels le SBC fermenté pendant 0, 3, 6, 9 et 12 jours a remplacé respectivement 10 % du tourteau d'arachide. Cependant, T2 ne subit aucun processus de fermentation (contrôle positif). Au total, soixante-douze (72) lapins sevrés croisés, âgés de 5 à 6 semaines et de sexes mixtes, ont été utilisés pour l'étude et répartis entre les six traitements, à raison de deux lapins par réplique et de six répliques par traitement. L'essai alimentaire a été mené pendant 12 semaines et l'essai de digestibilité a été réalisé à la fin de la 11^e semaine. Les résultats ont montré que le poids corporel final, le gain de poids corporel total, le gain de poids corporel quotidien moyen et le taux de conversion alimentaire étaient significativement ($P < 0,05$) meilleurs chez les lapins nourris avec des régimes contenant du SBC fermenté pendant 9 et 12 jours (régimes 5 et 6), bien que sans différence significative ($P > 0,05$) par rapport aux lapins nourris avec les régimes témoins (témoin négatif). De même, la teneur totale en nutriments digestibles (TDN) était significativement plus élevée pour le régime T3 (94,31 %), suivi des régimes T2 (91,23 %), T4 (91,87 %) et T5 (91,03 %), qui ne différaient pas de manière significative ($P > 0,05$) de celle du régime témoin (T1, 90,76 %). Les analyses du profil sanguin ont révélé que le PCV et le MCHC du T5 présentaient des valeurs supérieures, respectivement de 30,6 % et 29,33 %. On peut donc en conclure que la fermentation du SBC pendant 9 jours a permis d'obtenir des performances de croissance, une digestibilité apparente des nutriments et un profil hématologique optimaux chez les lapins sevrés.

Mots clés: tourteau de beurre de karité fermenté par *Apergillus niger*, performances, profil hématobiochimique, lapins.

Introduction

The astronomical increase in world population has led to a high demand in animal protein consumption obtained from poultry, cattle, sheep and goats in the developing countries of the world (Mohammed and Agwunobi, 2009). Rabbits have been identified to have the potential for filling the gap between demand and supply of high-quality protein in developing countries like Nigeria (Wafar *et al.*, 2018). Rabbits have high genetic potential, short generation interval, high fecundity, and high meat quality, with low cholesterol. They are also reported to be efficient converters of fibrous feed ingredients and agro-industrial by-products than other livestock species (Bassey *et al.*, 2008).

The feeding and nutrition of rabbits requires adequate supply of feed in both quantity and quality for optimal growth (Abonyi *et al.*, 2012). In developing countries, rabbit production is based primarily on grasses and legumes whose availability during the rainy season and growth during the dry season cannot sustain rabbit production (Olomu *et al.*, 2019). Thus, the search for cheaper and readily available feed stuffs that can sustain all-year-round rabbit production has been the focus of animal nutritionists in recent years.

Therefore, there is an urgent need for an alternative in livestock feeds, to reduce the current pressure on conventional feedstuffs as staple food for man, (Zulkifili *et al.*, 2000; Alu *et al.*, 2015). The use of agro by-products in rabbit nutrition has been documented (Okorie, 2003; Odeyinka *et al.*, 2007). One of such alternatives for replacement is the shea butter cake, which is an agroforestry by-product obtained from the processing of nuts of the shea butter tree (*Vitellaria paradoxa*) for fat with no economic value and environmental issue (Dei, *et al.*, 2008; Zanu, *et al.*, 2012). The shea butter cake is of no economic value and constitute environmental nuisance as waste but has been reported to possess adequate nutritional characteristics of higher protein and energy value compare to maize (Dei, *et al.*, 2007; Abdulmumeen, *et al.*, 2013; Agbo and Prah, 2014). Abdul-Mumeen, *et al.*, (2013) investigated Shea butter cake for proximate quality, and reported its overall nutritional value to be high, containing 13.03, 23.38, 4.25, 8.71, 59.37% and 4485.86kcal ME/kg of crude protein, crude fat, ash, crude fiber, carbohydrates and metabolizable energy respectively as well as rich in minerals like calcium, potassium and magnesium.

Shea nut cake is receiving increased attention as a potential feed ingredient for rabbits due to its availability and cheapness. The *Vitellaria paradoxa* is a widely distributed plant in arid and semi-arid areas of Nigeria and tolerates harsh agronomic and environmental conditions, with a high resistance to diseases and pests (Annongu *et al.*, 2006; Ugese *et al.*, 2010; Garba *et al.*, 2011). Shea nut tree and its products contain phenolics, tannins, saponins as well as alkaloid (theobromine) which makes it very bitter, unpalatable and irritates the digestive tract of animals (Oddoye, 2012; Dei *et al.*, 2008a).

However, the major nutritional setback of Shea butter cake utilization for monogastric animals is poor digestibility possibly due to the presence of anti-nutritional factors (ANF's) like saponins and most importantly tannins (Annongu *et al.*, 2006) and theobromine (Oddoye *et al.*, 2012; Abdul-Mumeen *et al.*, 2013).

Based on this, several methods of detoxification of shea nut meal have been proposed including boiling and fermentation (Dei *et al.*, 2008b; Annongu *et al.*, 1996). Nutritionists and researchers have used fermentation as a method of reducing the level of the ANF's in Shea butter cake in order to improve its utilization as alternative energy source in livestock feeding. The process does not require the use of chemicals and can be easily managed in a local condition or on an industrial scale (Yamamoto, *et al.*, 2007). Fermentation is a unique process with great potential for recycling some agro-industrial by-products into useful animal feeds in developing countries; thus, it does not require the use of chemicals and is easy to manage in a farmstead environment (Yamamoto *et al.*, 2007). The characteristics of the fermented products include their acceptability by animals and nutrient availability (Hong, *et al.*, 2004). Fermentation process can produce organic acids that break down saponins and tannins or create condition for the growth of native microbes that detoxify these components (Reddy and Pierson, 1994).

Solid-state fermentation (SSF) is a fermentation process in which microorganisms grow on a solid substrate with little to no free liquid phase (Chaitanya *et al.*, 2022). Unlike submerged fermentation (SmF), SSF provides a unique environment for microbial metabolism and growth. Filamentous fungi and yeasts, which can thrive under low-moisture conditions, are particularly

well suited for SSF (Banat *et al.*, 2021). SSF offers several technological advantages over SmF, including enhanced oxygen transfer due to the higher surface area of the solid substrate, which facilitates mass transfer (Ramos-Sánchez *et al.*, 2015).

Materials and Methods

Location of the study

The study was conducted at the Rabbitry Unit of the Department of Animal Production Teaching and Research Farm, Federal University of Technology, Minna, Niger State. Minna lies within Latitude 9° 39'11"N and Longitude 6° 30' 57"E (Yahaya *et al.*, 2020).

Source of experimental materials and preparation of Shea butter cake

A total of 72 weaned rabbits were used for the study. The rabbits were purchased from the Rabbitry Unit of the National Veterinary Research Institute, Vom, Plateau State. Shea butter cake was sourced from villages around Bida Local Government Area in Niger State. The *Aspergillus niger* strain that was used for this study was obtained from the Microbiology Department Laboratory of the Federal University of Technology, Minna.

Preparation of shea butter cake using *Aspergillus niger*

The shea butter cake was air-dried for seven days, and winnowed to remove impurities, then pulverized into powdery form. It was then mixed with water in the ratio 1:2 (1kg of shea butter cake to 2 L of water) after which the spores of *Aspergillus niger* (0.25 g/kg) were mixed with water properly for homogeneity. The mixture was packed in a plastic container, gently firmed, and sealed with adhesive film to provide anaerobic condition before being kept in an air-tight container at an ambient temperature of 28°C, and allowed to undergo solid state fermentation. The Shea butter cake was allowed to ferment for 0, 3, 6, 9 and 12 days, respectively.

Experimental design and the experimental diets

The seventy-two (72) crossbred weaner rabbits, aged 5-6 weeks of mixed sexes were allocated into six treatments and six replicates per treatment, with two rabbits per replicate, in a completely randomized design model. The experimental diets were formulated to be isocaloric and isonitrogenous (16 % CP and 3000 kcal/kg ME) to contain six (6) dietary treatments. Diet 1 was a maize-groundnut cake-based control diet having 0 % Shea nut cake. Diets 2, 3, 4, 5 and 6 contained 0, 3, 6, 9 and 12-days fermented Shea nut cake replacing groundnut cake (GNC) at 10 % replacement level (Table 1). A feeding trial lasted for 12 weeks and the rabbits were fed *ad-libitu*

Table 1: Ingredient composition of the experimental diets

Parameters	T1	T2	T3	T4	T5	T6
Maize	36.00	36.00	36.00	36.00	36.00	36.00
Rice husk	27.75	27.75	27.75	27.75	27.75	27.75
Shea butter cake (SBC)	0.00	0.55	0.55	0.55	0.55	0.55
Groundnut cake (GNC)	5.50	4.95	4.95	4.95	4.95	4.95
Full fat soya bean	26.00	26.00	26.00	26.00	26.00	26.00
Limestone	1.00	1.00	1.00	1.00	1.00	1.00
Bone meal	3.00	3.00	3.00	3.00	3.00	3.00
*Premix	0.25	0.25	0.25	0.25	0.25	0.25
Common salt	0.30	0.30	0.30	0.30	0.30	0.30
Lysine	0.10	0.10	0.10	0.10	0.10	0.10
Methionine	0.10	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.0	100.0	100.00	100.00	100.00
Calculated composition						
Crude protein	16.22	16.07	16.08	16.08	16.08	16.08
Metabolizable energy (kcal/kg)	2513	2508	2504	2504	2504	2504
Ether extract (%)	6.66	6.68	6.64	6.64	6.64	6.64
Crude fibre (%)	11.89	11.92	11.87	11.87	11.87	11.87
Calcium (%)	1.33	1.33	1.33	1.33	1.33	1.33
Available phosphorus (%)	0.68	0.68	0.68	0.68	0.68	0.68
Lysine (%)	1.11	1.11	1.11	1.11	1.11	1.11
Methionine+Cystine (%)	0.71	0.71	0.71	0.71	0.71	0.71

Premix supplied the following per kg of the premix: Vitamin A, 5000.00 IU; Vitamin D₃ 800,000IU; Vitamin E,

12,000 mg; Vitamin K, 1,500mg; Vitamin B , 1,000 mg; Vitamin B , 2,000 mg, Vitamin B , 1500 mg; Niacin,12,000 mg; Pantothenic acid, 20.00 mg; Biotin, 10,00 mg; Vitamin B , 300.00mg; Folic acid, 150,000 mg;Choline, 60,000 mg; Manganese, 10,000 mg; Iron, 15,000 mg; Zinc 800.) mg; Copper 400.00 mg; Iodine 80.00 mg; Cobalt 40 mg; Selenium 8.00 mg

T1 = Control diet containing no Shea butter cake (SBC) (-ve Control)

T2 = Diet containing SBC fermented for 0 day, replacing 10 % GNC (raw shea butter) (+ve Control)

T3 = Diet containing SBC fermented for 3 days, replacing 10 % GNC

T4 = Diet containing SBC fermented for 6 days, replacing 10 % GNC

T5 = Diet containing SBC fermented for 9 days, replacing 10 % GNC

T6 = Diet containing SBC fermented for 12 day, replacing 10 % GNC

Growth performance evaluation

Parameters measured for growth performance were initial body weight (g), average daily feed intake (g), average daily weight gain (g), and feed conversion ratio.

Average daily feed intake

The quantity of feed offered to each animal was weighed every morning using an electronic scale. Daily feed intake was calculated by subtracting the left-over feed from the quantity of feed offered. Feed Intake=Quantity of feed given–Quantity of left over feed

Average daily weight gain per rabbit:

This was estimated as the current weight of the rabbit less the previous weight of the rabbit, divided by the number of days.

Feed conversion ratio (FCR): This was calculated as the average daily feed intake divided by the average daily weight gain.

Apparent nutrients digestibility evaluation

At the end of the 11th week, one rabbit per replicate was selected randomly and taken into the metabolism cages. Three days of adaptation period were observed and the rabbits were fed known quantities of feed *ad-libitum* for four days; followed by daily faecal collection the following day for each of the replicate. The collection lasted for three days. Faecal samples collected were pooled together on a replicate basis after oven-drying at 100°C for 24 hours. The proximate composition of the experimental diets and the collected faecal samples were determined following the methods described by AOAC (2012). Using these procedures, dry matter, crude protein, ether extract, ash, crude fibre, and nitrogen free extracts were all determined.

Haematological and serum biochemical parameters determination

Five (5) mL of blood samples was collected from the does at slaughter from the jugular vein at the neck region. Two ml of the blood sample was put into ethylene diamine tetra acetic acid (EDTA) treated bottles and taken to the lab for analysis. The haematological parameters evaluated were

haemoglobin (Hb) concentration, packed cell volume (PCV), red blood cell (RBC) counts, white blood cell (WBC) counts and erythrocytes counts, mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC) and platelets as reported by Bitto and Gemade (2001).

The remaining three ml of blood sample was dispensed into a plain sample bottle, and taken to the laboratory for serum biochemical analysis. The serum biochemical parameters evaluated were aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphate (ALP) and total protein (TP).

Data analysis

Data collected during the experimental period were subjected to analysis of variance (ANOVA) using the Statistical Analytical System (SAS, 2012) Package. Variations in means, where they existed, were separated using the Duncan's Multiple Range Test, as contained in the Package.

Results and Discussion

The proximate composition of fermented shea butter cake is shown in Table 2. The results obtained shows raw sample to have moisture (5.68 %), crude protein (13.04 %), crude fibre (5.87 %), ash (4.78 %), ether extract (15.13 %) and the nitrogen free extracts (56.02 %). The results also showed an increase in the moisture content as the fermentation hours increased (9.40- 11, 62 %), and a decrease in the dry matter (90.60-88.38 %) and NFE (61.02-59.31 %). However, the crude protein increased as the fermentation hour increased (13.04-16.15 %). The results revealed that fermentation enhanced the nutritional content of shea butter cake, especially crude protein, when compared to the raw shea butter cake. This finding is in line with the results obtained by Mutayoba *et al.* (2011) who opined that fermentation improves the nutrient composition of feed stuffs.

Table 2: Proximate composition of fermented Shea butter cake

Parameters (%)	Fermentation period (days)				
	0	3	6	9	12
Dry matter	94.42	90.60	90.40	89.87	88.38
Crude protein	13.04	13.81	16.15	16.45	16.10
Crude fibre	5.87	2.50	2.50	2.20	2.25
Ash	4.78	10.0	8.50	9.00	8.00
Ether extract	10.13	3.40	3.21	2.98	2.72
Nitrogen free extract	61.02	60.89	59.04	59.24	59.31

Table 3 shows the effects of 10 % replacement level of fermented shea butter cake diets on the growth performance of weaner rabbits. The initial body weight of the rabbits used fed the diets were not significant among all the treatments. However, the final body weight, total body weight gain and average daily body weight gain were significantly ($P < 0.05$) higher for rabbits fed shea butter cake fermented for 9 and 12 hours (Diets 5 and 6); though not significant ($P > 0.05$) from those fed the Control Diet (Diet 1). Also, the feed conversion ratio (FCR) was the most optimum for rabbits on Diet 5 and Diet 6, though not significantly ($P > 0.05$) different from that of the Control Diet. This could be attributed to the reduction in the levels of anti-nutritional factors in the shea butter cake, because of the solid-state fermentation with *Aspergillus niger*. The feed intake was also significantly higher in fermented diets than in the diet with zero fermentation (Diet 2). This could be attributed to the high level of anti-nutrients, such as tannin and saponin, which might be present in the Shea butter cake (Afolabi *et al.*, 2015). The result is similar to what was obtained by the authors who observed an increase in nutrients and a decrease in the anti-nutrient profile of fermented Shea butter cake. The low FCR observed in T5 and T6, and being not significantly ($P > 0.05$) different from that of the Control Diet (T1) could be attributed to high acceptability of the diet due to reduction in the anti-nutrient profile and increase in the nutrient content due to fermentation, as reported by Afolabi *et al.* (2015).

The apparent nutrients digestibility of rabbits fed 10 % replacement level of Shea butter cake at different fermentation periods is shown in Table 4. Crude protein and crude fibre digestibility were significantly higher for T3 (Shea butter cake fermented for three days); though values obtained for T5 and T6 were not significantly different from the Control Diet (T1). The superior value obtained for the crude protein and crude fibre digestibility is an indication of the efficient utilization of dietary protein and crude fibre for these diets (Kehinde *et al.*, 2020). Also, the total digestible nutrient (TDN) of T3 was significantly ($P < 0.05$) higher than those

of the other treatments. However, there were no significant ($P > 0.05$) differences in the TDN between the Control Diet (T1) and diets T2, T4 and T5. This could be an indication of improved protein quality of the test ingredient due to fermentation and significant reduction in the anti-nutritional factors, like tannin, which have been incriminated in forming complexes with dietary proteins including enzymes in the gastrointestinal tract and thereby inhibiting the digestibility of proteins (Kehinde *et al.*, 2020).

Table 5 shows the haematological parameters of rabbits fed fermented Shea butter cake replacing 10 % groundnut cake in the diets. The haemoglobin and the packed cell volume (PCV) of the blood of the rabbits all increased with increase in the fermentation period. Hb and PCV are usually indicators of blood levels in animals. The result obtained are slightly at per with the one reported by Ansah *et al.* (2011) who reported a higher value for rabbits fed fermented Shea butter cake. The increase in the Hb and PCV could be attributed to the increase in protein content of the Shea butter cake due to fermentation, as protein is known to play a vital role in blood and tissue production. The MCV, MCHC and MCH results all showed Diet 4 (T4) to be significantly higher when compared to the other diets. RBC, which is the erythrocyte concentration, showed an increase with increase in the fermentation period. These results obtained are in line with the normal range for rabbits as reported by Igwebuike *et al.* (2008). There were no significant differences ($P > 0.05$) in the WBC, NEU, LYM and EOS values across all the diets for weaner rabbits. This outcome indicates that the Shea butter cake has no detrimental effect on the immune system of the rabbits. These findings are in agreement with the results of Butcher and Mile (2002) who reported that most changes in immunological indices seen in malnutrition are usually aligned after nutritional rehabilitation. The mesophil values increased, however, with increase in fermentation period.

Table 3: Growth performance of rabbits fed *Aspergillus niger* fermented shea butter cake diets

Parameters	Fermentation periods (days)						SEM	LOS	P-Value
	T1	T2	T3	T4	T5	T6			
Initial body weight (g)	682.50	645.50	682.50	665.93	709.50	720.00 ^S	12.90	NS	0.612
Final Body weight (g)	1434.74 ^a	1121.82 ^b	1193.75 ^b	1188.65 ^b	1462.47 ^a	1448.03 ^a	28.57	**	0.00
Total body weight gain (g)	752.24 ^a	476.32 ^b	511.25 ^b	522.73 ^b	752.97 ^a	728.03 ^a	25.47	**	0.00
Average body weight gain/day (g)	8.95 ^a	5.67 ^b	6.08 ^b	6.22 ^b	8.96 ^a	8.66 ^a	0.30	**	0.00
Total feed intake (g)	3991.91 ^a	3875.23 ^b	3969.48 ^{ab}	3944.94 ^{ab}	3967.93 ^{ab}	3954.24 ^{ab}	13.62	**	0.019
Average daily feed intake (day/g)	47.52 ^a	46.13 ^b	47.25 ^{ab}	46.96 ^{ab}	47.23 ^{ab}	47.07 ^{ab}	0.16	**	0.019
Feed conversion ratio	5.46 ^b	8.22 ^a	7.89 ^a	7.59 ^a	5.39 ^b	5.56 ^b	0.25	**	0.00
Mortality (%)	0.33	0.33	0.33	0.50	0.33	0.16	0.07	NS	0.931

^{abc}Means in the same row with different superscripts were significantly ($P < 0.05$) different.

T1 = Control diet containing no shea butter cake (-ve Control)
butter) (+ve Control)

T3 = Diet containing SBC fermented for 3 days, replacing 10 % GNC

T5 = Diet containing SBC fermented for 9 days, replacing 10 % GNC

TDN = Total digestible nutrient SEM = Standard error of the means

SBC = Shea butter cake

GNC = Groundnut cake

T2 = Diet containing SBC fermented for 0 days, replacing 10 % GNC (raw shea

T4 = Diet containing SBC fermented for 6 days, replacing 10 % GNC

T6 = Diet containing SBC fermented for 12 days, replacing 10 % GNC

LOS = Level of significance p-value = Probability value

Table 4: Apparent nutrients digestibility of diets containing *Aspergillus niger* fermented shea butter cake fed to rabbits

Parameters (%)	T1	T2	T3	T4	T5	T6	SEM	LOS	P-Value
Dry matter	91.01 ^a	88.93 ^{ab}	92.21 ^a	89.98 ^a	89.94 ^a	86.13 ^b	0.51	**	0.00
Crude protein	95.63 ^a	95.83 ^a	96.72 ^a	94.29 ^b	94.21 ^b	92.51 ^b	0.27	**	0.00
Ether extract	97.10 ^a	96.38 ^b	97.68 ^a	97.51 ^a	97.09 ¹	96.12 ^b	0.12	**	0.00
Crude fibre	84.54 ^c	89.76 ^b	93.77 ^a	89.53 ^b	88.07 ^b	84.73 ^c	0.65	**	0.00
Ash	82.85 ^{ab}	82.23 ^{ab}	86.49 ^a	83.01 ^{ab}	81.49 ^b	72.34 ^c	2.02	**	0.019
Nitrogen free extracts	90.26 ^a	85.75 ^b	90.44 ^a	87.40 ^b	85.87 ^b	81.47 ^c	0.63	**	0.019
TDN	90.76 ^b	91.23 ^b	94.31 ^a	91.87 ^b	91.03 ^b	88.00 ^c	0.39	**	0.00

^{abc}Means in the same row with different superscripts were significantly (P<0.05) different.

T1 = Control diet containing no shea butter cake (-ve Control)
butter) (+ve Control)

T3 = Diet containing SBC fermented for 3 days, replacing 10 % GNC

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T4 = Diet containing SBC fermented for 6 days, replacing 10 % GNC

T6 = Diet containing SBC fermented for 12 days, replacing 10 % GNC

LOS = Level of significance p-value = Probability value

Table 5: Haematological parameters of rabbits fed diets containing Shea butter cake fermented with *Aspergillus niger* for different time periods

Parameters	T1	T2	T3	T4	T5	T6	SEM	LOS
HB (g/dL)	9.21 ^b	7.87 ^c	8.03 ^c	8.63 ^{bc}	9.27 ^b	10.40 ^a	0.24	*
PCV (%)	27.67 ^{ab}	23.67 ^b	25.00 ^b	28.67 ^a	30.67 ^a	27.67 ^{ab}	0.69	*
MCV (ft)	86.33 ^c	86.67 ^c	88.00 ^{bc}	94.33 ^a	91.67 ^{ab}	86.00 ^c	0.90	*
MCHC (%)	29.33 ^a	27.00 ^b	29.67 ^a	30.00 ^a	30.00 ^a	29.67 ^a	0.30	*
MCH (pg)	28.67 ^{bc}	28.00 ^c	29.67 ^{ab}	30.67 ^a	30.67 ^a	29.00 ^{bc}	0.29	*
RBC (x10 ⁶ /L)	3.23 ^a	2.50 ^b	3.60 ^a	3.10 ^{ab}	3.03 ^{ab}	3.60 ^a	0.11	*
WBC (x10 ¹² /L)	13.67 ^a	12.23 ^a	13.47 ^a	14.27 ^a	9.50 ^a	14.77 ^a	0.75	NS
NEU (%)	35.66 ^a	36.33 ^a	36.00 ^a	38.67 ^a	39.00 ^a	31.33 ^a	1.22	NS
LYM (%)	57.67 ^a	56.67 ^a	56.67 ^a	56.33 ^a	55.33 ^a	63.00 ^a	1.15	NS
MES (%)	2.67 ^{ab}	2.33 ^{ab}	1.33 ^c	2.00 ^{bc}	2.33 ^{ab}	3.00 ^a	0.15	*
EOS (%)	4.00 ^a	3.33 ^a	3.67 ^a	3.00 ^a	3.00 ^a	2.67 ^a	0.17	NS

^{abc}Means on the same row with different superscripts are significantly (P<0.05) different.

T1 = Control diet containing no Shea butter cake (SBC) (-ve Control)

T2 = Diet containing SBC fermented for 0 day, replacing 10 % GNC (raw shea butter) (+ve Control)

T3 = Diet containing SBC fermented for 3 days, replacing 10 % GNC

T4 = Diet containing SBC fermented for 6 days, replacing 10 % GNC

T5 = Diet containing SBC fermented for 9 days, replacing 10 % GNC

T6 = Diet containing SBC fermented for 12 days, replacing 10 % GNC

SEM = Standard error of the means

LOS = Level of significance

The results of the serum biochemical parameters of rabbits fed diets containing 10 % inclusion level of fermented Shea butter cake is shown in Table 6. The parameters measured showed that the alkaline phosphatase values varied significantly ($P < 0.05$) across all the diets with T2 having significantly higher value (298.87 U/L) than the other

treatments. Alkaline phosphatase is an indicator of the functional ability of the liver. Alkaline phosphatase in high amount is an indication of liver disorder or bone enlargement (Lowe *et al*, 2021) while for AST, ALT and total protein, all were not significantly ($P > 0.05$) influenced by fermentation period of the Shea butter cake.

Table 6: Serum biochemistry of rabbits fed diets containing shea butter cake fermented with *Aspergillus niger* for different time periods

Parameters	T1	T2	T3	T4	T5	T6	SEM	LOS
ALP (UI/mol)	160.20 ^b	298.87 ^a	161.70 ^b	182.03 ^b	192.50 ^b	181.17 ^b	14.61	*
AST (UI/mol)	70.87 ^a	70.01 ^a	66.87 ^a	80.27 ^a	69.80 ^a	76.76 ^a	1.74	NS
ALT (UI/mol)	31.66 ^a	38.70 ^a	39.23 ^a	53.73 ^a	50.17 ^a	38.80 ^a	3.41	NS
TP (g/dL)	5.30 ^a	6.33 ^a	5.80 ^a	5.37 ^a	6.63 ^a	5.76 ^a	0.25	NS

^{ab}Means in the same row with different superscripts are significantly ($P < 0.05$) different.

T1 = Control diet containing no Shea butter cake (SBC) (-ve Control)

T2 = Diet containing SBC fermented for 0 day, replacing 10 % GNC (raw shea butter) (+ve Control)

T3 = Diet containing SBC fermented for 3 days, replacing 10 % GNC

T4 = Diet containing SBC fermented for 6 days, replacing 10 % GNC

T5 = Diet containing SBC fermented for 9 days, replacing 10 % GNC

T6 = Diet containing SBC fermented for 12 days, replacing 10 % GNC

SEM = Standard error of the means

LOS = Level of significance

Conclusion and Recommendations

The results obtained in this study revealed that Shea butter cake (an agro-industrial waste and by-product) can be incorporated into the diets of rabbits, replacing up to 10 % groundnut cake. Fermenting the Shea nut cake or meal with *Aspergillus niger* for 9 days using the solid-state fermentation technique, gave optimum growth performance and apparent nutrients digestibility in weaner rabbits. When fermented for 216 hours (9 days), it produced optimum haematological values for Hb, PCV, MCHC and WBC (9.27, 30.67, 29.67, and 14.77) in weaner rabbits. Hence, rabbit farmers and animal scientists are encouraged to use Shea butter cake fermented with *Aspergillus niger* for 216 hours (9 days) to compound feed for rabbits. It is a cheap and readily available feed resource and agro-industrial waste.

References

Abdul-Mumeen, I. H., Zakpaa, D. and Mills-Robertson, F. C. 2013. Biochemical and microbiological analysis of shea nut cake: A waste product from shea butter processing, *Journal of Agricultural Biotechnology and Sustainable Development*, 5 (4): 61-68.

Abonyi, F. O., Iyi E. O. and Machebe, N. S. 2012. Effects of feeding sweet potato (*Ipomoea batatas*) leaves on growth performance and nutrient digestibility of rabbits.

African Journal of Biotechnology, 11 (15): 3709-3712.

Afolabi, K. O., Orimoloye, P. O. and Ndele Kwate, E. T. 2015. Effect of cooking on the nutritional value of Nigerian Rubber seed, a potential animal feed stuff. *Nigerian Journal of Animal Science*, 17 (1): 56-64.

Agbo, N. W., and Prah, C. D. 2014. Evaluation of fermentation period on the proximate composition and tannin concentration of shea nut (*Vitellaria paradoxa*) meal. *Journal of Microbiology and Biotechnology Research*, 4(1), 21-27.

Alu, S. E., Ari, M. M., Rimbut, N. N., Owuna, I. K. and Kigbu. A. A. 2015. Effects of replacing maize with sugarcane scraping meal on the haematological parameters and serum biochemical variables of broiler finisher birds. *Proceedings of the 20 Annual Conference of the Animal Science Association of Nigeria. September 6 - 10, International Conference Centre, University of Ibadan, Nigeria.* Pp.100-104.

Annongu, A. A., Ogundu, N. J., Joseph, J. K., and Awopetu, V. 2006. Changes in chemical composition and bio assay assessment in nutritional potentials of almond fruit waste as an alternative feedstuff for livestock. *Biochemistry*, 18(1), 25-30.

- Annongu, A. A., Termeulen, U., Atten, J. O., & Apata, D. F. 1996.** Toxicological assessment of native and industrially fermented shea butter cake in the nutrition of broilers. *Archiv für Geflügelkunde*, 60(5), 221–226.
- AOAC 2012.** Association of Official Analytical Chemist, *official methods of Analysis, 19th edition*, Washington, D. C.
- Banat I. M., Carboue Q., Saucedo-Castaneda G., and de Jesus Cazares-Marinero J. 2021.** Biosurfactants: The green generation of speciality chemicals and potential production using Solid-State fermentation (SSF) technology. *Bioresource Technology*, 320, 124222.
- Bassey, I. O., Oluwatosin, O. O. and Olawoyin, O. 2008.** Performance characteristics of rabbits fed millet bran as a replacement for wheat bran. *African Journal of Animal Biomedical Science*, 3(2):1-4.
- Bitto, I. I., and Gemade, M. 2001.** Preliminary investigations on the effect of Pawpaw peel meal on growth, visceral organ and endocrine gland weights, testicular morphometry and the haematology of male rabbits. *Global Journal of Pure and Applied Science*, 7(4), 611–625.
- Chilakamarry C. R., Sakinah A. M., Zularisam A. W., Sirohi R., Khilji I. A., Ahmad N., and Pandey A. 2022.** Advances in solid-state fermentation for bioconversion of agricultural wastes to value-added products: Opportunities and challenges. *Bioresource Technology*, 343, 126065.
- Dei, H. K., Rose, S.P., Mackenzie, A.M. and Amarowicz, R. 2008.** Performance of Chickens fed diets containing shea nut (*Vitellariaparadoxa*, Gaertn.) meal fermented with *Aspergillusniger*. *Poultry Science*, 87 (9): 1773-1778.
- Garba, I. D., Nwawe, C. N. and Oisakede, I.L. 2011.** The potentials of Shea nut tree to the Nigerian economy, *Intl. J. of Agricultural Economic and Rural Dev.*, 4 (1): 62-72.
- Hong, K. J., Lu, C. H., and Kim, S. W. 2004.** *Aspergillus oryzae* fermentation improves nutritional quality of food soybean and feed soybean meals. *Journal of Medicinal Food*, 7, 430-435.
- Kehinde, A. S., Aguihe, P. C., Babatunde, T. O. and Kehinde, O. J. 2020.** Effect of different periods of fermentation on cooked Shea butter cake meal on performance, apparent nutrient digestibility, and carcass yield of broiler chicks. *Journal of Sustainable Development in Africa*, 22 (1):124-127.
- Mohammed, A. and Agwunobi, L. N. 2009.** Taro Cocoyam (*Colocasia esculenta*) meal as feed ingredient in poultry. *Pakistan Journal of Nutrition*, 8 (5): 668-673.
- Mutayoba, S. K., Dierenfeld, E., Mercedes, V. A., Frances, Y. and Knight, C. D. 2011.** Determination of chemical composition and anti-nutritive components of Tanzania locally available poultry feed ingredients. *International Journal of Poultry Science*, 10 (5): 350-357.
- Oddoye, E. O. K., Alemawor, F., Agyente-Badu, K. and Dzogbefia, V.P. 2012.** Proximate analysis of shea nut kernel cake/meal samples from industry and cottage industry and some methods of removal of anti-nutritional factors. *International Journal of Biochemistry and Biotechnology*, 1(9):239-242.
- Odeyinka, S. M., Olasunde, O. M., & Oyedele, O. J. 2007.** Utilization of soybean milk residue, cowpea testa and corn starch residue by weaner rabbits. *Livestock Research for Rural Development*, 19(9), Article 131. <http://www.lrrd.org/lrrd19/9/odey19131.htm>
- Okorie, K. C. 2003.** The effect of palmitic acid fortified maize wet milling by-product on the performance of weaner rabbits. *Czech Journal of Animal Science*, 48 (9): 365-370.
- Olomu J. M., Bamiko, M. A. and Olomu E. B. 2019.** *Rabbit Production and Nutrition*. A Jachem Publication, p. 101.
- Ramos-Sánchez L. B., Cujilema-Quitio M. C., Julian-Ricardo M. C., Cordova J., and Fickers P. 2015.** Fungal lipase production by solid-state fermentation. *Journal of Bioprocessing Biotech*, 5(2), 1.
- Reddy, N. R. and Pierson, M. D. 1994.** Reduction in anti-nutritional and toxic components in plant foods by fermentation. *Food Research International journal*, 27, 281-290.
- SAS. 2012.** *Statistical Analysis System*, SAS Institute Inc. Cary, Nc, USA.
- Ugese, F. D., Baiyeri, K. P. and Mbah, B. N. 2010.** Proximate traits of the seed and seed cake of shea butter tree (*Vitellaria paradoxa* C. F. Gaertn.) in Nigeria's savanna ecozone. *Journal of Applied Biosciences* 31: 1935

- Wafar, R. J., Yakubu, B., Yusuf, H. B. and Antyev, M. 2018.** Effect of feeding raw and differently processed Kapok (*Ceiba pentandra*) seed meal on the growth performance and carcass characteristics of weaner rabbits. *Nigerian Journal of Animal Science*, 20(2): 258-270.
- Yahaya, Y., Usman, B. M., Mohammad, T. Y., Rabiu, I. and Mukaram, A. 2020.** Effect of inadequate water supply to the community, with reference to Gidan Gwano in Niger State. *International Journal of Advanced Academic Research*, 6 (10): 109-110.
- Yamamoto, M., Saleh, F., Tahir, M., Ohtsuka, A. and Hayashi, K. 2007.** The effect of Koji feed (fermented distillery by-product) on the growth performance and nutrient metabolizability in broiler. *The Journal of Poultry Science*, 44, 291-296.
- Zanu, H. K., Adom S. O., and Appiah-Adu, P. 2012.** Response of cockerels to diets containing different levels of sheanut cake. *Agricultural Sciences Research Journal*, 2 (7): 420-423. 125.
- Zulkifili I., Abdullahi, N. Azrin, N.M. and Ho, Y.W. 2000.** Growth performance and immune response of two commercial broiler strains fed diets containing Lactobacillus cultures and oxytetracycline under heat stress conditions. *British Poultry Science*, 41: 593-597.

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