ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26mar1167

Growth Performance and Nutrient Digestibility of Weaner Rabbits Fed Diets Containing Graded Levels of Processed Bambara Nut (*Vigna subterranea*) Offal as a Replacement for Wheat Offal

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Publication Date: 2026/05/06

Abstract: This study evaluated the effect of replacing wheat offal with toasted Bambara nut offal (BNO) on growth performance and apparent nutrient digestibility of weaner rabbits. Twenty-four crossbred weaner rabbits (average weight 350-450 g) were allotted to four dietary treatments in a completely randomized design (CRD), with three replicates per treatment and two rabbits per replicate. Wheat offal was replaced with BNO at 0% (control), 25%, 50%, and 75% levels. The experiment lasted ten weeks, during which growth performance parameters were measured, followed by a four-day metabolic trial for digestibility determination. Results showed no significant (P>0.05) differences across treatments in final body weight, daily weight gain, feed intake, or feed conversion ratio. However, apparent nutrient digestibility was significantly (P<0.05) influenced by dietary treatments. Rabbits fed 75% BNO diet recorded the highest crude protein (86.08%) and crude fibre (81.58%) digestibility, while the control group had the lowest values for dry matter (84.11%) and crude protein (83.79%). Ether extract digestibility was highest (P<0.05) in rabbits fed 50% and 75% BNO diets (94.18% and 94.20%, respectively). It was concluded that toasted Bambara nut offal can replace up to 75% wheat offal in weaner rabbit diets without compromising growth performance, while significantly improving nutrient digestibility.

Keywords: *Bambara Nut Offal, Weaner Rabbits, Growth Performance, Nutrient Digestibility, Wheat Offal Replacement.*

How to Cite: Onigemo, M. A.; Oladigbolu, F. A.; Oso, Y. A. A.; Raji, M. O.; Olufeko, S. O.; Agbalaya K. K.; Agbaye, F. P.; Ishola, O. J.; Obasoyo, D. O.; Asafa, A. R.; Oyewole, O. Y.; Bamgbose, A. M. (2026) Growth Performance and Nutrient Digestibility of Weaner Rabbits Fed Diets Containing Graded Levels of Processed Bambara Nut (*Vigna subterranea*) Offal as a Replacement for Wheat Offal. *International Journal of Innovative Science and Research Technology*, 11(3), 4149-4157. https://doi.org/10.38124/ijisrt/26mar1167

I. INTRODUCTION

The greatest challenge facing livestock production in developing countries, including Nigeria, is the high cost of conventional feed ingredients, which accounts for 70-80% of total production costs (Wafar et al., 2019). This situation is exacerbated by intense competition between humans and livestock for staple feedstuffs such as maize, wheat, and soybean (Agunbiade et al., 2001). Consequently, there is an urgent need to explore non-conventional feed resources that

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26mar1167

have no direct value for human consumption and are readily available at lower costs.

Rabbit production offers a viable solution to animal protein deficiency in developing nations due to the species' high reproductive potential, rapid growth rate, short generation interval, and ability to utilize high-fibre diets (Hassan et al., 2012; Ubua et al., 2018; Oso, et al., 2022). Rabbits possess a unique digestive physiology that enables them to thrive on diets containing substantial amounts of fibrous by-products through post-gastric fibre digestion in the caecum (Belenguer et al., 2008). This characteristic makes them ideal animals for utilizing agro-industrial by-products that would otherwise constitute environmental waste.

Bambara groundnut (*Vigna subterranea (L.) Verdc*) is an indigenous African legume widely cultivated in Nigeria, particularly in the northern and eastern states (Bamshaiye et al., 2011). Processing of Bambara nuts into flour for human consumption (locally known as "okpa") generates significant quantities of offal, which currently has no industrial use and may pose disposal challenges (Amaefule and Osuagwu, 2005). This offal contains considerable amounts of crude protein (15-18%) and fibre, making it a potential feedstuff for rabbits (Oyeagu et al., 2016).

Previous studies on Bambara nut offal utilization in animal feeding have produced variable results depending on processing methods and inclusion levels. Amaefule et al. (2011) reported that raw Bambara groundnut offal could be included in growing rabbit diets up to 15% without adverse effects on performance. Similarly, Mbonu (2023) found that rabbits fed up to 15% raw Bambara groundnut offal showed no significant differences in nutrient digestibility compared to control groups, but 20% inclusion depressed digestibility coefficients. However, the presence of anti-nutritional factors such as trypsin inhibitors, tannins, and cyanogenic glycosides in raw Bambara nuts limits their utilization, particularly in monogastric animals (Soetan and Oyewole, 2009; Akande and Fabiyi, 2010).

Heat processing methods, including toasting, have been demonstrated to reduce or eliminate these anti-nutritional factors, thereby improving nutrient availability (Amaefule and Onwudike, 2000; Onigemo et al., 2022). Akinmutimi (2004) and Onigemo et al. (2020b) observed that while processing may not completely eliminate anti-nutrients, it reduces their concentrations to tolerable levels, enhancing the nutritional value of alternative feedstuffs. Despite these findings, information on the use of toasted Bambara nut offal as a replacement for wheat offal in rabbit diets remains limited.

Wheat offal is a conventional fibre source in rabbit nutrition, but its cost has increased substantially due to competition from the baking industry and its use in other livestock feeds. Identifying a cheaper, locally available alternative that does not compromise animal performance would significantly reduce production costs and enhance the profitability of rabbit farming enterprises.

Therefore, this study was designed to evaluate the growth performance and apparent nutrient digestibility of weaner rabbits fed diets containing graded levels of toasted Bambara nut offal as a partial replacement for wheat offal.

II. MATERIALS AND METHODS

➢ *Experimental Site*

The experiment was conducted at the Rabbit Unit of the Directorate of University Farms (DUFARMS), Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. The site is located in the rain forest vegetation zone of South-Western Nigeria on Latitude 7°13'49.66"N and Longitude 3°26'11.98"E, at an altitude of 76 m above sea level (Google Earth, 2020). The climate is humid with mean annual rainfall of 1,037 mm, annual mean temperature range of 34.7°C, and relative humidity of 83% (FUNAAB Meteorological Station, 2020).

➢ *Source and Processing of Test Ingredient*

Bambara nut offal was obtained as an agro-industrial by-product from commercial production of "okpa" for human consumption in Eleweran Community, Abeokuta, Ogun State, Nigeria. The foreign materials in the Bambara nut was removed by sieving, the seeds was then washed with clean water, roasted in a metal drum with continuous stirring for approximately 20 minutes until characteristic aroma developed and seeds were uniformly browned, thereafter, it was cooled and milled into flour and sieved into uniform particle size.

➢ *Experimental Design and Diets*

Following acclimatization, rabbits were weighed individually and allotted to four dietary treatments in a completely randomized design (CRD). Each treatment had three replicates, with two rabbits per replicate. Four experimental diets were formulated to meet the nutrient requirements of weaner rabbits as specified by NRC (1977). Wheat offal was replaced with Bambara nut offal at the following levels:

- Treatment 1 (T1): 0% BNO (control, 40% wheat offal)
- Treatment 2 (T2): 25% BNO replacement (30% wheat offal + 10% BNO)
- Treatment 3 (T3): 50% BNO replacement (20% wheat offal + 20% BNO)
- Treatment 4 (T4): 75% BNO replacement (10% wheat offal + 30% BNO)

The ingredient composition and determined nutrient content of the experimental diets are presented in Table 1.

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Table 1 Percentage Composition and Determined Nutrient Content of Experimental Diets for Weaner Rabbits

Ingredients (%)	**Bambara Nut Offal Inclusion Levels**			
	0%	**25%**	**50%**	**75%**
Maize	38.00	38.00	38.00	38.00
Soybean meal	17.00	17.00	17.00	17.00
Wheat offal	40.00	30.00	20.00	10.00
Bambara nut offal	-	10.00	20.00	30.00
Fish meal (72%)	0.50	0.50	0.50	0.50
Bone meal	2.50	2.50	2.50	2.50
Limestone	1.48	1.48	1.48	1.48
Premix	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
Toxin binder	0.02	0.02	0.02	0.02
Total	100.00	100.00	100.00	100.00
Determined analysis (%)				
Dry matter	88.00	88.00	88.50	89.00
Crude protein	16.04	16.34	15.98	16.85
Crude fibre	10.50	10.50	11.00	11.50
Ether extract	6.50	7.50	8.00	7.00
Ash	7.50	5.00	7.00	7.00
Nitrogen-free extract	46.02	47.46	48.15	48.66
Metabolizable energy (kcal/kg)	2781.01	2914.68	2849.96	2875.70

Premix per kg of diet: Vitamin A 15,000 IU, Vitamin D3 3,000 IU, Vitamin E 30,000 IU, Vitamin K 3,000 mg, Vitamin B1 3,000 mg, Vitamin B2 6,000 mg, Vitamin B6 5,000 mg, Vitamin B12 40 mg, Biotin 200 mg, Niacin 40,000 mg, Pantothenic acid 15,000 mg, Folic acid 2,000 mg, Choline 300,000 mg, Iron 60,000 mg, Manganese 80,000 mg, Copper 25,000 mg, Zinc 80,000 mg, Cobalt 150 mg, Iodine 500 mg, Selenium 310 mg, Antioxidant 20,000 mg. ME (kcal/kg) = 37 × CP% + 81.8 × EE% + 35.5 × NFE% (Pauzenga, 1985).

➢ *Proximate Analysis of Bambara Nut Offal*

Samples of processed Bambara nut offal were analyzed for proximate composition following AOAC (2000) procedures. Dry matter was determined by oven-drying at 105°C for 24 hours. Crude protein (N × 6.25) was determined using the micro-Kjeldahl method. Ether extract was determined by petroleum ether extraction using a Soxhlet apparatus. Crude fibre was determined by sequential digestion with 1.25% H_2SO_4 and 1.25% NaOH. Ash content was determined by incineration in a muffle furnace at 550°C for 6 hours. Nitrogen-free extract was calculated by difference. Fibre fractions (neutral detergent fibre, acid detergent fibre, acid detergent lignin) were determined according to Van Soest et al. (1991).

➢ *Experimental Animals and Management*

Twenty-four (24) crossbred Chinchilla weaner rabbits of unsexes, with an average initial weight of 350-450 g, were purchased from a reputable commercial rabbit farm in Ibadan, Nigeria. The rabbits were allowed to acclimatize for seven days during which they were vaccinated, dewormed, and treated against ectoparasites and coccidiosis following recommended veterinary protocols.

Rabbits were housed in wooden hutches with wire mesh floors (60 cm × 60 cm × 50 cm per cell) raised on metal stands. Hutches were washed and disinfected with appropriate disinfectants prior to rabbit arrival. Strict biosecurity measures were maintained throughout the experimental period, including daily cleaning of feeding and drinking troughs, restriction of predators, and application of black oil on hutch stands to prevent ant infestation. Feed and clean drinking water were provided *ad libitum* throughout the ten-week experimental period.

➢ *Growth Performance Parameters*

Data were collected on the following parameters throughout the ten-week experimental period:

- *Feed Intake:*

Known weights of feed were offered daily to each replicate, and leftover feed was collected and weighed the following morning. Daily feed intake was calculated as the difference between feed offered and leftover feed. Average daily feed intake was computed by dividing total feed intake by the number of experimental days.

- *Body Weight Gain:*

Rabbits were weighed individually at the beginning of the experiment and subsequently on a weekly basis using a sensitive weighing scale. Weight gain was calculated as the difference between final weight and initial weight. Average daily weight gain was computed by dividing total weight gain by the number of experimental days.

Feed Conversion Ratio (FCR): This was calculated as the ratio of total feed intake (g) to total weight gain (g).

➢ *Apparent Nutrient Digestibility Trial*

At the end of the ten-week feeding trial, three rabbits per treatment (one per replicate) were selected and transferred to metabolic cages equipped with facilities for separate

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26mar1167

collection of faeces. Rabbits were allowed to acclimatize to the metabolic cages for three days before a four-day collection period.

During the collection period, a known amount of feed was offered daily, and left over feed were collected and weighed in the following morning. Total faecal output from each rabbit was collected daily in the morning, weighed, and oven-dried at 65°C for 24 hours. Dried faecal samples from each rabbit over the four-day period were bulked, ground, and stored in airtight containers for proximate analysis.

Apparent nutrient digestibility coefficients were calculated using the formula:

Apparent Nutrient Digestibility (%) = [(Nutrient intake – Nutrient in faeces) / Nutrient intake] × 100

Where nutrient intake = (Feed consumed × % nutrient in feed) and nutrient in faeces = (Faecal output × % nutrient in faeces).

➢ *Statistical Analysis*

Data obtained were subjected to one-way analysis of variance (ANOVA) in a completely randomized design using SAS (2007). Significant differences among treatment means were separated using Duncan's Multiple Range Test (Duncan, 1955) at a 5% level of probability.

III. RESULTS

➢ *Chemical Composition of Bambara Nut Offal*

The proximate composition and fibre fractions of toasted Bambara nut offal used in this study are presented in Table 2. The offal contained 86.00% dry matter, 15.73% crude protein, 12.00% crude fibre, 9.00% ether extract, and 3.00% ash. The metabolizable energy value was calculated as 2,630.46 kcal/kg. Fibre fraction analysis revealed neutral detergent fibre (NDF) of 28.50%, acid detergent fibre (ADF) of 17.00%, and acid detergent lignin (ADL) of 5.00%.

Table 2 Determined Chemical Composition of Bambara Nut Offal

Parameters	Value
Dry matter (%)	86.00
Crude protein (%)	15.73
Crude fibre (%)	12.00
Ether extract (%)	9.00
Ash (%)	3.00
Metabolizable energy (kcal/kg)	2,630.46
Neutral detergent fibre (NDF, %)	28.5
Acid detergent fibre (ADF, %)	17.00
Acid detergent lignin (ADL, %)	5.00

➢ *Growth Performance of Weaner Rabbits*

The effects of partial replacement of wheat offal with Bambara nut offal on growth performance parameters are presented in Table 3. All growth parameters measured were not significantly (P>0.05) affected by dietary treatments. Initial body weights were similar across treatments, ranging from 646.67 g to 653.33 g. Final body weights ranged from 1,583.33 g in rabbits fed 0% and 25% BNO diets to 1,670.00 g in those fed 75% BNO diet, with no significant differences (P>0.05). Daily weight gain followed a similar pattern, with values ranging from 13.33 g/day (25% BNO) to 14.57 g/day (75% BNO). Total feed intake decreased as BNO inclusion increased, from 4,223.49 g in the control group to 4,030.02 g in rabbits fed 75% BNO diet, but these differences were not statistically significant (P>0.05). Daily feed intake followed the same trend, ranging from 57.57 g to 60.34 g. Feed conversion ratio improved with increasing BNO inclusion, from 4.51 in the control group to 3.95 in rabbits fed 75% BNO diet, although this improvement was not statistically significant (P>0.05).

Table 3 Effect of Partial Replacement of Wheat Offal with Bambara Nut Offal on Growth Performance of Weaner Rabbits

Parameters	**Bambara nut offal inclusion levels**				**SEM**	**P-value**
	0%	**25%**	**50%**	**75%**		
Initial body weight (g)	646.67	650.00	653.33	650.00	21.13	1.00
Final body weight (g)	1583.33	1583.33	1620.00	1670.00	58.99	0.96
Daily weight gain (g)	13.38	13.33	13.80	14.57	0.90	0.95
Total feed intake (g)	4223.49	4170.51	4135.47	4030.02	33.72	0.23
Daily feed intake (g)	60.34	59.58	59.08	57.57	0.60	0.23
Feed conversion ratio	4.51	4.47	4.28	3.95	0.30	0.82
SEM: Standard Error of Means; Means within rows with no superscripts are not significantly different (P>0.05)						

➢ *Apparent Nutrient Digestibility*

The effects of dietary treatments on apparent nutrient digestibility coefficients are presented in Table 4. All digestibility parameters, except ADF and ADL, were significantly (P<0.05) influenced by the replacement of wheat offal with Bambara nut offal.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26mar1167

Dry matter digestibility ranged from 84.11% to 87.48%, with rabbits fed 25% BNO (87.28%) and 75% BNO (87.48%) showing significantly (P<0.05) higher values compared to the control group (84.11%). Rabbits fed 50% BNO (86.61%) had intermediate values that did not differ significantly from other treatments.

Crude protein digestibility followed a graded response, with the 75% BNO group recording the highest value (86.08%), followed by 25% BNO (85.30%), 50% BNO (84.65%), and the control group showing the lowest value (83.79%). All differences were statistically significant (P<0.05) except between 25% and 50% BNO groups.

Ether extract digestibility was significantly (P<0.05) higher in rabbits fed 50% BNO (94.18%) and 75% BNO (94.20%) compared to the control group (92.67%), with the 25% BNO group (93.59%) showing intermediate values.

Crude fibre digestibility showed the most pronounced response, increasing progressively with BNO inclusion levels. The 75% BNO group recorded the highest value (81.58%), which was significantly (P<0.05) higher than all other treatments. This was followed by 50% BNO (72.75%), while the 25% BNO (69.96%) and control (67.79%) groups had the lowest values and did not differ significantly from each other.

Ash digestibility was significantly (P<0.05) lower in rabbits fed 25% BNO (65.27%) compared to all other treatments. The control (71.48%), 50% BNO (70.88%), and 75% BNO (74.33%) groups had similar values and were not significantly different from each other.

Neutral detergent fibre digestibility increased significantly (P<0.05) with BNO inclusion, with rabbits fed 50% BNO (75.82%) and 75% BNO (76.43%) showing higher values compared to the control group (65.53%). The 25% BNO group (72.45%) had intermediate values that did not differ significantly from other treatments.

Acid detergent fibre digestibility and acid detergent lignin digestibility were not significantly (P>0.05) affected by BNO inclusion.

Table 4 Effect of Partial Replacement of Wheat Offal with Bambara Nut Offal on Apparent Nutrient Digestibility (%) of Weaner Rabbits

Parameters (%)	Bambara nut offal inclusion levels				SEM	P-value
	0%	25%	50%	75%		
Dry matter	84.11^{b}	87.28^{a}	86.61^{ab}	87.48^{a}	0.49	0.041
Crude protein	83.79^{c}	85.30^{ab}	84.65^{bc}	86.08^{a}	0.23	<0.001
Ether extract	92.67^{b}	93.59^{ab}	94.18^{a}	94.20^{a}	0.25	0.096
Crude fibre	67.79^{c}	69.96^{c}	72.75^{b}	81.58^{a}	0.39	<0.001
Ash	71.48^{a}	65.27^{b}	70.88^{a}	74.33^{a}	0.91	0.001
NDF	65.53^{b}	72.45^{ab}	75.82^{a}	76.43^{a}	1.66	0.031
ADF	60.35	63.68	62.97	66.08	1.40	0.38
ADL	46.5	50.39	52.82	53.08	6.15	0.961

^{abc} Means within rows with different superscripts are significantly different (P<0.05); SEM: Standard Error of Means; NDF: Neutral Detergent Fibre; ADF: Acid Detergent Fibre; ADL: Acid Detergent Lignin

IV. DISCUSSION

➢ *Chemical Composition of Bambara Nut Offal*

The proximate composition of toasted Bambara nut offal obtained in this study (15.73% crude protein, 12.00% crude fibre) compares favourably with values reported in the literature. Amaefule and Osuagwu (2005) reported 17.70% crude protein for raw Bambara groundnut offal, while Ani (2008) recorded 17.00%. The slightly lower protein content in the present study may be attributed to differences in Bambara nut varieties, processing methods (particularly the extent of sieving during flour production), and possible heat damage during toasting. The toasting process, while beneficial for reducing anti-nutritional factors, may cause some protein denaturation or Maillard reactions that could slightly reduce measured crude protein (Akande and Fabiyi, 2010; Onigemo et al., 2020a).

The crude fibre content of 12.00% is higher than the 11.30% reported by Amaefule and Osuagwu (2005) and substantially higher than the 5.40% recorded by Amaefule and Iroanya (2004). This variation likely reflects differences in the efficiency of flour extraction during processing, with more thorough sieving removing more fibrous material and resulting in higher fibre content in the residual offal. The ether extract value (9.00%) falls between the 13.30% reported by Okah et al. (2006) and the 6.30% recorded by Olomu (1995), while the ash content (3.00%) is similar to the 3.15% reported by Okah et al. (2006).

The fibre fractions (NDF 28.50%, ADF 17.00%, ADL 5.00%) indicate that Bambara nut offal contains moderate levels of slowly fermentable fibre components. The relatively low lignin content suggests that the fibre may be reasonably digestible by rabbits, which possess caecal fermentation capabilities (Gidenne et al., 1998). The metabolizable energy value (2,630.46 kcal/kg) is adequate for meeting the energy requirements of growing rabbits, which typically range from 2,200 to 2,500 kcal/kg (NRC, 1977).

➢ *Growth Performance*

The absence of significant differences in all growth performance parameters measured (final body weight, daily weight gain, feed intake, and feed conversion ratio) indicates

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26mar1167

that toasted Bambara nut offal can effectively replace wheat offal up to 75% in weaner rabbit diets without compromising growth. This finding is consistent with several previous studies. Amaefule et al. (2024) reported that replacement of wheat offal with Bambara nut offal did not significantly influence growth performance of weaner rabbits across replacement ratios of 0:100, 25:75, 50:50, and 75:25. Similarly, Nnenna (2021) found no significant differences in final live weight and weight gain in rabbits fed up to 20% raw Bambara groundnut offal, with the 15% inclusion level producing numerically higher values.

The comparable feed intake values across treatments suggest that the palatability of diets containing toasted BNO was not inferior to the control diet. This contrasts with findings by Ani and Omeje (2007), who reported increased feed intake in chicks as raw Bambara nut offal levels increased to 50%. The difference may be attributed to the toasting process employed in the present study, which likely improved the organoleptic properties of the offal by reducing bitter or astringent compounds associated with anti-nutritional factors (Soetan and Oyewole, 2009; Onigemo et al., 2020b; Onigemo et al., 2022).

The feed conversion ratio ranged from 4.51 (controls) to 3.95 in rabbits fed 75% BNO, and were not statistically significant, suggests a trend toward better feed efficiency with increasing BNO inclusion. This observation aligns with Amaefule et al. (2011), who reported that growing rabbits fed 15% raw Bambara groundnut offal showed better feed conversion ratios compared to controls. The improved FCR may be related to the higher digestibility coefficients observed in BNO-fed rabbits, as discussed below.

The lack of significant differences in growth performance despite variations in nutrient digestibility suggests that the digestibility improvements were sufficient to maintain growth but not dramatic enough to produce statistically significant differences in weight gain within the ten-week experimental period. This is economically significant because it demonstrates that the cheaper BNO can replace the more expensive wheat offal without sacrificing animal performance.

- *Apparent Nutrient Digestibility*

The significant improvements in dry matter, crude protein, crude fibre, and ether extract digestibility with increasing BNO inclusion represent one of the most important findings of this study. These results demonstrate that the toasting process effectively improved the nutritional value of Bambara nut offal by reducing or eliminating anti-nutritional factors that typically limit nutrient utilization in raw legumes.

The progressive increase in crude protein digestibility from 83.79% in controls to 86.08% in rabbits fed 75% BNO indicates that toasted BNO protein is highly available to rabbits. This contrasts with findings from studies using raw Bambara nut offal. Mbonu (2023) reported that rabbits fed 20% raw Bambara groundnut offal had depressed apparent digestibility coefficients, while Amaefule et al. (2011) observed that 20% raw BGO depressed digestibility of ether extract (85.28%), crude fibre (65.80%), and nitrogen-free extract (89.54%). The superior protein digestibility in the present study can be attributed to the heat treatment, which denatures protease inhibitors (trypsin and chymotrypsin inhibitors) that interfere with protein digestion (Akande and Fabiyi, 2010; Onigemo et al., 2020a).

The remarkable improvement in crude fibre digestibility, from 67.79% in controls to 81.58% in rabbits fed 75% BNO, is particularly noteworthy. Rabbits have limited capacity to digest fibre compared to ruminants, with typical fibre digestibility ranging from 10-30% (Maertens, 1988). The high values obtained in this study may reflect several factors. First, the toasting process may have disrupted lignocellulosic bonds, making fibre components more accessible to caecal microbial fermentation (Gidenne et al., 1998). Second, the BNO fibre may contain a higher proportion of digestible fibre components (hemicellulose and cellulose) relative to indigestible lignin, as suggested by the ADL values (5.00%). Third, the increased fibre digestibility with higher BNO inclusion may indicate adaptation of the caecal microbial population to the fibre source over the ten-week feeding period (Gidenne and Bellier, 2000).

The significant increase in NDF digestibility (from 65.53% to 76.43%) with BNO inclusion supports the hypothesis that BNO fibre is highly fermentable. NDF represents the total fibre fraction including hemicellulose, cellulose, and lignin. The improved NDF digestibility indicates that the hemicellulose and cellulose components were well utilized by the rabbits. The lack of significant differences in ADF and ADL digestibility, despite improvements, suggests that the lignin fraction remained relatively indigestible regardless of treatment, which is consistent with the known limited ability of rabbits to digest lignin (Nicodemus et al., 2006).

The higher ether extract digestibility in BNO-fed rabbits (94.18-94.20%) compared to controls (92.67%) may be related to the fatty acid profile of Bambara nut oil. Minka and Bruneteau (2000) reported that Bambara groundnut fat is predominantly composed of linoleic, palmitic, and linolenic acids, which may be more readily digestible than the fat profile in wheat offal. Additionally, heat treatment may have disrupted lipid-protein complexes, making the oil more accessible to digestive enzymes (Amaefule et al., 2011).

The lower ash digestibility in rabbits fed 25% BNO (65.27%) compared to other treatments is difficult to explain and may represent an anomaly rather than a treatment effect, as the 50% and 75% BNO groups showed values comparable to controls. The mineral composition of BNO may differ from wheat offal, and the intermediate inclusion level might have created an imbalance in mineral ratios that affected absorption, but this would require further investigation.

The findings of this study have important practical implications for rabbit production in developing countries. Wheat offal is a conventional but increasingly expensive feed ingredient due to competition from other livestock species

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26mar1167

and the baking industry. Bambara nut offal, as a by-product with no direct human use, is considerably cheaper and readily available in areas where Bambara nuts are processed for human consumption (Okeke, 2000).

The ability to replace up to 75% of wheat offal with BNO without compromising growth performance means that farmers can significantly reduce feed costs while maintaining productivity. The improved nutrient digestibility, particularly of protein and fibre, suggests that rabbits may actually utilize BNO-based diets more efficiently than conventional wheat offal diets, potentially leading to better feed conversion ratios and reduced feed wastage.

The toasting process employed in this study is simple and can be implemented at the smallholder farmer level using locally available equipment. This makes the technology accessible to resource-poor farmers who constitute the majority of rabbit producers in developing countries. The reduction in anti-nutritional factors achieved through toasting ensures that the full nutritional potential of Bambara nut offal is realized, addressing concerns previously raised about the use of raw Bambara products in monogastric feeding (Soetan and Oyewole, 2009).

The results of this study both confirm and extend previous findings on Bambara nut offal utilization in rabbit feeding. Amaefule et al. (2011) concluded that growing rabbits could be fed diets containing up to 15% raw Bambara groundnut offal to enhance daily weight gain and reduce feed cost, without adversely affecting nutrient intake or digestibility. The present study demonstrates that with toasting, inclusion levels can be increased to 30% (75% replacement of wheat offal, which constituted 40% of the diet) without negative effects, and with improved digestibility.

The improvement in digestibility at higher inclusion levels in the present study contrasts with findings from raw BNO studies, where 20% inclusion depressed digestibility (Mbonu, 2023; Amaefule et al., 2011). This clearly demonstrates the value of heat processing in unlocking the nutritional potential of Bambara nut offal. The mechanism appears to be inactivation of heat-labile anti-nutritional factors, including protease inhibitors, tannins, and lectins, which interfere with nutrient digestion and absorption (Akande and Fabiyi, 2010).

The digestibility values obtained in this study are generally higher than those reported for many conventional rabbit feed ingredients. This may reflect the young age of the rabbits (weaners), which typically have higher digestive efficiency than adults, as well as the adaptation period to the diets. It may also indicate that Bambara nut offal, when properly processed, is a particularly suitable feedstuff for rabbits, given their adaptation to fibrous diets.

V. CONCLUSION AND RECOMMENDATIONS

This study demonstrates that toasted Bambara nut offal can effectively replace up to 75% of wheat offal in weaner rabbit diets without compromising growth performance. The toasting process effectively reduces or eliminates anti-nutritional factors, resulting in improved apparent nutrient digestibility, particularly of crude protein, crude fibre, and ether extract. The significant improvements in fibre digestibility with increasing BNO inclusion indicate that processed Bambara nut offal is a highly suitable fibre source for rabbits, supporting their unique caecal fermentation capabilities. The comparable growth performance across all dietary treatments, combined with improved nutrient utilization, in an indication that Bambara nut offal is nutritionally equivalent or superior to wheat offal when properly processed.

Hence, toasted Bambara nut offal up to 30% of the total diet (representing 75% replacement of wheat offal) in weaner rabbit diets is recommended for optimal nutrient digestibility without compromising growth performance.

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