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COMPARATIVE EFFECTS OF THREE PLANT PROTEIN CAKES ON PERFORMANCE, NUTRIENT DIGESTIBILITY, HAEMATOLOGY, SERUM BIOCHEMISTRY AND PRODUCTION ECONOMICS OF WEANER RABBITS

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ABSTRACT

This research was conducted to compare the effects of feeding three plant protein cakes, groundnut cake (GNC), cottonseed cake (CSC), and palm kernel cake (PKC) on performance, nutrient digestibility, haematology, serum biochemistry, and production economics of weaner rabbits. Twenty-four six weeks old, mixed-breed rabbits of both sexes were allotted into three groups randomly containing eight rabbits each. The treatment groups (T1, T2, and T3) were fed for five weeks on three different diets containing GNC, CSC, and PKC as protein sources respectively. Data generated were analyzed using one-way ANOVA. It was revealed that majority of the performance parameters were not affected ($p>0.05$) except final body weight which differed significantly ($p<0.05$) across the treatment groups. The ash contents of the diets also varied significantly ($p<0.05$) amid other parameters of nutrient digestibility. The diets had no adverse effects on hematological and biochemical parameters, but total bilirubin, creatinine, and sodium were affected ($p<0.05$). This study also revealed that CSC compared favorably with GNC in terms of growth performance and economics of rabbit production, while PKC had poor economic values for production. It was therefore suggested that the three cakes are non-toxic to the muscle, kidneys, and liver of rabbits at 17.43% inclusion level. This indicates that groundnut cake, cottonseed cake and palm kernel cake can be used as sources of protein in the diet of weaner rabbits without affecting the blood and serum biochemical parameters of weaner rabbits because the enzyme levels continued within the reference range of healthy rabbits.

Keywords: *Plant proteins, performance***,** *digestibility, biochemistry, weaner rabbits*

INTRODUCTION

Prevalent malnutrition in developing nations like Nigeria has been attributed to a deficiency in the intake of animal protein (Semba, 2016). The present-day economy i.e. recession coupled with the current inflationary trend, scarcity, high cost of production as well as covid-19 pandemic contributes to the short supply of animal protein (Madzorera *et al.,* 2021; Usman *et al.,* 2020). In Nigeria, the demand for animal protein is far beyond what is available (Benard *et al.,* 2010). According to Atsu (2002), the Nigerian average animal protein consumption put at 4.5 g/head/day is far less than the 35 g/head/day minimum requirement recommended by the Food and Agricultural Organization of the United Nations. This has been recently corroborated by De Vries-Ten Have *et al*. (2020) that animal proteins are being consumed to a lesser extent in Nigeria. The over-reliance on large animal species with extended production cycles, e.g., cattle, sheep, and goats has been implicated in the prevalent poor animal protein intake in many developing nations including Nigeria (Yusuf *et al.,* 2009). Therefore, there is in need to diversify and shift production interest to such food animals as rabbits that need relatively low capital input, less time to manage, easy maintenance, and short production cycles (Zamaratskaia *et al.*, 2023) and high conversion rate of feed-to-carcass (Owen *et al.*, 2009; Jiang *et. al.*, 2020; Mondin *et. al.*, 2021). Rabbit production has the potential to improve the poor animal protein intake in Nigeria and other developing tropical nations (Amaefule *et al.,* 2005). In addition to their prolific reproductive ability (Zamaratskaia *et al.*, 2023), rabbits have several advantages over other farm animal species, its meat has higher-quality protein (Ruleva *et al.*, 2015), significantly low fat and cholesterol content, high levels of unsaturated fatty acids and sodium (Cullere and Dalle Zotte, 2018). The energy content of rabbit meat is almost equal to that of red meat (Buitrago-Vera *et al.,* 2016), and it is a recommended meat-type for the children, the elderly and pregnant women (Składanowska-Baryza and Stanisz, 2019). Furthermore, it has been claimed that due to its extraordinarily low cholesterol and sodium levels in comparison to other animals, rabbit meat has a significant role in the prevention of vascular disease (Aduku & Olukosi, 1990; Hermida *et. al.*, 2006, Szkucik, *et. al.*, 2013). No religious edicts are preventing their production and consumption unlike pigs (Ayuk *et al.*, 2009). Rabbit production impacts positively in rural economy as a reliable source of revenue (Owen *et al.*, 2009; Cesari, *et. al.*, 2018; Mondin *et. al.,* 2021). However, feeding remained a major constraint in animal production due to the increasing cost of conventional feedstuffs brought about by the competition between man and animals for protein sources (Amaefule *et al.*, 2004). Protein is an important, but scarce and expensive feed nutrient in both human and animal nutrition. It is highly competitive for both plant and animal sources but, animal protein sources are more expensive and scarcer. For economic production, plant proteins now remain the most commonly supplemented ingredient in animal feeds.

Another challenge is that plant proteins are still not enough due to high demand and competition as human foods and raw materials for vegetable oil industries. Alternatives such as agro-industrial by-products include oilseed cakes like GNC, PKC, and CSC, which are good protein sources and are now being used in animal feed. Among these oilseed cakes, GNC is the most available and commonly used in animal feeds as groundnut is wide cultivation across all regions in Nigeria. Cakes of Palm Kernel and Cotton Seed have not been commonly used like GNC in preparing rabbit feeds. More so, available studies did not focus on comparing the productive performance, nutrient digestibility, haematology, serum chemistry, and economics of production of these oilseed cakes especially in rabbits. Therefore, the purpose of this study is to investigate how feeding GNC, PKC, and CSC-based diets to growing rabbits affects performance, nutrient digestibility, hematology, serum biochemistry, and economics of production of the rabbits.

Materials and Methods

This study was carried out at the Laboratory Animal Unit of the Veterinary Teaching Hospital, Usmanu Danfodiyo University, Sokoto, Nigeria, and it lasted for 35 days. The experimental diets were formulated and compounded using the three different plant protein cakes. Groundnut cake (GNC) was used as the base for diet 1, palm kernel cake (PKC) for diet 2, and cotton seed cake (CSC) for diets 3. The diets were compounded at the same commercial feed milling outlet in Kaduna, Kaduna State and transported to Sokoto for the study.

Table 1: Composition of the experimental diets

Ingredients	Diet 1	Diet 2	Diet 3
Maize	55.57	55.57	55.57
GNC	17.43	-	-
PKC	-	17.43	-
CSC	-	-	17.43
Fish meal	3.0	3.0	3.0
Wheat bran	21.0	21.0	21.0
Bone meal	2.0	2.0	2.0
Salt	0.5	0.5	0.5
Premix	0.5	0.5	0.5
Total	100	100	100
Calculated			
CP (%)	17.96	13.40	17.26
ME (kcal/kg)	2698.36	2727.99	2587.16

Experimental design, animals, and their management

Twenty-four mixed breeds of weaner rabbits made up of two New Zealand White, 14 Cottontail, and eight Dutch black about six weeks old were used for this investigation. They were distributed into three treatment groups, T1, T2, and T3, containing 8 rabbits per group in a completely randomized fashion, and randomized separately. Diets 1, 2, and 3 were correspondingly fed to treatment groups T1, T2, and T3 respectively. During the 14 days of acclimatization and before the real experiment commenced, however, the rabbits were housed in a deep litter pen, fed on wheat offal, and watered *ad libitum*. At this time, the animals were treated prophylactically with oxytetracycline powder, multivitamin powder (in drinking water), oral levamisole, and subcutaneous ivermectin injection against both external and internal parasites that may affect the growth of the experimental animals.

Data Collection

Performance and nutrient digestibility

Performance parameters: The rabbits were weighed on the first day of the trial to determine their initial body weight (BW), and then every week throughout the study. The body weight gain (BWG) was determined by subtracting the new week's body weight from the previous week. The weekly feed intake (FI) in each group was calculated by deducting the feed left over at the end of the week from the amount of feed served at the beginning of the week. The efficiency of feed utilization (EFU) was calculated by dividing the BWG by the overall FI of the rabbits per group.

For nutrient digestibility, faecal samples were collected daily for three days during the experiment and were air-dried. To determine how well the rabbits digested the feed ingredient, the dried faeces were examined for the proximate element. The apparent digestibility coefficient of the diet by the rabbits was calculated from the nutrient and faecal digestibility using the formula below;

Apparent Digestible Nutrient =

$$\frac{\text{Nutrient in feed consumed} - \text{Nutrient in droppings voided}}{\text{Nutrient in feed consumed}} \times 100\%$$

The proximate analysis for moisture, ash, crude fat, crude fibre, crude protein, and energy of the dietary samples and faecal samples was assessed by the Association of Official Analytical Chemists (1999).

Haematology and serum biochemistry

For haematology, three rabbits were randomly selected per group at the end of the feeding trial (5th week), and blood was collected from the Marginal ear vein of each rabbit. For haematological analysis, an initial 2 ml of blood was dispensed into a sample bottle coated with ethylene-diamine-tetra-acetic acid (EDTA). Another 3 ml of blood was dispensed into a plain sample bottle for serum biochemistry. The red blood cell (RBC) counts and packed cell volume (PCV) parameters were evaluated following the method of Ewuola and Egbunike (2008). The hemoglobin (Hb) concentration was determined by the cyan-methemoglobin method (Wickham *et al.*, 1990). The differential count of leucocyte sub-populations was estimated using the method of Svobodava, *et al*., (2003) and blood constants mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) were determined using appropriate formulae as follows:

Mean corpuscular volume (MCV)= $\frac{\text{PCV} \times 10}{\text{RBC}}$

Mean corpuscular haemoglobin concentration = $\frac{\text{RBC} \times 100}{\text{PCV}}$

For serum biochemistry, serum total protein is evaluated using the Biuret method as described by Kohn & Allen (1995). Liver function test (i.e. alkaline phosphates (ALP), alanine aminotransferase (ALT), aspartate aminotransferase activity (AST) were measured using the colorimetric method of Reitman & Frankel (1957), and total protein (TP), albumin was determined using Bromocresol Green (BCG) method as described by Peters *et al.* (1982). Total bilirubin and direct bilirubin were determined using the spectrophotometric method. Also, the creatinine and blood urea nitrogen was determined by biuret reaction (Meyer *et al*., 1992).

Statistical Analysis

Using SPSS software version 20.0, the study's data were subjected to a one-way analysis of variance (ANOVA), and the findings were presented in tables as mean ± standard deviation of the mean. Using Tukey HSD as the post hoc test, differences between the mean values of several groups were deemed statistically significant at P < 0.05.

RESULTS AND DISCUSSION

Table 2 presents the results of the proximate composition of the three-plant protein cake-based (GNC, PKC, and CSC) diets. The ash contents differed significantly (p<0.05) among the diets. It was revealed that the PKC-based diet had the lowest levels of all parameters tested except energy (71.06%). Second to the PKC-based diet is the CSC-based (64.27%) diet and the least was obtained GNC-based diet with (62.71%) energy content. The crude protein was highest in the CSC-based diet (10.06%), while such parameters as fat and fiber contents (6.0 and 7.0 %) were highest in the GNC-based diet compared to their contents in the PKC-based diet (3.83 and 4.83%) and CSC-based diet (4.17 and 6.67%) respectively. These results were used in the discussion of some other parameters analysed below in this study.

Table 2: Proximate analysis of the experimental diets

Parameters (%)	Diet 1(GNC)	Diet 2 (PKC)	Diet 3 (CSC)
Moisture	4.50	3.83	4.50
Ash	10.17a	7.83b	9.67a
Fat	6.00	3.83	4.83
Fibre	7.00	4.17	6.67
Nitrogen	1.54	1.48	1.61
Crude protein	9.63	9.28	10.06
Carbohydrate	62.71	71.06	64.27

*Performance characteristics***:** The performance characteristics of the experimental rabbits are shown in Table 3. The feeding trials had no effect (p>0.05) on the body weight gain (BWG), feed intake (FI), and efficiency of feed utilization (EFU), but the final body weight significantly differed (p<0.05). The initial BW of all experimental animals was statistically similar ranging from 1.10 ± 0.184 kg to 1.18 ± 0.227 kg. From this result, the final BW of the group fed with the CSC-based diet differed significantly (p> and had the highest (1.30 ± 0.085 kg) value, while GNC (1.20 ± 0.053 kg) and PKC (1.18 ± 0.077 kg) were statistically similar (p<…. More so, rabbits fed CSC-based diets had the highest FI (0.93 ± 0.027 kg), BWG (0.12 ± 0.234 kg), and the best EFU (1.333 ± 0.015). This is followed by the GNC-based diet which had BWG (0.09 ± 0.132 kg) and EFU (0.108 ± 0.013) and the least BWG (0.08 ± 0.216 kg) and EFU

(0.089± 0.011) were obtained in the PKC-based diet. The final body weight significantly differed (p>0.05) across the treatment groups being highest in the group fed with a CSC-based diet followed by a GNC-based diet and then a PKC-based diet. The significant body weight in T2 might be attributed to biological value and quality of protein of the CSC-based diet as well as highest feed intake in the group which could have led to improvement in body weight gains as suggested by Leaf and Antonio (2017). The least weight gains were recorded in the rabbits fed with the PKC diet, probably due to the relatively low protein content in the PKC-based diet. In addition, almost all plant protein sources have one or more anti-nutritional factors, the presence of phytic acid, tannic acid, and oxalate in PKC have reportedly reduced its nutritional value (Akinyeye *et al.*, 2011).

Table 3: Mean ± SD growth performance of weaner rabbits fed the three different plant proteins-based diets

Parameters (kg/rabbit)	T 1 (GNC)	T 2 (PKC)	T 3 (CSC)	P value
Mean initial body weight	1.11 ± 0.185	1.10 ± 0.184	1.18 ± 0.227	0.805
Mean final body weight	1.20 ± 0.053^{b}	1.18 ± 0.077^{b}	1.30 ± 0.085^{a}	0.043
Mean body weight gain	0.09 ± 0.132	0.08 ± 0.216	0.12 ± 0.234	0.932
Mean Feed intake	0.83 ± 0.018	0.89 ± 0.024	0.93 ± 0.027	0.420
Efficiency of Feed Utilization	0.108 ± 0.013	0.089± 0.011	1.333 ± 0.015	0.397

Means in the same row with different superscripts $^{a, \text{ and } b}$ are significantly different at p<0.05.
Key: GNC: groundnut cake; CSC: cottonseed cake; PKC: palm kernel cake, T1, T2, T3: treatments 1,2 and 3.

Nutrient digestibility: The nutrient digestibility of the weaner rabbits fed the three different plant protein sources is given in Table 4. The treatments implemented in this study had no effect (p>0.05) on the nutrient digestibility in the experimental weaner rabbits, but the ash. The digestibility of the ash content was highest (p<0.05) in the PKC-based diet (119.723 ± 30.103) followed closely by the GNC-based diet (72.22 ± 11.096) and least in the CSC-based diet (-63.78± 18.047). The crude protein digestibility was highest in the CSC-based diet (21.83 ± 13.719) and the least in the GNC-based diet (13.20 ± 2.892). Nutrient digestibility parameters showed no significance across the groups which implies that all the three cakes can be utilised in rabbit feed to get similar results. However, ash contents showed significant difference among the treatment diets with PKC, GNC, and CSC being the highest respectively.

Table 4. Mean ± SD digestibility of weaner rabbits fed the three different plant protein-based diets

Parameters (%)	T1 (GNC)	T2 (PKC)	T3 (CSC)	P value
Moisture	-310.32 ± 242.744	-56.92 ± 24.759	-16.35 ± 39.634	0.088
Ash	72.22 ± 11.096^{b}	119.723 ± 30.103^{a}	-63.78 ± 18.047^{c}	0.037
Crude Fiber	-328.01 ± 235.980	-416.20 ± 149.616	-306.34 ± 178.781	0.767
Crude Protein	13.20 ± 2.892	20.70 ± 8.302	21.83 ± 13.719	0.514
Carbohydrate	38 60± 5.839	34.59± 8.964	32.090 ± 10.530	0.663
Fat	51.94 ± 11.314	39.177 ± 20.052	51.76 ± 16.186	0.574

Means in the same row with different superscripts $^{a, b, \text{ and } c}$ are significantly different at p<0.05.
Key: GNC: groundnut cake; CSC: cottonseed cake; PKC: palm kernel cake, T1: treatment 1; T2: treatment 2; and T3: treatment 3

Haematology: As presented in Table 5 the effect of dietary treatment on the haematology of experimental rabbits was non-significant (p>0.05) and were all found to be within the reference values, but the haemoglobin concentration (Hb) which was recorded to be lower in all treatment groups. Mean corpuscular haemoglobin (MCH) was below normal in group fed a CSC-based diet (treatment 3), while together with MCHC was below normal in a PKC-based diet (treatment 2). In addition, neutrophils of rabbits under fed PKC- and CSC-based diets were subnormal, while lymphocytes of rabbits fed CSC-based diets were above normal. However, rabbits under the GNC-based diet had the highest value for MCHC (30.13 g/dl), neutrophils (20.33%), and eosinophils (1.00%) with the lowest value for lymphocytes (76.66%). The group fed PKC-based diet had the highest value for MCV (65.43 fl), MCH (19.40 pg), and monocytes (1.66%), while it had the lowest value for PCV (29.67%), Hb (8.80 g/dl), RBC (4.53 $\times 10^6/mm^3$), and WBC (7.13 $\times 10^3/mm^3$). On the other hand, rabbits in the CSC-based diet group were highest in PCV (32.40%), RBC (5.19 $\times 10^6/mm^3$), WBC (8.33 $\times 10^3/mm^3$) and lymphocytes (91.33%), while least in MCV (62.43 fl), MCH (18.23 pg), MCHC (29.23 g/dl), neutrophils (7.33%) and monocytes (0.66%). The type and quantity of feed consumed and accessible for the animal to meet its physiological, biochemical, and metabolic needs are reflections of the impacts of dietary therapies on animals in terms of hematological and serum biochemical indices (Ewuola, *et al*., 2004; Ewuola, *et al*., 2008). Because dietary elements can be measured in their impact on blood components, blood constituents are frequently utilized in animal nutrition evaluation and surveys (Church, *et al*., 1984). This study found that the hematological of experimental rabbits did not significantly differ across all experimental diets. This indicated that neither the groundnut cake, the cottonseed cake nor the palm kernel cake at 17.43% had any negative impact on the haemopoietic activities in the rabbits.

Table 5: Mean ± SD Haematology of weaner rabbits fed on the three different plant protein sources

Parameters	T1 (GNC)	T2 (PKC)	T3 (CSC)	P value	Ref. Range
PCV (%)	32.10 ± 3.005	29.67 ± 3.464	32.40 ± 4.158	0.615	26.7–47.2
Hb (g/dl)	9.67 ± 0.723	8.80 ± 1.000	9.53 ± 1.817	0.683	10 – 15
RBC ($\times 10^6/mm^3$)	5.08 ± 0.810	4.53 ± 0.516	5.19 ± 0.733	0.503	3.7 – 7.5
MCV (fl)	63.70 ± 5.211	65.43 ± 3.394	62.43 ± 2.020	0.642	58 – 79.6
MCH (pg)	19.23 ± 2.064	19.40 ± 1.178	18.23 ± 1.209	0.628	19 – 22
MCHC (g/dl)	30.13 ± 0.776	29.60 ± 0.346	29.23 ± 1.844	0.659	30 – 35
WBC ($\times 10^3/mm^3$)	7.66 ± 1.474	7.13 ± 0.750	8.33 ± 2.510	0.712	5.2 – 16.5
NEUT (%)	20.33 ± 8.082	11.33 ± 12.342	7.33 ± 10.115	0.352	22 – 38
LYM (%)	76.66 ± 10.692	79.66 ± 15.947	91.33 ± 9.291	0.368	40 – 80
MONO (%)	1.33 ± 2.309	1.66 ± 1.527	0.66 ± 1.154	0.780	1 – 4
BASO (%)	0.66 ± 0.577	0.00 ± 0.000	0.66 ± 1.154	0.492	0 – 4
EOSIN (%)	1.00 ± 1.732	0.66 ± 0.577	0.00 ± 0.000	0.533	1 – 7

Keys: NEUT: Neutrophils; LYM: Lymphocytes; MONO: Monocytes; BASO: Basophils; EOSIN: Eosinophils.

Serum biochemistry: The outcomes of the serum biochemistry of the experimental rabbits are presented in Table 6. In this study, the obtained values for creatinine and sodium were significantly ($p<0.05$) high compared to other groups, although there was no significant difference between GNC- and CSC-based diets in terms of serum sodium. In addition, the dietary treatment had no statistical ($p>0.05$) difference on the liver function test, except the total bilirubin, which was significantly ($p<0.05$) higher in the PKC-treated group (0.77 ± 0.058) and lowest in the CSC-treated group (0.57 ± 0.058). For the serum biochemical analysis, the results of kidney function and liver function tests conducted on the experimental growing rabbits fed on the three different dietary plant protein sources were within the normal rage of reported reference values (Jones, 1975; Mitruka ,1977; Kaneko, 1989; Kerr, 1989; Burke, 1994; Hillyer, 1994; Okerman, 1994; Esievo, 2017). except for creatinine (in T2), bicarbonate (in T1) and total bilirubin (in T2). Creatinine is a metabolite of creatine and phosphocreatine released from muscles into the blood and excreted through the kidney (Hillyer, 1994; Esievo, 2017). The creatinine plasma level as obtained (in T2) rabbits fed PKC-based diet is relatively too high compared to its values in T1 and T3 which are within the normal range of 0.7 to 1.2mg/dl in male and 0.5 to 1.0mg/dl in female animals are considered abnormal (Okerman, 1994; Esievo, 2017). Therefore, it is possible that blood samples have cell destruction been collected from rabbits with certain underlying inflammatory conditions of the kidney such as glomerulonephritis. while it requires more diagnostic tests such as postmortem and histopathology examinations to ascertain kidney insufficiency as the cause of the elevated creatinine level in T2, the tests were not part of design of this study. Further study may be conducted to investigate hepatotoxicity of PKC in rabbits. Low levels of bicarbonate in blood as recorded in T1 (GNC-based diet) may be due to metabolic acidosis, a condition in which pH of tissues decreases. Metabolic acidosis can happen due to loss of bicarbonate ion (HCO_3^-) from the body through diarrhoea. This result may be supported with the fact that rabbits (in T1) fed GNC-based diet were observed to be passing diarrhoeic faeces more frequent during the feeding trial. chronic diarrhoea is a non-infectious form (such as dietary diarrhoea) which may result from inflammation of gastrointestinal tract or nutrient malabsorption (Wenzl, 2012). There was slight (just 0.02 µg/dl higher than the reference range) elevated total bilirubin level in the PKC-treated group which may suggests onset of mild liver dysfunction or a condition favouring increased rate of red blood damage. From the findings of this study, PKC-based diet performed least, we therefore advocate for more investigations on the appropriate inclusion level of PKC in diet that will not compromise health status of rabbits. Rabbits are classical monogastric herbivores that require limited levels of concentrates in their diets. Owing to its high fibre content, some researchers have regarded PKC as a more suitable alternative protein source for ruminants than monogastric animals (Sharmila *et al.*, 2014). Report has indicated that feeding 16% PKC inclusion level of total dry matter is best for cull cows on feedlot (Santos *et. al.*, 2019). However, inclusion levels of PKC up to 30% in rabbit diet have reportedly been tolerated (Umar *et. al.*, 2020). It is therefore important to pain more attention to the clinical pathology of organs in nutritional studies involving feedstuffs with antinutritional factors.

Table 6: Mean ± SD Kidney and liver function tests of weaner rabbits fed on the three different plant protein sources

Parameters	T1 (GNC)	T2 (PKC)	T3 (CSC)	P value	Ref. range
Urea (mmol/l)	8.47 ± 1.07	9.00 ± 0.80	7.43 ± 0.91	0.112	9.1– 25.5
Creatinine (mg/dl)	0.83 ± 0.06^{b}	8.47 ± 1.069^{a}	1.03 ± 0.153^{b}	0.022	0.5 – 2.6
Sodium (mmol/l)	138.0 ±1.00^{ab}	140.0 ± 1.00^{a}	137.7 ± 0.58^{b}	0.035	130 –155
Potassium (mg/dl)	3.87 ± 0.15	4.20 ± 0.40	3.80 ± 0.20	0.237	4.0 – 6.5
Bicarbonate (mmol/l)	9.97 ± 10.42	23.67 ± 0.58	24.00 ±1.00	0.050	16.0 – 32.0
Total bilirubin (µg/dl)	0.63 ± 0.06^{ab}	0.77 ± 0.06^{a}	0.57 ± 0.06^{b}	0.014	0.0 – 0.75
ALP (IU/L)	58.67 ± 4.16	60.00 ± 1.00	56.67 ±2.08	0.387	10.0 – 96.0
AST (IU/L)	6.00 ± 2.00	6.67 ± 3.055	5.33 ± 2.31	0.813	5.0 – 98.0
ALT (IU/L)	11.00 ± 7.00	8.67 ± 5.033	8.00 ± 2.00	0.762	5.0 – 260
Total Protein (g/l)	60.33 ± 1.15	59.00 ± 1.00	59.67 ± 1.53	0.471	50.0 – 75.0
Albumin (g/l)	34.00 ± 1.00	33.00 ± 1.00	33.33 ± 1.15	0.533	25.0 – 40.0

Means in the same row with different superscripts $^{a, \text{ and } b}$ are significantly different at $p < 0.05$.
Key: ALP: alkaline phosphates; AST: aspartate aminotransferase activity; ALT: alanine aminotransferase.

Economic Analysis: The economic efficiency of the experimental diets is revealed in Table 7. It was revealed that it cost more to formulate and compound a GNC-based diet (₦212.47), followed by a CSC-based diet at ₦192.95 and the cheapest diet was the PKC-based diet at ₦181.9. The costs of average feed consumed per experimental rabbit showed that it was more expensive to raise rabbits on a CSC-based diet (₦179.44), followed by a GNC-based diet (₦176.35) and it was cheapest to raise rabbits on a PKC-based diet (₦161.95). For the economic or cost analysis of the dietary treatments, the price per kg of feed was ₦212.47, ₦181.9, and ₦192.95 for GNC-, PKC- and CSC-diets respectively. The most expensive dietary treatment was a GNC-based diet followed by a CSC-based diet and the least expensive was a PKC-based diet. The average cost of feed consumed per rabbit was calculated as ₦179.44 (CSC-based Diet), ₦176.35 (GNC-based Diet), and ₦161.95 (PKC-based Diet), showing that the PKC-based diet was the cheapest. Although CSC is available in some regions in northern Nigeria, it is almost as expensive as GNC. Unlike GNC however, CSC is not commonly sought for use in human food production. The competitive demand for GNC, both in human and animal feed formulation is among the reason for increased cost despite its wide cultivation and availability in almost all regions of Nigeria.

Table 7: Economic analysis of weaner rabbits fed the three-plant protein cake-based diets

Parameters	Diet 1 (GNC)	Diet 2 (PKC)	Diet3 (CSC)
Cost/kg feed (₦)	212.47	181.97	192.95
Mean feed intake (kg)	0.83	0.89	0.93
Cost/kg feed /rabbit (₦)	176.35	161.95	179.44

Key: GNC: groundnut cake; CSC: cottonseed cake; PKC: palm kernel cake

CONCLUSION AND RECOMMENDATION

This study revealed that the inclusion of groundnut cake, cottonseed cake, and palm kernel cake as dietary plant protein sources in rabbit diets had no negative impact on the hematological and serum biochemical parameters of rabbits. This study has also shown that CSC compared equally in terms of nutrient density and digestibility, and is cheaper with even better performance indices than GNC. This study, therefore, recommends that CSC can be included as a protein source in the rabbit diet at the rate of 17.43% with no adverse effect on haematological and biochemical indices of weaner rabbits.

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