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GROWTH, HAEMATOLOGICAL, AND SERUM BIOCHEMICAL CHARACTERISTICS OF ALBINO RATS FED DIETS CONTAINING FULL-FAT AND DEFATTED BALLNUT KERNEL (CALOPHYLLUM INOPHYLLUM) MEALS AS ENERGY SOURCES

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ABSTRACT

This study evaluated the growth and blood characteristics of albino rats fed diets containing full-fat and defatted ball nut kernel meals. Four experimental diets were formulated; diet 1 contained maize as the energy source and served as the control, whereas diets 2, 3, and 4 were the full-fat, mechanically defatted, and chemically defatted ballnut kernel meal and were used to replace maize as energy source respectively. Sixty male weanling albino rats with average initial weight of 93.7g ± 0.1 were assigned to the four treatments, with 15 rats in each group, using a completely randomized design. The rats were housed in individual metabolic cages. Each diet was provided to the rats in pelletized form, and water was given *ad libitum* for 28 days, during which the growth performance parameters (feed intake, weight gain, and feed conversion ratio) were monitored. At the end of the feeding trial, blood samples were collected from three rats per treatment by puncturing the lateral saphenous vein at the back of the hind leg with a syringe. Five milliliters of blood were collected into labeled specimen bottles, one containing EDTA (Ethylene Diamine Tetraacetate) for hematological (full and differential blood counts), and the other was a plane tube without EDTA for serum biochemical (Total protein, creatinine, Sodium and so on). The data generated from the study were analyzed using the General Linear Model (GLM) procedures of GenStat 14th edition, and significant means were separated using Duncan Multiple Test outlined in the same software. The results showed that rats fed the chemically defatted ballnut kernel meal diet had significantly ($p < 0.05$) higher final body weight (153.9g), average daily weight gain (2.2g), average daily feed intake (14.2g), and feed conversion ratio (6.00). The hematological indices indicated that rats fed with the chemically defatted ballnut kernel meal had the highest ($p < 0.05$) concentrations of white blood cells ($4.8 \times 10^3/mm^3$), red blood cells ($6.4 \times 10^6/mm^3$), hemoglobin concentration (13.0 g/dl), packed cell volume (35.8%), mean corpuscular haemoglobin (20.0 pg), mean corpuscular hemoglobin concentration (36.2 g/dl), and platelet count ($477.0 \times 10^3/mm^3$). The serum biochemical indices were within the recommended levels of 13-56 IU/L for aspartate aminotransferase, 95-611 IU/L for alanine phosphatase, 0.03 - 0.7mg/dl for creatinine. Overall, the chemically defatted ballnut meal supported the growth, hematological, and serum biochemical indices of the rats in comparison to the other treatment groups.

Key words: Ballnut, full-fat, fat-free, oil extraction, mechanical, chemical, phytochemical, albino rats

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INTRODUCTION

Various parts of the African savannah are home to forest tree species and oilseed plants, including ballnut (*Calophyllum inophyllum),* which have the potential to be used for food, wood, and traditional or medicinal purposes. The lack of information on the chemical composition of many of these species hinders their effective utilization for sustainable development [1]. The ballnut plant has numerous applications in medicine and cosmetology, as well as an alternative biofuel. Recently, its use in agriculture has gained traction as a feed ingredient for livestock and poultry. Ballnuts are found to contain a significant amount of crude protein and fat, which are essential nutrients for optimal yields in livestock and poultry [2]. However, it has also been discovered that ballnuts possess certain anti-nutritional (tannins, phytic acid, and oxalic acid) properties that reduce their overall nutritional value. Over the years, various studies have aimed to improve the nutritional quality of ballnut kernels, with varying degrees of success.

Traditional processing methods such as boiling, autoclaving, or enzymatic pre-treatment of the seeds are employed to reduce anti-nutritional factors and enhance the functionality of oilseeds [3]. These methods, however, are often time-consuming. According to Natalia *et al*. [4], enzymatic treatment can be challenging to control and is mainly designed for processing whole seeds, making it unsuitable for oilseed cakes from both economic and technological perspectives. However, if effectively processed, ballnut kernels could serve as a valuable alternative feed resource for poultry and pig farmers in Nigeria. With their high nutritional content, these kernels have the potential to improve livestock diets, offering a sustainable solution to the increasing demand for animal feed amid rising feed costs. By harnessing the potential of ballnut through proper extraction and processing techniques, farmers could reduce their reliance on conventional feed sources, enhance the nutritional quality of their livestock's diet, and ultimately promote a more sustainable agricultural system in the region. This shift could not only support local farmers economically but also mitigate the environmental issues associated with the disposal of unused agricultural byproducts.

Higher oil content lowers the proportion of other components (including protein, amino acids, and minerals) in the cake due to the oil taking up more space; essentially, a higher oil content means a higher energy density but potentially lower levels of other essential nutrients per unit weight of the cake [5].

Consequently, extracting oil from the kernel could enhance nutrient composition and availability for end users. Diana *et al*. [6] observed an increase in the crude protein content of sesame seed meal from 19% to 30% following oil extraction using the cold-press method. They also reported significantly higher total amino acid content in sesame cake compared to the seeds.

This study aims to evaluate the feeding value of the defatted ballnut kernel meal through rat studies.

MATERIALS AND METHODS

Location of the study

The proximate analysis using methods of AOAC [7] was conducted at the Faculty of Agriculture Central Laboratory, University of Calabar, Nigeria, while the biological evaluation took place at the Animal Experimental House of the Department of Animal Science, University of Calabar, Nigeria. The study was carried out from January 2023 to April 2023. The research site is located at latitudes 4°58.42821 and longitude 8°20.4602, with an annual precipitation of approximately 1,830 mm and an average temperature ranging from 24°C to 30°C.

Processing of the experimental materials

Two (2) kilograms of mature ballnut kernels being the quantity required for this study were collected from a plantation in Calabar, Cross River State, and oven-dried for 18 hours at 45°C to avoid burning until the moisture content reached 15%. The hard-shell casings were then cracked open, and the kernels were milled to create a ballnut kernel meal using an industrial blender (Kenwood model). The crushed ballnut kernel meal was divided into three equal samples of 600 g each. The first sample was stored in an airtight polythene bag as full-fat. The second underwent a manual oil extraction process using an indigenously made oil press. The third sample was subjected to a chemical oil extraction process; the kernel meal was placed in a conical flask, and petroleum ether was added in a 2:1 ratio. It was stirred vigorously for 12 hours until the oil extraction was complete [8].

After extraction, the petroleum ether was evaporated, and the sample was oven-dried at 45°C for 20 minutes. The proximate composition of the samples was analyzed in preparation for feed formulation.

Experimental diets formulation

Four experimental diets were formulated for this study (see Table 1). Diet 1 contained maize as the energy source, whereas diets 2, 3, and 4 completely replaced maize in the control diet with full-fat, mechanically defatted, and chemically defatted ballnut kernel meal, respectively. These diets were formulated to meet the nutritional requirements of the rats for protein, energy, vitamins, and minerals.

Experimental animals and management

Sixty healthy male albino rats, aged 14 to 18 days, were obtained from the rat colony of the Department of Pharmacology at the University of Calabar, Nigeria. The rats were weighed and randomly divided into four groups of fifteen rats each based on weight equalization. They were housed individually in stainless steel metabolic cages under standard laboratory conditions. Each group was assigned to one of the four experimental diets mentioned earlier and had free access to water and the experimental feeds throughout the 28-day experimental period during which the active components of the test sample must had a significant impact on the animals. The study adhered to the recommendations from the Declaration of Helsinki [9] on the guiding principles for the care and use of animals.

Data collection and analysis

Growth characteristics

Daily records of feed intake by the experimental rats were maintained by weighing the quantity of feed provided and the leftovers after 24 hours. The left-over feed was discarded after weighing Weight gain was determined by weighing the rats at the beginning and the end of the 28-day experimental period; the difference indicated the average weight gain of the rats.

Blood assay

At the end of the growth trial, three rats were randomly selected from each dietary treatment, and 5 ml of blood was collected by puncturing the lateral saphenous vein located at the back of the hind leg using a syringe and needle. Prior to blood collection, the area on the back of the hind leg was shaved with an electric trimmer until the saphenous vein became visible. Five milliliters (5 ml) of blood were transferred into labeled specimen bottles containing EDTA (Ethylene diamine tetraacetate) as an anticoagulant for hematological studies. The remaining 5 ml of blood were transferred to another set of specimen bottles without EDTA for serum biochemical assays. The blood analysis methods were based on the protocols outlined by Baker and Silverton [10].

The hematological parameters evaluated included hemoglobin (Hb), hematocrit (HCT) or packed cell volume (PCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), mean corpuscular volume (MCV), red blood cell (RBC) count, platelet (PLT) count, white blood cell (WBC) count, and the percentages of differential leukocyte counts (neutrophils, lymphocytes, monocytes, eosinophils, and basophils). Hematocrit evaluation was conducted using the RBC and MCV calculation methods [10]. Hemoglobin levels were measured using the sodium lauryl sulfate detection method [10]. The mean corpuscular hemoglobin was calculated from the hemoglobin and RBC figures, while the mean corpuscular hemoglobin concentration was determined using hemoglobin and hematocrit values. The mean corpuscular volume was obtained by calculating the average volume of individual erythrocytes. The red blood cell and platelet counts were evaluated using impedance technology with a hydrodynamic focusing method [10]. The white blood cell count, along with counts of neutrophils, lymphocytes, monocytes, and eosinophils, were obtained through fluorescence flow cytometry methods [10].

The serum biochemical parameters assessed included glucose, lipid levels, total cholesterol, triglycerides (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL), very low-density lipoprotein (VLDL), total protein, alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatinine, blood urea nitrogen (BUN), alkaline phosphatase (ALP), total bilirubin (TB), and conjugated bilirubin (CB). Serum electrolytes evaluated included calcium, phosphorus, sodium, and potassium. ALT levels were measured using the pyruvate hydrazone method, while the oxaloacetate hydrazone method [10] was used to assess AST. Albumin was evaluated using the bromocresol green method, and total protein was estimated via the biuret method. Creatinine levels were determined using the colorimetric Jaffe-kinetic method, while urea was measured using the urease-Berthelot colorimetric method [10]. Total cholesterol, triglycerides, ALP, HDL, LDL, and VLDL levels were analyzed using enzymatic colorimetric methods [10].

Statistical analysis

Data generated from this study were statistically analyzed using the General Linear Model (GLM) procedures of GenStat, 14th edition [11], and significant means were separated using Duncan multiple range test in the same statistical software.

RESULTS AND DISCUSSION

Growth response of white albino rats fed diets containing ballnut kernel meal diets.

The results of the growth characteristics of rats fed diets containing full-fat and defatted ballnut kernel meal, as shown in Table 2, revealed that albino rats fed a chemically defatted ballnut kernel meal diet had significantly higher outcomes ($p < 0.05$) in terms of final body weight (FBW), average daily weight gain (ADWG), average daily feed intake (ADFI), and feed conversion ratio (FCR). The corresponding values for these measures were 153.9g, 2.2g, 14.2g, and 6.6, respectively. In contrast, rats on the control diet (maize) exhibited the lowest values, with an FBW of 123.4g, ADWG of 1.1g, ADFI of 316.7g, and a less favorable FCR of 10.7. Meanwhile, the average daily weight gain (1.1g) and feed conversion ratio (10.3) of rats on the full-fat diet were statistically similar ($p > 0.05$) to those of rats consuming the control diet. Additionally, there was no significant difference ($p > 0.05$) in average daily feed intake between rats on the control diet and those on diets containing full-fat and mechanically extracted ballnut kernel cake.

The improved ADWG, ADFI, and FCR among the rats fed a diet containing chemically defatted ballnut kernel meal can be attributed to its higher protein content and better amino acid composition compared to the full-fat and mechanically defatted samples [12]. Furthermore, reductions in certain anti-nutritional factors may have enhanced the ability of rat to effectively utilize the available nutrients, particularly protein and certain minerals, following the oil extraction process. Reduction in the energy content of feed containing chemically defatted ballnut may have also been responsible for the higher ADFI recorded in this experiment. These findings are in agreement with the research conducted by Bello *et al*. [13], who observed significant weight gains in albino rats fed diets containing *Sesamum indicum* seed cake. Similarly, Alagbe *et al*. [14] reported a notable improvement in average daily weight gain and feed conversion ratios in rabbits fed diets with Albizia lebeck oil seed meal. Correia *et al*. [15] noted enhanced feed conversion ratios among piglets consuming diets high in dietary protein, and they further demonstrated improved growth performance linked to higher levels of dietary crude protein in pigs. Silver *et al*. [16] indicated that reducing dietary crude protein levels diminishes the supply of nitrogen and amino acids, affecting the expression of genes related to digestive enzymes such as carbohydrases and proteases in pigs. Morales [17] noted that plasma concentrations of amino acids can be influenced by dietary intake or by tissue absorption of circulating amino acids.

Haematological indices of albino rats fed ballnut seed meal diets

The results, as shown in Table 3, revealed that rats fed a diet containing chemically defatted ballnut kernel meal exhibited the highest ($p<0.05$) concentrations of various haematological indices: white blood cell (WBC) counts (4.8 × 10^3/mm^3), red blood cell (RBC) counts (6.4 × 10^6/mm^3), haemoglobin (Hb) concentration (13.0 g/dl), packed cell volume (PCV) (35.8%), mean corpuscular haemoglobin (MCH) (20.0pg), mean corpuscular haemoglobin concentration (MCHC) (36.2 g/dl), and platelet count (PLT) (477.0 × 10^3/mm^3). Conversely, rats that were fed diets containing mechanically defatted ballnut kernel meal recorded the lowest values: WBC (1.3 × 10^3/ml), RBC (1.2 × 10^6/ml), Hb (2.2 g/dl), and PLT (15.0 × 10^3/ml).

Among the differentials, rats on the full-fat ballnut kernel diet showed the highest percentages of neutrophils, monocytes, eosinophils, and basophils, with values of 55.3%, 4.1%, 0.3%, and 0.6%, respectively. In rats, elevated levels neutrophils, monocytes, eosinophils, and basophils in generally indicate an inflammatory response, potentially triggered by an infection (bacterial, viral, parasitic), allergic reaction, tissue injury, or stress, as each cell type plays a specific role in the immune response depending on the stimulus involved. The WBC concentration for rats fed the control diet was 4.4 × 10^3/mm^3, which was similar to the concentration of 4.8 × 10^3/mm^3 observed in the group that received the chemically defatted ballnut kernel meal diet. The low WBC counts (1.3 × 10^3/ml) in rats fed the full-fat ballnut kernel diet indicated a higher risk of disease infection. In contrast, rats consuming diets containing mechanically and chemically defatted ballnut kernel meals, which showed moderate counts (2.4 x 10mm^3 and 4.8 x 10mm^3) exhibited a higher resistance to diseases. According to Theml *et al*. [18], an unusually high WBC count in peripheral blood is often indicative of stress or inflammatory conditions due to infections, trauma, toxicities, or neoplasms.

The RBC count (3.1 × 10^6/mm^3), Hb concentration (6.1 g/dl), PCV (18.9%), MCHC (32.4 g/dl), and PLT (202.0 × 10^3/mm^3) observed in rats fed the control diet were similar to those recorded in rats fed the mechanically defatted ballnut kernel meal diet. Tvedten [19] notes that the blood parameters used to assess the presence and severity of anaemia include haemoglobin, mean corpuscular haemoglobin, and mean corpuscular haemoglobin concentrations. A decrease in these levels can indicate poor management of stressors. In this study, the rats fed control diets, full-fat ballnut kernel diets, and mechanically defatted test samples exhibited lower haemoglobin concentrations compared to the recommended range of 11.8 - 16.2 g/dl established by Vigneshwar *et al*. [20] Notably, MCV, MCH, and MCHC values for rats on the control and test diets fell within the recommended ranges (51-62 fl, 17.7-20.0 pg, and 32.7-36.2 g/dl, respectively) as reported by Vigneshwar *et al*.[20] This suggests that the test ingredient improved the rats' capability to withstand stress. A low MCHC value of less than 32.7 g/dl may indicate iron deficiencies or a lack of other trace elements. However, only the rats fed the chemically defatted ballnut kernel meal diet had an MCHC value above this threshold.

The platelet concentrations for the rats on the control diet (202.0 × 10^3/mm^3), full-fat ballnut kernel meal diet (150.0 × 10^3/mm^3), and mechanically defatted ballnut kernel diet (215.7 × 10^3/mm^3) were all below the normal range of 315 - 512 × 10^3/mm^3 reported by Vigneshwar *et al*. [20]. In contrast, those fed the chemically defatted ballnut seed meal were within the recommended range, indicating that animals in this group did not have difficulty forming blood clots, which is vital in preventing excessive bleeding. It is important to note that blood clots can lead to serious medical conditions if they lodge in critical areas such as the lungs, intestines, brain, or heart [21].

The percentage of neutrophils in rats on the control, full-fat ballnut kernel meal, and mechanically defatted ballnut kernel meal diets was above the normal range (23.4 - 40.5%), while the lymphocyte concentration was below the normal range (54.9 - 73.9%) reported by Zamora-Bello [22]. Maintaining a normal percentage of neutrophils is essential, as they play a crucial role in preventing bacterial infections in the body [23]. Adequate lymphocyte levels are necessary for the formation of antibodies necessary to protect the body from infections [18]. Monocytes function as phagocytic cells and serve as the body's initial defense against foreign objects. Rats on the control diet and those fed the mechanically defatted ballnut kernel meal displayed normal monocyte levels, while those consuming full-fat ballnut kernel meal and chemically defatted ballnut seed meal diets showed lower concentrations than the normal range (1 - 6%) reported by Weiss [24]. The concentrations of eosinophils and basophils in rats fed the test diet were within the recommended values of 0.3% and 0.0-0.1%, respectively. Overall, the results suggest that the rats' health status was not significantly affected by the dietary treatments. The observed decreases in basophils and monocytes may imply that the experimental conditions may have influenced their levels.

Serum biochemical profile of albino rats fed diets containing full-fat and defatted ballnut kernel meal

The serum biochemical profile of albino rats fed diets containing ballnut kernel meal is summarized in Table 4. Rats that were fed a diet containing full-fat ballnut kernel meal exhibited the highest concentrations of serum aspartate aminotransferase (AST) and alanine aminotransferase (ALT), with values of 44.8 IU/L and 16.7 IU/L, respectively. In contrast, rats that consumed a diet with chemically defatted ballnut kernel meal showed the lowest concentrations of AST (28.7 IU/L) and ALT (8.5 IU/L). Notably, the AST concentration in rats on the chemically defatted ballnut kernel meal diet was not significantly different ($p > 0.05$) from that of the control diet (34.2 IU/L) or the mechanically defatted ballnut kernel meal diet (29.5 IU/L). Additionally, the ALT concentration in rats fed the mechanically defatted ballnut kernel meal diet was statistically similar ($p > 0.05$) to that of the rats on the chemically defatted diet.

Interestingly, rats consuming the mechanically defatted ballnut kernel meal diet exhibited the highest alkaline phosphatase (ALP) concentration at 92.5 μmol/L, while those on the control diet had the lowest ALP value at 11.6 μmol/L. Increases in these enzyme levels are typically associated with liver or muscle damage due to the body's response to stress [25]. Rats fed the chemically defatted ballnut kernel meal diet recorded the lowest concentrations of these enzymes. The enzyme values observed in this study were below the recommended ranges (AST: 34-109 IU/L, ALT: 13.0-156 IU/L, ALP: 95-611 μmol/L) as reported by Vigneshwar *et al.* [20]. Therefore, the decrease in these enzymes following the consumption of defatted ballnut meal may indicate improved liver function.

Elevated serum levels of ALP can occur with increased osteoblastic activity related to bone formation and mineralization, which is associated with enhanced skeletal growth [25]. Furthermore, creatinine and urea concentrations were significantly higher ($p < 0.05$) in the albino rats fed diets containing full-fat ballnut kernel meal, followed by those on chemically defatted ballnut kernel meal, whose values were similar to those on mechanically defatted ballnut kernel meal. The control diet group recorded the lowest creatinine and urea levels. Measurement of blood creatinine and urea is a common practice for assessing renal function, and significant elevations in serum levels may indicate renal dysfunction [26]. In this study, the creatinine and urea concentrations were within the recommended levels as noted by Vigneshwar *et al*. [20], except for the rats on the full-fat ballnut kernel meal diet, which had a creatinine concentration of 0.7 mg/dL, exceeding the normal reference range of 0.3 - 0.7 mg/dL. This suggests that renal function was unaffected, and there was better protein utilization, as blood urea levels can be linked to protein breakdown.

The total serum protein level of 4.9 g/dL observed in rats fed a mechanically defatted ballnut kernel meal diet was significantly higher ($p<0.05$) compared to the values obtained for rats fed the control and other treatment diets. However, this total protein level was lower than the normal range of 5.1 - 7.6 g/dL reported by Vigneshwar *et al*. [20]. Among the groups, rats fed a chemically defatted ballnut kernel meal diet had the highest serum albumin concentration, while those fed a mechanically defatted ballnut seed meal diet had the highest globulin concentration. The lowest albumin concentration (23.0 g/dL) was noted in rats consuming a full-fat ballnut kernel meal diet. Furthermore, rats fed a chemically defatted ballnut seed meal diet exhibited the lowest globulin concentration at 15.0 g/dL. The albumin concentrations in rats fed both chemically and mechanically defatted ballnut kernel meal diets were close to the recommended range of 30.0 - 55.0 g/dL as reported by Vigneshwar *et al*. [20]. Low levels of albumin suggest that the blood may struggle to transport vital metabolites, such as hormones, which can lead to symptoms like fatigue, jaundice, and fluid retention. Vigneshwar *et al*. [20] also indicated a recommended serum globulin concentration of 20-35 g/dL for rats, which aligns with the findings of this study. Elevated globulin levels may indicate autoimmune diseases, infections, or cancer, while low levels could signal liver or kidney issues. In regard to serum sodium concentration, rats fed the control diet had significantly higher levels ($p<0.05$) compared to those on the experimental diets.

Conversely, rats on a chemically defatted ballnut kernel meal diet displayed the highest potassium concentration (5.1 mmol/L), while those consuming the control diet had the lowest potassium concentration (4.4 mmol/L). Rats fed the control diet and those on mechanically and chemically defatted ballnut kernel meals had similar chloride concentrations ($p<0.05$), but the value for rats on a full-fat ballnut kernel meal diet was significantly lower ($p<0.05$) compared to the other groups. Additionally, rats on the control diet showed similar serum bicarbonate concentrations to those fed full-fat and defatted ballnut kernel meat diets, respectively ($p>0.05$). Sodium is a crucial nutrient that regulates blood volume, pressure, osmotic equilibrium, and pH [27]. The kidneys manage sodium levels in the body through the renin-angiotensin-aldosterone system. Abnormal sodium regulation can lead to hypernatremia, hyponatremia, hypertension, and ultimately renal failure. The sodium concentration in this study fell within the recommended level of 130.9 - 148.8 mol/L as reported by Wikivet [28], suggesting that the tested sample did not contain substances that could impair the kidneys' ability to regulate sodium. Potassium is an essential intracellular mineral crucial for maintaining fluid and electrolyte balance in animals. Abnormal potassium regulation can result in hypokalemia [28]. According to Abubakar and Sule [29], hyperkalemia, or excess potassium in the serum, often occurs in cases of renal failure, where the kidneys lose the ability to excrete potassium. The potassium concentration in the blood of rats in this study was normal when compared to the recommended range of 4.6 - 6.0 mol/L as reported by Loab *et al*. [30], indicating normal renal function among the rats.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

This study concluded that rats fed chemically treated ballnut kernel meal exhibited better growth performance and normal blood characteristics compared to those fed full-fat and mechanically treated ballnut kernel meal. Chemically defatted ballnut seed meal may be considered as an alternative energy source in animal diets.

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Conflict of Interest

The authors declare that there are no conflicts of interest

Table 1: Ingredient composition of experimental diets (%)

Ingredient	**Control**	**Full-fat BKM**	**Mechanical *BKM**	**Chemical *BKM**
Maize	32.8	0.0	0.0	0.0
Ballnut kernel meal	0.00	32.8	32.8	32.8
Soybean meal	35.4	35.4	35.4	35.4
Palm kernel cake	10.0	10.0	10.0	10.0
Wheat offal	16.0	16.0	16.0	16.0
Fish meal	3.5	3.5	3.5	3.5
Dicalcium phosphate	1.5	1.5	1.5	1.5
Vitamin/mineral premix	0.5	0.5	0.5	0.5
Salt	0.3	0.3	0.3	0.3
Total	**100.0**	**100.0**	**100.0**	**100.0**
Nutrients composition (Calculated)				
Energy (kcal/kg ME)	2823.65	2952.23	2606.84	2464.44
Crude protein (%)	25.68	24.38	25.09	26. 51
Crude fibre (%)	5.47	5.73	5.84	6.21

Table 2: Growth response of white albino rats fed diets containing ballnut kernel meal diets

Treatment					
Parameter	**Control**	**Full-fat BKM**	**Mechanical *BKM**	**Chemical *BKM**	**SEM**
Initial weight (g)	93.7	93.7	93.8	93.7	0.01
Final weight (g)	123.4^{c}	125.6^{c}	139.5^{b}	153.9^{a}	3.72
Total weight gain (g)	29.8^{c}	31.9^{c}	45.7^{b}	60.1^{a}	3.71
Daily weight gain (g)	1.1^{c}	1.1^{c}	1.6^{b}	2.2^{a}	0.13
Total feed intake (g)	316.7^{b}	328.7^{b}	328.7^{b}	396.4^{a}	9.79
Daily feed intake (g)	11.3^{b}	11.7^{b}	11.7^{b}	14.2^{a}	0.35
Feed conversion ratio	10.7^{a}	10.3^{a}	7.2^{b}	6.6^{b}	0.55

SEM= standard error of mean
^{a,b,c} Means with different superscripts on the same row differ significantly ($p<0.05$)
***BKM =** Ballnut kernel meal

Table 3: Haematological indices of albino rats fed diets containing kernel meal

Treatment						
Parameter	**Control**	**Full-fat**	**Mechanical**	**Chemical**	**SEM**	***Normal Ranges**
WBC (×10^3/mm^3)	4.4^{a}	1.3^{b}	2.4^{b}	4.8^{a}	0.49	3.70-5.80*
RBC (×10^6/mm^3)	3.1^{b}	1.2^{c}	2.9^{b}	6.5^{a}	0.64	6.10-8.50*
HB (g/dl)	6.1^{b}	2.2^{c}	5.5^{b}	13.0^{a}	1.31	11.80-16.20*
PCV (%)	18.7^{b}	6.7^{c}	17.0^{b}	35.8^{a}	3.5	N A
MCV (fl)	61.0^{a}	57.0^{bc}	59.0^{ab}	55.3^{c}	0.69	51-62*
MCH (pg)	19.8	18.6	19.1	20.0	0.26	17.70-20.00*
MCHC (g/dl)	32.3^{b}	32.6^{b}	32.3^{b}	36.2^{a}	0.56	32.70-36.20*
PLT (×10^3/mm^3)	202.0^{b}	150.0^{c}	215.7^{b}	477.0^{a}	54.9	315-512*
Neutrophils (%)	44.5^{b}	56.0^{a}	55.3^{a}	35.0^{c}	2.9	23.40-40.50*
Lymphocytes (%)	52.0^{b}	43.0^{c}	39.7^{d}	64.0^{a}	3.1	54.90-65.30**
Monocytes (%)	3.4^{ab}	0.5^{b}	4.1^{a}	0.9^{b}	0.6	7.00-8.30***
Eosinophils (%)	0.2^{ab}	0.3^{a}	0.3^{a}	0.2^{ab}	0.05	0.30-3.40*
Basophils (%)	0.2^{b}	0.2^{b}	0.6^{a}	0.6^{a}	0.08	0-0.80*

SEM= standard error of mean

^{a,b,c} Means with different superscripts on the same row differ significantly ($p<0.05$)

WBC- White blood cell, RBC- Red blood cell, Hb- Haemoglobin, PCV- Pack cell volume

Source:
* Vigneshwar *et al*. [20]
** Zamara-Bellow [22]
*** Weiss [24]

Table 4: Serum biochemical indices of albino rats fed diets containing ballnut kernel meal

Treatment						
Parameter	**Control**	**Full-fat**	**Mechanical**	**Chemical**	**SEM**	***Normal ranges**
AST (IU/L)	34.2^{b}	44.8^{a}	29.5^{b}	28.7^{b}	18.54	34-109***
ALT (IU/L)	15.1^{a}	16.7^{a}	9.7^{b}	8.5^{b}	10.48	13-56***
ALP(IU/L)	11.6^{b}	20.6^{a}	92.5^{bc}	71.1^{c}	15.06	95-611***
Creatinine (mg/dl)	0.3^{c}	0.7^{a}	0.5^{b}	0.6^{b}	0.03	0.30-0.70***
Urea (mg/dl)	6.8^{c}	13.1^{a}	9.7^{b}	10.1^{b}	0.70	12.30-20.10*
Total protein (g/dl)	4.7^{ab}	3.9^{c}	4.8^{a}	4.4^{b}	1.17	5.10-7.6*
Albumin (g/l)	27.0^{b}	23.0^{c}	28.0^{ab}	29.0^{a}	0.66	30.00-55.00*
Globulin (g/l)	20.0^{a}	16.0^{b}	20.5^{a}	15.0^{b}	0.83	15.00-40.00*
Sodium (mol/l)	135.0^{a}	133.0^{b}	133.0^{b}	132.5^{b}	0.30	130.92-148.76*
Potassium (mol/l)	4.4^{c}	4.7^{b}	4.5^{bc}	5.1^{a}	0.08	4.6-6.0***
Chloride (mg/l)	108.0^{a}	104.0^{b}	110.0^{a}	108.5^{a}	0.84	95-115**
Bicarbonate (meg/L)	16.0	16.0	14.3	15.0	0.4	22.8-31.1***

^{a,b,c} Means along the rows with different superscripts differ significantly ($p<0.05$)

Source: *Vigneshwar *et al.* [20]
**Wikivet [28]
*** Loeb *et al.* [30]
AST: Aspartate aminotransferease
ALT: Aspartate alanine transferase
ALP: Alanine phosphatase

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