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Blood profile characteristics of West African dwarf does fed tiger nut seed meal as a replacement for wheat offal

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Abstract

A 63-day feeding trial was conducted to evaluate the haematological, serum biochemical, electrolyte, and lipid profiles of West African Dwarf (WAD) does fed diets containing wheat offal replaced with tiger nut seed meal (TNSM). Five diets containing TNSM at 0% (A), 5% (B), 10% (C), 15% (D), and 20% (E) were formulated and fed to 20 WAD does (4 does per treatment). Results revealed significant (p<0.05) increases in packed cell volume (24.50–30.00%) and red blood cell count (9.84–12.34 × 10v /μL) with TNSM inclusion. Glucose, triglycerides, and high-density lipoprotein levels increased, while cholesterol and low-density lipoprotein decreased. Total protein (65.52 g/L), albumin (31.84 g/L), and globulin (33.69 g/L) were highest in does fed diet D. All serum electrolytes increased except for calcium. These findings suggest that replacing wheat offal with TNSM up to 15% enhances blood profiles and health status, making it a viable option for goat farmers.Top of FormBottom of Form

Key words: *Blood, Health, Replacement, Ruminant, Serum Biochemistry*

1. Introduction

Ruminants play a critical role in global agricultural production systems, contributing significantly to the supply of animal protein in human diets (Fajemisin, 2023). In Nigeria, goats are economically important livestock for rural households, serving as a buffer against food insecurity and playing a major role in the economy of farmers, as goats are frequently sold to generate income (Fajemisin, 2023).

Although natural pastures are considered the most economical feed for ruminants (Akinrinde and Olanite, 2014), it is well-established that they cannot sustain animals year-round. These pastures are often deficient in essential nutrients and low in high-quality protein, particularly during the dry season when pasture availability is limited, leading to poor health and reduced performance (Omotoso *et al.*, 2017). To address these

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challenges, the provision of concentrate diets can help meet the nutritional needs of ruminants by supplying the essential nutrients required for growth and development, thereby supporting biological processes and the synthesis of important substances within the body (Adetuyi *et al.*, 2022).

Tiger nut (*Cyperus esculentus*) is an underutilized tuber belonging to the Cyperaceae family, widely cultivated by rural farmers, particularly in the northern states of Nigeria. Tiger nuts are rich in energy (1652.53 ME/kcal), protein (12.09%), fat (8.94%), fiber (7.02%), ash (2.57%), moisture (3.73%), and essential minerals (Aremu *et al.*, 2015), making them an ideal ingredient for formulating concentrate diets that help improve the general health and performance of livestock. Studies have shown that tiger nuts promote a healthy digestive system, enhance nutrient intake, boost blood production, and support the immune and reproductive systems of animals (Rebezov *et al.*, 2021; Ibhaze *et al.*, 2024).

Hence, this study aims to use blood (haematology and serum) biochemistry as a diagnostic tool to evaluate nutrition quality, confirm suspected diseases, assess prognosis, and evaluate the effectiveness of tiger nut seed meal (TNSM) as a feed ingredient in improving the blood parameters of West African Dwarf (WAD) goats.

2. Materials and methods

2.1. Experimental site

The study was carried out at the small ruminant unit of the Teaching and Research Farm of the Federal University of Technology, Akure, Ondo State, located between longitude 4.944055°E and 5.82864°E, and latitude 7.491780°N with annual rainfall ranging between 1300 and 1650 mm and annual daily temperature ranging between 27 and 38 °C (Daniel, 2015).

2.2. Procurement of experimental does

The West African Dwarf breed of goat used for this research was purchased from a reputable farm within Ondo state, Nigeria. The does were housed intensively in well-ventilated pens and allowed to acclimatize for fourteen days during which routine management like cleaning and feeding was done while treated against endemic diseases.

2.3. Procurement and formulation of experimental diets

Dried tiger nut (*Cyperus esculentus*) seed was sourced from the Shasha market, in Akure, Ondo State Nigeria, where it is readily available. Before use, dirt, stones, and other foreign contaminants were removed. Other feed ingredients were sourced from reputable feed mills**.** Tigernut seed meal (TNSM) concentrate diet was formulated to meet the nutrient requirement of the does with allowance for maintenance and growth. The TNSM was substituted at the rate of 5.00 kg/100.00 kg as follows: diet A: Control diet (0% TNSM), B (5.00% TNSM), C (10.00% TNSM), D (15.00% TNSM) and E (20.00%) (Table 1). The diets were then pelletized into 6mm sizes to prevent the separation of feed ingredients and sorting of the diet by the experimental animal.

Table 1: Ingredient composition (%) of concentrate diets containing varying inclusion levels of Tigernut seed meal (TNSM)

Ingredients	A	B	C	D	E
Tigernut	0.00	5.00	10.00	15.00	20.00
Wheat Offal	20.00	15.00	10.00	5.00	0.00
Cassava peel	55.00	55.00	55.00	55.00	55.00
Palm kernel cake	22.00	22.00	22.00	22.00	22.00
Dicalcium Phosphate	1.00	1.00	1.00	1.00	1.00
Salt	1.00	1.00	1.00	1.00	1.00
Sulphur	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00

Note: A = (Control diet) 0% Tigernut inclusion with 20% Wheat offal: (0.00% replacement); B = 5% Tigernut inclusion with 15% Wheat offal: (25.00% replacement); C = 10% Tigernut inclusion with 10% Wheat offal (50.00% replacement); D = 15% Tigernut inclusion with 5% Wheat offal (75.00% replacement); E = 20% Tigernut inclusion with 0% Wheat offal (100.00% replacement)

2.4. Experimental design and feeding trail

The experimental does were randomly assigned to the five experimental diets, with four does per replicates, in a completely randomized design (CRD) experiment. The feeding trial lasted for 63 days, with 300 g of the experimental diets provided in the morning at 7:00 am and Panicum maximum (supplementary diet) given in the afternoon at 2:00 pm. Fresh, clean water was provided ad libitum throughout the study.

2.5. Blood sample collection

Blood sample of 10ml was collected from each goat from the puncture of jugular vein at the end of the feeding trial. The blood samples were collected in the morning to reduce stress, excessive bleeding from the animal, and lysis of blood cells. The blood collected was placed in an ethylene diamine tetra acetic acid (EDTA) bottle and plain bottle for further haematology and serum analysis.

2.6. Determination of haematology and serum biochemical indices

The methods described by Dacie and Lewis (1991) were used to assay packed cell volume (PCV), haemoglobin (Hb) count, red blood cell (RBC) and white blood cell (WBC) counts, mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC), lymphocytes, and monocytes. The BIOBASE automatic biochemistry analyzer (Biobase Biodusty, Shandong, Co., Ltd, China) was employed to measure levels of creatinine, aspartate aminotransferase (AST), alanine aminotransferase (ALT), cholesterol, total protein, albumin, and globulin.

The serum levels of triglycerides were determined using a colorimetric method following enzymatic hydrolysis with lipases. High-density lipoprotein (HDL) and total cholesterol were measured using the precipitant method. All analyses were performed using standard commercial test kits (RANDOX Laboratory Profile Ltd., Ardmore, Diamond Road, Crumlin, Co. Antrim, United Kingdom), strictly following the manufacturer's instructions. Low-density lipoprotein (LDL) cholesterol, measured in mg/dL, was calculated using the formula described by Friedewald *et al.* (1972):

LDL – Cholesterol = Total Cholesterol – Triglycerides /2.2 – HDL-Cholesterol.

3. Statistical analysis

Data collected were subjected to a one-way analysis of variance (ANOVA) using the general linear model procedure of SPSS (Version 26). Where significant differences were observed, Duncan's Multiple Range Test (DMRT) was used to separate the means. The level of significance was set at $P < 0.05$.

4. Results

4.1. Haematological indices of west african dwarf does fed concentrate diets containing varying inclusion levels of tigernut seed meal

The result of the haematological indices of WAD does fed experimental diets is presented in Table 2. The observed values showed that there was no significant ($p > 0.05$) difference in the Basophil, Monocyte and

Table 2: Haematological parameters of West African Dwarf (WAD) does fed diets containing varying inclusion levels of Tigernut seed meal (TNSM)

Parameters	A	B	C	D	E
Packed cell volume (%)	24.50±0.29^{b}	26.00±1.16^{b}	27.00±1.73^{ab}	26.00±0.02^{b}	30.00±0.58^{a}
Red blood cell (x 10^6/µL)	9.84±0.39^{b}	10.10±0.04^{b}	11.77±0.45^{a}	11.56±0.32^{a}	12.34±0.38^{a}
White blood cell (x 10^3/µL)	9.94±0.17	9.77±0.20	10.15±0.09	10.25±0.06	10.07±0.50
Haemoglobin (g/dL)	7.17±0.10^{b}	7.85±0.10^{ab}	9.00±0.58^{a}	8.56±0.06^{a}	8.84±0.48^{a}
MCHC (g/dl)	29.24±0.04^{b}	30.35±1.75^{ab}	33.33±0.00^{a}	32.92±0.24^{a}	29.41±1.04^{b}
MCV (fl)	24.95±0.70^{ab}	25.77±1.24^{a}	22.89±0.61^{b}	22.54±0.63^{b}	24.33±0.028^{ab}
MCH (pg/cell)	7.30±0.19	7.78±0.07	7.63±0.20	7.42±0.26	7.15±0.17
Neutrophil (%)	58.00±0.00^{a}	55.00±0.58^{ab}	54.50±1.44^{b}	58.00±1.15^{a}	57.00±0.58^{ab}

Table 2 (Cont.)					
Parameters	**A**	**B**	**C**	**D**	**E**
Basophil (%)	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00
Lymphocyte (%)	40.50±0.29^{ab}	41.00±0.58^{ab}	41.50±2.02^{ab}	44.00±2.30^{a}	37.00±0.58^{b}
Monocyte (%)	1.50±0.29	2.00±0.00	2.00±0.58	2.00±0.58	2.00±0.58
Eosinophil (%)	1.50±0.29^{b}	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}

Note: ^{abcd} Means within the same row with different superscripts are significantly different (p < 0.05); A= (Control diet) 0% Tigernut inclusion with 20% Wheat offal: (0.00% replacement); B= 5% Tigernut inclusion with 15% Wheat offal: (25.00% replacement); C = 10% Tigernut inclusion with 10% Wheat offal (50.00% replacement); D = 15% Tigernut inclusion with 5% Wheat offal (75.00% replacement); E = 20% Tigernut inclusion with 0% Wheat offal (100.00% replacement); MCHC = Mean Cell Haemoglobin Concentration; MCV = Mean Corpuscular Volume; and MCH = Mean Corpuscular Haemoglobin.

Eosinophil. The PCV (Packed cell volume), RBC (Red Blood Cell), Haemoglobin, MCH, MCHC and lymphocyte reported in this experiment were significantly (P<0.05) different. The PCV and RBC were observed to be highest (30.00% and 12.34 $x10^6/\mu L$) in does fed diet E (20%TNSM) while the least (24.50% and 9.84 $x10^6/\mu L$) in does fed diet A (control) respectively. The Haemoglobin and MCHC values were observed to be highest (9.00g/dL and 33.333g/dL) in does fed diet C (10%TNSM) while the least (7.17g/dL and 29.24g/dL) in does fed diet A (control) respectively. The highest (7.78pg/cell) MCH was observed in does fed diet B (5% TSNM) while least (7.15pg/cell) in does fed diet E (20% TSNM). The highest (44.00%) lymphocyte was observed in does fed diet D (15% TNSM) while the least (37.00%) in does fed diet E (20%TNSM).

4.2. Serum biochemical indices of the west african dwarf does fed concentrate diets containing varying inclusion levels of tigernut seed meal

The Serum biochemical indices of West African Dwarf does fed the experimental diet are presented in Table 3. All parameters evaluated were significantly (P<0.05) different except the albumin/globulin ratio and Alkaline phosphatase (ALP) concentration. The total protein, albumin and globulin concentrations were observed to be least (56.92 g/L, 26.98 g/L, and 30.00 g/L) from does fed diet T1 while the highest (65.52 g/L, 31.84 g/L, and 33.69 g/L) from does fed diet T4 respectively. The AST concentration was found to be highest (27.75 U/L) in does fed diet T5 will the least (178.75 U/L) from does fed diet E. Total bilirubin concentration decreases as the substitution increase with the highest value (0.56 Mg/dL) from does placed on diet A and the least (0.48 Mg/dL) from does fed diet E. The least (0.90 Mg/dL) creatinine concentration was obtained from does fed diet A while the highest (1.03 Mg/dL) portion from does fed diet C.

4.3. Serum electrolytes indices (mg/dl) of west african dwarf does fed concentrate diets containing varying inclusion levels of tigernut seed meal

The result for the serum electrolytes of does fed experimental diets is presented in Table 4. All electrolytes evaluated were significantly (p < 0.05) influenced by the substitution of TNSM in the diet. Does fed diet D had

Table 3: Serum biochemical indices of West African Dwarf (WAD) does fed diets containing varying inclusion levels of tigernut seed meal (TNSM)					
Parameters	**A**	**B**	**C**	**D**	**E**
Total protein (g/L)	56.92±1.33^{d}	60.53±0.56^{bc}	62.66±0.20^{b}	65.52±0.62^{a}	59.53±0.81^{c}
Albumin (g/L)	26.98±0.23^{d}	28.61±0.31^{c}	30.15±0.23^{b}	31.84±0.84^{a}	28.64±0.19^{c}
Globulin (g/L)	30.00±1.12^{c}	31.92±0.34^{abc}	32.51±0.39^{ab}	33.69±0.22^{a}	30.88±0.74^{bc}
Albumin/Globulin	0.90±0.03	0.90±0.01	0.93±0.02	0.95±0.03	0.93±0.02
AST (U/L)	178.75±4.76^{b}	211.75±7.94^{b}	173.25±4.76^{b}	206.25±26.99^{b}	277.75±4.76^{a}
ALT (U/L)	15.60±0.23^{a}	15.13±0.41^{ab}	14.40±0.12^{b}	14.55±0.38^{b}	14.50±0.29^{b}
ALP (U/L)	187.68±2.53	198.72±1.59	183.54±2.98	176.64±1.59	187.68±3.19
Total bilirubin (Mg/dL)	0.56±0.05^{a}	0.54±0.08^{ab}	0.48±0.09^{ab}	0.35±0.01^{b}	0.48±0.02^{ab}

Table 3 (Cont.)					
Parameters	**A**	**B**	**C**	**D**	**E**
Creatinine (Mg/dL)	0.90±0.04^{b}	1.02±9.04^{a}	1.03±0.02^{a}	1.01±0.01^{a}	0.96±0.02^{ab}
Urea (Mg/dL)	7.63±1.10^{b}	8.59±0.55^{ab}	10.26±0.42^{ab}	12.56±1.56^{a}	11.45±2.20^{ab}

Note: ^{abcd} Means within the same row with different superscripts are significantly different (p < 0.05) ; A= (Control diet) 0% Tigernut inclusion with 20% Wheat offal: (0.00% replacement); B= 5% Tigernut inclusion with 15% Wheat offal: (25.00% replacement); C = 10% Tigernut inclusion with 10% Wheat offal (50.00% replacement); D = 15% Tigernut inclusion with 5% Wheat offal (75.00% replacement); E = 20% Tigernut inclusion with 0% Wheat offal (100.00% replacement); AST = Aspartate amino transferase; ALT = Alanine amino transferase; ALP = Alkaline phosphatase.

the highest (10.34 Mg/dL) value for calcium concentration while the least (8.60 Mg/dL) was observed from does fed diet A. All other electrolytes were found to be highest in does fed diet E while the least from does fed diet A found to increase with increased substitution of tiger nut.

4.4. Glucose and lipid profile (mg/dl) of west african dwarf does fed concentrate diets containing varying inclusion levels of tigernut seed meal

The Table 5 shows the glucose and lipid profile of the WAD does fed experimental diets. Serum lipid profiles were significantly (p < 0.05) different except cholesterol and triglyceride concentration. It was observed that does fed diet A had the least (63.00 Mg/dL, 86.09 Mg/dL) value for glucose and HDL respectively while and the highest (74.22 Mg/dL, 95.44 Mg/dL) from does fed diet E. It was observed that LDL decreased as the substitution of TNSM increased, with the highest concentration (41.99 Mg/dL) in does fed diet A while the least (19.25 Mg/dL) from does fed diet E.

Table 4: Serum Electrolytes indices (Mg/dL) of West African Dwarf (WAD) does fed diets containing varying inclusion levels of tigernut seed meal (TNSM)

Parameters	**A**	**B**	**C**	**D**	**E**
Calcium	8.60±0.35^{c}	9.45±0.03^{b}	9.95±0.03^{ab}	10.34±0.19^{a}	9.88±0.07^{ab}
Phosphorus	7.37±0.14^{c}	7.69±0.33^{c}	10.50±0.43^{b}	12.19±0.54^{a}	12.56±0.76^{a}
Potassium	4.33±0.04^{b}	4.33±0.15^{b}	4.68±0.13^{a}	4.71±0.11^{a}	4.71±0.04^{a}
Magnesium	3.00±0.03^{b}	3.00±0.13^{b}	3.31±0.11^{a}	3.33±0.10^{a}	3.33±0.03^{a}
Zinc	0.07±0.00^{b}	0.18±0.06^{ab}	0.39±0.14^{a}	0.43±0.12^{a}	0.43±0.04^{a}
Iron	1.22±0.02^{c}	1.25±0.09^{bc}	1.48±0.11^{ab}	1.51±0.09^{a}	1.51±0.03^{a}

Note: ^{abcd} Means within the same row with different superscripts are significantly different (p < 0.05); A= (Control diet) 0% Tigernut inclusion with 20% Wheat offal: (0.00% replacement); B= 5% Tigernut inclusion with 15% Wheat offal: (25.00% replacement); C = 10% Tigernut inclusion with 10% Wheat offal (50.00% replacement); D = 15% Tigernut inclusion with 5% Wheat offal (75.00% replacement); E = 20% Tigernut inclusion with 0% Wheat offal (100.00% replacement).

5. Discussion

5.1. Haematological indices of west african dwarf does fed concentrate diets containing varying inclusion levels of tigernut seed meal

Haematology is a good indicator and reflection of health status and can be used to evaluate the effect of diets on the health and physiological status of the animal, used in disease prognosis and feed stress monitoring (Ibhaze *et al.,* 2016). It is a means of assessing the clinical and nutritional health status of animals in feeding trials (Togun and Oseni, 2005).

The Packed cell volume (PCV) in this study ranged from 24.50-30.00% which were all within the recommended value of 21-37% as reported for healthy goats by (Kalio *et al.* 2014). Ebuzor (2018) stated the normal range for PVC in a healthy goat is between 22-38%. Below this is an indication of anaemia and poor quality of crude protein in the diet (Omotoso, *et al.,* 2017). It can be said that the substitution of TNSM in ruminant diet can help alleviate the risk of anaemia and improve the oxygen-carrying capacity of the whole blood.

The Red blood cell (RBC) content obtained in this study was in line with the report of Plumb (1999) for healthy goats as 8.00 to 18.00 x $10^6/\mu L$. It was observed that RBC significantly improves as the inclusion level of TNSM increases, which suggests that it contain nutrients that aid erythropoiesis. This was in line with the observation of Airaodion and Ogyebuchi (2020) who observed that Tiger nut improve RBC count in Wister rats as the inclusion level increases. Deficiency in RBC suggests that the animal may be suffering from anaemia due to deficient blood formation, and diseases of the kidney or bone marrow. Poor nutrition (including dietary deficiency of iron, copper, vitamins, or amino acids) which are all predisposing factors to low RBC in goats (Isaac *et al.*, 2013) is adequate in these experimental animals.

The WBC is an indicator of the immune response to foreign bodies in an organism (Ibhaze and Fajemisin, 2017). The values obtained in this study were 9.94 to 10.25 x $10^3/\mu L$ which are within 4-13 x $10^3/L$ recommended by (Susan, 2015). However, there was no significant ($p < 0.05$) effect of the test ingredient on the WBC which is contrary to the report of Airaodion and Ogyebuchi (2020). This implies that the animal doesn't undergo any form of stress in form of infection, immune system disorder, nutrition or environment that could ensure the production of white blood cells (leucocytosis) for defence. Haemoglobin concentration values obtained in this study fall within the range of haemoglobin values (7-15g/dl) suggested for healthy goats (Susan, 2015), the highest value was obtained from T3 (10% Tigernut inclusion with 10% wheat offal) to be 9.00 g/dL This is an indication that the test ingredient (Tiger nut) has the potential of improving haemoglobin (vehicle for the transportation of oxygen and carbon dioxide in the body) level in goat when inclusion level is up to 10%. The Mean cell haemoglobin concentration (MCHC) of does were between 29.24 to 33.33g/dl which was in the range of 30.0-36.0 g/ dL as prescribed by (Susan, 2015). This shows that the animals are not predisposed to any anaemic condition. The mean Corpuscular Volume (MCV) obtained was within the normal range as prescribed by Plumb (1999) and Susan, (2015) as 16.0-25.0fl. A low MCV is an indication of chronic disease and haemoglobin disorder such as thalassaemia, anaemia due to blood cell destruction or bone marrow disorders and also an indicator of iron deficiency (Ogunjemite *et al.*, 2021) all these were not observed in the experimental goats. The mean cell haemoglobin (MCH) was not significantly ($p < 0.05$). However, values were within the values as prescribed for healthy goats by Plumb (1999) to be 5.2-8.0 (pg/cell)

The lymphocyte value obtained was between 37.00-44.00 % which were lower than the recommendation of Susan (2015) that stated 50-70% in healthy goat. However, there was no noticeable viral infection which is usually fought against by the lymphocyte cells. Basophil, monocyte and eosinophil were all within the recommended range of 0 -1%, 0 – 4%, and 1-8 % (Plumb, 1999) respectively.

Table 5: Glucose and Lipid Profile (Mg/dL) of West African Dwarf (WAD) does fed diets containing varying inclusion levels of tigernut seed meal (TNSM)

Parameters	A	B	C	D	E
Glucose	63.00±2.87^{bc}	65.86±0.63^{b}	72.60±1.08^{a}	67.75±2.83^{b}	74.22±1.02^{a}
Cholesterol	134.22±8.11	131.93±2.00	129.97±0.25	128.36±0.61	120.92±5.16
Triglyceride	30.73±1.04	28.92±0.52	29.37±3.91	27.11±1.57	31.18±2.35
HDL	86.09±0.50^{c}	91.09±1.12^{b}	93.26±0.38^{ab}	94.04±0.43^{a}	95.44±1.38^{a}
LDL	41.99±3.40^{a}	35.06±1.23^{ab}	30.84±1.41^{abc}	28.90±0.72^{bc}	**19.25±2.31^{c}**

Note: ^{abcd} Means within the same row with different superscripts are significantly different (P<0.05) A= (Control diet) 0% Tigernut inclusion with 20% Wheat offal: (0.00% replacement)B= 5% Tigernut inclusion with 15% Wheat offal: (25.00% replacement)C = 10% Tigernut inclusion with 10% Wheat offal (50.00% replacement)D = 15% Tigernut inclusion with 5% Wheat offal (75.00% replacement)E = 20% Tigernut inclusion with 0% Wheat offal (100.00% replacement)HDL= High-Density LipoproteinLDL= Low-Density Lipoprotein.

5.2. Biochemical indices of west african dwarf does fed concentrate diets containing varying inclusion levels of tigernut seed meal

Use of serum biochemical parameters has become a wide tool in evaluating the welfare and health status of livestock (Kuczyńska *et al.*, 2021), this also reveals metabolism activities and functionality of organs within the body of an animal (Jiwuba *et al.*, 2021). In the words of Ikhimioya and Imasuen (2007) serum protein can indirectly be used as an index for assessing the quality of protein in the diet, and how well the experimental animals digest and utilize the protein in the diet. Serum proteins are mainly synthesized by the liver and they function in maintaining blood volume through colloidal osmotic effect, buffer blood pH, transport hormones and drugs (Ayeni *et al.*, 2024). Increase in the serum protein as the substitution of TNSM increased could therefore be linked to the value and quantity of protein in the test ingredients (Ibhaze *et al.*, 2024).

Serum albumin begin the most abundant protein in the serum has been used to evaluate the protein status within the animal's cell (Hernandez *et al.*, 2020). The albumin recorded was higher than the report of Ogunjemite *et al.* (2021) when does was fed with raw cash nut shell. The increase in the albumin observed implies that TNSM support it synthesis. Albumin enhance the process of blood clotting during injury, increase in the ability to prevent haemorrhage (Ibhaze *et al.*, 2021). Thus, the higher the value, the better it is for the animal. The globin value reported in this study was lower when compared to the value reported by Ibhaze *et al.* (2021) but in the normal range (24-44 mg/dl) as reported by (Susan, 2015). The greater the globulin concentration over albumin the better, this implies the animal has better immunity and ability to resist infection, thus use of TNSM in the diet of goats tends to boost immune response.

The serum enzymes AST, ALT, and ALP values were all in the range 66 -230 U/L, 15.30-52.30 U/L and 66.00-230.00 U/L recommended to be safe ranges for goats (Opara, 2010). AST been a liver enzyme are used to diagnosis liver damage, diseased condition, injury or excess protein in diet. AST increases when there is low detoxification and deamination process in the liver, liver damage (Adekomi, 2021). The increase in AST values observed were within the safe range, while may implies no threat on the functionality of the liver in these does. Mahgoub *et al.* (2008) stated that ALT concentration in serum is higher than AST during liver inflammation. However, ALT reduced along the dietary treatments in this study, the values were lower than the AST values indicative of liver health and no inflammation. Alkaline phosphate (ALP) concentration which are used to diagnosis for bile malfunction and obstruction, bone and liver disease were within the reference safe range.

Serum bilirubin in the serum of the does was observed to decrease as the substitution of TNSM increased. Bilirubin is formed from the breaking down process of haemoglobin in the spleen, liver, or born marrow (Kabita *et al.*, 2022). Hence, increase in value above safe range may indicate a case of rapid deterioration of the haemoglobin cells, or autoimmune response, toxic or infectious disease of the liver. Also, the inability of the liver to extract the bilirubin out of the body may lead to increase concentration and clinical manifestation of jaundice (Joseph and Samant, 2020). Hence the experimental diet does not pose a health risk on the does' spleen, liver or bile rather it reduces haemoglobin catabolism and improves the ability of the liver to excrete bilirubin.

Urea and creatinine concentration are indicators of protein catabolism and renal functionality of the kidney. The creatinine value 0.90 to 1.03 Mg/dL and urea 7.73 to 12.56 Mg/dL were within the normal physiological range (1.20-1.90Mg/dL and 5.20-15.30) as reported by Plumb (1999) for healthy goats. This implies that the protein ingested by the does were well utilized for the biosynthesis of amino acids an indicator of feed protein quality (Jiwuba *et al.*, 2021). It was observed that there was an increase in the serum urea as the substitution of TNSM progresses, suggesting to support biosynthesis of amino acids as required within the body. Since value obtained were within the safe range this implies there was proper glomerular and tubular filtration of urea (Othman *et al.*, 2022). Variations in the serum indices with other research work could also be due to variation in feed composition used, handling of blood samples, breed and genetics difference, environment, sex, and age of animals, production status and disease condition (Ocheja *et al.*, 2021).

5.3. Serum electrolyte indices of west african dwarf does fed concentrate diets containing varying inclusion levels of tigernut seed meal

Serum electrolytes play an important role in the synthesis of hormone, immune response, growth and reproduction in livestock (Galęska *et al.*, 2022). There was significant ($p < 0.05$) increase in the concentration of all serum evaluated as the substitution of TNSM increased, which implies that it is capable of increasing the availability and functionality of these serum electrolytes. The serum calcium is adequate to support smooth muscle contractility and neuromuscular transmission (Hernandez *et al.*, 2020). Magnesium concentration in the serum were comparable to the range of 4.00 to 8.00 mg/dL recommended for goat and sheep (NRC, 2007). This implies that the diets were adequately fortified with magnesium as it promotes blood function, activation of enzymes and other biochemical function.

Zinc which acts as coactive, catalytic and structural role in many enzymes (e.g., testosterone, insulin) and regulating many physiological processes was observed to range between 0.07 to 0.43 Mg/dL which is adequate enough to elicit those functions. Iron is a vital electrolyte that assists in the production of haemoglobin and myoglobin in the body of an animal. There was a significant ($p < 0.05$) increase in the concentration of iron in the serum as the substitution of TNSM increased thus helping to alleviate anaemic condition and improve the oxygen carrying capacity of the blood.

5.4. Glucose and lipid indices of west african dwarf does fed concentrate diets containing varying inclusion levels of tigernut seed meal

Glucose and lipid profile are used as diagnostic tool to measure lipid metabolism and its deposition within the tissues of the body. Glucose is the principal source of energy in mammalian species. The values obtained were within 60-100 mg/dL recommended by James (2015), this indicate that the does do not suffer shortage in glucose supply as it is required for various energy demanding activities and no need for the cell to generate energy through gluconeogenesis pathway rather excess glucose been stored in form of glycogen the liver, muscle for further use (Seo *et al.*, 2018).

The cholesterol values obtained were within the recommended range, but observed to decrease as the substitution of TNSM increased this may be linked to the presence of high oleic acid and vitamin E in the tiger nut seed meal which helps to reduce cholesterol level and prevents heart attacks and thrombosis (Rebezov *et al.*, 2021). Cholesterol, a precursor for the biosynthesis of steroid hormones, bile acid, and vitamin D (Idoko *et al.*, 2020), its gradual reduction seems beneficial to the health status of the does as increased deposition may expose the does to atherosclerotic plague and hyperadrenocorticism. A block in blood vessels may result in a myocardial infarction or heart attack. Wang *et al.* (2018) stated that low concentration of cholesterol is beneficial to goats even to people who consume meat from such animals as high accumulation of cholesterol in meat increases the risk of developing metabolic and dietary diseases such as insulin resistance, type II diabetes, hypertension, atherosclerosis etc (Mazhangara *et al.*, 2019). Triglycerides concentration recorded was within the acceptable range and the diet does not pose health risk on the does.

Lipoproteins (HDL and LDL) are the main carriers of cholesterol in the blood delivers cholesterol from the liver to the peripheral tissues and is returned to the liver (Mahmoudian *et al.*, 2018). However, high LDL in the serum indicates more cholesterol in the bloodstream than necessary which is bad, as it tends to plaque and clog the arteries, increase the risk of heart attack due to the fact that LDL contained more lipids than proteins (Wang *et al.*, 2018). It is generally accepted that the risk of cardio-vascular disease decreases as LDL concentration decreases, hence LDL is termed bad cholesterol (Rhoads and Major, 2018).

The HDL also called good cholesterol is the smallest of the lipoprotein produced by the liver to transport cholesterol and other lipids (Rhoads and Major, 2018). Higher concentration over LDL is beneficial as it contained higher proportion of protein than lipids, hence not clogging the arteries leading to other circulatory diseases. Thus, tiger nut seed meal is capable of reducing the accumulation of LDL in the blood, rather increases LDL concentration, this was similar to the report of (Adelakun *et al.*, 2022).

6. Conclusion and recommendation

The present study established the significant impact of Tigernut seed meal on the haematology, serum indices, electrolytes, and lipid profile. It could be said that the substitution of wheat offal for Tigernut seed meal up to 15.00 % in the diet of WAD does could best be adopted, helping to improve and stabilize the serum constituent of WAD goats. Substitution of Tigernut seed meal does not have detrimental effect on the blood constituent therefore it can be introduced in goat diet as it enhances the health status.

Conflict of interest

The authors declare no conflicts of interest regarding the publication of this manuscript.

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