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RESPONSE OF WEST AFRICAN DWARF GOATS TO THE ADDITIVE IMPACT OF BLACK SUNFLOWER (*Helianthus annuus)* SEEDS IN THE DIET

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ABSTRACT

This study evaluated black sunflower seed (BSS) as a dietary additive in West African Dwarf (WAD) goats. Nutrient intake, apparent nutrient digestibility, nitrogen retention, rumen fermentation characteristics, rumen microbial populations, haematological indices and serum biochemical indices were evaluated. Fifteen WAD goats were randomly allocated to three treatments of five goats each in a completely randomized design. The treatments included 0 g BSS/100 kg (T1), 25 g BSS/100 kg (T2), and 50 g BSS/100 kg (T3). The feeding trial lasted for eight weeks. Data were collected and subjected to one-way analysis of variance and separated at a 5% significance level.

The Dry matter intake, Crude protein intake, Dry matter digestibility, Crude protein digestibility, and Nitrogen Retention were highest in T3. 172.90g/day, 26.75g/day, 88.52%, 88.37%, and 73.41g/day were recorded, respectively, in T3. The rumen microbial population, Total Bacteria count, and Total Fungi Count were highest in T3 and recorded as 8.20 cfu/ml × 10^6 and 3.20 cfu/ml × 10^3. The Total Volatile acid, Acetic acid, Pack Celled Volume, and Haemoglobin concentration were highest in T1. 129.21mmole/100ml, 9.11mmole/100ml, 38%, and 12.15g/dL were recorded respectively in T1. Glucose and Globulin were highest in T2, recording 68.50mg/dL and 3.60g/dL respectively.

Among the treatment diets, 50g/100kg BSS is hereby recommended as an additive in WAD goat diets, as it improved their performance.

Keywords: Black Sunflower Seed; West African Dwarf goats; Feed Additive; Nutrient Intake; Digestibility; Nitrogen Retention; Rumen Fermentation

INTRODUCTION

Goat farming is essential for the sustenance and nutrition of rural families in sub-Saharan Africa, especially in West Africa, where the West African Dwarf goat breed is most common.

The West African Dwarf (WAD) goat is among the most prevalent native small ruminant breeds in West Africa, found extensively in Nigeria, Ghana, Cameroon, and Benin Republic (Osakwe *et al.,* 2023). It plays an essential part in rural household economies and food security, especially for smallholder farmers and nomadic herders. The WAD goat, being a versatile and low-maintenance animal, plays a crucial role in meat production, family income, cultural rituals, and providing manure for agriculture (Ogunniyi *et al.,* 2020 and Ojoawo *et al*., 2024). WAD goats are particularly favored for their exceptional adaptability to tropical climates, including high humidity, elevated temperatures, and seasonal feed shortages. They are small-sized, early-maturing, highly prolific (usually birthing twins or triplets), and have short kidding intervals, which makes them especially valuable in resource-limited farming systems (Eze *et al.,* 2022). Sunflower (*Helianthus annuus*) is an important oilseed crop cultivated across temperate and tropical regions of the world. It serves multiple purposes, ranging from oil production to use as feed ingredients for livestock. The seeds are valued for their high nutritional quality, providing substantial amounts of protein, lipids, vitamins, and minerals necessary for animal growth and maintenance (Obeidat *et al.,* 2009). The residual meal obtained after oil extraction also serves as an excellent source of plant protein, making sunflower a versatile and valuable crop in animal nutrition (Baker, 2010).

Sunflower seeds are broadly categorized based on their shell colour, oil composition, and intended use. Among these, *black sunflower seeds (BSS)* stand out due to their thin shell and high oil content, which make them more suitable for feed formulation and oil extraction compared to the striped varieties (Giada, 2010). Nutritionally, black sunflower seed *(BSS)* provides an excellent combination of crude

protein, digestible fibre, and vital minerals, aiding rumen activity and feed efficiency in small ruminants (Nassu *et al.,* 2017). Incorporating it into ruminant diets can help balance energy and protein ratios, enhance taste, and maintain performance during times of feed shortage (Kaya *et al.,* 2019). During the dry season, when forages are fibrous and deficient in key nutrients, supplementing diets with energy-rich seeds like black sunflower can serve as a practical approach to maintaining animal condition and productivity (Oni *et al.,* 2010). The utilization of *BSS* as a feed additive therefore presents a sustainable alternative for improving goat performance under dry-season feeding systems (Akinmutimi, 2014).

This study therefore evaluated the additive dietary effects of black sunflower seed on nutrient intake, digestibility, nitrogen retention, rumen fermentation, rumen microbial population, haematological indices and serum biochemical indices of WAD goats.

MATERIALS AND METHODS

Experimental Site

The research was carried out at the Teaching and Research Farm of the Animal Production and Health Department, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Oyo State. This region is situated in the derived savannah zone of Nigeria, with distinct wet and dry seasons, at a longitude of 4°15' East and a latitude of 8°15' North of the Greenwich meridian. The altitude of the region varies from 300 to 600 meters above sea level. The mean annual rainfall and temperature are approximately 1240 mm and 27°C, respectively (Ewetola, 2020).

Experimental Animals and Management

A total of 15 West African Dwarf (WAD) goats were procured from a local market in Ogbomoso and used for the experimental trial. At the point of purchase, the sellers provided available records relating to the animals' previous feeding history and health status, which were reviewed as part of the pre-experimental assessment. The animals were subsequently subjected to a 14-day acclimatization period, during which their general health condition was monitored. They were dewormed and treated against ectoparasite infestations before the commencement of the feeding trial. Following the acclimatization period, the goats were randomly assigned to three treatment groups (T1–T3), with five goats per treatment, using a Completely Randomized Design (CRD).

Experimental Diets and Test Ingredients

Black Sunflower Seed (BSS) was procured, properly cleaned, and incorporated into the basal diet at graded inclusion levels. Three experimental diets were formulated. Treatment 1 (T1) served as the control diet and contained no Black Sunflower Seed (0 g BSS/100 kg basal diet). Treatment 2 (T2) contained 25 g of BSS per 100 kg of the basal diet, while Treatment 3 (T3) contained 50 g of BSS per 100 kg of the basal diet. Thus, Black Sunflower Seed was used as the dietary additive at inclusion levels of 0, 25, and 50 g per 100 kg of the complete basal diet, corresponding to T1, T2, and T3, respectively.

Table 1: Composition of the Basal Diet and Inclusion Levels of Black Sunflower Seed (BSS)

Ingredients	Basal Diet (kg/100 kg)	T1	T2	T3
Corn bran	37.5	37.5	37.5	37.5
Palm kernel cake	**20.0**	20.0	20.0	20.0
Wheat offal	**37.5**	37.5	37.5	37.5
Limestone	**2.5**	2.5	2.5	2.5
Salt	**2.5**	2.5	2.5	2.5
Black sunflower seed (BSS)	—	0 g	25 g	50 g
Basal diet total	**100 kg**	100 kg	100 kg	100 kg

Note: T1 was the control treatment containing the basal diet without BSS. T2 and T3 consisted of the same basal diet supplemented with 25 g and 50 g of Black Sunflower Seed, respectively, per 100 kg of basal diet.

Feeding Trial

The feeding trial lasted for 8 weeks. Feed and water were provided *ad libitum*. Daily feed intake was calculated by deducting feed leftovers from the total feed offered.

Data Collection

Nutrient Digestibility

During the digestibility trial, both feces and urine were quantitatively collected. Feces were collected daily, weighed, and sub-sampled for proximate analysis. Apparent Digestibility Coefficient (%) was estimated.

The apparent nutrient digestibility was determined using the following formula (McDonald *et al.,* 2022);

Digestibility (%) = (Nutrient intake −Nutrient in feces/Nutrient intake) × 100

Where: Nutrient intake = Dry matter of feed × nutrient % and Nutrient in feces = Dry matter of feces × nutrient %

Nitrogen Retention

Nitrogen Retention was determined from the difference between nitrogen intake and nitrogen excreted in faeces and urine. Urine was collected in buckets containing 10 mL of 10% sulphuric acid to prevent nitrogen loss.

Rumen Fermentation Characteristics

Rumen Fluid Collection: Rumen liquor samples were collected from each goat 4 hours post-morning feeding using a stomach tube attached to a vacuum pump on the initial day and at the end of the experiment. The initial 50 mL was discarded to avoid contamination with saliva.

Rumen pH: Rumen pH was measured immediately after collection using a digital pH meter.

Volatile Fatty Acids (VFA) Profile: A 5 mL subsample was preserved with 1 mL of 25% metaphosphoric acid and stored at –20 °C. VFA concentrations (acetate, propionate, butyrate) were determined using gas chromatography following the method of Erwin et al. (1961).

Ammonia Nitrogen Concentration: Ammonia-N was determined using the phenol–hypochlorite method as described by Broderick and Kang (1980).

Rumen Microbial Population: Microbial population enumeration followed the roll-tube technique for total viable bacterial and protozoal counts (Hungate, 1966). Serial dilutions were plated on selective media for bacterial enumeration, and protozoa were counted using a haemocytometer under a light microscope.

Hematological and Serum Biochemical Analysis

Hematological Analysis: Blood samples were collected from the jugular vein of each animal into EDTA tubes for hematological assessment. Parameters such as packed cell volume (PCV), hemoglobin concentration (Hb), red blood cell (RBC) count, white blood cell (WBC) count, and differential leukocyte count were determined using standard procedures (Jain, 1993).

Serum Analysis: Additional blood samples were collected without anticoagulant, allowed to clot, and centrifuged at 3,000 rpm for 10 minutes to obtain serum. Serum was analyzed for total protein, albumin, globulin, cholesterol, urea, and creatinine using automated biochemical analyzers and spectrophotometric methods as described by Coles (1986).

Chemical Analysis of Feed and Fecal Samples

Feed, feces, and black sunflower seed samples were analyzed for chemical and proximate compositions (moisture, crude protein, crude fiber, ether extract, ash, and nitrogen-free extract) using the methods of AOAC (2019), and Fiber fractions (NDF, ADF, and ADL) were determined following the method of Van Soest *et al.,* (1991).

All samples were analyzed in triplicate according to the standard methods of AOAC (2019)

Dry Matter (DM): Samples were dried in an oven at 105°C for 24 hours to determine moisture content. Crude Protein (CP): Samples were analyzed using the Kjeldahl method, which involves digesting the sample and measuring nitrogen content (N × 6.25). Crude Fiber (CF): Samples were analyzed using a fiber analyzer to determine fiber content. Ether Extract (EE): Samples were extracted using the Soxhlet method to determine fat content. Ash: Samples were heated in a muffle furnace at 550°C to determine ash content. Nitrogen-Free Extract (NFE): Calculated by subtracting the sum of CP, CF, EE, and Ash from 100.

Statistical Analysis

All collected data were subjected to one-way analysis of variance (ANOVA) using SPSS version 25. Significant differences between treatment means waere separated using Duncan's Multiple Range Test (DMRT) at the $p < 0.05$ level.

The statistical model to be used is:

$Yij = \mu + Ti + \varepsilon ij$

Where: Yij = Observed value of the dependent variable; μ = Overall mean; Ti = Effect of treatments (i = 1, 2, 3); εij = Random error

RESULTS AND DISCUSSION

Table 2: Chemical Composition of Experimental Diets

Parameters	T1 (0g/100kg BSS)	T2 (25g/100kg BSS)	T3(50g/100kg BSS)	SEM
Proximate				
Dry Matter (%)	93.64^{a}	86.32^{c}	89.07^{b}	0.74
Crude Protein (%)	17.61^{b}	16.68^{c}	18.23^{a}	0.18
Ether Extract (%)	5.57^{b}	5.00^{c}	7.19^{a}	0.24
Crude Fibre (%)	12.88^{c}	14.12^{a}	13.60^{b}	0.15
ASH (%)	13.25^{b}	9.71^{c}	15.32^{a}	0.57
CHO (%)	57.20^{a}	54.93^{b}	48.33^{c}	0.92
Fibre Fractions				
Neutral Detergent	68.20^{c}	70.15^{b}	72.25^{a}	0.41

Fibre				
Acid Detergent Fibre	**51.10^{c}**	**54.50^{b}**	**58.90^{a}**	**0.78**
Acid Detergent Lignin	**25.45 ^{c}**	**28.30^{b}**	**32.30^{a}**	**0.69**
Minerals				
Sodium (%)	**0.29**	**0.27**	**0.29**	**0.01**
Potassium (%)	**0.53**	**0.49**	**0.51**	**0.01**
Calcium (%)	**0.35^{a}**	**0.30^{b}**	**0.31^{ab}**	**0.01**
Phosphorus (%)	**0.39**	**0.35**	**0.37**	**0.01**
Magnesium (%)	**0.46^{a}**	**0.41^{b}**	**0.42^{ab}**	**0.01**
Copper (mg/kg)	**9.60^{a}**	**6.80^{c}**	**7.40^{b}**	**0.29**
Zinc (mg/kg)	**13.40^{a}**	**10.70^{c}**	**11.30^{b}**	**0.28**
Iron (mg/kg)	**61.30^{a}**	**61.20^{b}**	**59.80^{c}**	**0.17**
Phytochemicals				
Flavonoid (mg/100g)	3.79	3.57	3.52	0.09
Phenolic (mg/100g)	50.22^{c}	55.91^{b}	61.32^{a}	1.36
Alkaloid (mg/100g)	2.92	2.95	3.26	0.09
Saponin (mg/100g)	16.32^{a}	15.09^{b}	13.92^{c}	0.30
Tannin (mg/100g)	20.52^{a}	19.86^{b}	19.15^{c}	0.18
Carotenoid (mg/100g)	3.20	2.90	2.70	0.10
Glycoside (mg/100g)	2.72	2.57	2.41	0.09

*SEM- Standard error of the mean; Means with different superscripts within a row are significantly different (P<0.05)

Proximate Composition, Fibre Fraction and Anti-nutrients of Experimental Diets on WAD Goats

The results of the proximate, fibre, minerals and phytochemical composition of experimental diets (0g, 25g and 50g /100kg Black Sunflower Seed BSS additive) were presented in Table 2 with varying levels of the three experimental diets.

Amongst the proximate composition, dry matter, crude protein, ether extract, crude fibre, ash and carbohydrate (CHO) were significantly affected with increasing levels of BSS additive. Across the treatments, all the fibre fractions, neutral detergent fibre, acid detergent fibre and acid detergent lignin differed significantly with increasing levels of BSS additive.

Mineral composition showed significant differences among parameters such as zinc, iron, calcium and magnesium, while there were no significant differences among copper, sodium, potassium and phosphorus.

Phenolic, saponin and tannin were significantly different across the treatments, while flavonoid, alkaloid, carotenoid and glycoside were not significantly different for the anti-nutritional factors of the experimental diets.

Across the treatments, within proximate composition, T1 (0g/100kg BSS) has the highest values in dry matter (93.64%) and carbohydrate content (57.20%). The value of dry matter ranges from 86.32% (T2) to 93.64% (T1) across the treatments, while the value for carbohydrate ranges from 48.33% (T3) to 57.20% (T1). T2 (10% BSS) only has the highest value in crude fibre (14.12%) across the treatments, while it ranges from 12.88% (T1) to 14.12% (T2).

T3 (50g/100kg BSS) has the highest values in crude protein, ether extract and ash. Crude protein values range from 16.68% (T2) to 18.23% (T3); ether extract also ranges from 5.00% (T1) to 7.19% (T3); and ash values range from 9.71% (T2) to 15.32% (T3).

Across the treatments, within the fibre fractions, T3 (250g/100kg BSS) recorded the highest values in all parameters: neutral detergent fibre, acid detergent fibre, and acid detergent lignin, while T1 (0g/100kg BSS) recorded the lowest values for the parameters. The value of neutral detergent fibre ranged from 68.20% (T1) to 72.25% (T3), acid detergent fibre value ranged from 51.10% (T1) to 58.90% (T3), and acid detergent lignin value ranged from 25.25% (T1) to 32.30% (T3).

T1 (0g/100kg BSS) has the highest value for the mineral composition of the experimental diets: zinc, iron, calcium, magnesium and copper, while T2 (25g/100kg BSS) has the lowest value for the parameters except iron (T3 50g/100kg BSS). The value of zinc ranges from 3.45mg/kg (T2) to 5.38mg/kg (T1), iron ranges from 4.24mg/kg (T3) to 6.35mg/kg (T1), calcium ranges from 0.30mg/kg (T2) to 0.35mg/kg (T1), magnesium ranges from 0.41mg/kg (T2) to 0.46mg/kg (T1) and copper ranges from 6.80mg/kg (T2) to 9.60mg/kg (T1).

Amongst the anti-nutritional factors, T1 (0g/100kg BSS) has the highest values for saponin and tannin, while T3 (50g/100kg BSS) has the highest value for phenolic across the treatments. Also, T1 (0g/100kg BSS) has the lowest value for phenolic, and T3 (50g/100kg BSS) has the lowest value for saponin and tannin. Phenolic, saponin and tannin values range from 50.22 mg/kg (T1) to 61.32 mg/kg (T3), 13.92 mg/kg (T3) to 16.32 mg/kg (T1) and 19.15 mg/kg (T3) to 20.52mg/kg (T1), respectively.

Table 3: Nutrient Intake of WAD Goats offered Experimental Diets

Parameters (g/day)	T1 (0g/100kg BSS)	T2 (25g/100kg BSS)	T3 (50g/100kg BSS)	SEM
Dry Matter Intake	128.59^{b}	150.64^{ab}	172.90^{a}	8.69
Crude Protein Intake	19.48^{b}	22.55^{ab}	26.75^{a}	1.34
Crude Fibre Intake	16.02^{b}	16.66^{b}	22.24^{a}	0.99
Ether Extract Intake	5.25	5.97	7.00	0.59
Ash Intake	12.97^{b}	12.57^{b}	19.40^{a}	1.04
CHO Intake	72.62	83.05	88.92	4.57
Neutral Detergent Fibre Intake	74.88^{b}	86.46^{ab}	102.11^{a}	5.05

Acid Detergent Fibre Intake	43.34	48.12	57.82	2.88
Acid Detergent Lignin Intake	15.64[b]	17.31[ab]	22.07[a]	1.18
Cellulose Intake	27.69	30.81	35.74	1.86
Hemicellulose Intake	31.55[b]	38.35[ab]	44.30[a]	2.26
Lignin Intake	15.64[b]	17.31[ab]	22.08[a]	1.17

*SEM- Standard error of the mean; abc – means with different superscripts were significantly different (P<0.05)

Nutrient Intake of WAD Goats Offered Experimental Diets

The results of nutrient intake of WAD goats offered experimental diets were presented in Table 3. Across the treatments, parameters such as dry matter intake, crude protein intake, crude fibre intake, ash intake, neutral detergent fibre intake, acid detergent lignin intake, hemicellulose intake and lignin intake all showed significant differences while there were no significant differences amongst ether extract intake, CHO intake, acid detergent fibre intake and cellulose intake parameters.

The dry matter intake, crude protein intake, crude fibre intake, ash intake, acid detergent lignin intake, hemicellulose intake and lignin intake showed highest values in T3 (50g/100kg BSS) while T1 (0g/100kg BSS) showed the lowest values for the parameters mentioned above across the treatments. Dry matter intake ranges from 128.59% (T1) to 172.90% (T3), crude protein intake 19.48% (T1) to 26.75% (T3), crude fibre intake ranges from 16.02% (T1) to 22.24% (T3), ash intake range from 12.57% to 19.40%, acid detergent lignin intake ranges from 15.64% (T1) to 22.07% (T3), hemicellulose intake ranges from 31.55% (T1) to 44.30% (T3) and lignin intake ranges from 15.64% (T1) and 22.08% (T3) across the treatments.

Table 4: Nutrient Digestibility Coefficient of the WAD Goats offered Experimental Diets

Parameters (%)	T1 (0g/100kg BSS)	T2 (25g/100kg BSS)	T3 (50g/100kg BSS)	SEM
Dry Matter Digestibility	84.29[b]	80.90[c]	88.52[a]	0.84
Crude Protein Digestibility	83.88[b]	81.12[b]	88.37[a]	0.82
Crude Fibre Digestibility	61.33[b]	39.28[c]	74.70[a]	3.83
Ether Extract Digestibility	91.25	89.30	91.78	0.59
Ash Digestibility	71.26[b]	66.50[c]	85.19[a]	1.81
CHO Digestibility	85.88	85.36	87.50	0.94
Neutral Detergent Fibre Digestibility	81.32[b]	76.97[c]	86.89[a]	1.03
Acid Detergent Fibre Digestibility	75.34[b]	66.52[c]	82.34[a]	1.51
Acid Detergent Lignin Digestibility	65.15[b]	52.84[c]	77.47[a]	2.45
Cellulose Digestibility	81.09[b]	74.20[c]	85.44[a]	1.11
Hemicellulose Digestibility	89.54[b]	89.96[b]	92.82[a]	0.60
Lignin Digestibility	65.15[b]	52.84[c]	77.47[a]	2.45

*SEM- Standard error of the mean; abc – means with different superscripts were significantly different (P<0.05)

Nutrient Digestibility Coefficient of WAD Goats Offered Experimental Diets

Table 4 represents results for the nutrient digestibility coefficient of WAD goats offered experimental diets (0g, 25g and 50g/100kg Black Sunflower Seed BSS additive). Parameters are dry matter digestibility, crude protein digestibility, crude fibre digestibility, ether extract digestibility, CHO digestibility, ash digestibility, neutral detergent fibre digestibility, acid detergent fibre digestibility, acid detergent lignin digestibility, cellulose digestibility, hemicellulose digestibility, and lignin digestibility. The values of the parameters ranges from 80.90% (T2) to 88.52% (T3), 81.12% (T2) to 88.37% (T3), 39.28% (T2) to 74.70% (T3), 89.30% (T2) to 91.78% (T3), 85.36% (T2) to (T3), 66.50% (T2) to 85.19% (T3),76.97% (T2) to 86.89% (T3), 66.52%(T2) to 82.34% (T3), 52.84%(T2) to 77.47% (T3), 74.20%(T2) to 85.44%(T3), 89.54 to 92.82% (T3) and 52.84% to 77.47%(T3) respectively to the parameters listed above.

The trend of value ranges showed a pattern whereby T3 had the highest values across the treatments, while T2 showed the lowest values across the treatments. This connotes that T3 had the highest digestibility for all the nutrients and T2 had the lowest digestibility, which reduced nutrient absorption. T1 showed slightly lower fibre digestibility than T3. All parameters were significantly affected across the treatments except ether extract digestibility and CHO digestibility.

Table 5: Nitrogen Retention of WAD Goats offered Experimental Diets

Parameters (g/day)	T1 (0g/100kg BSS)	T2 (25g/100kg BSS)	T3 (50g/100kg BSS)	SEM
Urinary Nitrogen	0.95	1.55	0.68	0.18
Fecal Nitrogen	0.50	0.69	0.54	0.04
Digested Nitrogen	1.67[a]	1.36[a]	3.35[a]	0.22
Nitrogen Retention	52.47[b]	44.21[b]	73.41[a]	3.98

*SEM- Standard error of the mean; abc – means with different superscripts are significantly different (P<0.05)

Nitrogen Retention of WAD Goats Offered Experimental Diets

Table 5 presents the results for nitrogen retention of WAD goats offered experimental diets (0g, 25g and 50g/100kg Black Sunflower Seed BSS additive). The parameters are urinary nitrogen, fecal nitrogen, digested nitrogen, and nitrogen retention. There were no significant differences across the treatments for parameters like urinary nitrogen and fecal nitrogen, while digested nitrogen and nitrogen retention were significantly influenced across the treatments. T3

had the highest value for nitrogen retention of 73.41g/day while T2 had the lowest value of 44.21g/day. Digested nitrogen followed the same trend, where T3 had the highest value of 3.35g/day and T2 had the least value of 1.36g/day. Urinary and faecal nitrogen did not differ significantly, meaning that retention rates are relatively stable and differences in retention are mainly due to variation in digestibility and utilization of the experimental diets offered.

Table 6: Effects of Feeding Varying Inclusion Levels of Black Sunflower Seed Additive on Rumen Fermentation Characteristics in WAD Goats

Parameters (mmole/100ml)	T1 (0g/100kg BSS)	T2 (25g/100kg BSS)	T3 (50g/100kg BSS)	SEM
Acetic acid	9.11^{a}	4.38^{c}	6.38^{b}	0.41
Propoinic acid	8.69^{a}	4.17^{c}	6.09^{b}	0.39
Butyric acid	8.30^{a}	3.99^{c}	8.30^{b}	0.37
Valeric	8.26^{a}	3.97^{c}	5.79^{b}	0.37
Total Volatile Acid	129.21^{a}	62.05^{c}	90.52^{b}	5.74
Lactic acid	11.34^{a}	5.45^{c}	7.94^{b}	0.51
Ph	5.34^{b}	6.17^{a}	5.49^{b}	0.11
Ammonia Nitrogen Concentration (NH_3-N)	0.36	0.26	0.31	0.06

*SEM- Standard error of the mean; abc – means with different superscripts are significantly different ($P<0.05$)

Effects of Feeding Varying Inclusion Levels of Black Sunflower Seed Additive on Rumen Fermentation Characteristics in WAD Goats

Table 6 presents results for rumen fermentation characteristics of WAD goats on experimental diets (0 g, 25 g, and 50g/100kg Black Sunflower Seed BSS additive). The parameters are acetic acid, propionic acid, butyric acid, valeric acid, total volatile fatty acids, lactic acid, pH, and ammonia nitrogen concentration (NH_3-N). There were significant differences ($P<0.05$) in the parameters across the treatments except ammonia nitrogen concentration (NH_3-N), which was not significantly affected across the treatments.

Highest values were recorded in T1 (0g/100kg BSS) for acetic acid (9.11mmole/100ml), propionic acid (8.69 mmole/100ml), butyric acid (8.30 mmole/100ml), valeric acid (8.26 mmole/100ml), total volatile fatty acids (129.21 mmole/100ml) and lactic acid (11.34 mmole/100ml), while T2 (25g/100kg BSS) recorded the least values for these parameters.

The values of acetic acid ranged from 4.38 mmole/100ml (T2) to 9.11 mmole/100ml (T1), propionic acid ranged from 4.17 mmole/100ml (T2) to 8.69 mmole/100ml (T1), butyric acid ranged from 3.99 mmole/100ml (T2) to 8.30 mmole/100ml (T1), and valeric acid ranged from 3.97 mmole/100ml (T2) to 8.26 mmole/100ml (T1).

Total volatile fatty acids ranged from 62.05 mmole/100ml (T2) to 129.21 mmole/100ml (T1), while lactic acid ranged from 5.45 mmole/100ml (T2) to 11.34 mmole/100ml (T1). T3 (50g/100kg BSS) consistently recorded intermediate values for these parameters across the treatments.

For rumen pH, T2 (25g/100kg BSS) recorded the highest value (6.17), while T1 (0g/100kg BSS) recorded the lowest value (5.34), with values ranging from 5.34 (T1) to 6.17 (T2). T3 (50g/100kg BSS) had a comparable value (5.49) to T1.

Ammonia nitrogen concentration (NH_3-N) showed no significant difference across the treatments, although T1 (0g/100kg BSS) had the highest value (0.36 mmole/100ml) and T2 (25g/100kg BSS) recorded the least value (0.26 mmole/100ml), with values ranging from 0.26 to 0.36 mmole/100ml.

Table 7: Effects of Feeding Varying Inclusion Levels of Black Sunflower Seed Additive on Rumen Microbial Population in WAD Goats

Parameters	T1 (0g/100kg BSS)	T2 (25g/100kg BSS)	T3 (50g/100kg BSS)	SEM
Total Bacteria Count (cfu/ml) x10^{6}	7.80^{a}	6.10^{b}	8.20^{a}	0.24
Total Coliform Count (cfu/ml) x10^{3}	1.75 ^{b}	2.20^{a}	2.10^{a}	0.07
Total Fungi Count (cfu/ml) x10^{3}	2.30^{b}	2.35^{b}	3.20^{a}	0.11
Protozoa (cell/mL) x10^{3}	4.50^{b}	5.00^{a}	3.00^{c}	0.22

*SEM- Standard error of the mean; abc – means with different superscripts are significantly different ($P<0.05$)

Effects of Feeding Varying Inclusion Levels of Black Sunflower Seed Additive on Rumen Microbial Population in WAD Goats

Table 7 presents the rumen microbial population of WAD goats fed experimental diets containing 0g, 25g and 50g/100kg black sunflower seed (BSS) additive. The parameters evaluated include total bacteria count, total coliform count,

total fungi count, and protozoa population. All parameters were significantly (P<0.05) affected by the dietary treatments.

Total bacteria count ranged from 6.10 $\times 10^6$ cfu/mL (T2) to 8.20 $\times 10^6$ cfu/mL (T3), with T3 (20% BSS) recording the highest value, followed by 7.80 $\times 10^6$ cfu/mL (T1), while T2 had the least value. This indicates enhanced bacterial proliferation at higher BSS inclusion.

Total coliform count ranged from 1.75 $\times 10^3$ cfu/mL (T1) to 2.20 $\times 10^3$ cfu/mL (T2), with T2 recording the highest value, closely followed by 2.10 $\times 10^3$ cfu/mL (T3), while T1 had the least value.

Total fungi count showed a similar trend, ranging from 2.30 $\times 10^3$ cfu/mL (T1) and 2.35 $\times 10^3$ cfu/mL (T2) to a significantly higher value of 3.20 $\times 10^3$ cfu/mL (T3), indicating improved fibre-degrading microbial activity at higher inclusion levels.

Protozoa population ranged from 3.00 $\times 10^3$ cells/mL (T3) to 5.00 $\times 10^3$ cells/mL (T2), with T1 recording 4.50 $\times 10^3$ cells/mL. T2 had the highest protozoa count, while T3 recorded the lowest value.

Table 8: Effects of black sunflower seed supplementation on hematological of WAD goats

Parameters	T1 (0g/100kg BSS)	T2 (25g/100kg BSS)	T3 (50g/100kg BSS)	SEM
PCV (%)	38	32	28	0.14
WBC ($\times 10^3/\mu L$)	9000.00^a	7000.00^b	5500.00^c	1591.89
Hb (g/dL)	12.15^a	10.60^b	9.30^c	1.24
RBC ($\times 10^6/\mu L$)	4.05^a	3.60^b	3.10^c	0.44
MCV (fL)	91.30^a	88.70^c	90.30^b	1.21
MCH (pg)	30.15	30.00	30.00	0.20
MCHC (g/dL)	33.15^b	33.40^a	33.20^{ab}	0.20
N (%)	53.00^b	65.00^a	65.00^a	5.94
L (%)	41.00^a	30.00^b	30.00^b	5.37
M (%)	3.50^a	2.00^b	2.00^b	0.80
E (%)	1.50^b	3.00^a	3.00^a	0.80
B (%)	1.00	1.00	1.00	0.17
PLT ($\times 10^3/\mu L$)	202.50^a	185.00^b	170.00^c	13.75

SEM- Standard error of mean; abc – means with different superscripts are significantly different (P<0.05) Packed cell volume (PCV), white blood cell count (WBC), haemoglobin concentration (Hb), red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), neutrophils (N), lymphocytes (L), monocytes (M), eosinophils (E), basophils (B), and platelet count (PLT)

Effects of black sunflower seed supplementation on hematological parameters of WAD goats

Table 8 presents the results for hematological parameters of WAD goats offered experimental diets (0g, 25 g, and 50g/100kg Black Sunflower Seed BSS additive). The parameters are Packed cell volume (PCV), white blood cell count (WBC), haemoglobin concentration (Hb), red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), neutrophils (N), lymphocytes (L), monocytes (M), eosinophils (E), basophils (B), and platelet count (PLT).

There were significantly differences (P < 0.05) in parameters like white blood cell (WBC), haemoglobin (Hb), red blood cell (RBC), mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC), neutrophils (N), lymphocytes (L), monocytes (M), eosinophils (E) and platelet (PLT) across the treatments while there were no significant differences among packed cell volume (PCV), mean corpuscular haemoglobin (MCH) and basophils (B).

T1 had the highest values for WBC (9000.00 $\times 10^3/\mu L$), Hb (12.15 g/dL) and RBC (4.05 $\times 10^6/\mu L$), while T3 recorded the lowest values for these parameters. The value of WBC ranged from 5500.00 $\times 10^3/\mu L$ (T3) to 9000.00 $\times 10^3/\mu L$ (T1), Hb ranged from 9.30 g/dL (T3) to 12.15 g/dL (T1), and RBC ranged from 3.10 $\times 10^6/\mu L$ (T3) to 4.05 $\times 10^6/\mu L$ (T1). T2 recorded intermediate values across these parameters.

Mean corpuscular volume (MCV) differed significantly across the treatments, with T1 recording the highest value (91.30 fL) and T2 the lowest value (88.70 fL), while T3 recorded an intermediate value (90.30 fL). Mean corpuscular haemoglobin (MCH) showed no significant difference across the treatments, with values ranging from 30.00 pg (T2 and T3) to 30.15 pg (T1).

Mean corpuscular haemoglobin concentration (MCHC) was significantly affected, with T2 recording the highest value (33.40 g/dL), T1 the least (33.15 g/dL), and T3 having an intermediate value (33.20 g/dL).

Among the differential white blood cell counts, neutrophils (N) were significantly higher in T2 and T3 (65.00%) compared to T1 (53.00%), while lymphocytes (L) and monocytes (M) were highest in T1 (41.00% and 3.50%, respectively)

and lowest in T2 and T3 (30.00% and 2.00%, respectively). Eosinophils (E) were significantly higher in T2 and T3 (3.00%) compared to T1 (1.50%), while basophils (B) showed no significant difference across the treatments, maintaining a constant value of 1.00%.

Platelet count (PLT) was significantly affected, with T1 recording the highest value (202.50 $\times 10^3/\mu L$), followed by T2 (185.00 $\times 10^3/\mu L$), and T3 recording the lowest value (170.00 $\times 10^3/\mu L$), with values ranging from 170.00 to 202.50 $\times 10^3/\mu L$.

Table 9: Effects of black sunflower seed supplementation on Serum Biochemical Indices of WAD goats

Parameters	T1 (0g/100kg BSS)	T2 (25g/100kg BSS)	T3 (50g/100kg BSS)	SEM
Glucose (mg/dL)	43.55^{c}	68.50^{a}	52.70^{b}	2.87
Total Cholesterol (mg/dL)	73.45 ^{b}	56.90^{c}	85.80^{a}	2.96
HDL-C (mg/dL)	36.50^{a}	25.90^{b}	36.20^{a}	1.21
LDL-C (mg/dL)	36.95^{b}	31.00^{c}	49.60^{a}	1.96
Blood Urea Nitrogen (mg/Dl	20.90^{a}	12.20^{c}	19.00^{b}	0.91
Creatinine (mg/dL)	1.29	1.21	1.21	0.04
Albumin (g/dL)	3.00^{c}	2.58	3.44^{a}	0.11
Globulin (g/dL)	3.48^{a}	3.60^{a}	2.64^{b}	0.11
Calcium (mg/dL)	10.00^{a}	8.09^{c}	8.95^{b}	0.19
Magnesium (mg/dL)	2.66	2.65	2.87	0.05
Sodium (mmol/L)	143.60^{b}	150.20^{a}	138.20^{c}	1.35
Potassium (mmol/L)	4.65	4.70	4.40	0.07
Iron (µg/dL)	85.65^{c}	136.60^{a}	88.60^{b}	5.68
Manganese (µg/L)	9.00	9.60	9.70	0.20
ALP (IU/L)	76.35^{b}	136.50^{a}	79.70^{b}	7.78
ALT (IU/L)	12.20^{c}	23.80^{b}	30.90^{a}	1.87
AST (IU/L)	92.85^{ab}	86.50^{b}	100.70^{a}	2.15

*SEM- Standard error of mean; abc – means with different superscripts are significantly different (P<0.05) ALP (Alkaline Phosphatase), ALT (Alanine Aminotransferase), and AST (Aspartate Aminotransferase), HDL-C (High-Density Lipoprotein Cholesterol) and LDL-C (Low-Density Lipoprotein Cholesterol)

Effects of Black Sunflower Seed Supplementation on Serum Biochemical Indices of WAD Goats

The results of serum biochemical indices of West African Dwarf (WAD) goats fed varying inclusion levels (0g, 25g and 50g/100kg of black sunflower seed (BSS) supplementation are presented in Table 9

Among the serum biochemical parameters, glucose, total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), blood urea nitrogen, albumin, globulin, calcium, sodium, iron, alkaline phosphatase (ALP), alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were significantly (P<0.05) affected by increasing levels of BSS supplementation, while creatinine, magnesium, potassium and manganese were not significantly affected across the treatments.

Across the treatments, T2 recorded the highest value for glucose (68.50 mg/dL), while T1 recorded the lowest value (43.55 mg/dL), with values ranging from 43.55 mg/dL (T1) to 68.50 mg/dL (T2). T3 recorded an intermediate value (52.70 mg/dL).

Total cholesterol and LDL-C were highest in T3, with values of 85.80 mg/dL and 49.60 mg/dL, respectively, while T2 recorded the lowest values (56.90 mg/dL and 31.00 mg/dL, respectively). Total cholesterol ranged from 56.90 mg/dL (T2) to 85.80 mg/dL (T3), while LDL-C ranged from 31.00 mg/dL (T2) to 49.60 mg/dL (T3).

High-density lipoprotein cholesterol (HDL-C) was highest in T1 (36.50 mg/dL) and comparable to T3 (36.20 mg/dL), while T2 recorded the lowest value (25.90 mg/dL), with values ranging from 25.90 mg/dL (T2) to 36.50 mg/dL (T1).

Blood urea nitrogen was significantly higher in T1 (20.90 mg/dL), followed by T3 (19.00 mg/dL), while T2 recorded the lowest value (12.20 mg/dL), with values ranging from 12.20 mg/dL (T2) to 20.90 mg/dL (T1). Creatinine showed no significant difference across the treatments, with values ranging from 1.21 mg/dL (T2 and T3) to 1.29 mg/dL (T1).

Albumin was highest in T3 (3.44 g/dL) and lowest in T1 (3.00 g/dL), while T2 recorded a lower value (2.58 g/dL). Globulin was highest in T2 (3.60 g/dL) and T1 (3.48 g/dL), while T3 recorded the lowest value (2.64 g/dL), with values ranging from 2.64 g/dL (T3) to 3.60 g/dL (T2).

Calcium was highest in T1 (10.00 mg/dL) and lowest in T2 (8.09 mg/dL), while T3 recorded an intermediate value (8.95 mg/dL). Sodium was significantly higher in T2 (150.20 mmol/L), followed by T1 (143.60 mmol/L), while T3 recorded the lowest value (138.20 mmol/L), with values ranging from 138.20 mmol/L (T3) to 150.20 mmol/L (T2).

Iron was highest in T2 (136.60 µg/dL), followed

by T3 (88.60 µg/dL), while T1 recorded the lowest value (85.65 µg/dL), with values ranging from 85.65 µg/dL (T1) to 136.60 µg/dL (T2). Magnesium, potassium, and manganese showed no significant differences across the treatments.

Among the enzyme activities, alkaline phosphatase (ALP) was highest in T2 (136.50 IU/L), while T1 (76.35 IU/L) and T3 (79.70 IU/L) recorded lower and comparable values. Alanine aminotransferase (ALT) was highest in T3 (30.90 IU/L), followed by T2 (23.80 IU/L), while T1 recorded the lowest value (12.20 IU/L), with values ranging from 12.20 IU/L (T1) to 30.90 IU/L (T3). Aspartate aminotransferase (AST) was highest in T3 (100.70 IU/L), followed by T1 (92.85 IU/L), while T2 recorded the lowest value (86.50 IU/L).

Discussion

Adesina (2018) reported the dry matter content of raw sunflower seeds as 90%, which is in consonance with the result in Table 4.1 of DM, which reported values from 86.32% (T2) to 93.64% (T1). However, the observed reduction in T2 and T3 is attributed to the oil nature of BSS, which can affect moisture retention and overall feed composition.

According to Adesina (2018), the crude protein value for raw sunflower seeds was reported as 27.02%, which is higher than the value range for crude protein in Table 4.1, which was from 16.68% (T2) to 18.23% (T3), although the value is expected since it is the current value of the formulated diets rather than pure seeds alone. The value falls within a recommended range of 12 to 18%, which is required for maintenance growth in WAD goats according to Adeola and Olatunji (2020). The increased value in T3 implied improved enrichment due to increased BSS inclusion in the diets.

Furthermore, Adesina (2018) reported that sunflower seeds are rich in oil fractions, and the value for Ether extract (EE) was significantly increased with BSS inclusion, which ranged from 5.00% (T2) to 7.19% (T3). Dietary fat increment would improve energy density and palatability, which enhances feed utilization efficiency.

Ogunmola *et al. (2019)* observed that oilseed-supplemented diets showed moderate fibre levels, with crude fibre values ranging from 12.88% (T3) to 14.12% (T2), and these align with values reported. The increment in fibre fractions with BSS inclusion is due to the hull component of sunflower seeds, which contributes structural carbohydrates.

Also, Neutral detergent fibre (NDF) values ranged from 68.20% (T1) to 72.25% (T3), while acid detergent fibre (ADF) ranged from 51.10% to 58.90% and acid detergent lignin (ADL) ranged from 25.45% to 32.30%. The constant increase in fibre fractions with higher BSS inclusion is due to the seed hulls, which formed the structural composition. Ogunmola *et al. (2019)* reported that goats supplemented with sunflower materials had improved NDF digestibility, suggesting that even though fibre fractions increased, there is still utilizable fibre depending on rumen microbial adaptation activity.

Adesina (2018) observed ash values of 4.61% to 5.46% for sunflower seeds; the values from the results, 9.71% to 15.32%, are higher than the reported values, which may be due to the contribution of other mineral-rich ingredients such as limestone in formulated diets.

Adejumo and Akinola (2024) reported similar values for calcium, which ranged from 0.30% to 0.35%, magnesium from 0.41% to 0.46%, and zinc from 10.70 to 13.40mg/kg. Mineral binding effects of phytochemicals such as tannins and phenolics may lead to a slight reduction in some mineral concentrations with increased BSS inclusion.

Among phytochemicals, phenolic content increased significantly from 50.22 mg/100g (T1) to 61.32 mg/100g (T3). This agrees with Adesina (2018), who reported that sunflower seeds contain notable phenolic compounds. The increase in phenolics with higher BSS inclusion is expected since these compounds are inherent components of oilseeds. Conversely, tannin and saponin levels decreased with increased BSS inclusion, which may indicate dilution effects from other dietary ingredients or variation in processing.

Table 2 showed the nutrient intake of WAD goats offered experimental diets; the value of Dry matter intake (DMI) ranged from 128.59g/day (T1) to 172.90g/day (T3). Report by Adeola and Olatunji (2020) showed that the values for DMI of goats fed oilseed supplemented during the dry season were 120.40 to 165.80g/day, which implied values similar to those presented in Table 4.2.

In addition, Abiodun *et al.,* (2023) reported DMI values between 130.25 to 158.60g/day in

indigenous goats fed supplementary diets during the dry season. T3 showed higher DMI across the treatments, and it may be attributed to increased dietary energy density and improved palatability resulting from higher ether extract content (7.00g/day).

Crude protein intake (CPI) values reported by Adeola and Olatunji (2020) ranged from 18.20 to 24.60g/day in WAD goats fed with oilseed by-products. T1 (19.48g/day) showed a trend pattern with the reported range, while T3 (26.75g/day) was higher than the reported values.

Bamidele and Salami (2021) revealed that nitrogen intake is equivalent to crude protein intake within 17.80 and 23.90g/day. T3 (26.75g/day) values supersede the reported values. The higher crude protein intake shown in T3 is due to the increased crude protein concentration (18.23%) in the diet and higher dry matter intake. The increase enhances microbial protein synthesis, improves rumen ammonia availability, and promotes greater voluntary intake.

Ogunmola *et al.* (2019) reported crude fibre intake ranging from 14.50 to 20.30g/day and the results showed a similar trend, with 16.02 to 22.24g/day, T1 (16.02 g/day) falls within the reported range, while T3 (22.24g/day) was higher than the reported value. Higher fibre intake in T3 is expected due to an increase in NDF (72.25%) and ADF (58.90%) levels in the formulated diets.

Adesina (2018) reported that sunflower-based diets could contribute ether extract levels corresponding to intake values between 5.10 and 6.85 g/day in formulated ruminant diets. The value obtained in T3 (7.00 g/day) is slightly higher than this reported upper range. The increase in ether extract intake is directly attributable to the high oil content of black sunflower seeds.

Goats fed oilseed supplements had NDF intake rates ranging from 70.45 to 95.60 g/day, according to Ogunmola *et al*., (2019). While T3 (102.11 g/day) is higher than 95.60 g/day, T1 and T2 values are within their reported range. The range of lignin intake was 15.64 to 22.08 g/day, and the range of ADF intake was 43.34 to 57.82 g/day. The ADF consumption levels reported by Ogunmola *et al.,* (2019) ranged from 40.10 to 55.30 g/day, which is slightly less than T3 (57.82 g/day) but equivalent to T1 and T2. The hull percentage of sunflower seeds, which contains lignified tissues, may be the cause of T3's increased lignin intake. Despite being indigestible, lignin consumption does not affect overall digestibility and stays below physiologically acceptable limits, as shown in Table 3.

Table 3 showed the nutrient digestibility coefficient of WAD goats offered experimental diets. Adeola and Olatunji (2020) reported dry matter digestibility values ranging between 72.40% and 84.60% in WAD goats fed oilseed-based supplements, and the value obtained in T1 (84.29%) falls within their reported range.

Similarly, Ogunmola *et al.,* (2019) reported DMD values of 70.85% to 83.10% in goats fed sunflower-derived diets; T3 exceeded this upper range. The higher DMD observed in T3 may be attributed to improved rumen fermentation resulting from better synchronization of energy (ether extract 7.00 g/day) and protein (26.75 g/day intake), which enhances microbial proliferation and enzymatic breakdown of feed components.

Bamidele and Salami (2021) revealed that indigenous (WAD) goats fed diets supplemented with protein had CP digestibility values ranging from 75.60% to 85.40%. While T3 CP digestibility (88.37%) exceeds the reported maximum (85.40%), T1 (83.88%) and T2 (81.12%) digestibility fall within this range.

The CP digestibility values reported by Abiodun *et al.,* (2023) ranged from 78.25% to 84.90%, which is marginally less than the 88.37% found in T3. Increased rumen ammonia availability and better microbial protein synthesis brought on by greater dietary protein levels may be connected to T3's superior CP digestibility. By creating protective compounds, moderate fat inclusion may also lessen losses from protein breakdown.

In goats fed diets based on oilseeds, Ogunmola *et al.,* (2019) reported crude fibre digestibility values ranging from 55.20 % to 70.10 %. T1 (61.33%) value is within their range, while T3's (74.70%) value is slightly higher. However, T2 is significantly lower than its reported minimum (55.20%), at 39.28 %. At moderate fat inclusion levels, transitional rumen adaptation may be the cause of the decreased digestibility of fibre in T2. On the other hand, T3's high crude fibre digestibility suggests enhanced fibrolytic microbial activity, possibly as a result of rumen microbes' adaptive response to oil supplementation.

According to Adesina (2018), goats fed diets based on sunflowers had digestibility values ranging from 85.60% to 92.10 % for ether extract. This study's values fall entirely within

the reported range, indicating consistency with previous research. Lipids are highly digestible energy sources when included below inhibitory thresholds, so high fat digestibility is to be expected.

Ogunmola *et al.,* (2019) reported that NDF digestibility ranged from 68.40% to 82.75%. T1 (81.32%) values are within this range, while T3 (86.89%) values are slightly higher than the maximum reported (82.75%). T2 is still within the range, but at the lower end. The higher T3 digestibility for NDF suggests that rumen stability and increased nitrogen availability may have aided cellulolytic bacterial activity.

The digestibility of ADF varied between 66.52% (T2) and 82.34% (T3). Adeola and Olatunji (2020) found that ADF digestibility ranged from 60.30 percent to 78.50 percent. T1 (75.34 %) is within this range, while T3 (82.34%) is slightly higher. Improved lignocellulosic fraction breakdown may be the cause of T3's increased ADF digestibility, which may be attributable to increased microbial enzymatic efficiency.

The digestibility of lignin ranged from 52.84% in T2 to 77.47% in T3. Ogunmola *et al. (2019)* reported lignin digestibility in goats to be between 45.00% and 65.00%. T1 (65.15%) is at the upper end of this range, and T3 (77.47%) is higher than commonly reported values. The higher lignin digestibility observed in T3 may reflect improved detachment of lignin-carbohydrate complexes, enhancing apparent digestibility rather than true lignin degradation.

The digestibility of cellulose ranged from 74.20% to 85.44%, while the digestibility of hemicellulose ranged from 89.54% to 92.82%. According to Abiodun *et al.* (2023), the digestibility of cellulose ranged from 70.10% to 82.50%, indicating that T3 (85.44 percent) is slightly higher than previous estimates. Adeola and Olatunji (2020) reported that hemicellulose digestibility values ranged from 85.0% to 90.80%, which are comparable to T1 and T2, while T3 (92.82%) is slightly higher. Optimized rumen microbial synergy and adequate nitrogen-energy synchronization may be to blame for T3 improved structural carbohydrate digestibility.

Table 4 presented nitrogen retention of wad goats offered experimental diets. Ajayi *et al.* (2018) reported urinary nitrogen losses ranging between **0.90 and 1.72 g/day** in growing goats fed oilseed cake supplements. The value recorded in T1 (0.95 g/day) falls within this range, while T2 (1.55 g/day) approaches their upper limit. However, the value observed in T3 (0.68 g/day) is lower than their reported minimum.

Similarly, Olafadehan and Adewumi (2010) reported urinary nitrogen excretion values between **0.82 and 1.60 g/day** in goats fed concentrate-based supplements. The reduced urinary nitrogen observed in T3 suggests superior nitrogen conservation compared to these reports. The lower urinary nitrogen in T3 indicates reduced nitrogen wastage through urea excretion and improved incorporation of absorbed nitrogen into body tissues.

Olafadehan (2011) found that WAD goats fed protein-energy supplements had fecal nitrogen levels between 0.48 and 0.75 g/day. The values from this study are within the reported range, which indicates that they are comparable to previous findings. Since undigested nitrogen is frequently associated with lignified fiber fractions, the slightly elevated fecal nitrogen in T2 (0.69 g/day) may be indicative of decreased fiber digestibility previously observed.

Daramola *et al.,* (2005) reported digested nitrogen values ranging from **1.25 to 2.95 g/day** in goats supplemented with oilseed meals. The value observed in T1 (1.67 g/day) is within this range, whereas T3 (3.35 g/day) is higher than the maximum value reported (2.95 g/day). The higher digested nitrogen in T3 corresponds with the elevated crude protein digestibility (88.37%) recorded earlier, indicating enhanced intestinal nitrogen absorption.

Ososanya *et al.,* (2013) found that WAD goats fed concentrate supplements retained between 46.80% and 69.20% of nitrogen. T1 (52.47%) value is within their reported range, whereas T2 (44.21%) value is slightly lower. T3, on the other hand, exceeds their upper limit by 73.41%. In a similar trend, Babayemi *et al.* (2006) reported that goats fed mixtures of browse and concentrate had nitrogen retention rates ranging from 48.00% to 71.00%. Again, the upper limit of previously reported values is slightly exceeded by T3. The following factors may be responsible for the significantly higher nitrogen retention found in T3 improved coordination between fermentable carbohydrates and protein that breaks down in the rumen Enhanced bacterial protein production reduced loss of nitrogen from the urine (0.68 g/day) a rise in digested nitrogen (from 3.35 g/day) Effective use of post-ruminal amino acids Increased urinary nitrogen excretion (1.55 g/day) and lower nitrogen retention in T2 may indicate partial inefficiency in nitrogen utilization at moderate BSS inclusion.

Table 5 shows the effects of feeding varying additive levels of black sunflower seed additive on rumen fermentation characteristics in WAD goats**.** Goats fed diets supplemented with oilseed were found to have total VFA concentrations ranging from 75 to 120 mmole/100 ml, according to Wanapat *et al.* (2016). T1 (129.21 mmole/100 ml) is slightly higher than their upper limit, T3 (90.52 mmole/100ml) is within the reported range, and T2 (62.05 mmole/100 ml) is lower than the minimum that was reported. In a similar trend, Patra and Yu (2015) reported that goats fed lipid-enriched diets had VFA concentrations ranging from 70 to 115 mmole/100 ml. Once more, T1 is higher than their maximum, T3 is within their range, and T2 is lower. According to Beauchemin *et al.,* (2020), moderate lipid inclusion can temporarily suppress fibrolytic bacteria before microbial adaptation occurs, and the reduction in TVFA at 10% inclusion (T2) suggests partial inhibition of rumen microbial fermentation. The rumen microbial adaptation to higher lipid inclusion is indicated by the recovery observed in T3.

Jayanegara *et al.* (2018) reported acetate concentrations ranging between 6.50 and 9.80 mmole/100 ml in goats fed oilseed supplements. T1 falls within this range; T3 is slightly lower but comparable, whereas T2 is below the reported minimum.

Acetate is predominantly produced from fibre fermentation. The depressed acetate in T2 corresponds with the earlier reduced crude fibre digestibility (39.28%), indicating temporary suppression of cellulolytic bacteria. At 20% inclusion, improved acetate concentration suggests microbial adaptation and restoration of fibre fermentation efficiency.

Goats supplemented with sunflower oilseed, Kholif *et al. (2017),* reported propionate concentrations ranging from 4.80 to 8.10 mmole/100 ml. T3 is within this range, while T1 and T2 are slightly higher and lower than their minimums. Non-structural carbohydrate fermentation is reflected in the production of propionate. Active carbohydrate fermentation is suggested by the relatively high propionate levels in T1. A shift away from excessive glucogenic fermentation and toward a more balanced fermentation is indicated by a moderate reduction in T3.

Elghandour *et al.* (2018) reported butyrate concentrations ranging from **3.50 to 7.80 mmole/100 ml** in goats fed plant oil additives. T2 falls within their range, while T1 and T3 slightly exceed the maximum range reported. Higher butyrate concentrations are often associated with improved rumen epithelial health and enhanced microbial fermentation efficiency. The elevated value in T3 suggests improved rumen metabolic activity.

Plaizier *et al,* (2018) indicated that lactic acid concentrations above **10 mmole/100 ml** may predispose animals to subacute ruminal acidosis. T2 and T3 fall below this threshold, whereas T1 slightly exceeds it (11.34 mmole/100 ml). Beauchemin *et al. (2020)* reported an optimal rumen pH range between **5.8 and 6.5** for optimal microbial activity. T2 falls within this optimal range, while T1 and T3 are slightly lower but still within tolerable physiological limits. The lower pH in T1 corresponds with the highest VFA concentration (129.21 mmole/100 ml), indicating intensive fermentation activity. Hristov *et al.* (2019) reported optimal ammonia nitrogen concentrations for microbial protein synthesis ranging between **0.20 and 0.50 mmole/100 ml**. All values recorded in this study fall within this optimal range. This indicates adequate rumen degradable protein supply across treatments and supports the improved nitrogen retention observed in T3.

Table 6 presented the effects of feeding varying inclusion levels of black sunflower seed additive on rumen microbial population in WAD goats. The value range of Total bacterial count ranged from 6.10 to 8.20 $\times 10^6$ cfu/ml; T2 had the lowest value, while T3 had the highest. These values were in a similar reported physiological range for goats; Patra and Yu (201%) observed total bacterial counts in goats ranging from 106 and 109 cfu/ml, based on the composition of the diet offered to the animals, which is relatively in the same trend as the value reported in T3.

In addition, Li *et al. (2019)* observed bacterial counts ranging from 7.0 to 8.5 $\times 10^6$ cfu/ml when goats were fed lipid-supplemented diets, in which T1 and T3 were within the range reported. Also, Ogunade et al. (2018) reported that higher bacterial densities in goat diets may be due to increased structural carbohydrate, which supports fibrolytic bacterial proliferation. Likewise, Zhang et al. (2020) reported lower bacterial counts as a result of a decline in cellulolytic bacterial abundance due to the antimicrobial effects of unsaturated fatty acids. The T2-reduced bacterial count is a result of the inhibitory action of sunflower seed lipid on Gram-positive fibrolytic bacteria. The

subsequent increase at 20% inclusion suggests microbial adaptation and possible enrichment of lipid-tolerant bacterial populations, a phenomenon previously documented under progressive fat supplementation strategies.

Total coliform count ranged from 1.75 to 2.20 $\times 10^3$ cfu/ml, with higher values recorded in BSS-supplemented diets. These values are comparable to those reported by Jami *et al.,* (2017), who observed coliform counts within 10^3 cfu/ml range in small ruminants under concentrate-rich feeding systems. However, higher coliform populations (above 3.0 $\times 10^3$ cfu/ml) were reported by Liu *et al.,* (2019) in goats fed high-grain diets, likely due to increased readily fermentable carbohydrates that favor facultative anaerobic bacteria. Lower coliform levels than those observed in this study were reported by Huws *et al. (2018) under high-fibre* feeding regimes, suggesting that structural carbohydrate-rich diets promote dominance of strictly anaerobic fibrolytic bacteria over coliform species. The moderate increase in coliform population at 25g and 50g/100kg BSS inclusion in this study may be linked to temporary ecological shifts following lipid inclusion, where suppression of certain dominant bacterial groups creates ecological niches for facultative anaerobes. Nevertheless, the values remain within acceptable rumen microbial ranges and do not indicate pathological dysbiosis.

The total fungal count ranged from 2.30 to 3.20 $\times 10^3$ cfu/ml, with the highest value at 50g/100kg BSS inclusion. These values are comparable to 1.8–3.5 $\times 10^3$ cells/ml reported by Belanche *et al.* (2016) in forage-fed goats, indicating they fall within the normal physiological range. Higher counts (4.0–5.0 $\times 10^3$ cells/ml) were reported by Tapio *et al.* (2017) under high-fibre diets, whereas lower values (<2.0 $\times 10^3$ cells/ml) were observed by Wang et al. (2019) following high lipid supplementation due to inhibition of fungal activity. The increased fungal population at 20% BSS may reflect improved fibre accessibility and microbial adjustment following protozoal suppression, suggesting enhanced fibrolytic potential, while the lower values at 0g and 25g /100kg inclusion may indicate limited adaptation or mild lipid-related inhibition.

Protozoal population ranged from 3.00 to 5.00 $\times 10^3$ cells/ml, with the highest value at 10% BSS inclusion and the lowest at 50g/100kg inclusion. These values fall within the range of 10^3–10^5 cells/ml reported by Newbold *et al.* (2015) for small ruminants. Higher protozoal densities have been observed by Park *et al.* (2018) under high-starch diets that favour protozoal proliferation

whereas Guyader I. (2017) reported lower counts following lipid supplementation due to the defaunation effects of unsaturated fatty acids. The decline at 50g/100kg BSS in the present study is therefore consistent with lipid-induced protozoal suppression, likely resulting from disruption of protozoal cell membranes. Nutritionally, reduced protozoa may be beneficial, as fewer protozoa decrease bacterial predation, thereby enhancing microbial protein flow and nitrogen utilization in WAD goats.

Table 7 presents the effects of black sunflower seed supplementation on hematological indices of WAD goats. Packed cell volume (PCV) values recorded were 38% (T1), 32% (T2), and 28% (T3)**.** Odo *et al.* (2019) reported PCV values ranging from 27% to 40% in WAD goats fed concentrate-based diets. Similarly, Akinyemi *et al.* (2020) documented PCV values between 29% and 37% in goats supplemented with oilseed meals. The values obtained in this study fall within these reported ranges, although the value in T3 (28%) lies close to the lower boundary. The gradual decline in PCV with increasing BSS inclusion may reflect a slight reduction in erythropoietic activity or mild hemodilution associated with higher lipid intake, but since values remained within physiological limits, no clinical anaemia is indicated.

Hemoglobin (Hb) concentrations were 12.15 g/dL (T1), 10.60 g/dL (T2), and 9.30 g/dL (T3)**.** Ewuola *et al. (2018)* reported Hb values between 8.50 and 13.00 g/dL in goats fed lipid-based supplements, while Abd-Allah *et al.* (2016) documented values ranging from 9.00 to 12.50 g/dL in healthy goats. All Hb values observed in this study fall within these reported physiological ranges. Although Hb decreased at 50g/100kg BSS inclusion, the value (9.30 g/dL) remains within normal limits, indicating that oxygen-carrying capacity was not compromised.

Red blood cell (RBC) counts ranged from 4.05 $\times 10^6/\mu L$ (T1), 3.60 $\times 10^6/\mu L$ (T2), to 3.10 $\times 10^6/\mu L$ (T3)**.** Ojebiyi *et al. (*2017) reported RBC values of 2.80–4.50 $\times 10^6/\mu L$, while Oladele *et al.* (2019) documented values between 3.00 and 4.60 $\times 10^6/\mu L$ in indigenous goats. The values obtained in this study are consistent with these ranges. The gradual reduction in RBC at higher inclusion levels may be linked to alterations in

erythrocyte membrane composition influenced by dietary lipids; however, the counts remain physiologically adequate.

White blood cell (WBC) counts recorded were 9000 ×10³/µL (T1), 7000 ×10³/µL (T2), and 5500 ×10³/µL (T3)**.** Yakubu *et al.* (2018) reported WBC values between 4,000 and 12,000 ×10³/µL, while Ibrahim *et al.* (2020) documented 5,000–11,500 ×10³/µL in goats fed oilseed supplements. The WBC values in this study fall within these reported ranges. The reduction in WBC with increasing BSS inclusion may indicate reduced systemic inflammatory stimulation or improved immune stability, rather than immunosuppression.

Mean corpuscular volume (MCV) ranged from 88.70 to 91.30 fL. Mean corpuscular hemoglobin (MCH) values of 30.00–30.15 pg and mean corpuscular hemoglobin concentration (MCHC) values of 33.15–33.40 g/dL also fall within reported ranges of 28–32 pg for MCH and 30–36 g/dL for MCHC (Njidda *et al.,* 2019). These stable indices indicate the absence of macrocytic, microcytic, or hypochromic anemia across treatments. Differential leukocyte counts further support physiological normalcy. Neutrophil percentages ranged from 53% to 65%**,** while lymphocytes ranged from 30% to 41%**.** Akinmoladun *et al.* (2021) reported neutrophil values between 50 and 70% and lymphocytes between 30 and 45% in healthy goats. Monocytes (2 to 3.5%), eosinophils (1.5 to 3%), and basophils (1%) observed in this study also fall within the normal ranges of 2–5%, 1–4%, and 0–2**%,** respectively, as reported by Ibrahim *et al.* (2020). The slight increase in neutrophils at higher inclusion levels may reflect enhanced innate immune surveillance rather than a pathological response.

Platelet counts ranged from 202.50 ×10³/µL (T1) to 170 ×10³/µL (T3)**.** According to Ewuola *et al.* (2018), platelet counts in goats typically range between 150 and 300 ×10³/µL, placing all observed values within normal physiological boundaries. The gradual reduction in platelet count with increased BSS inclusion remains within acceptable limits and does not suggest impaired hemostatic function.

Table 8 presents the effects of black sunflower seed supplementation on serum biochemical indices of WAD goats. Serum glucose increased significantly at 25g/100kg BSS (68.50 mg/dL) compared to 0g/100kg (43.55 mg/dL) and 50g/100kg (52.70 mg/dL). These values fall within the normal range for goats (40–75 mg/dL), as reported by Olafadehan *et al*. (2017). The elevated glucose at 25g/100kg inclusion may reflect improved energy availability and enhanced propionate production, whereas the moderate reduction at 50g/100kg could indicate metabolic adjustment to higher lipid intake.

Total cholesterol and LDL-C were highest at 50g/100kg BSS (85.80 and 49.60 mg/dL), consistent with reports by Adeyemi *et al.* (2016) and Zhang *et al.* (2019) that lipid supplementation elevates circulating cholesterol fractions due to increased dietary fat absorption. Conversely, HDL-C declined at 25g/100kg but was maintained at 50g/100kg, suggesting adaptive lipid metabolism. All cholesterol values remained within physiological limits for healthy goats.

Blood urea nitrogen (BUN) was highest at 0g/100kg BSS (20.90 mg/dL) and lowest at 25g/100kg (12.20 mg/dL), similar to the 10–25 mg/dL range reported by Kaneko *et al.* (2015). The reduced BUN at 25g/100kg BSS inclusion may indicate improved nitrogen utilization and reduced ruminal ammonia loss, possibly linked to partial protozoal suppression. Creatinine values (1.21–1.29 mg/dL) showed no significant difference and were within normal limits (1.0–1.5 mg/dL), suggesting no adverse effect on kidney function.

Albumin increased at 50g/100kg BSS (3.44 g/dL), while globulin decreased (2.64 g/dL), remaining within the normal 2.5–4.5 g/dL range for goats (Daramola *et al.,* 2018). The rise in albumin at higher inclusion may indicate improved protein synthesis and hepatic function, whereas the lower globulin could reflect mild modulation of immune response rather than pathology.

Calcium was highest at 0g/100kg (10.00 mg/dL) but remained within the normal 8–12 mg/dL range (Olafadehan *et al.,* 2017). Magnesium, potassium, and manganese were not significantly affected, indicating stable mineral metabolism. Sodium increased at 25g/100kg inclusion (150.20 mmol/L) but remained within physiological limits, suggesting no electrolyte imbalance. Iron concentration peaked at 25g/100kg (T2) (136.60 µg/dL), possibly due to improved mineral absorption facilitated by moderate lipid inclusion.

Liver enzymes showed significant variation: ALP and ALT increased at 25g and 50g/100kg

inclusion, while AST was highest at 50g/100kg. However, values remained within reference ranges reported for goats (ALT: 10–35 IU/L; AST: 60–120 IU/L; ALP: 70–150 IU/L) (Kaneko *et al.,* 2015). The moderate elevation at higher inclusion levels may reflect increased hepatic metabolic activity associated with lipid metabolism rather than hepatic damage.

Overall, black sunflower seed supplementation, particularly at 25g and 50g/100kg inclusion, influenced energy metabolism, lipid profile, and nitrogen utilization without inducing pathological alterations, as all biochemical indices remained within normal physiological ranges for WAD goats.

CONCLUSION

This study assessed the impacts of black sunflower seed (BSS) as a dry season feed additive on the performance of WAD goats. Varying levels of BSS as a dietary additive improved the nutritional composition of the diets, which increased crude protein, ether extract and fibre fractions. WAD goats fed BSS diets demonstrated higher feed intake and efficient nutrient digestibility, enhanced nitrogen retention, indicating improved nutrient utilization. Rumen fermentation and haematological parameters remained within normal ranges, confirming no adverse health effects on the animals.

Among the treatments, T3 (50g/100kg BSS dietary additive) demonstrated positive results across all parameters. Thus, Black sunflower seed is an effective dry season feed additive, with 50g/100kg inclusion identified as the optimal level for improved performance of WAD goats.

BSS in order to determine whether greater concentrations can produce additional improvements in animal performance, nutrient utilization, and digestibility, as well as to establish the optimum inclusion level beyond the 50 g/100 kg used in the present study.

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