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Performance and Thermo-Physiological Responses to Heat Tolerance Coefficient of Sheep Offered Diets Supplemented with Lemon Seed Powder in Tropical Humid Zone of Nigeria

Okoruwa M. I.[1]*, Ikhimioya I.[2]
[1,2] Department of Animal and Food Sciences, Faculty of Agriculture, Natural Resources and Food Science. Ambrose Alli University, P.M.B. 14, Ekpoma, Edo State, Nigeria

ABSTRACT: The study was carried out to determine the effect of dietary supplementation with lemon seed powder on growth, nutrient digestibility, blood indices with thermo-physiological parameters, heat stress and heat tolerances co-efficient of West African dwarf sheep. Two hundred West African dwarf male sheep aged etween 7 and 8 months old with initial average live body weight of 7.00 ± 0.15kg were used for the study. They were randomly allotted to four dietary treatments with fifty sheep per treatment in a completely randomized design. The prepared experimental diets that were offered to sheep comprised TD_1 (60% guinea grass with 40% formulated diet that contained no lemon seed powder as control group), TD_2 (60% guinea grass with 40% formulated diet that contained 0.50% lemon seed powder), TD_3 (60% guinea grass with 40% formulated diet that contained 1.00% lemon seed powder) and TD_4 (60% guinea grass with 40% formulated diet that contained 1.50% lemon seed powder). All parameters obtained in the study were subjected to one-way analyses of variance (ANOVA). Results showed that feed conversion ratio (4.28), digestibility of ether extract (70.13%), faecal with urinary nitrogen output (4.05 and 1.87g/day), total nitrogen output (5.92g/day), cholesterol (64.01mg/dl), creatinine (1.03mg/dl), urea (11.96mg/dl), relative humidity (morning 95.92%, midday 60.73% & evening 90.73%), rectal temperature (morning 38.70 ^{0}C, midday 39.76 ^{0}C & evening 38.96^{0}C), respiratory rate (morning 24.36 breaths/min, midday 25.43 breaths/min & evening 24.73 breaths/min), heart rate (morning 83.92 beats/min, midday 89.71 beats/min & evening 80.23 beats/min), skin surface (morning 29.01 ^{0}C, midday 32.46 ^{0}C & evening 30.67^{0}C), temperature humidity index (morning 73. 37, midday 80.94 & evening 73.33), black globe humidity index (morning 75.48, midday 79.82 & evening 77.34) and heat stress index (morning 79.55, midday 82.70 & evening 75.77) were significantly ($p<0.05$) higher in diet TD_1 than diets TD_2, TD_3 and TD_4. Sheep on diet TD_4 were significantly ($p<0.05$) increased in daily feed intake (264.32g/day), final body weight (13.52kg), total with daily weight gain 6.39kg and 71.00g), digestibility of dry matter(71.02%), crude protein (72.04%), crude fiber (70.41%), ash (67.14%), nitrogen free extract(70.76%), neutral and acid detergent fiber (68.16 and 60.37%), nitrogen intake (14.06g/day), nitrogen balance (9.82g/day), nitrogen retention % intake (69.84%), packed cell volume (28.07%), haemoglobin (10.47g/dl), red blood cell (9.63 x10^6/ml), mean corpuscular value (34.37fl), mean corpuscular haemoglobin (10.46pg), mean corpuscular haemoglobin concentration (32.75%), white blood cell (11.02 x10^6/ml) lymphocytes (62.18%), neutrophils (32.87%), total protein (8.01g/dl), albumin (4.16g/dl), glucose (70.02 mg/dl), Benezra heat tolerance co-efficient (morning 1.86, midday 1.86, & evening 1.83), Iberia heat tolerance co-efficient (morning 135.10, midday 121.20 & evening 140.80), Rhoad heat tolerance index (morning 128.64 & evening 134.53), Singh physiological response index (morning 0.93, midday 0.94 & evening 0.92) and Davis heat tolerance coefficient (morning 0.90, midday 0.90, & evening 0.90) than those on other diets. Meanwhile, no significant differences ($p>0.05$) were found in initial body weight, nitrogen retained in gram per day, eosinophils, monocytes, basophils, globulin, triglycerides, dry bulb temperature, dew point temperature, black globe temperature, sweating rate, and midday Rhoad heat tolerance co-efficient index. It can be concluded that diets TD_3 and TD_4 that contained 1.00% and 1.50% lemon-seed powder improved performance, boost immunity and heat tolerance co-efficient with reduced heat stress in sheep.

KEYWORDS: lemon seed powder, performance, thermo-physiological responses, sheep

INTRODUCTION

Ruminant livestock provides the major affordable quality of animal protein through milk and meat to human populace in Nigeria. These animal products contribute significantly to the nutritional needs and economic livelihoods of humans as global food security in the tropics (FAO, 2020). However, achieving optimal growth and healthier performance remain the major challenges affecting sheep productivity in rural communities. The conversion of large area of natural grassland to arable farm land and human settlement due to continue increase in human population have led to inadequate availability of grass forages for sheep production in the humid tropic region (Aregawi, 2014). The fewer quantity and quality of available forages are always deteriorated in the dry season which adversely affects sheep performance. Therefore, any intervention that will provide good nutritive feed during the dry season is strategic in the alleviation of poor-quality forage production. The use of unconventional feeds such as agro-industrial by-products in sheep nutrition are important options in this regard. Okoruwa and Eguabor (2025), found that consumption of poor-quality feeds by sheep can be enhanced to some extent by supplementation with agro by-products. Though they reduce feeding expenses, most of them are not usually degradable in their nutritive values due to their high fiber component materials and residual content of anti-nutrients.

Furthermore, addition of herbal plant materials to poor quality feeds of animals have attracted ruminant researchers due to their low risk of residue impact, less poisonous and their potential or integrity which can boost animal's productivity (Al-Suwaiegh, 2023). They also possess medicinal, antimicrobial and antioxidant properties that improve feed utilization, body physiological status and growth rate of sheep. Base on these fore mentioned benefits, there are needs for ruminant nutritionists to increase their interest in improving the utilization of poor-quality feeds with herbal plant-based feed resources as feed supplements to enhance sheep performance. Lemon seed powder is one of such herbal plant materials that can support immune system and feed efficiency in livestock (Sharoba *et al.,* 2013). However, lemon seed has phytochemical bioactive components; such as flavonoids, limonoids and phenolic acids that can limit the potentials when consumed in high quantity by livestock. Notwithstanding, the used of lemon seed powder in sheep production is limited, hence this study was carried out. The objective of this study therefore, was to determine the dietary inclusion effects of lemon seed powder on performance and thermo-physiological responses to heat tolerance co-efficient of sheep in tropical humid zone of Nigeria.

MATERIALS AND METHODS

Study Area and Experimental Duration

This study was conducted at the Small Ruminant Unit of the Teaching and Research Farm, Faculty of Agriculture, Natural Resources and Food Science, Ambrose Alli University, Ekpoma, Nigeria. The area lies on longitude 6.09^{0}E and latitude 6.42^{0}N within the humid tropic climatic zone of Nigeria. The mean annual rainfall and temperature of the region are about 1556mm and 31^{0}C respectively, with average relative humidity of about 80% (Oyewole *et al.*, 2018). Duration of the experiment was 126 days which is a total of 4 to 5 months that started, from August/September 2025 and ended November/December 2025.

Experimental Diets

Succulent guinea grass was obtained at the university farm at re-growth stage of between 8 and 9 weeks and allowed to wilt overnight before it was chopped with an electric forage cutter (forage SFC1400, Central Commercial Company, Osaka, Japan) into small sizes of approximately 4 to 5cm lengths to ease feed consumption as a basal diet. Lemon seed was collected from local lemon fruit juice processing center, sun dried for five days to get a constant dry weight. Thereafter, they were milled to pass through a 0.15mm sieve to obtain lemon seed powder and stored in airtight bag at room temperature. Different proportions of the lemon seed powder were in the following inclusion levels; 0%, 0.50%, 1.00% and 1.50% with other feed ingredients that were used to prepare the four compared supplementary diets as showed in Table, 1. However, basal and supplementary diets were offered in a ratio of 60: 40 to the sheep respectively. The prepared treatment diets comprised the following; TD_1 (60% guinea grass with 40% formulated diet that contained no lemon seed powder as control group), TD_2 (60% guinea grass with 40% formulated diet that contained 0.50% lemon seed powder), TD_3 (60% guinea grass with 40% formulated diet that contained 1.00% lemon seed powder), and TD_4 (60% guinea grass with 40% formulated diet that contained 1.50% lemon seed powder)

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Table 1. Gross composition (%DM) of supplementary diets

Ingredients	Treatment Diets			
	TD_1	TD_2	TD_3	TD_4
Wheat bran	35.00	34.00	33.00	32.00
Dried brewers grain	27.00	26.00	25.00	24.00
Maize offal	21.00	22.50	24.00	25.50
Cowpea Husk	7.00	7.00	7.00	7.00
Broken groundnut/shell	5.00	5.00	5.00	5.00
Lemon seed powder	-	0.50	1.00	1.50
Bone meal	2.50	2.50	2.50	2.50
Vitamin premix	1.50	1.50	1.50	1.50
Salt	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00

Experimental Design, Animals and Management

A total of two hundred intact West African dwarf male growing sheep of about 7 to 8 months old with an average initial body weight of 7.00 ± 0.15kg were used for the study. On their arrival, they were confined for a preliminary period of fourteen days to allow them adapted to the environment and treated against internal and external parasites. After the adaption period, they were randomly assigned to the four treatment diets. Each treatment contained 50 sheep with two replicates per treatment and each replicate consist of 25 sheep. However, treatments were applied in a completely randomized design. They were housed in individual semi-open partitioned pens, equipped with feeders and water troughs. The saw dust was changed twice weekly through the study. Diets that were offered to each sheep twice daily (8:00am and 4:00pm) were calculated on the basis of 5% dry matter of their body weight. The ratio of the basal diet of guinea grass to each of the supplementary diet was used to determine the proportion of each diet that was offered to the sheep. The amount of diet supplied to each sheep was adjusted daily based on the voluntary intake of the sheep with an estimated leftover of 15%. They had free access to drinking water and similar management practices irrespective of their treatment group. The feeding trial lasted for 90 days while the thermo-physiological study took 36 days making a total of 126 days exclusive the 14 days of acclamation period

Variables Measured

Growth Study

The average daily feed intake was determined by the difference between the amount of feed given and leftover. Initial body weight of sheep was weighed and recorded at the beginning of the experiment. Subsequently, weekly weighing was done by using the measuretech® hanging scale, prior to morning feeding to estimate change in body weight. Total body weight was done by difference between the final and initial body weight. The average daily weight gain was calculated from weekly weight in individual sheep over the entire period of the trial. However, daily feed intake with body weight gain was used to calculate the feed conversion ratio.

Nutrient Digestibility and Nitrogen Retention

After the growth study, the experiment preceded by a 14-day metabolic trial to determine apparent nutrient digestibility and nitrogen retention of the diets. Twenty sheep of similar body weight were randomly selected from each experimental treatment group and housed separately in individual metabolic cages designed for feeding, watering with separate collection of faeces and urine. Feed given, leftover, faeces and urine were collected, weighed and recorded daily for duration of 14days, which comprised a 7-day of total collection after a 7-day of adaption period. A sub-sample of about 10% of the total faecal output was taken and bulked before properly mixed and pooled for each animal before stored in plastic container and freeze (-20%) for later analysis. Urine from each animal was also collected in a plastic container containing 100 ml of 3.6 mol/L H_2SO_4. The collected urine was strained through a layer of grass wool to remove detached hair fragments and other solid contaminants. The volume was measured and then diluted to 5 L using tap water and a sample of 20 ml was collected, pooled for each animal to prevent loss of nitrogen due to volatilization before stored at -20^{0}C for total nitrogen determination. Nutrient Digestibility (ND) of each treatment

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diet was calculated for dry matter, crude protein, crude fiber, ether extract, ash and nitrogen free extract, neutral and acid detergent fiber using the equation proposed by McDonald *et al.* (2002).

$$\text{ND \%} = \frac{\text{Total amount of nutrients in feeds} - \text{Total amount of nutrients in faeces}}{\text{Total amount of nutrients in feeds}} \times 100$$

Nitrogen retention was calculated by standard procedures outlined for direct estimation of animal digestion (McDonald *et al.* (2002). Nitrogen balance was determined as the differences between nitrogen intake and nitrogen excreted in faeces and urine. The nitrogen retention percentage was estimated from the nitrogen balance expressed as a percentage of nitrogen intakes.

Haematological and Serum Biochemical Studies

After the metabolic trial, 10ml of blood sample was collected from each sheep in the following day through jugular venipuncture, using disposable heparinised syringe into sterilized evacuated collection tubes before morning feeding. Sub-sample of 5ml was draw into labeled sterilized universal bottle containing Ethylene Diamine Tetra-acetic Acid (EDTA) as anti-coagulant to determine haematological traits. Packed cell volume (PCV) was determined with wintrobe's micro-haematocrit while Red Blood Cell (RBC) and White Blood Cell (WBC) were determined with improved Neubauer haemocytometer. Differential counts of WBC such as lymphocytes, eosinophils, neutrophils, monocytes and basophils were determined by making differential smear using wright stain and percentage. The haemoglobin concentration (Hb) was measured by cyano-methaemoglobin method. The erythrocytic indices, Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH) and Mean Corpuscular Haemoglobin Concentration (MCHC) were computed as described by Jain, (1993).

The second 5ml sub-samples were transferred into anti-coagulant free plastic tubes and gently inverted a couple of times, kept in an ice box to allow coagulation at room temperature. They were later centrifuged for 15 minutes at 890xg at 4^0C and maintained for 8 hours in refrigerator at 4^0C prior to biochemical analysis and separation of supernatant serum. The plasma was also transferred to a storage tube and stored at -20^0C until analysis.

The biochemical constituents of the serum samples measured were; total protein and albumin that were analyzed by using commercial kits (Biuret method, chemelex, SA Barcelona), Urea was estimated by diacetylmonoxime method, creatinine by Jaffe reaction method while glucose, triglyceride and cholesterol were by enzymatic colorimetric test. Globulin was calculated by subtracting albumin from total protein serum. However, serum biochemical analysis followed the procedures reported by Chen *et al.* (2015).

Thermo-physiological Measurements and estimated Heat Stress with Heat Tolerance Co-efficient

Weather data from the environment and thermo-physiological indices from the sheep observed in the study were measured at three intervals daily; morning between 7 and 8am, midday between 12 and 2pm and evening between 4 and 6pm to calculate heat stress and heat tolerance co-efficient parameters. Dry bulb temperature (Tdb) and Relative Humidity (RH) were measured with digital hygrometer--thermometer data loggers and calibrated digital thermo---hygrometer hung in a ventilated white shade that were at the same height as the animals at 1.2 to 1.5m above the ground that gave Tdb + RH measurements at the same time. Dew point temperature (Tdp) was measured with dew point meter or by calculating the addition of dry bulb temperature and moisture or chilled mirror hygrometer. Black globe temperature (Tbg) that measured radiant heat load from sun and surroundings was by black globe thermometer. This was done by placing a sensor bulb thermometer at the center of a hollow black sphere. The three common formulas used in estimating heat stress in this study include;

1. Temperature Humidity Index (THI) Rahman *et al*. (2007),
   $$\mathbf{THI = Tdb + 0.36 \times Tdp + 41.2}$$
2. Black Globe Humidity Index (BGHI) Rahman *et al*. (2007),
   $$\mathbf{BGHI = Tbg + 0.36 \times Tdp + 41.2}$$
3. Heat Stress Index (HSI) Rahman *et al*. (2007) ; Silanikove (2000),
   $$\mathbf{HSI = 0.8 \times Tdb + [(RH/100) \times (Tdb - 14.4)] + 46.4}$$

Where, Tdb = dry bulb temperature ^{0}C, Tdp = dew point temperature ^{0}C, Tbg = black globe temperature ^{0}C,
RH = Relative Humidity %

Thermo-regulatory parameters such as rectal temperature was measured by inserting a rectal digital thermometer approximately 10cm into the rectum of the sheep for three minutes (^{0}C) and recorded immediately. Respiration rate was estimated by visually counting uninterrupted number of flank or abdominal movements during breathing for one minute from a 2-meter distance without disturbing the sheep (breaths/minute). Heart or pulse rate was determined by placing a stethoscope near the left axilla bone for one minute (beats/minute). Alternatively, it could also be recorded by placing the finger tips on the femoral arteries of the hind linb for minute and read from the stopwatch or heart rate monitor. Sweating rate was measured on shorn skin patches using sweat meters or by weighing filter paper before and after contact with skin. However, skin/wool surface temperature was measured with infrared thermometer on shorn patch or bare skin areas such as ear and nose.

Heat Tolerance Coefficient (HTC) for comparing animals' temperature to a standard was calculated in this study using five most common formulas below;

1. Heat Tolerance Coefficient (Benezra, 1954); **HTC = RT/RTn + RR/RRn**
2. Heat Tolerance Coefficient (Iberia, 1982) ; **HTC = 100 – 10 X (RT– RTn)**
3. Heat Tolerance Index (Rhoad, 1944); **HTI = 100 – 10 X (RT-38.33)–0.2 X (RR – 23)**
4. Physiological Response Index (Singh *et al.,* 1980); **PRI = 0.5 X (RT/RTn) + 0.5 x (RR/RRn)**
5. Heat Tolerance Coefficient (Davis, 1948); **HTC = (RR/60) + (RT/70)**

Where, RT = rectal temperature of sheep under heat stress (^{0}C). RTn = normal rectal temperature of West African dwarf sheep in the tropical humid zone of Nigeria is 39.0^{0}C (Akinlade *et al.,* 2010). RR = Respiration rate of sheep at under heat stress, breaths/min. RRn = normal respiration rate of West African dwarf sheep in the tropical humid zone of Nigeria is 24 breaths/min (Ayoola *et al.,* 2019).

Chemical Analysis

Dry matter was determined by drying guinea grass, feeds, orts, and faecal samples in an air-forced oven at 135^{0}C for 2 h (AOAC, 2005); crude ash content was measured by placing the samples into a muffle furnace at 550 ^{0}C for 24h. Nitrogen was determined using the Kjeldahl method, using selenium as a catalyst (AOAC, 2005) and crude protein was calculated using the formula 6.25 x N. The ether extract was measured by calculating the weight loss of the dry matter on extraction with diethyl ether using the soxhlet extraction apparatus for 8 h (AOAC, 2005). Crude fiber and its fractions were determined using Tecator Line (FT122 Fibertee TM).

Statistical Analysis

Data generated from growth, digestibility, nitrogen retention, blood constituents and thermo-physiological indices, heat stress as well as heat tolerance ability were analyzed by one-way analysis of variance (ANOVA) by comparing mean values at difference treatments through SPSS version 26 (IBM, 2019). The Duncan Multiple Range Test (DMRT) separated mean values between treatment groups at 5% level of significance (Steel and Torrie, 1990).

RESULTS

As referred in Table 2, Guinea Grass (GG) and Lemon Seed Powder (LSP) examined had higher content of dry matter but lower in ash. However, crude fiber and it fractions with nitrogen free extract were higher in GG but relatively lower in crude protein and ether extract values as compared with LSP. Treatment supplementary diets of crude protein and nitrogen free extract had similar higher values with little remarkable difference among treatments. Diet TD_1 recorded higher value in ash content but lower values in dry matter, ether extract, crude fiber, neutral and acid detergent fiber as compared with test diets TD_2, TD_3 and TD_4.

Table 2: Chemical composition (%DM) of experimental diets of sheep.

	Feed Ingredients		Treatment Supplementary Diets			
	GG	LSP	TD_1	TD_2	TD_3	TD_4
Dry matter	88.46	91.02	89.86	91.53	92.06	92.32
Crude protein	7.39	20.10	16.07	16.11	16.15	16.19
Ether extract	2.33	31.26	3.82	4.58	4.71	5.63
Crude fiber	33.04	7.34	23.39	23.56	23.95	24.05
Ash	5.82	2.59	7.02	6..41	5.92	5.50
Nitrogen free extract	43.49	23.48	57.44	57.28	57.31	57.62

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Neutral detergent fibber	57.36	21.42	44.07	44.26	45.59	46.57
Acid detergent fiber	30.62	9.73	27.23	27.62	29.23	29. 49

GG = Guinea grass, LSP = Lemon Seed Powder, TD_1 = 0% Lemon Seed Powder, TD_2 =0.50% Lemon Seed Powder, TD_3 = 1.00% Lemon Seed Powder, TD_4 = 1.50% Lemon Seed Powder

As spotlighted in Table 3, daily feed intake was significantly ($p<0.05$) higher in sheep placed on diet TD_4 followed by those on diets TD_3, TD_2 and TD_1. However, noticeable significant ($p<0.05$) difference were observed in mean values of final body weight and total weight gain with sheep on test diets TD_4 and TD_3 appeared higher in values than those on diets TD_2 and TD_1. However, daily weight gain that ranged from 59.56 to 71.00g followed the same trend as obtained in total weight gain. Feed conversion ratio was found to be significantly higher in sheep on diets TD_1 and TD_2 as compared to diets TD_3 and TD_4. Initial body weight of sheep in the study that ranged between 7.13 and 7.62 kg in values had no significant difference ($P>0.05$) among treatment diets.

Digestibility of dry matter, crude protein, crude fiber and ash as seen in Table 3, were significantly ($P<0.05$) improved with progressive increased in the levels of lemon seed powder in the treatment diets. Hence, values registered in sheep on test diets (TD_4, TD_3 and TD_2) showed higher digestion than the control diet (TD_1). Sheep on control diet TD_1 had relatively higher significant ($P<0.05$) values of digestibility of ether extract as compared with test diets TD_2, TD_3 and TD_4 that was not affected. Digestibility of nitrogen free extract varied significantly ($P< 0.05$) among treatment diets, sheep on test diets TD_4 and TD_3 showed higher values than those recorded in diets TD_2 and TD_1. However, neutral and acid detergent fiber that ranged from 55.07 to 68.16% and 48.52 to 60.37% respectively followed the same pattern of variation as observed in digestibility of crude fiber.

Nitrogen intake for sheep was significantly ($P<0.05$) affected by treatment diets with highest consumption values obtained in diets TD_4 and TD_3 but lowest in diet TD_1. Faecal and urinary nitrogen output showed fairly higher significant ($P<0.05$) values in sheep on diets with 0% and 0.50% lemon seed powder (TD_1 and TD_2) than diets with 1.00 and 1.50% lemon seed powder (TD_3 and TD_4). Total nitrogen output was also found to be significantly ($P< 0.05$) higher in sheep on diets TD_1 and TD_2 as compared with diets TD_1 and TD_2. Consequently, nitrogen balance for sheep was noticed to be significantly ($P< 0.05$) increased in diets with test ingredient than the control diet. Nitrogen retained in sheep that ranged between 0.34 and 0.70 g/day was not affected by treatment diets. Above all, nitrogen retention percentage of nitrogen intake showed similar significantly improved ($P<0.05$) values in sheep on test diets than the control diet.

Table 3: Growth, nutrient digestibility and nitrogen retention in sheep fed experimental diets

Parameters	Treatment Diets				
	TD_1	**TD_2**	**TD_3**	**TD_4**	**SEM$\pm$**
Growth Performance					
Daily feed intake, g/day	248.76^d	259.62^c	260.89^b	264.32^a	1.04
Initial body weight kg	7.62	7.48	7.25	7.13	0.03
Final body weight kg	12.98^b	13.29^a	13.38^a	13.52^a	0.06
Total weight gain kg	5.36^b	5.81^b	6.13^a	6.39^a	0.05
Daily weight gain g	59.56^c	64.56^b	68.11^{ab}	71.00^a	0.42
Feed conversion ratio #	4.28^a	4.02^a	3.83^b	3.72^b	0.02
Nutrient Digestibility %					
Dry matter	65.28^c	69.45^b	70.11^a	71.02^a	0.91
Crude protein	68.91^c	70.23^b	70.89^b	72.04^a	0.53
Crude fiber	62.08^c	68.95^b	70.36^a	70.41^a	0.76
Ether extract	70.13^a	65.84^b	62.83^c	60.52^c	0.89
Ash	60.49^c	63.97^b	64.68^b	67.14^a	0.67
Nitrogen free extract	64.82^c	67.89^b	70.37^a	70.76^a	0.59
Neutral detergent fiber	55.07^c	59.72^b	64.03^a	68.16^a	0.73
Acid detergent fiber	$48..52^c$	51.94^b	56.99^{ab}	60.37^a	0.64

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Nitrogen Retention					
Nitrogen (N) intake (g/day)	12.99^{c}	13.48^{b}	13.92^{b}	14.06^{a}	0.06
Faecal - N - output (g/day)	4.05^{a}	3.96^{b}	3.58^{b}	3.23^{b}	0.02
Urinary – N – output (g/day)	1.87^{a}	1.25^{a}	1.09^{a}	0.99^{b}	0.02
Total –N – output (g/day)	5.92^{a}	5.21^{a}	4.67^{b}	4.25^{b}	0.05
Nitrogen balance (g/day)	7.07^{c}	8.27^{b}	9.25^{a}	9.82^{a}	0.07
Nitrogen retained (g/day)	0.54	0.63	0.67	0.70	0.04
Nitrogen retention % intake	54.43^{c}	61.35^{b}	66.45^{a}	69..84^{a}	0.48

^{a,b,c,d} *Means in the same row without common superscript differ at p< 0.05, SEM = Standard error of mean, # =Feed intake/live weight gain,* , TD_1 = 0% Lemon Seed Powder, TD_2 = 0.50% Lemon Seed Powder, TD_3 = 1.00% Lemon Seed Powder, TD_4 = 1.50% Lemon Seed Powder

Pointed out in Table 4 are haematological and serum biochemical parameters of sheep as influenced by varying levels of lemon seed powder. Packed cell volume and haemoglobin values that ranged from 25.75 to 28.07% and 8.99 to 10.47 g/dl respectively were significantly (P<0.05) higher in sheep on diets with test ingredient than the control diet. In this same vein, red blood cell (7.76 to 9.63 x10^6/ml) also registered higher values in sheep on test diets TD_4, TD_3 and TD_2 as compared with control diet TD_1. On the other hand, mean corpuscular volume was found to be significantly (P<0.05) increased in diets with 1.00% and 1.50% lemon seed powder (TD_3 and TD_4) than diets with 0% and 0.50% lemon seed powder (TD_1 and TD_2). Mean corpuscular haemoglobin and mean corpuscular haemoglobin concentrations were observed to be improved significantly (P<0.05) in sheep on test diets than those on control diet. Sheep on test diet TD_4, had relatively higher (P<0.05) value of white blood cell followed by test diets TD_3 and TD_2 before the control diet TD_1. Lymphocyte mean values seen to be significantly (P<0.05) increased in sheep on diet TD_4 than other diets (TD_1, TD_2 and TD_3), unlike neutrophil values that were significantly (P<0.05) highest in diets TD_4 and TD_3, but lowest in diets TD_2 and TD_1. However, values recorded for eosinophils, monocytes, basophils in sheep were not significantly (P>0.05) influenced by treatment diets.

Parameters observed in serum biochemistry of sheep were significantly (P<0.05) affected by treatment diets except globulin and triglyceride that were unaffected (P>0.05). Total protein and albumin values recorded in sheep were significantly (P<0.05) higher on diet TD_4 followed by diets TD_3, TD_2 and TD_1. Glucose concentration that ranged from 63.99 to 70.02g/dl in sheep was highest in diets TD_4 and TD_3, and lowest in diets TD_2 and TD_1. Cholesterol, creatinine and urea mean values had significant (P<0.05) variations among treatment diets, with sheep on control group recorded highest values and those on test groups had the lowest values.

Table 4: Mean values for haematological and serum biochemical parameters of sheep fed experimental diets.

Parameters	Treatment Diets				
	TD_1	TD_2	TD_3	TD_4	SEM ±
Haematological indices					
Packed cell volume (%)	25.75^{b}	27.03^{a}	27.61^{a}	28.07^{a}	0.53
Haemoglobin (g/dl)	8.99^{b}	9.77^{ab}	10.24^{a}	10.47^{a}	0.09
Red blood cell (x10^6/ml)	7.76^{b}	8.58^{ab}	9.25^{a}	9.63^{a}	0.05
MCV (fl)	33.72^{b}	33.82^{b}	34.07^{a}	34.37^{a}	0.46
MCH (pg)	9.07^{b}	10.12^{a}	10.36^{a}	10.46^{a}	0.08
MCHC (%)	30.96^{b}	31.69^{ab}	32.46^{a}	32.75^{a}	0.58
White blood cell (x10^6/ml	8.97^{b}	10.34^{a}	10.82^{a}	11.02^{a}	0.09
Lymphocytes (%)	60.43^{b}	60.22^{b}	60.73^{b}	62.18^{a}	0.62
Eosinophils (%)	3.49	3.14	3.42	3.51	0.02
Neutrophils (%)	30.36^{b}	30.77^{b}	31.99^{a}	32.87^{a}	0.49
Monocytes (%)	1.01	1.03	2.05	2.09	0.03

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Basophils (%)	1.34	1.45	1.56	1.74	0.02
Serum biochemical indices					
Total protein (g/dl)	6.01^{c}	7.24^{b}	7.83^{b}	8.01^{a}	0.04
Albumin (g/dll)	3.01^{b}	3.65^{b}	4.09^{a}	4.16^{a}	0.05
Globulin (g/dl)	3.00	3.59	3.75	3.85	0.01
Glucose (mg/dl)	63.99^{c}	66.72^{b}	68.59^{a}	70.02^{a}	0.12
Triglyceride (mg/dl)	21.54	21.39	21.27	21.15	0.52
Cholesterol (mg/dl)	64.01^{a}	57.12^{b}	52.41^{c}	50.92^{c}	0.64
Creatinine (mg/dl)	1.03^{a}	1.00^{a}	0.94^{b}	0.88^{b}	0.03
Urea (mg/dl)	11.96^{a}	9.74^{b}	8.36^{c}	8.03^{c}	0.07

^{a,b,c} Means in the same row with varying superscript differ significantly (P < 0.05), MCV = Mean Corpuscular Volume, MCH = Mean Corpuscular Haemoglobin, MCHC = Mean Corpuscular Haemoglobin Concentration. TD_1 = 0% Lemon Seed Powder, TD_2 = 0.50% Lemon Seed Powder, TD_3 = 1.00% Lemon Seed Powder, TD_4 = 1.50% Lemon Seed Powder

The variance analysis of prevailed weather data from dry bulb, dew point and black globe temperature were not significantly (P>0.05) affected by treatment diets except relative humidity observed in the morning, midday and evening that were significantly affected (P<0.05). Relative humidity increased progressively across the diets with decreased in lemon seed powder inclusion as indicated in Table, 5. Meanwhile, thermo-regulatory parameters such as rectal, respiratory rate and heart/pulse rate mean values recorded in the study also showed significant (P>0.05) higher values in sheep on control group than those on test groups. Similarly, skin surface temperature followed the same pattern of variation as observed in rectal temperature. Conversely, sweating rate had no significant influenced (P>0.05) in the morning, midday and evening among treatment groups.

Table 5: Physiological parameters of sheep fed experimental diets in the tropical humid zone of Nigeria

Parameters		Treatment Diets				
		TD_1	TD_2	TD_3	TD_4	SEM$\pm$
Weather Variables						
Dry bulb T^0C	Morning	23.56	23.34	23.12	23.08	0.02
	Midday	31.98	31.36	31.22	31.13	0.03
	Evening	24.84	24.23	24.15	24.04	0.06
Dew point T^0C	Morning	23.92	23.76	23.68	23.56	0.03
	Midday	21.56	21.34	21.09	21.07	0.05
	Evening	20.24	20.05	20.03	20.02	0.02
Black globe T^0C	Morning	25.67	25.52	25.42	25.24	0.05
	Midday	30.86	30.72	30.59	30.43	0.08
	Evening	28.85	28.52	28.47	28.26	0.07
R H %	Morning	95.92^{a}	93.64^{b}	93.46^{b}	93.56^{b}	0.09
	Midday	60.73^{a}	58.63^{b}	58.40^{b}	58.25^{b}	0.08
	Evening	90.73^{a}	88.45^{b}	88.23^{b}	88.09^{b}	0.06
Thermo-regulatory	Parameters					
Rectal T^0C	Morning	38.70^{a}	35.64^{b}	35.52^{b}	35.49^{b}	0.02
	Midday	39.76^{a}	36.92^{b}	36.90^{b}	36.88^{b}	0.04
	Evening	38.96^{a}	35.42^{b}	35.11^{b}	34.89^{c}	0.03
Respiratory rate (breaths/min)	Morning	24.36^{a}	22.01^{b}	21.90^{c}	21.82^{c}	0.04
	Midday	25.43^{a}	21.80^{b}	21.52^{b}	21.29^{b}	0.05

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	Evening	24.73^{a}	21.00^{b}	20.94^{c}	20.85^{c}	0.03
Heart/pulse rate (beats/min)	Morning	83.92^{a}	77.84^{b}	76.75^{b}	75.52^{c}	0.04
	Midday	89.71^{a}	86.36^{b}	85.82^{b}	85.25^{b}	0.07
	Evening	80.23^{a}	77.19^{b}	76.47^{b}	75.52^{c}	0.06
Skin surface T.^{0}C	Morning	29.01^{a}	27.24^{b}	27.13^{b}	27.02^{b}	0.06
	Midday	32.46^{a}	28.93^{b}	28.67^{b}	28.54^{b}	0.02
	Evening	30.67^{a}	27.64^{b}	27.49^{b}	27.36^{b}	0.04
Sweating rate (g/m^{2} /h)	Morning	0,51	0.50	0.50	0.50	0.01
	Midday	1.69	1.42	1.39	1.09	0.03
	Evening	0.62	0.60	0.60	0.60	0.02

^{a,b,c} Means in the same row with varying superscript differ significantly (P < 0.05), TD_1 = 0% Lemon Seed Powder, TD_2 =0.50% Lemon Seed Powder, TD_3 = 1.00% Lemon Seed Powder, TD_4 = 1.50% Lemon Seed Powder, T^0C = Temperature degree Celsius, RH = Relative Humidity percentage, g/m^{2} /h = grams per meter square per hour.

As shown in Table 6, are mean values of heat stress in experimental sheep using different calculated formulas. Temperature Humidity Index (THI) showed significant difference (P< 0.05) in the morning, midday and evening with control diet higher than test diets. Black Globe Humidity Index (BGHI) in the morning and evening values were significantly (P< 0.05) higher in sheep on control diet and lower in those on test diets but midday values were not significantly (P> 0.05) influenced by treatment diets. Heat Stress Index (HIS) values obtained in the morning, midday and evening were higher (P< 0.05) in control diet and inversely lower in sheep on test diets.

Calculated Heat Tolerance Co-efficient (HTC) from different formulas was also highlighted in Table 6. Benezra calculated HTC values in the morning, midday and evening were affected significantly (P> 0.05) by treatment diets with test diets seem higher than control diet. Iberia HTC almost followed the same pattern of variation as observed in Benezra HTC with higher values registered in test diets as compared with control group. Rhoad Heat Tolerance Index (HTI) calculated values in the midday showed no significant (P> 0.05) difference among treatment diets but morning and evening were significantly (P<0.05) varied by treatment effects, with sheep on control diet had lower values than those on test diets. Meanwhile, Singh calculated Physiological Response Index (PRI) followed the same trend as observed in Benezra calculated HTC in the morning, midday and evening. However, Devis calculated HTC in the morning, midday and evening had relatively higher significant (P> 0.05) values in test diets than control diets. .

Table 6: Heat stress and heat tolerance co-efficient indices of sheep fed experimental diets in the tropical humid zone of Nigeria.

Parameters		Treatment Diets				
		TD_1	TD_2	TD_3	TD_4	SEM$\pm$
Heat stress						
Temperature Humidity. Index (THI)	Morning	73.37^{a}	73.09^{a}	72.84^{b}	72.76^{b}	0.07
	Midday	80.94^{a}	80.24^{a}	79..98^{b}	79.90^{b}	0.04
	evening	73.33^{a}	72.65^{b}	72.56^{b}	72.65^{b}	0.05
Black Globe Humidity Index (BGHI)	Morning	75.48^{a}	75.27^{a}	75.14^{a}	74.92^{b}	0.06
	Midday	79.82	79.60	79.38	79.22	0.02
	evening	77.34^{a}	76.94^{b}	76.88^{b}	76.67^{b}	0.06
Heat Stress Index. (HSI)	Morning	79.55^{a}	73.47^{b}	73.01^{b}	72.88^{b}	0.04
	Midday	82.70^{a}	81.49^{b}	81.14^{b}	74.31^{c}	0.07
	evening	75.77^{a}	74.43^{b}	74.29^{b}	74.11^{b}	0.05

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Heat Tolerance Coefficient						
Benezra HTC	Morning	1.80[c]	1.83[b]	1.85[a]	1.86[a]	0.05
	Midday	1.83[b]	1.86[a]	1.86[a]	1.86[a]	0.02
	evening	1.81[b]	1.82[a]	1.82[a]	1.83[a]	0.04
Iberia HTC	Morning	124.00[b]	123.90[b]	134.80[a]	135.10[a]	0.72
	Midday	120.50[b]	120..80[b]	121.00[a]	121.20[a]	0.59
	evening	123.80[c]	125.80[b]	138.90[a]	140.80[a]	0.82
Rhoad HTI	Morning	117.63[b]	117.10[b]	129.10[a]	128.64[a]	0.77
	Midday	114.10	114.34	114.60	114.84	0.83
	evening	117.41[c]	119.50[b]	132.60[a]	134.53[a]	0.69
Singh PRI	Morning	0.90[b]	0.93[a]	0.93[a]	0.93[a]	0.05
	Midday	0.90[b]	0.94[a]	0.94[a]	0.94[a]	0.04
	evening	0.90[b]	0.92[a]	0.92[a]	0.92[a]	0.06
Davis HTC	Morning	0.86[c]	0.86[c]	0.88[b]	0.90[a]	0.03
	Midday	0.87[c]	0.88[b]	0.90[a]	0.90[a]	0..04
	evening	0.87[c]	0.87[c]	0.88[b]	0.90[a]	0.03

[a,b,c] Means in the same row with varying superscript differ significantly ($P < 0.05$), TD_1 = 0% Lemon Seed Powder, TD_2 = 0.50% Lemon Seed Powder, TD_3 = 1.00% Lemon Seed Powder, TD_4 = 1.50% Lemon Seed Powder, HTC = Heat Tolerance Coefficient, HTI = Heat Tolerance Index, PRI = Physiological Response Index

DISCUSSION

The chemical composition of guinea grass and lemon seed powder observed in this study were within the reported ranged values of Ikhimioya *et al.* (2026) and Satari (2013) respectively. Differences noticed in the chemical analysis of supplementary diets could be a reflection of types and inclusion levels of feed ingredients. However, crude fiber and protein values recorded in the supplementary diets were within 25% CF and 12% CP average values required for small ruminants' performance as noted by Okoruwa and Eguabor. (2025).

The test ingredient that was lemon seed powder possesses some phytogenic properties and bioactive components that seem beneficial (Khan *et al*., 2012) as they were able to increase appetite stimulant, aroma/palatability and anti-bloating in sheep on test diets. This was in agreement with the report of Sharoba *et al.* (2013) who observed that lemon seed has citrus oils and mild bitter taste that stimulates saliva and gastric juice of sheep to consume more feeds. In addition, it was also observed (Satari, 2013) that inclusion of lemon seed powder at 0.5 to 1.5% levels in diets produced lemon scent that masks off-flavors in low-quality feeds for better feed acceptability and intake in animals. The higher final body weight as well as total and daily weight gain obtained in sheep on test diets could probably be connected to better nutrient availability and utilization that improve feed efficiency for heavier weight gain. This inference was in consistency with the earlier report of Khan *et al.* (2012) who noted that lemon seed bioactive phytochemical properties such as limonene, flavonoids and citric acid improve feed utilization that supply balance nutrient requirement at the site of metabolism for higher weight gain of animals. Feed Conversion Ratio (FCR) was better in sheep on diets TD_3 and TD_4, indicating good feed utilization that attest the superiority of the diets. However, FCR recorded in this study was slight lower than the mean value of 6.41 reported by Okoruwa and Akazue (2025), for sheep fed pawpaw seed powder supplement.

The notable increase observed in the digestibility of dry matter, crude protein and crude fiber with ash in the test diets could probably be traced to nutrient content and antimicrobial content from limonene and flavonoids in the lemon seed powder that gave room for rumen stimulates fiber-degrading microbes to breakdown cellulose in diets. In accordance with the previous findings of Karaman *et a*l. (2021), lemon seed meal is classified as digestion enhancer and natural dewormers as it contains some secondary metabolites and vitamin C with 18 to 22% crude protein that improves digestion process. The decreased digestion of fat and oils in the test diets as compared to control diet could be as a result of indigestible complex enzymes activity in the test ingredient that disrupted ether extract degrading components in sheep. Meanwhile, the considerable improvement in the digestibility of nitrogen free extract in sheep on test diets, further affirmed the positive interaction between lemon seed powder and treatment diet components that enhanced nutrient availability for effective digestion. The possible increased in the ability of sheep to properly modify and utilize neutral and acid detergent fiber in the test diets could be linked with lemon seed essential oil properties that improved in rumen fermentation process. This was earlier confirmed in the findings of El-Zaiat (2021) that antimicrobial and antiparasitic properties in herb plants powder could have modulation effect for proper functioning of rumen ecology and high fermentable cell wall fractions in stimulating the activity of cellulolytic rumen floral for better fiber combination components digestion.

The differences observed in the values of nitrogen intake were mainly attributed to the contributory effects of the dietary supplements in the study that tend to increase protein content of the diets. Furthermore, higher mean values of faecal, urinary and total nitrogen excreted recorded in sheep on control group could be a reflection of rapid breakdown of protein content to ammonia in the rumen by microbial fermentation activity that increased nitrogenous excretion (McDonald *et al*, 2002). The higher positive nitrogen balance and retention percentage of nitrogen intake in sheep on test diets showed that lemon seed flavonoids, citric acid and limonoids increased dietary protein escape from rumen to intestines. This is in harmony with previous study of Okoruwa and Akazue (2025) who observed that antimicrobial effects from herbal plant additives delay rumen protein degradation by suppressing bacteria population and make denatured protein absorbed and utilized in the post-rumen digestion of animals. This obviously buttresses the fact that more nitrogen was actually absorbed from feeds for better utilization and less protein wastage in sheep. Nitrogen retention values obtained in this work were comparable with the mean reference value of 64.95% reported by Ikhimioya *et al.* (2026).

Packed Cell Volume (PCV), Haemoglobin (Hb) and Red Blood Cell (RBC) in this study remained within the normal range values that support normal healthy condition and reduce anemia among sheep (Okoruwa and Eguabor, 2025). However, the higher values observed in sheep on test diets indicated that the test ingredient was non-toxic rather increased blood volume that could withstand some levels of respiratory stress and improved oxygen carrying capacity in the blood (El-Zaiat *et al*., 2021). The greater values of mean corpuscular volume, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration obtained in sheep on test diets further explained that they were able to tolerant lemon seed powder in the blood which explains the better bone marrow capacity for blood cells production. White Blood Cell (WBC) that was disease fighting ability in animals' remained normal and made sheep stayed healthy by boosting the immune response. Their higher values observed in sheep on test diets were not negatively affected by sheep but probably reduced oxidative stress, protected WBC and improved immune cell activity response. Hence, their recorded values tallies with the average value of $7.82 x 10^6$/ml for sheep as observed by Okoruwa and Eguabor (2025). The better values for lymphocytes and neutrophils recorded in the white blood differential counts implied that sheep on these diets had the tendency of not being susceptible to microbial infection or disease condition. Meanwhile, the low similar values of monocytes, eosinophils and basophils in the WBC were indications that their immune systems were not challenged with any toxic substance; hence no clinical sign was noticed.

The higher total protein and albumin obtained in sheep on diets with lemon seed powder could be traced to the phytogenics properties in lemon that increased dietary protein escape from rumen to intestines which led to their higher production in the serum. This further explained the better protein supply from the test diets for muscle growth and immune functions (El-Zaiat *et al*., 2021). Consequently, values of total protein and albumin obtained in this study were within the mean values of 6.86 and 3.55 g/dl previously reported by Okoruwa and Akazue (2025). The similar globulin values observed in sheep among treatments showed efficient immune response that made them to be disease free and caused an excessive production of stronger antibodies through gamma globulin production (Rahman *et al*., 2022). The favourable roles of the essential oils in the test diets, perhaps gave way for more energy from volatile fatty acids in the rumen to increase serum glucose for better energy metabolic efficiency absorbed which modulate more energy for muscle gain. This probably translated to the healthier sheep with increment in their body weight gain and disease resistance. The reduction observed in serum triglyceride and general low cholesterol in sheep on test diets were expected as phytogenics and flavonoids in lemon seed powder were reported to have lower effect on blood lipids by interfering with cholesterol absorption in the gut (El-Zaiat *et al*., 2021). In addition, lemon phytochemicals such as vitamin C and flavonoids with biohydrogenated dietary fats in the rumen contributed to VFAs for energy as seen in serum glucose. Furthermore, triglycerides prevent blood lipids peroxidation to improve fat quality instead of quantity (Rahman *et al.,* 2022). The low creatinine and urea levels observed in sheep on test diets, suggested that they had efficient

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nitrogen utilization that made them not to survive at the expense of their body reserves, this corresponds with the findings of Rahman *et al*. (2022).

Dew point and black globe temperature variables observed in this study were within the 20 – 24^{0}C and 25 – 32^{0}C annual range temperature as previously supported by Ayoola *et al*. (2019) for tropical humid zone of Nigeria. However, dry bulb midday temperature values recorded were higher than the annual range temperature of 25 – 32^{0}C also reported by Ayoola *et al*. (2019) for most humid region in Nigeria. Relative humidity mean data obtained in this study were within the 80% average value reported by Oyewole *et al*. (2018) but slightly above the mean value of 85% as stated by Akinlade *et al*. (2010). The weather variables obtained in this work, indicated that sheep were slightly beyond comfortable environmental conditions in the morning and evening but exposed to heat stress during the midday. The lower rectal temperature, respiratory and heart/pulse rate values found in sheep on diets with lemon seed powder in the morning, midday and evening had positive relationship with increased feed intake and higher weight again of sheep on test diets. Rectal temperature values observed were within the narrow limits of stress, if sheep welfare is to be safe guarded and production maintained at acceptable levels (Okoruwa, 2015). Respiratory rate could be used as an indicator of stress and estimate the adverse effects of environmental temperature, Hence, Al-Haidary *et al.* (2013) suggested that respiratory rate is a practical and reliable measure of heat load and when the value is above 20 breaths per minute for sheep is an indication of stress. However, the ability of sheep to maintain their respiratory threshold could be linked to their panting ability in order to increase body cooling by respiratory evaporation. Since panting is the major evaporator heat mechanism and respiratory frequencies that tend to follow closely the heat loss by evaporation (Silanikove, 2000). The higher heart/pulse rate in sheep on control diet could be associated with higher rectal temperature and respiratory rate that exceeded the comfort zone which led to redistribution of blood to peripheral tissue such as shifting to skin during heat exposure (Al-Haidary *et al*., 2012). The Skin Surface Temperature (SST) that is the true body heat dissipation has a direct relationship with rectal temperature, as it does the control with temperature humidity index (Okoruwa, 2015). The SST of sheep on test diets were within the normal range of 30-35^{0}C that does not exceeded threshold as classified under heat stress (Amir *et al*., 2025). Sweating rate was within the normal low range values of 0.5-3.5g/m2/h of West African dwarf sheep (Ayoola *et al.,* 2019). This is expected because West Africa dwarf sheep are poor sweaters that depend mainly on panting and respiratory cooling not sweating. Sweating rate is harder in sheep than cattle and goats due to wool blocks evaporation, hence it might not be a better heat stress indicator (Okoruwa, 2015).

Heat stress was used to detect early stress, guide cooling, feeding and breeding decisions with the use of weather data in the environment without animal measurements as suggested by Okoruwa (2015). The decreased in calculated heat stress values from Temperature Humidity Index (THI), Black Globe Humidity Index (BGHI) and Heat Stress Index (HSI) in sheep on test diets had a positive relationship with previous variables description from Rectal Temperature (RT), Respiratory Rate (RR) and Heart Rate (HR) observed in test diets (Table, 5). The phytochemical components in test ingredient would have acted as the antioxidant protection against heat – induced oxidative stress (Amir *et al*. 2025). In addition, Islam *et al.* (2021) confirmed in their findings that HR variable can be used to assess the heat stress of animals for short term, but additional variables such as RR and RT are required to assess prolong animal exposure to heat stress. However, some authors (Amir *et al.,* 2025; Gaughan *et al*., 2008) also established that management and individual animal factors such as health, genotype, coat characteristics and physiological responses are not considered in the THI.

The potential thermo-tolerance of sheep observed in this present study was illustrated by calculated formulas of Heat Tolerance Co-efficient (HTC). The three notable thermo-physiological traits that were indicators of heat tolerance ability of sheep to heat stress were RT, RR and HR. Notwithstanding, RT was reported to be the primary method to describe the heat production of animal body, while RR was an early indicator of heat stress but increased HR was to maintain homeostatic conditions of animal's body (Pinto *et al.,* 2020; Godyri *et al*., 2019). However, sheep on control diet respond to increase in temperature by increasing RR as an action for heat loss that offset heat production. Benezra coefficient illustrated the action of increasing heat loss to keep the sheep body homeostatic (Akinlade *et al*.,2010). The increased in heat tolerance ability of sheep on test diets could be probably linked with bioactive properties in lemon seed powder that helped the sheep to cope with heat by reducing oxidative damage, boosting immunity, improving feed efficiency and supporting liver function that made sheep to tolerate heat better for higher body weight gain. Moreover, heat tolerance of sheep on test diets were better with Benezra HTC and Iberia HTC values of 2.00 and 100 respectively, that were reported by Akinlade *et al. (*2010) to be the best maximum tolerance. Rhoad HTI that had similar values as Iberia HTC was also highlighted by Akinlade *et al.* (2010). In contract, Singh PRI and Davis HTC values were low generally, though sheep on test diets were also numerically higher than the control diet. However, their values in the study were differed from values reported by Marai *et al.* (2009) because their heat tolerance measurement was based per observation time. The adaptation capacity to harsh environment can be evaluated using RT, RR, HR and heat tolerance, where average relative deviation from normal is due to exposure to hot weather in thermal parameters of the sheep that can be used in the estimation of adaptability to hot weather (Marai *et al*., 2007)

CONCLUSION

The study deduced that the potential alternative of using lemon seed powder as dietary supplement to sheep diets contributed valuable benefits in enhancing feed intake, digestibility with nitrogen utilization, boost immunity and control diseases by maintaining normal blood cell. It also increased disease resistance and heat tolerance coefficient with reduction in heat stress. These translated to healthier sheep with higher daily weight gain, better feed conversion ratio and improved feed efficiency without anti-biotic. Thus, these diets could serve as economic benefits for farmers' interns of making animal protein available at affordable prices to an average Nigerian.

From the result of this study, it can therefore be concluded that dietary supplementation with lemon seed powder improved sheep diets, these improvements were more pronounced in sheep on diets TD_3 and TD_4 that contained 1.00% and 1.50% lemon seed powder. Thus, they were likely to provide more practical approach to sheep feeding regime strategies for sustainable production in the tropical humid zone of Nigeria than other diets.

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