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Effects of breed, sex, and diet on thermo-physiology response of Nigerian goats, using variability chart and descriptive statistics

Iliya Mallam^{*1}, Emmanuel Ojogbane Negedu² and Usman Abdullahi Eshimutu³

¹Department of Animal Science, Kaduna State University, Kafanchan Campus, Kaduna State, Nigeria

²Animal Feed Production Unit, Bioprocessing Division, Abuja, BODEC, National Biotechnology Research and Development Agency, Off Umaru Musa Yar'adua Way, Lugbe, Abuja

³Department of Animal Health and Production Technology, Federal College of Agriculture, Akure, Ondo State, Nigeria

*Corresponding author: mallamiliya2011@gmail.com; iliya.mallam@kasu.edu.ng

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Abstract: Understanding the complex interplay between breed, diet, and sex on thermo-physiology is crucial for developing effective strategies to manage heat stress in Nigerian goat production. This experiment was conducted to study the effects of breed, diet, and sex on the thermos-physiological response of Nigerian goats. A total of 36 weaner goats of two breeds (West African dwarf, n=18; 9 males + 9 females) and Red Sokoto goats, n=18; 9 males + 9 females) were used for the experiment. A 2×3×2 factorial experiment comprising two breeds, three diet groups, and two sexes in a completely randomized design. The data collected included rectal temperature, pulse rate, respiratory rate, and the heat stress index, which was also calculated. The effects of the collected data were analyzed using SAS JMP software. The effect of breed, as indicated by the variability chart and summary, on the thermo-physiological indices of goats revealed variability in pulse rate and respiratory rate. The diet showed differences in rectal temperature, pulse rate, and respiratory rate. According to the chart, male goats exhibited higher thermo-physiology indices compared to females. It can be concluded that the experimental goats experienced minor or moderate heat stress, which is crucial for maintaining productivity, growth, and overall well-being.

Keywords: Breed; diet; sex; thermo-physiology; variability chart; Nigerian goats

INTRODUCTION

Goats are integral to the livelihoods of many Nigerian farmers; therefore, examining their thermal comfort and physiological responses is crucial for maintaining their health and productivity (Mallam et al., 2024). In livestock, particularly goats, various factors significantly influence the thermoregulatory mechanisms. Among these factors, breed, sex, and diet play pivotal roles in determining the thermo-physiological parameters of goats. Understanding these influences is crucial for optimizing goat management practices, enhancing productivity, and ensuring animal welfare, particularly in Nigeria's diverse

climatic conditions. Indigenous Nigerian breeds, such as the West African Dwarf (WAD) and Red Sokoto (RS) goat, are known for their resilience to heat stress compared to exotic breeds. These adaptations may include differences in body size, coat characteristics, and metabolic rates that affect how heat is dissipated. West African Dwarf goats have been observed to possess superior mechanisms for thermo-regulation, such as increased surface area-to-volume ratios and more efficient sweating rates, which enhance their ability to cope with high ambient temperatures typical of many regions in Nigeria (Ayo et al., 2009; Oduguwa et al., 2010). Research indicates that

male goats typically have greater muscle mass and higher metabolic rates, resulting in increased heat production during physical exertion (Nwosu et al., 2018). Conversely, female goats may demonstrate better adaptability to heat stress due to their reproductive physiology and fat distribution patterns. Diets rich in fiber may enhance thermoregulation by promoting fermentation processes that generate heat while providing essential nutrients for growth and reproduction (Khan et al., 2016). To comprehensively understand the effects of breed, sex, and diet on the thermo-physiology of Nigerian goats, variability charts can be employed. Such graphical representations facilitate a clearer understanding of how these factors interact and influence goat health and productivity. By investigating these relationships through systematic research and using tools such as variability charts and summary tables, we can enhance our understanding of goat physiology in response to environmental stresses. This knowledge is crucial for developing targeted interventions that enhance goat management practices, ultimately leading to improved productivity and sustainability within the Nigerian goat farming sector.

Therefore, the objective of this study is to assess the effects of breed, sex, and diet on the thermo-physiological response of Nigerian goats using a variability chart and descriptive statistics.

MATERIALS AND METHODS

The study area

This experiment was carried out at the Livestock Teaching and Research Farm of the Animal Science Department, Faculty of Agriculture, Shabu-Lafia Campus, Nasarawa State University, Keffi. Lafia is located on latitude 08° 35" and longitude 08° 33" (Ovimap, 2023). It is geographically located in the Guinea Savanna Zone of North Central Nigeria. It has a mean maximum monthly temperature of 35.06 °C and a mean minimum monthly temperature of 20.16 °C, with a mean monthly relative humidity of 74%. The annual rainfall is approximately 168.90 mm (Ni-Met, 2023).

Sources of experimental materials

The grass (*Digitaria smutsii*) was sourced from the National Animal Production Research Institute (NAPRI) at Ahmadu Bello University, Shika, Zaria, Nigeria. In contrast, the two legumes (groundnut haulms and cowpea husk) were sourced from farms after harvest in Lafia, Nasarawa State.

Experimental diets

The diet groups included 100% *Digitaria smutsii* (diet 1), 50% *Digitaria smutsii* +50% groundnut haulms (diet 2), and 50% *Digitaria* + 50% cowpea husk (diet 3).

Experimental Goats and Management

Physically sound goats were randomly sourced from reputable local farms in Lafia, Nasarawa State. A total of 36 weaner goats of two breeds (West African dwarf, n=18; 9 males + 9 females) and Red Sokoto goats, n=18; 9 males + 9 females) of about 3-4 months of age were sourced from farmers for the experiment. Upon arrival, the experimental goats were allowed to acclimatize for a period of 2 weeks during which they were dewormed against parasites and vaccinated against *Peste des petits ruminants* (PPR). Diets and water were provided *ad libitum*, and other routine management practices were adopted throughout the experimental period, as described by Timveh et al. (2022).

Thermo-physiology data collected

The thermo-physiology data collected included rectal temperature (RT), pulse rate (PR), and respiratory rate (RR), while the heat stress index (HSI) was calculated. A digital thermometer was used to take each animal's rectal temperature. After disinfecting the sensory tip of the digital thermometer, it was placed into the rectum. This was taken out following the alarm signal, and the displayed body temperature was recorded. Pulse rate was determined by counting the heartbeats using a stethoscope over a specified time period and expressed as the number of beats per minute. This was achieved by positioning the stethoscope on the left side of

the chest. The respiratory rate was measured by counting the movements of the flanks around the lower back area per minute using a stopwatch. The RT, PR, and RR were taken between 6:30 am and 9:30 am, and 1:00 pm and 3:00 pm every day.

Heat stress index (HSI) was calculated as:
$$HSI = RR/PR \times NP/NR$$

Where RR actual respiratory rate; PR = actual pulse rate; NP = normal pulse rate; NR normal respiratory rate. In both goat breeds, the basal reference value for NR was 30 breaths/minute, while that of NP was 90 beats/minute (Yakubu et al. 2017b).

Statistical Analysis

Data collected on the thermo-physiological parameters were analyzed using a Variability / Attribute Gauge Chart in SAS JMP for the variability chart and summary.

RESULTS AND DISCUSSION

A variability chart and summary showing the rectal temperature of different breeds, sexes, and diet groups of the experimental goats are presented in Figure 1 and Table 1, respectively. The average means for Red Sokoto females showed that goats fed 100% DS and 50%DS + 50%CH were similar, while the least was found in goats fed 50%DS + 50%CH. For the Red Sokoto male, it was revealed that goats fed 50%DS + 50%CH had a higher temperature. The average rectal temperature of West African Dwarf female goats showed that goats fed 100DS and 50%DS + 50%CH had similar average rectal temperatures, while the lowest was found in goats fed 50%DS + 50%CH. The temperature of West African Dwarf male goats indicated that goats fed 50% DS50 % GH had the highest rectal temperature, while those fed 100% DS and 50%DS + 50%CH had simi-

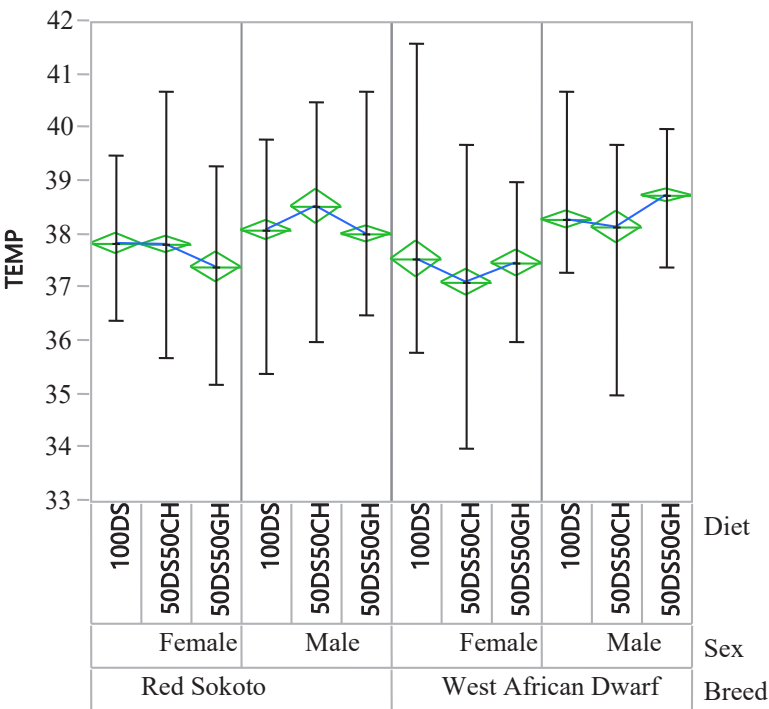


Figure 1. Variability chart showing the temperature of different breeds, sexes, and diet groups of the experimental goats

TEMP= Rectal temperature, DS= Digitaria smutsii, CH= Cowpea husk, GH= Groundnut haulms

Table 1. Variability Summary for Temperature of the experimental goats

Factors	Temperature (°C)							
	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%	Minimum	Maximum	Range
Breed[RS]	37.96189	1.066612	0.042327	37.87877	38.04501	35.2	40.7	5.5
Breed[WAD]	37.87511	1.43003	0.054244	37.76861	37.98161	34	41.6	7.6
Breed[RS] Sex[F]	37.7214	0.958115	0.058201	37.60682	37.83599	35.2	40.7	5.5
Breed[RS] Sex[M]	38.14093	1.108544	0.058104	38.02667	38.2552	35.4	40.7	5.3
Breed[WAD] Sex[F]	37.32655	1.576106	0.083769	37.1618	37.4913	34	41.6	7.6
Breed[WAD] Sex[M]	38.44457	0.978027	0.052963	38.3404	38.54875	35	40.7	5.7
Breed[RS] Sex[F] Diet[100DS]	37.84051	0.848758	0.095493	37.65039	38.03062	36.4	39.5	3.1
Breed[RS] Sex[F] Diet [50DS50GH]	37.8252	0.855416	0.07713	37.67252	37.97789	35.7	40.7	5
Breed[RS] Sex[F] Diet [50DS50GH]	37.4	1.168332	0.140651	37.11934	37.68066	35.2	39.3	4.1
Breed[RS] Sex[M] Diet 100DS]	38.09202	1.175101	0.092041	37.91027	38.27378	35.4	39.8	4.4
Breed[RS] Sex[M] Diet [50DS50CH]	38.53871	1.266641	0.160864	38.21704	38.86038	36	40.5	4.5
Breed[RS] Sex[M] Diet [50DS50GH]	38.02086	0.902129	0.076518	37.86956	38.17216	36.5	40.7	4.2
Breed[WAD] Sex[F] Diet [100DS]	37.55138	1.790128	0.171463	37.21151	37.89125	35.8	41.6	5.8
Breed[WAD] Sex[F] Diet [50DS50CH]	37.1125	1.597573	0.123255	36.86916	37.35584	34	39.7	5.7
Breed[WAD] Sex[F] Diet [50DS50GH]	37.47532	1.086176	0.123781	37.22879	37.72186	36	39	3
Breed[WAD] Sex[M] Diet [100DS]	38.292	0.905325	0.080975	38.13173	38.45227	37.3	40.7	3.4
Breed[WAD] Sex[M] Diet [50DS50CH]	38.15065	1.314356	0.149785	37.85233	38.44897	35	39.7	4.7
Breed[WAD] Sex[M] Diet [50DS50GH]	38.7446	0.713348	0.060505	38.62497	38.86424	37.4	40	2.6

RS= Red Sokoto, WAD= West African dwarf, DS= Digitaria smutsii, CH= Cowpea husk, GH= Groundnut haulms, StdDev= Standard deviation, Std Err= Standard error.

lar rectal temperatures. The variability summary presented in Table 1 indicates that the mean rectal temperature ranges from 37.1125 °C to 38.7446°C, with a minimum rectal temperature of 34 °C and a maximum rectal temperature of 41.6 °C.

The average rectal temperature values observed in the study across the breeds were within the range reported by Timveh et al. (2022), who reported 38.93 ± 0.10 °C for West African dwarf goats and 38.59 ± 0.10 °C for Red Sokoto goats. The breed did not affect the heat stress index, as observed in the present study. The similar temperature profiles found in the WAD and RS goats support studies that show domestic goats are among the best adapted to extreme climates compared to other ruminant species. The rectal temperature values obtained in this study were within the range of 38.40 ± 0.36 °C to 39.30 ± 0.67 °C, as previously reported by Ajayi et al. (2010) and Sanusi et al. (2011) for WAD goats. The higher rectal temperatures observed for WAD goats on

diets 50%DS+50%GH and 100%D may be a result of the increased heat generated during the breakdown of the feeds. This finding is in agreement with the results of Hicks et al. (2001), who previously reported that rumen temperature is influenced by body temperature and can be used to predict diseases or heat stress.

Figure 2 and Table 2 present the variability chart and summary of pulse rates for different breeds, sexes, and diets of the experimental goats. The average means for Red Sokoto females showed that goats fed 100%DS had the highest pulse rate, followed by those fed 50%DS50%CH, and the least was seen in those fed 50%DS50%GH, while the pulse rate of Red Sokoto males revealed that goats fed 100%DS had the highest pulse rate, followed by those fed 50%DS50%GH, and the least was observed in those fed 50%DS50%CH. The pulse rate of female WAD goats showed that goats fed 50% DS 50% GH had the highest pulse rate, followed by goats fed 50% DS 50% CH, and

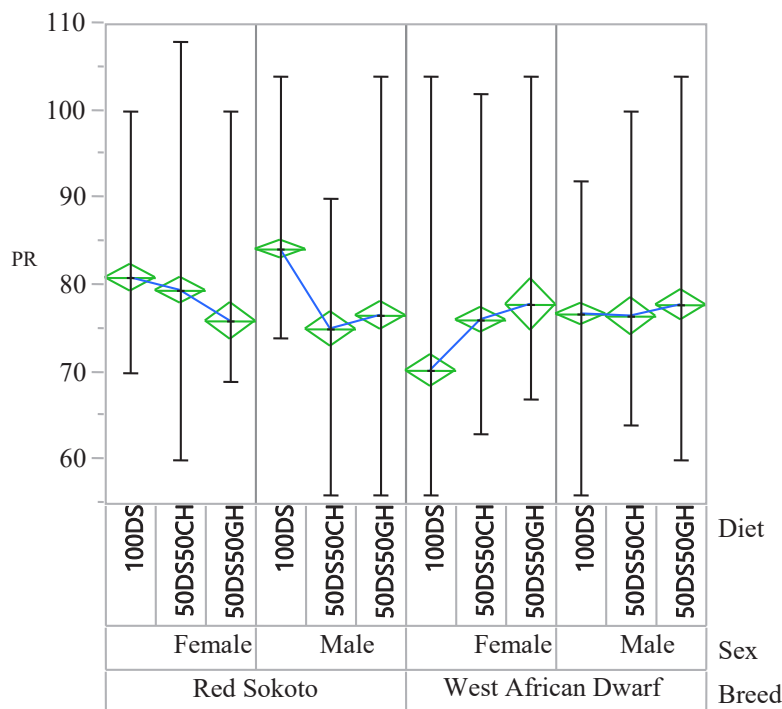


Figure 2. Variability chart showing pulse rate of different breeds, sex, and diet group of the experimental goats

PR= Pulse rate, DS= *Digitaria smutsii*, CH= Cowpea husk, GH= Groundnut haulms

Table 2. Variability Summary for Pulse Rate of the Experimental Goats

Factors	Pulse Rate (beats/minute)									
	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%	Minimum	Maximum	Range	Median	
Breed[RS]	79.40299	8.692221	0.34494	78.72563	80.08036	56	108	52	80	
Breed[WAD]	75.86331	10.01966	0.380067	75.11709	76.60953	56	104	48	72	
Breed[RS] Sex[F]	78.98118	8.23626	0.500317	77.99616	79.9662	60	108	48	80	
Breed[RS] Sex[M]	79.71703	9.015117	0.47252	78.78781	80.64625	56	104	48	80	
Breed[WAD] Sex[F]	74.66102	10.77471	0.572669	73.53474	75.78729	56	104	48	72	
Breed[WAD] Sex[M]	77.11144	9.017771	0.48834	76.15089	78.07198	56	104	48	77	
Breed[RS] Sex[F] Diet[100DS]	80.89873	6.879168	0.773967	79.35788	82.43958	70	100	30	80	
Breed[RS] Sex[F] Diet [50DS50CH]	79.4626	8.300448	0.748426	77.98102	80.94419	60	108	48	80	
Breed[RS] Sex[F] Diet [50DS50GH]	75.92754	8.792241	1.058461	73.81541	78.03966	69	100	31	71	
Breed[RS] Sex[M] Diet [100DS]	84.18405	6.662257	0.521828	83.15359	85.21451	74	104	30	82	
Breed[RS] Sex[M] Diet [50DS50CH]	75.01613	7.8521	0.997218	73.02207	77.01019	56	90	34	74	
Breed[RS] Sex[M] Diet [50DS50GH]	76.57554	9.538616	0.809055	74.97579	78.17529	56	104	48	74	
Breed[WAD] Sex[F] Diet [100DS]	70.25688	9.608449	0.920322	68.43264	72.08112	56	104	48	68	
Breed[WAD] Sex[F] Diet [50DS50CH]	76.06548	9.354713	0.721732	74.64058	77.49037	63	102	39	72.5	
Breed[WAD] Sex[F] Diet [50DS50GH]	77.83117	13.16735	1.500558	74.84255	80.81979	67	104	37	70	
Breed[WAD] Sex[M] Diet [100DS]	76.728	6.929805	0.619821	75.5012	77.9548	56	92	36	77	
Breed[WAD] Sex[M] Diet [50DS50CH]	76.49351	9.383108	1.069304	74.3638	78.62321	64	100	36	73	
Breed[WAD] Sex[M] Diet [50DS50GH]	77.79856	10.38723	0.881034	76.05649	79.54063	60	104	44	72	

RS= Red Sokoto, WAD= West African dwarf, DS= Digitaria smutsii, CH= Cowpea husk, GH= Groundnut haulms, StdDev= Standard deviation, Std Err= Standard error.

the lowest was observed in goats fed 100% DS. Similarly, male WAD goats fed 50% DS and 50% GH had the highest pulse rate, while those fed 100% DS and 50% DS50 % CH had similar pulse rates. The variability summary presented in Table 2 indicates that the mean pulse rate ranged from 70.25688 to 84.18405 beats/minute, with a minimum of 56 beats/minute and a maximum of 108 beats/minute, as observed in Table 2.

The pulse rates observed in this study were higher than the values reported by Timveh et al. (2022). This may be due to changes in the age of the animals, season, and other environmental factors during the study. The increased pressure in the RS goats may be due to increased blood flow from the core to the skin surface, allowing more heat to pass through the skin. The pulse rate was significantly affected by dietary intake, with those fed 100% DS having a higher pulse rate compared to those on diets 50% DS + 50% GH and 50% DS + 50% CH. This difference in pulse rate was reported by Ogebe et al. (1996), who not-

ed that the speed at which the heart pumps blood throughout the body, hence the pumping rate of blood in goats on a 100% DS diet, was higher than in diets 50%DS+50%GH and 50%DS+50%CH. Timveh et al. (2022) reported that pulse rate was higher in females (54.70 ± 0.24 versus 53.73 ± 0.24), which differs from the present study, in which pulse rate in males was higher than in their female counterparts.

Figure 3 and Table 3 present the variability chart and summary of respiratory rates for different breeds, sexes, and diets of the experimental goats. The average means for Red Sokoto females showed that goats fed 50% DS and 50% CH had the highest respiratory rate, followed by those fed 100% DS. The least was found in those fed 50% DS and 50% GH. The respiratory rate of Red Sokoto male goats fed 100% DS was the highest, followed by those fed 50% DS and 50% GH, and the lowest was observed in those fed 50% DS and 50% CH. The respiratory rate of female West African Dwarf goats showed that goats fed 50% DS

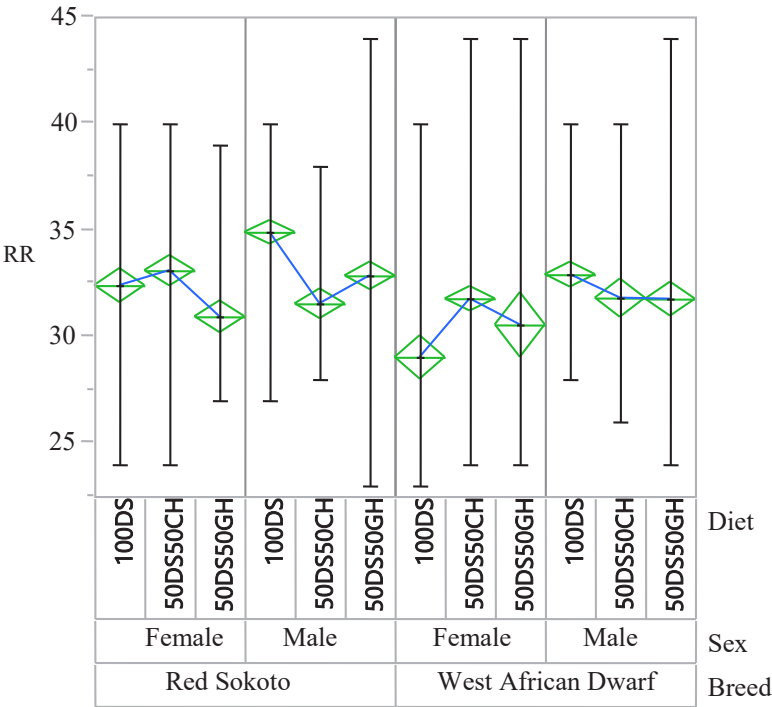


Figure 3. Variability chart showing the respiratory rate of different breeds of goats, sex, and diet group
RR= Respiratory rate, DS= *Digitaria smutsii*, CH= Cowpea husk, GH= Groundnut haulms

Table 3. Variability Summary for Respiratory Rate of Goats

Factors	Respiratory Rate (breaths/minute)						
	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%	Minimum	Maximum
Breed[RS]	33.04094	3.829764	0.15198	32.7425	33.33939	23	44
Breed[WAD]	31.42302	4.752314	0.180266	31.06909	31.77695	23	44
Breed[RS] Sex[F]	32.35055	3.764206	0.228659	31.90037	32.80074	24	40
Breed[RS] Sex[M]	33.55495	3.80224	0.199292	33.16303	33.94686	23	44
Breed[WAD] Sex[F]	30.67232	5.173475	0.274967	30.13154	31.2131	23	44
Breed[WAD] Sex[M]	32.20235	4.137006	0.224031	31.76168	32.64301	24	44
Breed[RS] Sex[F] Diet [100DS]	32.40506	3.557293	0.400227	31.60827	33.20185	24	40
Breed[RS] Sex[F] Diet [50DS50CH]	33.10569	4.015978	0.362109	32.38886	33.82252	24	40
Breed[RS] Sex[F] Diet 50DS50GH]	30.94203	3.124307	0.376122	30.19149	31.69257	27	39
Breed[RS] Sex[M] Diet [100DS]	34.90798	3.562164	0.27901	34.35701	35.45894	27	40
Breed[RS]Sex[M] Diet [50DS50CH]	31.54839	2.767951	0.35153	30.84546	32.25132	28	38
Breed[RS]Sex[M] Diet [50DS50GH]	32.86331	3.910598	0.331693	32.20745	33.51917	23	44
Breed[WAD] Sex[F] Diet [100DS]	29.0367	5.395345	0.51678	28.01235	30.06105	23	40
Breed[WAD]Sex[F]Diet [50DS50CH]	31.78571	3.784847	0.292007	31.20921	32.36222	24	44
Breed[WAD] Sex[F] Diet [50DS50GH]	30.55844	6.699359	0.763463	29.03787	32.07901	24	44
Breed[WAD] Sex[M] Diet [100DS]	32.92	3.320513	0.296996	32.33216	33.50784	28	40
Breed[WAD] Sex[M] Diet [50DS50CH]	31.81818	3.982618	0.453861	30.91424	32.72213	26	40
Breed[WAD] Sex[M] Diet[50DS50GH]	31.76978	4.773594	0.404891	30.96919	32.57038	24	44

RS= Red Sokoto, WAD= West African dwarf, DS= Digitaria smutsii, CH= Cowpea husk, GH= Groundnut haulms, StdDev= Standard deviation, Std Err= Standard error.

50% CH had the highest respiratory rate, followed by goats fed 50% DS 50% GH, and the least was observed in goats fed 100% DS. However, male West African Dwarf goats fed 100% DS had the highest respiratory rate, while those fed 50% DS, 50% CH, and 50% GH were similar and had the least. The variability summary presented in Table 3 indicates that the mean respiratory rate ranges from 29.0367 to 34.90798 breaths/minute, with a minimum pulse rate of 23 breaths/minute and a maximum respiratory rate of 44 breaths/minute, as observed in Table 3.

Respiratory rate serves as a dependable measure of heat load and is an indicator of thermal stress (Alam et al., 2011). The basal reference respiratory rate is 15–30 breaths/minute in goats (Robertshaw and Dmi’el, 1983). So, measuring the rate of breathing and determining if an animal is panting, along with assessing the level of heat stress based on the panting rate in different climates (low: 40–60, medium: 60–80, high: 80–120, and severe heat stress: >200) appears to be the most accessible and most straightforward

method for evaluating the impact of heat stress on animals under extreme conditions. Therefore, the values in this study were slightly above the normal range. Increased respiration in RS goats fed 100% DS is a clear indication that respiration increases with temperature (environment) and weight during the goat maturation cycle to establish homeostasis (Singh et al., 2002). However, the findings were previously reported by Sanusi et al. (2011) for WAD goats.

A variability chart and summary showing the heat stress index of different goat breeds, sex, and diet groups are presented in Figure 4 and Table 4, respectively. The average means for Red Sokoto females showed that goats fed 50% DS50 % CH and 50% DS50 % GH had similar heat stress indices, while the least was found in goats fed 100% DS. For the Red Sokoto male, the results revealed that goats fed 50% DS50 % CH had the highest heat stress index, while those fed 100% DS and 50% DS50 % CH were similar. The heat stress index for WAD female goats showed that goats fed 100% DS and 50% DS50 % CH had

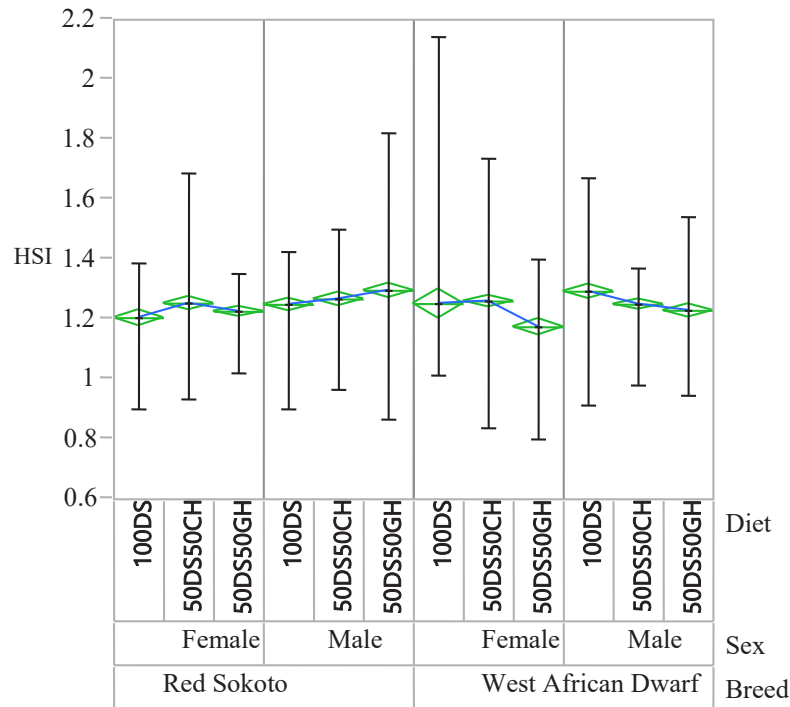


Figure 4. Variability chart showing heat stress index of different breeds of goats, sex, and diet group

HSI= Heat stress index, DS= *Digitaria smutsii*, CH= Cowpea husk, GH= Groundnut haulms

Table 4. Variability Summary for Heat stress index of goats

Factors	Heat stress index									
	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%	Minimum	Maximum	Range	Median	
Breed[RS]	1.253834	0.126682	0.005027	1.243962	1.263706	0.865979	1.821429	0.955449	1.275	
Breed[WAD]	1.247681	0.155943	0.005915	1.236067	1.259295	0.80	2.142857	1.342857	1.246753	
Breed[RS] Sex[F]	1.232218	0.112733	0.006848	1.218736	1.245701	0.90	1.6875	0.7875	1.242857	
Breed[RS] Sex[M]	1.269927	0.134044	0.007026	1.256111	1.283743	0.865979	1.821429	0.955449	1.285714	
Breed[WAD] Sex[F]	1.238798	0.179498	0.00954	1.220036	1.257561	0.80	2.142857	1.342857	1.232877	
Breed[WAD] Sex[M]	1.256902	0.126566	0.006854	1.243421	1.270384	0.913043	1.671429	0.758385	1.253165	
Breed[RS] Sex[F] Diet [100DS]	1.204823	0.118791	0.013365	1.178215	1.231431	0.90	1.3875	0.4875	1.233333	
Breed[RS] Sex[F] Diet [50DS50CH]	1.253317	0.124408	0.011218	1.23111	1.275523	0.933333	1.6875	0.754167	1.275	
Breed[RS] Sex[F] Diet [50DS50GH]	1.225974	0.069209	0.008332	1.209349	1.2426	1.02	1.352113	0.332113	1.267606	
Breed[RS] Sex[M] Diet [100DS]	1.248855	0.135664	0.010626	1.227872	1.269839	0.90	1.425	0.525	1.275	
Breed[RS] Sex[M] Diet [50DS50CH]	1.267225	0.089303	0.011341	1.244546	1.289903	0.965517	1.5	0.534483	1.275	
Breed[RS] Sex[M] Diet [50DS50GH]	1.295842	0.144666	0.01227	1.27158	1.320105	0.865979	1.821429	0.955449	1.285714	
Breed[WAD] Sex[F] Diet [100DS]	1.251656	0.256886	0.024605	1.202884	1.300428	1.0125	2.142857	1.130357	1.153846	
Breed[WAD] Sex[F] Diet [50DS50CH]	1.260029	0.127684	0.009851	1.24058	1.279477	0.837209	1.736842	0.899633	1.273973	
Breed[WAD] Sex[F] Diet [50DS50GH]	1.174277	0.120829	0.01377	1.146852	1.201702	0.8	1.4	0.6	1.175676	
Breed[WAD] Sex[M] Diet [100DS]	1.292599	0.135526	0.012122	1.268606	1.316591	0.913043	1.671429	0.758385	1.275	
Breed[WAD] Sex[M] Diet [50DS50CH]	1.249747	0.076731	0.008744	1.232331	1.267163	0.979592	1.37037	0.390779	1.235294	
Breed[WAD] Sex[M] Diet [50DS50GH]	1.228765	0.133193	0.011297	1.206427	1.251103	0.945652	1.541667	0.596014	1.25	

RS= Red Sokoto, WAD= West African dwarf, DS= Digitaria smutsii, CH= Cowpea husk, GH= Groundnut haulms, StdDev= Standard deviation, Std Err= Standard error.

similar average heat stress indices, and the least was found in goats fed 50% DS+50% GH. The heat stress index of WAD males indicated that goats fed 100% DS had the highest value, while those fed 50% DS, 50% CH, and 50% GH had the lowest values, which were similar. The variability summary presented in Table 4 indicates that the mean heat stress index ranges from 1.174277 to 1.295842, with a minimum of 0.8 and a maximum of 2.142857.

Thermal stress index values of RS goats fed 100%DS, 50% DS+50% GH, and 50%DS+50%CH diets were found to be 1.25, 1.24, and 1.26, respectively. Those fed a 50% DS+50% CH diet, though not different from others, the results were in line with Okoruwa et al. (2013), who found that temperature and pulse rate are utilized in assessing the physiological condition and adaptability of domestic animals. The higher heat stress index in males in the present study is consistent with the finding of Timveh et al. (2022), who reported a higher heat stress index in males (2.35) compared to females (2.26). The male goats showed to be more stressed based on the heat stress index. This finding aligns with the results of Facanha et al. (2012), who reported that goats subjected to heat stress exhibited an increased respiratory rate, a dependable indicator of heat load and thermal stress (Okoruwa et al., 2013). Female small ruminants appear to be better equipped to handle heat stress than their male counterparts, despite both sexes being affected by it, as reported by Schoenian (2019).

CONCLUSION

West African Dwarf (WAD) and Red Sokoto (RS) goats have similar rectal temperatures within normal ranges, showing breed does not significantly affect heat stress. Males exhibit slightly higher temperatures and pulse rates than females. Diets combining 50% *Digitaria smutsii* with groundnut haulms or cowpea husk affect thermophysiological responses, with some diets, such as 50% DS + 50% GH, better mitigating heat stress, especially in female WAD goats. Respiratory

rates rise with specific diets, indicating increased heat load. Overall, the goats demonstrate good adaptability to the local climate.

RECOMMENDATIONS

Incorporating a mix of *Digitaria smutsii* with groundnut haulms or cowpea husk can influence heat load management and should be optimized to improve animal comfort and productivity. Diets higher in fiber (such as 50% DS + 50% GH) may reduce excessive heat production compared to feeding 100% DS. Selection for breeding should consider physiological resilience to heat stress in both RS and WAD goats, with the understanding that males may require closer monitoring under heat-stress conditions. More frequent monitoring of rectal temperature, pulse, and respiratory rate, especially during the hotter parts of the day, can help in the early detection of heat stress. Providing shade, water *ad libitum*, and dietary adjustments during peak ambient temperatures will enhance goats' thermoregulation and overall welfare.

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