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Research Article

Temperature Humidity Index: Influence on Milk Yield and Milk Composition of Multiparous West African Dwarf Does

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Abstract

This study examined the influence of ambient temperature (AT), relative humidity (RH) and temperature-humidity index (THI) on milk yield (MY) and milk compositions (MC) of West African Dwarf (WAD) goats using a total of thirty-six (36) lactating does. The goats were milked twice daily for twelve (12) weeks during which, AT and RH were monitored. The AT and RH data were used to generate THI. The milk collected at every milking was quantified and also analysed for MC, The AT, RH and THI during each milking period were categorized into low, medium and high ranges, under which the corresponding MY and MC were fixed. The data generated were subjected to Analysis of Variance of a Completely Randomized Design. The result revealed that the highest MY (350.28 mL), recorded during low AT range, was not significantly different from 329.43 mL obtained during medium AT, while high RH range (70-99%) facilitates higher MY (364.30 mL) compare to low and medium ranges. AT exerted no significant difference on all the MCs except protein. Milk fat was highest (7.34%) at low THI, while the lactose (11.30%) at high THI range was significantly higher compared to other ranges. A relatively higher MY (324.35 mL) and milk density (1034.94 kg/m^3) was obtained within medium THI range (75.6-85.6). It is concluded that, AT and RH exhibit a synergistic effect on MY and some of the MCs.It is recommended that thermo-comfort THI for dairy WAD goats is between 75.6 and 85.6.

Keywords: Ambient temperature, Milk composition, Milk yield, Relative humidity, and Temperature- humidity index

Introduction

Agriculture contributes to climatic change and as well, being negatively affected by it. The nature and the extent of animal agriculture practised in any region of the globe are commonly influenced by the interactions among numerous physical, biological and socioeconomic factors [1,2]. As agriculture tends towards increased commercialization, impact on climate change becomes more apposite [3]. Thus, improving animal agriculture needs to consider the interactions between animals and the environment. Complexities between livestock sector and climatic change were identified to be significant and generally overlooked, particularly in Africa where livestock plays a crucial role in poverty alleviation and rural development [4].

Small ruminants play a predominant role in the economy of million people and have provided meat, milk, skin and many other indirect benefits for centuries [5]. The demand for livestock (including small ruminants) products and consequential increase in production has been largely driven by the rapid growth of human population, increases in income and urbanization [6]. Therefore, climatic change becomes a serious long- term challenge faced by small ruminants' owners worldwide. The influence of climatic change in terms of sudden temperature change has caused significant losses in animal production [7] and therefore generates the need for detailed studies on the adaptive processes of breeds, especially goats, to better understand the adaptation parameters and processes of these animals.

Change in relative humidity and ambient temperature constitute meaningful effects on animal behaviour as a result of neuron endocrine response which consequently influences production and health status of animals [8,9]. Thus, temperature change is a major threat to the viability and sustainability of milk production in goats as well as relative humidity [10]. Livestock generally express their full potential when environmental conditions are favourable.

Earlier researchers demonstrated that air temperature and relative humidity are the major natural physical environmental factors affecting livestock. Changes in these factors are recognized as a potential hazard in livestock growth and production [4] and thus, seasonal variations in these factors are therefore undeniable physiological stressors which affect the animal's biological systems.

High-producing animals tend to have reduced productivity when subjected to greater influence by climatic factors, particularly those raised under tropical conditions, due to high air temperature and relative humidity [11]. Some authors also asserted that high temperatures may reduce feed intake, lower milk production, leading to energy deficits that may lower fertility, fitness and longevity in animal [12]. Research findings by [13,14], indicated that effective environmental temperature above 30ºC activates the stress response system in lactating goats and in response goats reduces intake of feed which is directly associated with negative energy balance, which is largely responsible for the decline in milk synthesis. However, the findings by [15] concluded that goat breeds differ in capability to tolerate heat. Evaluation of goat milk yield and composition with respect to ambient temperature and relative humidity on West African Dwarf does is practically non-existent in literature. Therefore, this study was designed to investigate the influence of ambient temperature, relative humidity and relative-humidity index on the milk yield and milk composition of West African Dwarf does.

Materials and Methods

Ethical Approval

All the handling of the goats conforms to the guidelines of Ethical Review Committee of University of Ilorin, Nigeria. Ethical approval to undertake the research was given by the Ethical Review Committee of University of Ilorin, Nigeria. The protocol identification Code and Ethical Approval Number assigned to the research are UERC/AGR/174 and UERC/ASN/2020/2039 respectively.

Experimental Site

This research was carried out at the Small Ruminant Unit of the Teaching and Research Farm, University of Ilorin, Nigeria. The ambient temperature of the site ranges from 19.00°C to 42°C while its relative humidity ranges from 21-83% depending on the period of the year.

Animals and Management

This research was conducted using thirty-six (n=36) apparently healthy lactating West African Dwarf (WAD) does. The does were free of mastitis and other physiological disorder. All the does were fed *ad-libitum* with the same ration *(Table 1)*, compounded to satisfy the nutrient requirement of lactating does [16]. The experiment lasted for a period of twelve weeks. The does were managed within housing units that permit ample exercise and limited degree of freedom which was strictly in line with guideline of University of Ilorin ethical review committee. The milking of each of the does commenced at five-day post-paturm and for a period of twelve weeks. The records of milk yield, ambient temperature and relative humidity were taken at every milking period.

Table 1. *Composition of diets fed to experimental goats*

Feed Ingredient	Percentage (%)
Wheat Bran	25
Palm Kernel Cake	15
Groundnut Cake	5
Rice Bran	5
Corn Bran	10.5
Maize	20
Cassava Peel	19
Salt	0.5
Estimated TDN	59.09
Estimated CP	12.23

Experimental Design and Data Collection

This experiment was laid out in a Completely Randomized Design (CRD). The does were milked twice daily (morning: 07.00 am - 09.00 am; evening: 05.00 am - 07.00 am) for a period of twelve weeks. Hand stripping was done in order to stimulate milk let down before the use of the milking machine, which has a calibrated cylinder for measuring the milk yield of each doe. Milk samples from the does were taken to the laboratory for milk composition analysis using a milk analyzer (Milch analyser, Ultrascan 3100, count: 1288, SN: 28214 PC151). A digital thermo-hygrometer placed within the housing unitswas used to monitor the ambient temperature (AT) and relative humidity (RH) twice per day during every milking process. The recorded morning and evening AT and RH values were averaged to obtain daily day AT and RH during the period of the experiment. These values were categorized as low, medium and high. The AT ranges for each of the categories are: low (17.5-25.6); medium (25.7-33.8) and; High (33.9-42.0) while the ranges for the RH are: low (10-39%); medium (40-69%); and high (70-99%). The sample sizes being the total number of animals whose data collection period fell within the stated categories of AT and RH throughout the period of the experiment were: Low (n=31), Medium (n=27), and High (n=26) for AT, while that of RH are; Low (n=27), Medium (n=28), and High (n=29). Collected data on AT and RH were used to calculate temperature-humidity index (THI) as reported [17].

THI = 0.8×AT+RH%× (AT-14.4) + 46.4

where, AT = air temperature in °C; RH = relative humidity in %.

The THI values were also categorized as: low (65.5-75.50; medium (75.6-85.6) and; high (85.7-95.7). The sample sizes being the number of animals observed within each THI categories were: Low (n=28), Medium (n=26) and High (n=30).

Statistical Analysis

The three categories of each of AT, RH and THI (low, medium and high) were treated as independent variables while the corresponding values of milk yield and milk composition were considered as dependent variable. The data obtained were tested for normal distribution using DATAtab statistic calculator. The parameter whose data that did not follow normal distribution were transformed prior analysis of variance using Minitab Statistical package Version 17. Least Significant Difference Test was used for post hoc.

Results

The influence of ambient temperature on daily milk yield (DMY) and milk composition of WAD does is presented in *Table 2*. A significant difference (P<0.05) was observed in the DMY of the multiparous WAD does at different ranges of ambient temperature (AT). The DMY when AT was medium (350.28 mL/day) as well as low (329.43 mL/day) were not significantly different from each other but were significantly higher (P<0.05) than 210.56 mL/day obtained when AT was within high range. All the milk compositions evaluated were not affected by ambient temperature except milk protein. The average milk protein of the does during the days within high AT (4.72%) was significantly higher (P<0.05) compare to when AT was either within low or medium range. The milk produced during the days with medium and low AT had comparable milk protein of 3.83 and 3.85% respectively.

The influence of relative humidity (RH) on the milk yield and milk composition of WAD does is presented in *Table 3*. The DMY of the multiparous WAD does was significantly (P<0.05) influenced by RH with the highest yield (364.30 mL/day) being produced when the RH of the day was high. The yield during moderate RH (332.18 mL/day) was also significantly higher than 257.48 mL/day produced during the day with low RH range. The milk fat obtained when the RH was on the high side was also significantly lower compare to when RH was low or medium. All other milk compositions were not affected by RH. The SNF, density, FP, protein, lactose and salt content of the milk showed no significant difference (P>0.05) at the different levels of relative humidity.

The influence of temperature-humidity index (THI) on milk yield and milk composition of lactating WAD goats is presented in *Table 4*. Significant differences (P<0.05) were observed in the milk yield of the does and, in the fat, density and lactose content of the milk at the three THI categories (low, medium and high). The highest milk yield (324.35 mL) and milk density (1034.94 kg/m^3) were obtained when the THI range was medium. These values were significantly higher than the corresponding values obtained at low and high THI (MY: 246.30 mL vs 205.00 mL; Density: 1032.38 vs1030.10). The milk fat and milk density during the days that exhibited medium and high THI were not significantly different from each other. A significantly higher milk fat, and lower milk density was however recorded during the day with low THI. The milk lactose recorded during high THI days (11.30%) was significantly higher than 5.66 and 6.07% recorded for low and moderate THI days respectively. No significant difference (P>0.05) was observed between classes of THI with respect to SNF, FP, protein and salt content of the milk.

Table 2. *Influence of ambient temperature on average milk yield and milk composition of West African Dwarf does*

Milk Parameters	Ambient Temperature			SEM	P-Value
	Low (n =31)	Medium (n =27)	High (n =26)		
DMY (mL)	350.28[a]	329.43[a]	210.56[b]	22.45	0.001
Fat (%)	7.09	6.95	7.76	0.85	0.114
SNF (%)	11.03	10.94	10.65	0.19	0.955
Density (kg/m^3)	1033.19	1034.30	1034.15	1.15	0.167
FP (°C)	-0.68	-0.50	-0.73	0.29	0.692
Protein (%)	3.83[b]	3.86[b]	4.72[a]	0.54	0.018
Lactose (%)	5.68	6.05	7.05	0.39	0.131
Salt (%)	0.86	0.90	0.87	0.06	0.442

[a,b] *Means with different superscript in the same row are significantly P<0.05 different from one another. DMY: Daily Milk Yield; SNF: Solid Non-Fat; FP: Freezing point*

Table 3. Influence of relative humidity on milk yield and milk composition of lactating West African Dwarf goats

Milk Parameters	Relative Humidity			SEM	P-Value
	Low (n = 27)	Medium (n=28)	High (n=29)		
DMY (mL)	257.48[c]	332.18[b]	364.30[a]	25.55	0.000
Fat (%)	7.34[a]	7.33[a]	6.17[b]	0.98	0.000
SNF (%)	10.46	11.57	10.38	1.34	0.300
Density (kg/m^3)	1034.17	1033.42	1034.44	0.79	0.228
FP (°C)	-0.72	-0.69	-0.36	0.39	0.345
Protein (%)	4.32	3.87	3.82	0.57	0.146
Lactose (%)	6.46	5.77	6.16	0.72	0.397
Salt (%)	0.87	0.87	0.90	0.06	0.561

[a,b,c] *Means with different superscript in the same row are significantly P<0.05 different from one another. DMY: Daily Milk Yield; SNF: Solid Non-Fat; Fp: Freezing point*

Table 4. Influence of Temperature-humidity index on milk yield and milk composition of West African Dwarf does

Milk Parameters	Temperature-Humidity Index			SEM	P-Value
	Low (n = 28)	Medium (n=26)	High (n=30)		
DMY (mL)	246.30[b]	324.35[a]	205.00[c]	23.45	0.000
Fat (%)	7.55[a]	6.78[b]	7.13[b]	0.38	0.009
SNF (%)	11.41	10.62	10.77	0.82	0.590
Density (kg/m^3)	1032.38[b]	1034.94[a]	1030.01[c]	2.36	0.000
FP (°C)	-0.68	-0.52	-0.726	0.32	0.772
Protein (%)	3.80	4.05	4.00	0.27	0.482
Lactose (%)	5.66[b]	6.07[b]	11.30[a]	3.23	0.000
Salt (%)	0.86	0.89	0.90	0.08	0.373

[a,b,c] *Means with different superscript in the same row are significantly P<0.05 different from one another. DMY: Daily Milk Yield; SNF: Solid Non-Fat; FP: Freezing point*

Discussion

Variation in adaptability to fluctuations in weather and other environmental factors is one of the primary factor responsible for global distribution of species and breeds of livestock [18-20]. Despite being reported to be adaptable to a vast weather condition, some specific breeds of goat are strictly predominant in few regions than others. Thus, definition of thermo-comfort zone using temperature range subsists. However, discrepancies exist in the reported range, as some researchers [21,22] concluded that goats in the hot climate are liable to perform excellently between (12-24°C) while other researchers [23] indicated between 20 and 30°C. The current result, however, disagrees with the thermo-comfort temperature specified for goat by these authors, with the comparable yield (350.28 mL and 329.43 mL) obtained at low (17.5-25.6) and medium (25.7-33.8) ambient temperature ranges focused in the current study. This may suggest breed variation in adaptability to AT, which was also reported by some authors [24,25]. A marked reduction in the milk yield at AT of between 33.9 and 42.0°C suggests inhibition of production capacity and thermo-regulatory compensation for energy balance [26]. The milk yield obtained during low and medium AT in the current study are of close range with 3339.20mls reported for white WAD goat [27].

The present result also corroborates with the report in which the production and quality of goat's milk were indicated to be directly related to climatic variations and the combined action of these factors [23]. The significant effect of AT on protein, RH on fat and THI on fat, density and lactose reveals that synergy exist between AT and RH. However, the present study contradicts [28] who reported that stressful environmental conditions may not alter the composition of goat milk if they are well adapted to their environment. The trends of THI, RH and AT impacts on milk fat, protein and other compositions in the current study may explain the complexities in the thermo-regulatory mechanisms in goat and thus reaffirm the statement that environmental effects on milk composition is not conclusive [26]. A similar increase in milk protein but not other milk compositions, as observed in the current study, was also reported [26] in goat during period of high AT while some previous studies [10,29,30] reported a contrary result. Reduction in milk yield at the expense of maintaining milk fat at high AT and, increased milk protein at low RH, as well as high lactose when THI was high substantiates the influence of these environmental factors on metabolic changes and hormonal reactions [24]. In contrary to some authors [31] who noted that goats are more comfortable in environment where average RH is 65%, the highest milk in the current study was recorded when RH was between 70-99%. This might suggest breed variation in adaptability to weather factors [15].

Defining heat stress using THI in goat has been discussed by several authors [32,33]. There is, however, a clear demarcation of discomfort levels across breeds. This is equally noticed in the current study with WAD goat producing significantly higher milk yield at THI higher than 79 which was reported [34] to be a dangerous level for Saanen goats managed in Brazil. The result in the current study aligns with the report by some authors [35] which indicated in good performance in Anglo-Nubian goat at THI of 83.00 denoting better adaptability of these breeds to tropical regions. A relatively high milk yield between the THI of 75.6 and 85.6 in the present study portrays a disagreement with the earlier findings [36] which noted 80-85 THI as a dangerous level. However, a marked reduction when THI is between 85.7 and 95.7 may be an indication that the WAD goats are heat-stressed within this range [29]. The effect of heat stress on milk fat content is contentious. Some authors reported a negatively correlated effects [37,38] while [39] established no relationship. The present result, however, agrees with [40], who found lower values of milk fat content when the temperature-humidity index was higher than 75. Similarly, earlier findings [39,40] found milk lactose content to be non-significantly between dairy animals maintained at temperature-humidity index <75 and those maintained at temperature-humidity index >75 but, the current study is not in line with these two reports as the lactose content recorded for high (85.7-95.7) temperature-humidity index was significantly different (P<0.05) from the lactose content recorded for low (65.5-75.5) and moderate (75.6-85.6) temperature-humidity index. Alteration in milk protein reported by these authors as temperature humidity index changes was also not observed in the current study. All contradictions might be as a result in difference in species, breed, nutrition and other environmental factors. The response of the goats in relation THI result in the current study aligns with the report that there is higher tendency of better performance at THI of between 65-72 [30].

It is concluded that changes ambient temperature, relative humidity and temperature-humidity influence milk yield in a non-uniform trend while only THI affects more milk compositions than AT and RH. It is also concluded that WAD goat for dairy purpose perform optimally at AT of 17.5 to 33.8°C, RH of 70-99%, and THI of between75.6 and 85.6.

Declarations

Availability of Data and Materials: The data that supports the findings of this study are available on request from the corresponding author (A. T. Yusuff).

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