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Research article

Impact of heat stress on reproductive performances in dairy goats under tropical sub-humid environment

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ABSTRACT

Reproductive parameters of dairy animals are generally affected by meteorological factors. This study aimed to investigate the effects of heat stress (HS) on reproductive parameters Saanen and Saanen× Red Maradi (½S½RM) dairy goats reared on a private farm in a tropical sub-humid environment in Benin. To assess the reproductive performances 103 goats (46 Saanen and 57 ½S½RM) were followed up from January 2015 to December 2019. The temperature-humidity index (THI) was obtained during the same period using meteorological data such as ambient temperature (AT) and relative humidity (RH). Pearson correlation matrix analysis was then performed between the environmental variables and the reproductive parameters. Reproductive parameters of ½S½RM goats were better than those of Saanen goats. The conception (92.09%), prolificacy (156.54%) and fecundity (117.11%) rates of ½S½RM goats were significantly higher than those of Saanen goats (67.16%; 149.41% and 89.70%). The conception rate of Saanen goats was not affected by the level of THI. The conception, prolificacy, and fertility rates of ½S½RM goats decreased from 97.22%, 161.35% and 121.52%, at moderate THI to 83.89%, 148.86%, and 110.04% at extreme THI, respectively. In summary, although Saanen goats were very efficient in milk production, their reproductive performance was affected by the level of THI. On the contrary, the ½S½RM crossbred goats had a better conception, prolificacy and fertility rates in the sub-humid tropical climate of Benin.

1. Introduction

Ruminants, especially goats are considered the main source of protein and micronutrients necessary for human welfare (Mottet et al., 2017). To promote and improve dairy goat breeding in Benin, specialized breeds such as "Saanen", from climate zones and "Red Maradi", a rustic breed with a double function, imported from the Sahel region, have been introduced in the Sudano-Guinean region since 2012 on a private farm (Offoumon et al., 2019). This farm practices a system of crossbreeding between those two breeds (Offoumon et al., 2019). The same authors evaluated the reproduction performances of these goats and found that the Red Maradi goats showed better reproduction performances than Saanen and their crossbreed. With the global warming, it's important to select more heat-tolerant dairy goat breeds. Under certain environmental conditions, the improvement of the animals' ability to cope with environmental stressors is based on heat tolerance indicators (Amamou et al., 2019). Therefore, the description of the production environment in farming is desperately needed and important because each breed has distinct adaptability features (Ribeiro et al., 2018). In the northern Benin a sub-humid tropical climate predominates. Previously, Adjassin et al. (2020), in their study on the characterization of the thermal environment indicated that dairy animals introduced in Benin are under the constant effect of thermal discomfort all year round with 8 months of moderate stress ($75 \leq THI<78$) and 04 months of extreme stress ($THI \geq 78$). These breeds undergo more heat stress, partly due to their productivity, which reduces their thermal comfort threshold. The effect of heat stress differs not only among regions but also among animal species and type of production which could either be positive or negative (Sejian et al., 2017). Exposure of goats to HS results in changes in physiological functions with an impact on the production and productivity of the animals (Kadzere et al., 2002; Ribeiro et al., 2018; Osei-Amponsah et al., 2019). According to NOAA (2017), the effects of global average yearly temperature have

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increased by 0.94 °C compared to the average for the 20th century. That results in an unprecedented global warming rate over the past 10.000 years. These effects are worst nowadays. It is increasingly exposing farm animals to stressful conditions worldwide. Several researchers have shown that animal performance has severely deteriorated when animals are subjected to Heat stress (HS) (Silanikove, 2000). HS occurs when farm animals are exposed to combinations of high temperatures, solar radiation, and relative humidity and therefore are no longer able to properly dissipate stored heat (Das et al., 2016; Sejian et al., 2017). Dairy farms are currently facing the challenge of overcoming the negative effects of hot weather conditions on animal performance (Polsky and von Keyserlingk, 2017). However, knowing how the reproductive system of animals is more sensitive to temperature than other parts of the body becomes relevant. At high ambient temperature various organs of the reproductive system in both sexes of the animal are altered. In males, it reduces libido by affecting the level of testosterone, ejaculate volume, sperm motility by increasing the proportion of morphologically abnormal sperm in the ejaculate (Pérez-Crespo et al., 2008). In females, it reduces the growth of ovarian follicles, maturation of oocytes (Mustafi et al., 2009). It also affects the development of embryos and the conception rate (Rojas-Downing et al., 2017). Many scientists have taken into account data from weather stations located near farms for assessing the impact of weather conditions in the production of farm animals (Beux et al., 2017; Kekana et al., 2018). Such an approach is acceptable when assessing the effect of high temperatures on animals, not only on grazing areas, but also inboxes where the microclimate is similar to the state of the environment (Lambertz et al., 2014). Similarly, several bioclimatic indices have been developed to assess the impact of environmental factors on animals. The most commonly used is the THI which combines the effects of AT and RH (Bohmanova et al., 2007; Mylostyvyi and Sejian, 2019). Despite the large number of studies conducted on dairy goats, little is known about the effect of heat stress on their reproductive performances. To the best of our knowledge, there no such studies documented in tropical sub-humid environment. Therefore, understanding in depth how meteorological variables influence reproductive performances is crucial in the context of tropical sub-humid environment of Benin. It is also a way to improve dairy goat farming beyond the borders of this region. So, this study attempts to use the THI to assess the impact of HS on the reproductive parameters of Saanen and crossbred Saanen× Red Maradi dairy goats.

2. Material and methods

2.1. Ethical approval

All experimental animals were approved and conducted according to established animal welfare guidelines by the Human and Animal Ethical Committee of University of Parakou, Benin.

2.2. Study area

This study was conducted in the "Fermier Sans Frontière" a Non-Governmental Organization (NGO) farm which is located 60 km away from Parakou at an altitude of 380.89 m and 2°40′26″ N and 9°40′07″ E. The climate is tropical with alternating rainy season (June to September) and dry season (December to March). The transition from one season to another is marked by a transition period (April to May and October to November). The annual mean rainfall amount is on average about 1100 mm. The area is a moderately warm temperature zone with a mean daily temperature range from 28 - 32 °C.

2.3. Housing and feeding management

The goats were housed in communal enclosures with a solid floor, with an east-west. The goats were not sent for grazing. Feed was supplied two times a day (at 07: 00 am and 4: 00 pm) and consisted of 50 % *Panicum maximum C1*, 20 % *Andropogon gayanus* 30% *Leucaena leucocephala* in the green chopped form and *ad libitum*. A concentrated supplement of a mixture of soybean, rice bran, powder of *Parkia biglobosa*, mineral and salt at 30, 46, 21, 2 and 1 percent respectively. This supplement was provided at 2 kg concentrate per animal/day (1.2 kg in the morning and 0.8 kg in the afternoon). The goats have free access to drinking water and mineral salt.

2.4. Reproductive performances data

The study was conducted during five consecutive years (2015–2019) and included 103 dairy goats, 46 Saanen and 57 ½S½RM between 7 to 8 months old. Their mean weight was ranging between 32.96 ± 3.59 kg and 35.37 ± 1.24 kg, and showing good health on clinical examination. The data was collected during extreme and moderate heat stress conditions. Data included goat identification, number of lactations, date of birth, age of reproduction (AR), the weight of reproduction (WR), age at first kidding (AFK), kidding interval (KI), gestation length (GL) and parity. The number of kids born for each kidding was additionally obtained. GL is the interval between the date of mating and kidding. Reproductive performances (1,2 and 3) were determined according to the formula provided by Charring et al. (1992):

$$\text{Fertility} = \frac{\text{Number of alive kids born}}{\text{Number of doe}} \times 100 \quad (1)$$

$$\text{Prolificacy} = \frac{\text{Number of live or dead kids born}}{\text{Number of doe kidding}} \times 100 \quad (2)$$

$$\text{Conception rate} = \frac{\text{Number of gestating does (aborted or kidding)}}{\text{Number of doe}} \times 100 \quad (3)$$

2.5. Measurement of climatic variables

A database including records of AT and RH was provided by the synoptic station of Parakou, 60 km far from the study area. These meteorological data corresponding to the maximum and minimum daily values was recorded during the period 2015 to 2019. They enabled us to calculate the THI, which combines ambient temperature (AT, °C) and relative humidity (RH, %) according to formula (4) described by Mader et al. (2006):

$$\text{THI} = (0.8 \times \text{AT}\ ^{\circ}C) + \left[\left(\frac{\%\text{RH}}{100}\right) \times (\text{AT}\ ^{\circ}C - 14.4)\right] + 46.6 \quad (4)$$

where: AT = ambient temperature in °C and RH = relative humidity in %

THI values obtained were distributed according to the classification of Silanikove (2000). The purpose of this classification is to evaluate the intensity of heat stress according to the following appreciation: the different classes are “no effect”, “low”, “moderate” and “extreme”. They respectively correspond to the following THI thresholds: THI <70; $70 \leq$ THI<75; $75 \leq$ THI<78; THI ≥ 78.

2.6. Statistical analysis

The data were recorded and managed in an Excel spreadsheet. A generalized linear model (GLM) was performed to the data to determine the effect of the following factors THI, breed, the interaction THI*breed and parity on gestation length, kidding interval, conception rate, prolificacy and fertility. The fixed model (5) is presented as follows:

$$\gamma_{ijklm} = \mu + THI_i + breed_j + THI*breed_{ij} + parity_k + e_{ijk} \quad (5)$$

Where Y_{ijk} is the dependent variable (gestation length, kidding interval, conception rate, prolificacy or fertility); μ is the overall mean; THI_i (moderate stress and extreme stress); $breed_j$ (purebred and crossbred); $THI*breed_{ij}$ the interaction between stress condition and breed parity is the number of kids per kidding and e_{ijk} refers to the residual effect. Comparison of means was performed by ANOVA test. The Pearson correlation coefficients were determined between the parameters of climatic conditions and reproductive performances. The values are expressed as mean ± Standard deviation. A difference with value $p < 0.05$ was considered statistically significant. The categorical variables were presented as frequencies and chi-square tests were applied to assess the dependence between reproductive parameters and the heat stress index. The analyses were performed using software R.3.6.2 (R Core Team, 2018).

3. Results

3.1. Environmental conditions in tropical sub-humid environment of Benin

The monthly mean values of ambient temperature (AT, °C), relative humidity (RH, %) and THI for the study area are presented in Table 1. Significant variation in AT and RH was observed in tropical sub-humid environment of Benin. The monthly mean AT ranged from 25.25 to 30.97 °C, and mean RH ranged from 33.92 to 81.74%. The monthly mean AT and THI values reached a maximum in March (30.97 °C and 81.74 °C, respectively) and a minimum in August (25.25 °C and 76.17 °C, respectively). RH peaked in August (81.74%) and reached a minimum value in January (33.92%).

3.2. Influence of heat stress conditions, breed and their interaction on the reproductive parameters of dairy goats

Table 2a and 2b show the mean values of the THI values and the possible effect of THI, breed and their interaction on the reproductive parameters of Saanen and ½S½RM goats under moderate and extreme stress conditions. The results revealed that the reproductive parameters varied significantly ($p < 0.001$) according to breed, except for gestation length (p˃ 0.05). The effect of the interaction of these two factors was significant ($p < 0.001$) for the age of reproduction, the weight of reproduction and kidding interval of dairy goats except for age at first kidding and gestation length (p˃ 0.05). In addition, the fertility rate of ½S½RM goats was higher (117.11%) than Saanen goats (89.70%). ½S½RM goats had a higher fertility rate (121.52%) than the Saanen (91.94%) under moderate conditions, versus 110.04% and 84.57%, respectively, under extreme stress conditions. Conception rate was higher under moderate stress conditions (83.53%) than under extreme climatic conditions (77.94%) (Table 2b). Analysis of variance revealed a significant effect of climatic conditions on the kidding interval, which was almost one month longer in the hottest months of the year than in the generally colder months. Results obtained from the effect of heat stress conditions on reproductive parameters revealed that ½S½RM goats showed higher conception, prolificacy, and fecundity rates compared to the purebred (Saanen).

Table 1. Monthly variation of climatic parameters and THI index according to heat stress conditions.

HS conditions	Month	AT (° C)	RH (%)	THI
Moderate	December	27.72 ± 0.95	41.63 ± 5.50	76.03 ± 1.42
	January	27.72 ± 1.04	33.92 ± 9.03	74.68 ± 2.55
	February	28.09 ± 1.12	41.28 ± 10.48	77.29 ± 3.16
	July	25.94 ± 0.52	78.71 ± 1.58	76.92 ± 0.73
	May	26.25 ± 0.67	78.87 ± 2.87	77.11 ± 0.58
	June	25.85 ± 0.55	79.85 ± 1.39	77.14 ± 0.71
	August	25.25 ± 0.49	81.74 ± 1.20	76.17 ± 0.60
	September	25.82 ± 0.54	79.75 ± 0.99	77.05 ± 0.77
Extreme	October	26.97 ± 0.55	74.23 ± 2.81	78.50 ± 0.72
	November	28.27 ± 0.81	56.50 ± 7.16	78.74 ± 1.13
	March	30.97 ± 0.69	51.21 ± 6.69	81.74 ± 1.49
	April	29.80 ± 0.85	63.84 ± 2.97	81.44 ± 0.81

AT: Ambient Temperature; RH: Relative Humidity.

3.3. Correlation between environmental factors and reproductive parameters of dairy goats

Tables 3 and 4 show the Pearson correlation of environmental factors and reproductive parameters of Saanen and ½S½RM goats, respectively. Indicators of the reproductive parameters of Saanen dairy goats revealed that positive and significant correlations were observed between AT, prolificacy (0.83) and fecundity (0.91) rates (Table 3). A low and no significant negative correlation was observed between AT and conception rate (−0.08). On the other hand, negative and significant correlations between the THI index and the prolificacy (−0.83) and fertility (−0.91) rates (Table 3) were observed. The same observations were made with RH. Reproductive parameters most affected by the THI were fertility rate with a negative correlation coefficient (−0.91). THI was also found to have a negative and significant correlation with the fertility rate (−0.83). The parameter least affected was the conception rate with a correlation coefficient of 0.02.

In ½S½RM goats, indicators of reproductive parameters were positively and significantly correlated with AT and the prolificacy rates (0.82), conception (0.80) and fertility (0.82) (Table 4). The results showed a negative and significant negative correlation between THI and the prolificacy rates (−0.93), conception (−0.99) and fertility (−0.95). Furthermore, the results revealed that the second climate variable negatively correlated with the prolificacy rate (−0.82), conception (−0.79) and fertility (−0.80) rates of ½S½RM goats was RH.

4. Discussion

Among the environmental stress factors, ambient temperature is mainly the most important (Horowitz, 2002). Heat stress is increased when the ambient temperature is combined by high relative humidity (Chauhan et al., 2021). An ambient temperature between 25-26 °C is considered a threshold above which zootechnical performance is affected (Kadzere et al., 2002). In this study, a significant variation in the ambient temperature and relative humidity was observed during the five years of study. In addition, the dairy goat breeding environment has a sub-humid tropical climate that is influenced by the harmattan a hot dry wind from the Sahara that blows during the dry season. Indeed, above 25 °C, the goat experiences a HS, and its respiration accelerates to best remove heat (Reece et al., 2015). However, THI is considered a sensitive indicator of stressful climatic conditions (Silanikove, 2000). Furthermore, a THI value of 70 or less indicates a comfortable condition, while values of 71–78 are considered stressful and those above 78 cause great suffering in the animal, where it is unable to maintain thermoregulatory mechanisms and normal body temperature. The THI values obtained in this study show that dairy goats were exposed to moderate ($74.68 \leq THI \leq 77.05$) and extreme ($78.14 \leq THI \leq 81.74$) stress conditions. Indeed, the combination of AT and RH values obtained represents a heat stress condition and indicates that Saanen and ½S½RM goats raised in a sub-humid tropical climate are under heat stress year-round (Adjassin et al., 2020). Environmental conditions were therefore high enough to induce heat stress throughout the year with months characterized by moderate stress conditions (December, January, February, May, June, July, August, and September) and extreme stress conditions (October, November, March, April). During periods of extreme stress conditions, there is a possibility that the animal may lose enough heat through

Table 2a. Least squares (mean ± standard error) of THI values, breed and their interaction on reproduction parameters of Saanen and ½S½RM goats.

Parameters	N	AR (Month)	AFK (Month)	WR (Kg)	GL (days)	IK (Month)
Breed		***	***	***	NS	***
Saanen	46	7.38^a ± 0.92	12.48^a ± 0.93	35.37^a ± 1.24	153^a ± 2.4	13.63^a ± 1.24
½S½RM	57	7.88^b ± 0.90	12.98^b ± 0.90	32.96^b ± 3.59	152.7^a ± 2.7	7.53^b ± 0.77
HS conditions		NS	NS	NS	NS	*
Moderate	103	7.65^a ± 0.90	12.75^a ± 0.90	33.87^a ± 3.22	152.7^a ± 2.7	9.34^a ± 3.01
Extreme	103	7.70^a ± 1.02	12.80^a ± 1.03	34.22^a ± 3.26	153.0^a ± 2.4	10.44^b ± 3.19
Breed × HS conditions		**	NS	***	NS	***
Saanen×moderate	46	7.39^a ± 0.82	12.48^a ± 0.83	35.13^b ± 1.93	152.7^a ± 2.7	13.14^c ± 1.23
Saanen×extreme	46	7.35^{ab} ± 1.12	12.46^a ± 1.14	35.92^b ± 1.79	153.0^a ± 2.4	13.84^d ± 1.19
½S½RM×moderate	57	7.87^b ± 0.90	12.97^a ± 0.90	32.87^a ± 3.68	152.7^a ± 2.7	7.22^a ± 0.73
½S½RM×extreme	57	7.90^b ± 0.90	13.0^a ± 0.91	33.10^a ± 3.47	153^a ± 2.4	7.73^b ± 0.74

N: Number of Saanen and crossbreed goats; ***p < 0.001; **P < 0.01; *P < 0.05; NS = No Significant P> 0.05; a, b and c Means followed by different letters in the same column are significantly different according to the Tukey's tests (p < 0.05).
AR: age of reproduction; AFK: age at first kidding; WP: weight of reproduction; GL: gestation length; IK: kidding interval.

Table 2b. Frequency of THI values, breed and their interaction on reproduction parameters of Saanen and crossbred (½S½RM) dairy goats.

Parameters	N	F (%)	CR (%)	P (%)	χ^2
Breed					2.68
Saanen	46	89.70^a ± 3.76	67.16^a ± 1.13	149.41^a ± 5.15	
½S½RM	57	117.11^b ± 6.86	92.09^b ± 0.07	156.54^a ± 7.44	
HS conditions					10.14
Moderate	103	108.37^a ± 14.78	83.53^a ± 15.04	157.29^a ± 4.74	
Extreme	103	100.90^b ± 13.37	77.94^b ± 10.24	146.75^b ± 6.70	
Breed × HS conditions					35
Saanen × moderate	46	91.94^b ± 0.91	67.30^a ± 1.11	152.22^c ± 1.26	
Saanen × extreme	46	84.57^a ± 2.56	67.10^a ± 1.15	142.99^a ± 4.93	
½S½RM×moderate	57	121.52^d ± 0.96	97.22^c ± 0.50	161.35^d ± 1.40	
½S½RM×extreme	57	110.04^c ± 6.32	83.89^b ± 7.96	148.86^c ± 6.68	

N: Number of Saanen and crossbreed goat; F: fertility; CR: conception rate; P: prolificacy.

evaporation (da Silva et al., 2012; Souza et al., 2008). The higher THI observed during the months characterizing the extreme stress conditions was due to the substantial increase in relative humidity during this period due to the higher precipitation, while the ambient temperature did not decrease. Thus, this period is characterized as the most favorable for causing more pronounced heat stress in goats.

In this study, the results revealed that the dairy goats subjected to extreme heat stress conditions showed the lowest reproductive performances. This result is similar to those reported by Fatet et al. (2011). A significant influence of year on reproductive parameters of small ruminants has been noted in the literature (Yavarifard et al., 2015; Das et al., 2016; Mustefa et al., 2019; Hansen, 2019). Mellado and Meza-Herrera (2002) reports that the mating season is one of the main factors influencing the conception rate of goats. Indeed, climatic conditions can reveal negative impacts on the reproduction performances in livestock (El-Tarabany and El-Bayoumi, 2015). Heat stress induces a

Table 3. Pearson's correlation coefficient between the reproduction parameters of Saanen dairy goats and climatic variables.

Parameters	AR	AFK	WR	GL	IK	P	CR	F	Ta	RH	THI
AR	1.00										
AFK	0.97***	1.00									
WR	0.15^{NS}	0.16^{NS}	1.00								
GL	0.11^{NS}	0.20*	0.07^{NS}	1.00							
KI	0.09 ^{NS}	0.08 ^{NS}	-0.03^{NS}	-0.04^{NS}	1.00						
P	0.03 ^{NS}	0.03 ^{NS}	-0.15^{NS}	-0.07^{NS}	0.05^{NS}	1.00					
CR	-0.03 ^{NS}	-0.02 ^{NS}	-0.03^{NS}	0.03^{NS}	0.00^{NS}	0.08^{NS}	1.00				
F	-0.02 ^{NS}	-0.02 ^{NS}	-0.16^{NS}	-0.09^{NS}	0.20*	0.91***	0.08^{NS}	1.00			
AT	0.02^{NS}	0.01^{NS}	-0.19^{NS}	0.05^{NS}	0.26*	0.83***	-0.08^{NS}	0.91***	1.00		
RH	-0.01^{NS}	-0.01^{NS}	0.19^{NS}	0.05^{NS}	-0.21*	-0.81***	0.02^{NS}	-0.89***	-0.99***	1.00	
THI	-0.02^{NS}	-0.01^{NS}	0.19^{NS}	0.05^{NS}	-0.26*	- 0.83***	0.08^{NS}	-0.91***	-0.99***	0.99***	1.00

*** = p < 0.001; ** = p < 0.01; * = p < 0.05; NS = No Significant p˃ 0.05.
AR: age of reproduction; AFK: age at first kidding; WR: weight of reproduction; GL: gestation length; KI: kidding interval; P: prolificacy; CR: conception rate; F: fertility; AT: Ambient Temperature; RH: relative humidity; THI: temperature humidity index.

Table 4. Pearson's correlation coefficient between the reproduction parameters of crossbred (½S½RM) dairy goats and climatic variable.

Parameters	AR	AFK	WR	GL	IK	P	CR	F	AT	RH	THI
AR	1.00										
AFK	0.98***	1.00									
WR	0.10^{NS}	0.10^{NS}	1.00								
GL	-0.01^{NS}	0.08*	0.07^{NS}	1.00							
KI	-0.09 ^{NS}	-0.11 ^{NS}	-0.06^{NS}	-0.16^{NS}	1.00						
P	0.03 ^{NS}	0.03 ^{NS}	0.05^{NS}	0.00^{NS}	0.34***	1.00					
CR	0.02 ^{NS}	0.02 ^{NS}	0.04^{NS}	0.00^{NS}	0.39***	0.94***	1.00				
F	-0.01 ^{NS}	-0.01 ^{NS}	0.01^{NS}	-0.02^{NS}	0.40***	0.91***	0.96^{NS}	1.00			
AT	-0.01^{NS}	-0.01^{NS}	-0.03^{NS}	-0.01^{NS}	0.32***	0.82***	0.80***	0.82***	1.00		
RH	0.01^{NS}	0.01^{NS}	0.01^{NS}	0.00^{NS}	-0.31***	-0.82***	-0.79***	-0.80***	-0.99***	1.00	
THI	-0.02^{NS}	-0.02^{NS}	-0.05^{NS}	-0.02^{NS}	-0.39***	-0.93***	-0.99***	-0.95***	-0.75***	0.75***	1.00

*** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$; NS = No Significant p˃ 0.05.
AR: age of reproduction; AFK: age at first kidding; WR: weight of reproduction; GL: gestation length; KI: kidding interval; P: prolificacy; CR: conception rate; F: fertility; AT: Ambient Temperature; RH: relative humidity; THI: temperature humidity index.

disturbance of hypothalamo-hypophyseal and ovarian hormonal secretions. It is also associated with a decrease in oocyte quality, an alteration of folliculogenesis and a disturbance of the uterine environment. The result is a decrease in heat expression, lower oocyte quality and altered embryonic development. The consequences of these alterations on reproductive performance are delayed recovery of ovarian activity, increased anovulatory anoestrus, decreased fertility and increased embryonic mortality (Marai et al., 2004; Sejian et al., 2012).

During both heat stress conditions (moderate or extreme) ½S½RM goats showed better reproductive parameters compared to Saanen goats. This could be explained by the fact that crossbred goats adapted well to the environment unlike Saanen goats. This variation among crossbreds can be explained by the genetic potential of local goat used as a dam line and prolificacy of does. The variation of prolificacy observed among Saanen and ½S½RM goats is probably related to the genetic potential of breeds (ability to ovulate more ova and survival rates of embryo or foetuses), the variation of climatic conditions and management conditions. The low reproductive performance of Saanen goats is probably due to their origins, while ½S½RM also shows in their ancestry, Red Maradi goat traits are more adapted to warm climates, but more productive than the Saanen. The low reproductive performance observed in the Saanen goats is probably due to their origins, while ½S½RM goats also have in its ancestry, Red Maradi, traits more adapted to hot climates, but more productive than the Saanen goats. In this same order of thought, some authors (Hansen, 2009) have reported that extreme heat waves are much more devastating when animals are not acclimatized.

The analysis of correlation demonstrated that temperature, relative humidity, THI and reproduction parameters dairy goats were highly and inversely associated. A great of evidence reported a relationship between temperature, relative humidity, THI and reproduction parameters, widely studied in dairy cows (Ratchamak et al., 2021; Gloria et al., 2021), but little in dairy goats. In this study, we found negative and significant correlations between THI, prolificacy and fertility rates, while no significant negative correlation was observed between AT and conception rate. These results indicated that the conception rate is more susceptible to relative humidity than temperature in Saanen goats. In ½S½RM goats, we found positively and significantly correlation between AT, prolificacy, fertility and conception rates. The results also revealed that prolificacy, fertility, and conception rates more susceptible to humidity than tha ambient temperature. Herbut et al. (2018) and Ouellet et al. (2021) showed that prolonged exposure to ambient temperatures combined with high relative humidity over the critical physiological mechanism level could contribute to an increase of heat stress in livestock. Although ambient temperature and relative humidity have been widely used as indicators of heat stress in livestock, it should be noted that reproduction parameters are affected depends on genotype.

5. Conclusion

From this study, it can be concluded that reproduction parameters were very sensitive to heat stress, and the stress levels depend on breed types. This study revealed that the reproduction performances of ½S½RM goats was higher than Saanen goats in the both heat stress conditions. The low fertility, prolificacy and conception rates were obtained in both breeds under extreme stress conditions. Indeed, Moderate stress conditions were more favorable for dairy goats. Therefore, this study on the impact of heat stress on dairy goats contributed to the existing research. However, further research is needed, such as gene analysis showing heat tolerance and the effect of hormones on reproduction.

Declarations

Author contribution statement

Josias Steve Adjassin: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Alassan Seidou Assani; Abou Adam Bani; Cham Donald Adégbeïga Alabi: Performed the experiments; Analyzed and interpreted the data.

Hilaire Sorébou Sanni Worogo; Brice Gérard Comlan Assogba: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Erick Bertrand Virgile Azando: Conceived and designed the experiments.

Ibrahim Traoré Alkoiret: Analyzed and interpreted the data; Wrote the paper.

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The data that has been used is confidential.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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