Received: 11 February 2023, Accepted: 03 March 2023

Original Research

Journal of Advanced Veterinary Research
(2023) Volume 13, Issue 2, 271-276

Using a Sprinkler Fan System for Cooling Heat-stressed Goats under Desert Conditions

Diya AL-Ramamneh*

Biology Department, Faculty College of Tayma, University of Tabuk, Tabuk, PO Box 741, Tabuk 71491 Kingdom of Saudi Arabia.

***Correspondence**
Diya AL-Ramamneh
E-mail address: dsa0410@gmail.com

Abstract

Goats' health, productivity, and behavior are drastically altered during heat stress. Heat dissipation methods become inadequate when environmental temperatures exceed an animal's internal body temperature. Recently there has been increasingly interested in strategies to reduce thermal stress on livestock. Sprinklers may help reduce accumulated heat and improve goat heat dissipation. Ten indigenous adult dry does were randomly assigned to two treatment groups, the non-cooling group as a control and the treatment group with two sprinkler and fans cooling systems. Feed and water consumption, breathing rate, rectal, external, and ambient temperatures, and relative humidity were recorded daily. For two weeks of the investigation, body weight was recorded once a week. The results showed that the control group consumed more water, and the ratio of water drunk/ dry matter intake tended to be higher than the treatment counterparts. Neither group showed significant differences in dry matter intake. Respiratory rates were greater in the control group compared to the treatment counterpart. Despite the marked difference between climatic conditions of both groups' rooms, no significant difference in rectal body temperatures was found. The temperatures of the eyes and legs were not significantly different in either group. In contrast, the calculated correlation between the rectal temperature with the highest value was found for the negative relation with rump and neck temperature. In conclusion, spraying goats and continual air movement under dry weather alleviate heat stress and improves goat welfare.

KEYWORDS
Fan, Goat, Heat stress, Thermoregulation, Physiology, Sprinkler

INTRODUCTION

A key challenge for livestock producers worldwide is heat stress. Elevated air temperatures, moisture, and solar radiation are the most stressful for animals (Silanikove, 2000). The effects of heat stress on animals can be devastating, resulting in impaired growth, milk production, reproduction performance, and low immunity, making the animals more susceptible to illnesses and mortality in extreme cases; these expenses millions of dollars each year (Brown-Brandl *et al*., 2005; Mader *et al*., 2006). Goats can cope with many climates and geographies due to their small body size, low body mass, low metabolic needs, the efficiency of utilizing water and high fiber forage, and ability to reduce metabolism (Silanikove, 2000; AL-Ramamneh *et al*., 2010). It is well known that anatomical variations are part of adapted responses to a broad range of geographies and environments, depending on where they originate. Goats' morphological characteristics (size, shape, coat color, pigmentation) play a crucial role in their energy exchange with the surrounding environment, which is controlled by evaporation, radiation, and convection (West, 2003; Collier *et al*., 2006). Accordingly, goats in African deserts (hot areas) are much more miniature than in Europe (cold areas). Several factors affect the apparent heat loss of the animal, including the surface area, the color of the coat, and temperature gradients between the goat and the surroundings (Daramola and Adeloye, 2009). It has been observed that hair coats that are light in color and sleek and shiny are more likely to reflect more than dark or denser hair coats (Asres and Amha, 2014).

Moreover, in hot tropical regions, pigmented skin prevents direct short-wave UV radiation from reaching deep tissues. This prevents goats from gaining excessive heat from direct solar radiation. There is a strong correlation between acute stressors and physiological adaptations. These adaptations include sweating, respiration, heart rates, core, and skin temperatures (Silanikove, 2000). Goats react to heat stressors primarily by raising their respiratory rate (Ghassemi Nejad and Sung, 2017; Ribeiro *et al*., 2018). When goats cannot maintain homeothermy through sweating and respiration will experience an elevation in rectal temperature (Kadzere *et al*., 2002). Accordingly, it is a helpful sign of excessive heat and may be utilized to evaluate a goat's temperature and adaptability (Kadzere *et al*., 2002). despite the labor-intensive and may affect animal behavior. therefore, infrared thermography (IR) non-invasive techniques offer high precision; it does not require direct contact with the animals and will not disturb animal behavior, which can be utilized to estimate the heat status of the animals (AL-Ramamneh *et al*., 2012). Thermo-

ISSN: 2090-6277/2090-6269/

graphs measure surface body temperatures using infrared radiation. Furthermore, they can determine the temperature of tissues deep beneath the skin and the surface temperature (Heath *et al*., 2001). Goats usually have a rectal temperature between 38.3 and 40.0 °C. During stressful conditions, animals' heart rates increase to allow more blood to flow from their cores to their surfaces, thereby increasing the chance of losing heat in sensible and insensible ways (Collier *et al*., 2006; West, 2003). If the respiratory mechanism cannot sustain physiological homeostasis, evaporative heat losses are activated by increasing sweating rates and breathing min volumes (Finch *et al*., 1980). Collier *et al*. (2008) demonstrated that sweating efficiency relies on a combination of environmental (air temperature, relative humidity, and wind speed) and animal characteristics (sweat glands dense and functioning, hair coats dense and thick, color and length of hair, skin color, and epidermis vascular supply). Changing the environment is generally a more effective and less time-consuming means of improving welfare, production, and reproduction than improving genetic selection for heat tolerance. To increase heat loss, either radiant heat load can be reduced, convective heat loss can be increased, or evaporative heat loss can be increased by wetting the animal (Beede and Collier, 1986; Flamenbaum *et al*., 1986). Several methods have been used to increase convective heat losses by abatement ambient temperatures; they either cool the animals or the surrounding environment. Such as providing shaded (Armstrong, 1994), cooling the head alone (West, 2003), cooling the resting area (Gomila *et al*., 1977; Fournel *et al*., 2017), or using air-conditioned structures such as fans, misters, sprinklers, and cooled waterbeds (Smith *et al*., 2006; Fournel *et al*., 2017; AL-Rammaneh, 2022). These methods transfer heat from dry air to water vapor, reducing air temperature using mechanical refrigeration or evaporative cooling. Conversely, these methods increase ambient humidity, which reduces the animal's evaporative loss and lowers costs; among them, providing shade, ventilation, cold drinking water, air conditioning, evaporative cooling, and thermoelectric refrigeration (Smith *et al*., 2006; Fournel *et al*., 2017; AL-Rammaneh, 2022). For evaporative cooling systems, tiny droplets (2–60 μm diameter) of water are used to enhance heat transfer between air and water (Almuhanna *et al*., 2021). This technique is favorably effective in cooling shelters. Water is usually turned into tiny droplets by high-pressure nozzles that evaporate before falling to the ground, resulting in a cooling effect on both the surrounding air and the animal, which is less expensive and more effective than other cooling methods (Arbel *et al*., 1999). Several cooling systems have been tested in arid climates like Saudi Arabia to reduce the adverse effects of heat stress on livestock (Ryan *et al*., 1992; Correa-Calderon *et al*., 2004). Studies have shown that evaporative cooling systems enhance the production of dairy cattle in dry environments (Ryan *et al*., 1992; Correa-Calderon *et al*., 2004). Dairy farmers use the Korral Kool cooling system to cool the air around dairy cows by using fans to push air through vanes; the system injects fine fog into the air and creates a cyclonic airflow down to the cows (Armstrong, 1994). Evaporative cooling is desirable in dry, hot, and temperate climates because of its cheapness and effectiveness (Costelloe and Finn, 2003; Smith *et al*., 2007). Flamenbaum *et al*. (1986) and Strickland *et al*. (1989) indicated that in humid climates, sprinkling large droplets is more effective than fogging or misting. A fine mist can produce a humid microenvironment and decrease the vapor pressure at the surface, which speeds up the cooling process. The evaporative cooling system is effective in extreme environments where the mean summer temperature exceeds 40°C, as demonstrated by Willits (2003) and Toida *et al*. (2006). In these systems, water is evaporated mechanically to produce latent heat from sensible heat (Armstrong, 1994). When animals were subjected to moderate continuous heat stress, fan cooling led to rapid reductions in their core body temperatures (Spain and Spiers, 1998). A study by Turner *et al*. (1997) found that installing cooling fans improved growth rates in cows, while sprinklers and fans provided the best performance. Igono *et al*. (1987) found that cows produced more milk when they were handled by fans and misted than when they were handled by shade alone. Flamenbaum *et al* (1986) found that cooling cows with spray and fans for 15, 30, and 45 min declined the core temperature by 0.6, 0.7, and 1°C, respectively. Darcan and Cankaya (2008) showed that kids had better fatten and meat quality when provided cooling with ventilation in humid and hot climates. Furthermore, economic analyses showed an increase in the profit for kids kept cool with ventilation compared to non-cooling kids (Darcan and Cankaya, 2008). Goat cooling systems have yet to be thoroughly investigated in arid environments. Thus, this investigation aimed to evaluate the potential effects of a sprinkler and fan cooling technique on goat comfort and temperature regulation by assessing surface temperature, core body temperature, and respiratory rate as indices in arid areas.

MATERIALS AND METHODS

Ten indigenous adult dry does were randomly selected for the experiment conducted at Al-Ghaith Farming Station, Tayma, Tabuk Region, Saudi Arabia. The selected goats were aged 3-4 years. Does were randomly allocated to two treatment groups under the same conditions (feeding, drinking, disease control, lighting, and space….). The control group were assigned to a room without cooling systems, whereas the treatment group were assigned to another room with two sprinklers and fans (MIXC 26.2 FT, China, with five mist 0.012 mm nozzles jet) system. Sprinklers were triggered every five min for 15 min, and the fans continuously ran during the day. A sprinkler and fan system were operated three days before the test to acclimate the goats to the experimental procedures. The cooling fans and sprinklers were placed 2.5 m high from the animal in the opposite direction from each other. Each group's goat was retained in individual pens of 1.5 X 1.5 m; all animals were given alfalfa (*Medicago sativa* L.) hay *ad libitum* during the experimental period that lasted 2 weeks. Food and water consumption were calculated by subtracting the quantity given to animals from the quantity not consumed (refusal) each day at the same time. A bucket containing water (10 L) was placed in an adjacent area to correct water evaporation. To determine the exact water ingested by the animals, we subtracted the evaporated water from the total amount consumed by the animals. The room temperature and relative humidity were monitored using a thermal data logger hanged 1 meter of the floor level. The average daily temperature was 34.96 and 30.41°C. At the same time, the highest were 38.7 and 31.1°C, and the lowest temperatures were 33.1 and 29.6°C. The average relative humidity was 15.0 and 19.18% in the control and treatment groups, respectively, during the trial that lasted for 2 weeks.

Physiological parameters respiration rate (RR) was counted three times daily (at 8:00, 12:00, and 17:00) by monitoring the flank motion per min. Rectal temperature (RT) was taken once daily at noon using a clinical thermometer. Body weight was measured once a week. Infrared images were recorded daily for both groups. One hundred fifty thermographic Pictures were collected from the goats during the experimental period. The distance of the animal from the camera was 2 meters. The individual picture was analyzed to estimate the surface temperatures of the animals, and for effective surface temperature measurement area was further divided into several parts (Head, eye, ear, rump, and leg; the left side of the animal). Images were analyzed as described previously by AL-Ramamneh *et al*. (2011). PROC MIXED was applied to examine the data (SAS, 2001). For the statistical analyses. For all traits recorded, the statistical model included the fixed effect of the treatment (Cooling vs non-cooling), the time (day), the respective interaction, and the random effect of animals. The model was:

$$Yijkl = \mu + C_i + T_j + CT_{ij} + A_k + e_{ijkl}$$

Where Yijkl is the observation value; μ the overall mean; C_i is the treatment (cooling vs non-cooling); T_j is the time (day); CT_{ij} is the interaction; Ak is the random effect of animals; and e_{ijkl} the residual error. An integrated Tukey test was used to detect differences between LS means with a 5% significance level. All values were presented as LS means±standard error unless otherwise mentioned. Based on raw data, Kendall's Tau b rank correlations were computed between respiratory rate, rectal, ambient, and surface temperature measurements across and between the two groups.

RESULTS

The ambient temperature was 34.96 and 30.41°C, and the average relative humidity was 15.00 and 19.18% in the control and treatment groups, respectively. Table 1 shows that the control group's average day-to-day water consumption was consistently more excellent ($P < 0.01$), with the control group drinking about 27% more water than the treatment counterparts, whether expressed on a total body mass basis or a metabolic mass level. With the proceeding duration of the experiment, mean dry matter intake (DMI) didn't indicate any significant variations between groups ($P = 0.06$), whether expressed on a total body mass basis or a metabolic mass level. Thus, the ratio of water drunk/ DMI tended ($P < 0.01$) to be more significant in control than in the treatment group (Table 1). Average daily respiratory rates were consistently more significant for the control goats than for the treatment goats ($P < 0.01$); the RR of the control goats exceeded ($P < 0.01$) that of the treatment counterparts by about 18% (Table 1). Despite the marked difference between climatic conditions of both rooms, no significant variation (P = 0. 55) in rectal body temperatures was found (38.76±0.17 and 38.82±0.17°C, for the control and treatment groups, respectively (Table 2).

In this study, goats responded more predictably to ambient temperature changes than surface or rectal temperatures (Table 3). The temperature of the eyes and legs was not significantly different between the two groups ($P > 0.05$). Overall, all traits measured were closely related to ambient temperature. Ambient and surface temperatures showed medium to high correlations (Tables 3, 4). In contrast, both groups' calculated correlations between rectal and ambient temperatures were low (Table 4). In contrast, the estimated correlation between the rectal temperature with the highest value was found for the negative relation with rump and neck temperature (Table 3). Correlations between rump, neck, eye, ear and leg temperatures ranged between medium and high. Table 4 shows a higher correlation estimated between the rump and neck (r = 0.89) in the control and treatment groups (r = 0.73). The rectal, eye, and leg temperatures were loosely related to all traits measured (Table 3).

Table 1. The average body weight, water drunk, dry matter intake, water intake to dry matter intake ratio, and respiration rate of goats after sprinkler fan cooling vs. none cooling control group.

Trait	None-cooling Control group (n=5)	Sprinkler-Fan Cooling group (n=5)	P-value
Body weight (kg)	54.32±0.72	53.93±0.72	0.49
Metabolic body weight ($kg^{-0.75}$)	20.00±0.20	19.90±0.20	0.49
Water drunk (L Day^{-1})	3.67±2.57^{a}	2.68±2.57^{b}	< 0.01
Water drunk (g kg BW)	67.63±4.28^{a}	49.84±4.28^{b}	< 0.01
Water drunk (g kg $BM^{-0.75}$)	183.63±11.91^{a}	134.99±11.91^{b}	< 0.01
Dry matter intake (kg day^{-1})	1.11±67.36	1.03±67.36	0.06
Dry matter intake (kg BW^{-1})	20.48±1.10	19.23±1.10	0.12
Dry matter intake (g kg $BM^{-0.75}$)	55.62±3.07	52.06±3.07	0.1
WD / DMI*1	3.44±0.15^{a}	2.62±0.15^{b}	< 0.01
Respiratory rate (breath min^{-1})	30.81±0.52^{a}	25.41±0.52^{b}	< 0.01

Values are means±SE. *1WD/DMI: Water drunk per dry matter intake.
[a, b]: values in raw with different letters differ significantly (P< 0.05)

Table 2. The average ambient and core body temperature (°C) and relative humidity (%) and surface body temperature (°C) were measured by infrared thermography of goats after sprinkler fan cooling vs. none cooling control group.

Measurements	None-cooling Control group (n=5)	Sprinkler-Fan Cooling group (n=5)	P-value
Ambient temperature (°C)	34.96±0.12	30.41±0.12	< 0.01
Relative humidity (%)	15.00±0.19	19.18±0.19	< 0.01
Rectal temperature (°C)	38.76±0.17	38.82±0.17	0.55
Eye temperature (°C)	33.65±0.25	34.05±0.25	0.27
Neck temperature (°C)	27.70±0.36	26.51±0.36	2
Ear temperature (°C)	30.36±0.51	28.89±0.51	0.04
Rump temperature (°C)	25.83±0.36	24.54±0.37	0.01
Leg temperature (°C)	27.94±0.62	27.55±0.62	0.66

Values are means±SE.
[a, b:] values in raw with different letters differ significantly (P< 0.05)

Table 3. Kendall's Tau b correlations between rectal, ambient temperatures and surface temperatures of the eye, neck, rump, leg and the ear, across both goat groups (Sprinkler fan cooling vs. none cooling control group), based on raw data.

	Rectal	Eye	Neck	Rump	Leg	Ear
Ambient	0.6	0.24*	0.38*	0.46*	0.37*	0.26*
Rectal		0.08	-0.25*	-0.26*	-0.04	0.01
Eye			0.14*	0.14*	0.19*	0.17*
Neck				0.86*	0.45*	0.34*
Rump					0.44*	0.32*
Leg						0.67*

*P < 0.05

Table 4. Kendall's Tau b correlations between rectal, ambient temperatures and surface temperatures of the eye, neck, rump, leg and ear, of the sprinkler fan cooling group (Vertical) and none cooling control group (Horizontal), based on raw data.

		None cooling control group						
		Ambient	Rectal	Eye	Neck	Rump	Leg	Ear
Sprinkler fan cooling treatment group	Ambient		0.07	0.28*	0.34*	0.38*	0.42*	0.32*
	Rectal	0.07		-0.11	-0.39*	-0.36*	-0.13	-0.01
	Eye	0.23*	0.27*		0.20*	0.21*	0.28*	0.24*
	Neck	0.53*	0.11	0.24*		0.89*	0.48*	0.32*
	Rump	0.68*	0.03	0.23*	0.73*		0.47*	0.34*
	Leg	0.33*	0.13	0.17*	0.53*	0.44*		0.69*
	Ear	0.22*	0.12	0.19*	0.34*	0.26*	0.62*	

*P < 0.05

DISCUSSION

The present study revealed that intermittent sprinklers and continual fan cooling systems mitigated animal heat stress. Continuous ran of the fan's forces air over the goat's body, increasing convective heat loss and evaporative cooling, lowering ambient temperatures, and increasing heat exchange between goats and their environment without accumulating the humidity due to water spray around the animals. In a study by Beede and Collier (1986), the animal's water consumption was significantly affected by the requirements of preserving body temperature under heat stress. The obtained results were consistent with those reported in the literature (Silanikove, 2000; AL-Ramamneh *et al*., 2010, 2011, 2012). Goats increased their water intake to replace water loss by evaporative cooling (panting, sweating) in the control group compared to their counterparts. Maia *et al* (2005) found that cows lose approximately 85% of their heat through evaporation from the skin at 30°C. Goats increased their daily water intake to counter water losses by evaporation (Olsson and Hydbring, 1996). To decrease the effect of heat stress, Smith *et al*. (2006) suggested animal thermoregulation processes that can transfer heat with the surroundings if the ambient temperature is maintained less than their core body temperature. In the current trial, goats were under heat stress and had a greater water intake than the treatment goats. The cooling system used in this study allowed the release of water droplets into the air through fans and created a circular air motion down to the goats; this enabled water droplets to evaporate before reaching the floor, therefore results in cooling the air around the animals. In contrast, it cooled with fans, circulation, and convection, which exchange heat with the animal. There was remarkable resilience in goats to heat stress in the present study. Both groups maintained their DMI, and animals in the current experiment did not experience depression in BW; both groups might be explained by maintaining the apparent dry matter digestibility (Brosh *et al*.1983; Silanikove 1985). It was reported by Hirayama *et al*. (2004) that goats ate more during heat periods and ruminated less.

Consequently, goats consumed more food. In this investigation, the environmental temperature exceeded the comfortable temperature of goats (20-24°C), and animals exposed to temperatures above thermoneutrality experienced an extra heat load, which triggered several thermophysiological changes. It is possible to divide these mechanisms into those that modulate thermal production and those that regulate thermal flow inside or outside the body (Bligh, 1998; Maia *et al*., 2005). The body's most essential heat transfer medium is water, which transfers heat between the surface and the core through convection, conduction, and radiation. Heat can be transferred insensibly (from the organism to the environment) by evaporating water (Maia *et al*., 2005). In accordance with Avendaño-Rayes *et al*. (2006) and Yousef (1985), animals release warmth from their body by raising their core temperature, heart rate, and breathing rate.

Results from this study showed that average daily respiratory rates were consistently greater in the control group than in the counterpart group; the RR of the control goats exceeded that of the treatment counterparts by about 18%. Goats had a lower respiratory rate (< 30 breaths/min); as Silanikove (2000) pointed out, respiration rate may be used to accurately estimate farm animal heat stress (low: 40-60 breaths per min; medium-high: 60-80 breaths per min; high: 80-120 breaths per min; and severe heat stress above 150 breaths per min) it's can be considered as low heat stress for well-adapted goats to dry environments. Results in the present study are in harmony with other studies that showed that sprinklers and shade reduced respiratory rates of grazing dairy cows by 60 and 30%, respectively, in contrast with cows kept in the shade and sprinklers (Kendall *et al*., 2007). In heat-stressed animals, sweating, panting, and vasodilation may enhance heat loss and create a thermal gradient between the core and peripheral tissues (Kadzere *et al*., 2002). It is essential to evaluate the features of the animal body and surrounding environment. Several morphological features of the skin (color, texture, sweat glands, angle of the hairs on the surface of the skin, etc.)

affect the skin's protective properties; animals can evaporate a significant amount of sweat to keep body temperatures constant due to their higher heat loading (Bernabucci *et al*., 2010; Helal *et al*., 2010; Abdoun *et al*., 2013). Darcan *et al*. (2009) mentioned that many animals have pigmentation such as haemes (red), carotenoids, melanoid (black and brown), and guanine (white and iridescent), adapted to their environment to help them survive as well as Seo *et al*. (2007) reported that melanin is a natural defensive system of the skin that is produced in response to UV rays. Most of the goat's coat colors used in this investigation ranged between white and brown, which helped reflect more heat and reduced animal heat load.

Furthermore, goats have thinner hair coats on their ventral surfaces than on their dorsal surfaces. As a result, more air can flow into and around this thermal window, dissipating heat by evaporative cooling through sweating. Smith *et al*. (2006) pointed out that evaporative cooling is practical in dry climates for decreasing heat stress when operated for extended periods. It has been demonstrated that if water accumulates on an animal's coat, humidity around the animal may increase, thus, reducing the effectiveness of the cooling approach (Means *et al*., 1992). According to this, we operated the sprinklers in this study every five min for 15 min; however, this schedule may not have been sufficient to lower goat temperatures to their natural thermal range during summer heat stress. It was found by Flamenbaum *et al*. (1986) that spraying cattle for 20-30s was more efficient than spraying them for only 10s. According to Becker and Stone (2020), most sprinkler timing schedules involve a 5-min cycle of 30s. of spraying followed by 2.5s of high-speed air circulation. Flamenbaum *et al* (1986) found that 5 to 7 watering periods (sprinklers and fans) every day for 30 to 45 min improved milk production in hot weather. According to Correa-Calderon *et al*. (2004), using fans and sprinklers together produced significantly more evaporative cooling in cattle than either fan or sprinkler alone. Correa-Calderon *et al* (2004) noted that the physiological reactions (body temperature and Respiratory rate) in dairy cattle to two cooling strategies (misters and fans vs fan-cooled sprinklers) and compared to the non-cooling cows with either cooling system had lower body temperatures (0.7 and 0.9^{o}C for the cooling system) in contrast to the controls. Treatment groups with cooling experienced lower respiratory rates than the control group (Correa-Calderon *et al*., 2004). In heat-stressed animals, sweating, panting, and vasodilation may enhance heat loss (Kadzere *et al*., 2002). As the Rump, neck, and ear surface temperature increased with heat exposure, vasodilation was shown to be effective for heat transfer through a sensible heat transfer route with the ongoing operation of fans. According to Yousef (1985) and Kadzere *et al*. (2002), perpendicular ears are characteristic of domestic species adapted to extreme temperatures (Marai *et al*., 2006). Little hair covering the head and body may have a positive effect due to enhanced peripheral blood flow (Weissenböck *et al*., 2010). Among all farm animals, goats are the only species capable of maintaining body temperatures below 38.5°C (Devendra, 1987; Avendaño-Reyes *et al*., 2006). They breathe at a rate of 25-30 breaths/min (Silanikove, 2000), whereas their basal heart rate is about 65-80 beats/min (Devendra, 1987).

CONCLUSION

It could be concluded that spraying goats and continual air movement under dry weather alleviate heat stress and improves goat welfare. A cooling system is crucial to reduce the unfavorable impacts of heat stress in the goat's rearing system.

ACKNOWLEDGMENTS

The author highly appreciates Alghaith Farming Station and the workers there for hosting this project. Special thanks to Eng. Mohammad Abdallah for his technical assistance in the cooling system operation.

CONFLICT OF INTEREST

The author declares that there is no conflict of interests.

REFERENCES

Abdoun, K., Samara, E., Okab, A., Alhaidary, A., 2013. The relationship between coat color and thermoregulation in dromedary camels (*Camelus dromedarius*). Journal of Camel Practice and Research 20, 251-255.

Almuhanna, E.A., Gamea, G.R., Osman, O.E., Almahdi, F.M., 2021. Performance of roof-mounted misting fans to regulate heat stress in dairy cows. Journal of Thermal Biology 99, 102984.

Al-Ramamneh, D. 2022. Utilization of air-cooled ventilation to reduce heat stress in Nuami sheep in Saudi Arabia. Open Access Research Journal of Biology and Pharmacy 6, 47–53.

Al-Ramamneh, D., Gerken, D.M., Riek, A., 2011. Effect of shearing on water turnover and thermobiological variables in German Blackhead mutton sheep. Journal of Animal Science 89, 4294-4304.

Al-Ramamneh, D., Riek, A., Gerken, M., 2010. Deuterium oxide dilution accurately predicts water intake in sheep and goats. Animal 4, 1606-1612.

Al-Ramamneh, D., Riek, A., Gerken, M., 2012. Effect of water restriction on drinking behaviour and water intake in German black-head mutton sheep and Boer goats. Animal 6, 173-178.

Arbel, A., Yekutieli, O., Barak, M., 1999. Performance of a Fog System for Cooling Greenhouses. Journal of Agricultural Engineering Research 72, 129-136.

Armstrong, D.V., 1994. Heat stress interaction with shade and cooling. Journal of Dairy Science 77, 2044-2050.

Asres, A., Amha, N.J., , 2014. Physiological Adaptation of Animals to the Change of Environment: A Review. Journal of Biology, Agriculture and Healthcare 4, 146-151.

Avendaño-Reyes, L., Alvarez-Valenzuela, F.D., Correa-Calderón, A., Saucedo-Quintero, J.S., Robinson, P.H., Fadel, J.G., 2006. Effect of cooling Holstein cows during the dry period on postpartum performance under heat stress conditions. Livestock Science 105, 198-206.

Becker, C.A., Stone, A.E., 2020. Graduate Student Literature Review: Heat abatement strategies used to reduce negative effects of heat stress in dairy cows. Journal of dairy science 103, 9667-9675.

Beede, D.K., Collier, R.J., 1986. Potential Nutritional Strategies for Intensively Managed Cattle during Thermal Stress. Journal of Animal Science 62, 543-554.

Bernabucci, U., Lacetera, N., Baumgard, L.H., Rhoads, R.P., Ronchi, B., Nardone, A., 2010. Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal 4, 1167-1183.

Bligh, J., 1998. Mammalian homeothermy: An integrative thesis. Journal of Thermal Biology 23, 143-258.

Brosh, A., Sneh, B., Shkolnik, A., 1983. Effect of severe dehydration and rapid rehydration on the activity of the rumen microbial population of black Bedouin goats. The Journal of Agricultural Science 100, 413-421.

Brown-Brandl, T.M., Eigenberg, R.A., Nienaber, J.A., Hahn, G.L., 2005. Dynamic Response Indicators of Heat Stress in Shaded and Non-shaded Feedlot Cattle, Part 1: Analyses of Indicators. Biosystems Engineering 90, 451-462.

Collier, R.J., Collier, J.L., Rhoads, R.P., Baumgard, L.H., 2008. Invited review: genes involved in the bovine heat stress response. Journal of Dairy Science 91, 445-454.

Collier, R.J., Dahl, G.E., VanBaale, M.J., 2006. Major advances associated with environmental effects on dairy cattle. Journal of Dairy Science 89, 1244-1253.

Correa-Calderon, A., Armstrong, D., Ray, D., DeNise, S., Enns, M., Howison, C., 2004. Thermoregulatory responses of Holstein and Brown Swiss Heat-Stressed dairy cows to two different cooling systems. International Journal of Biometeorology 48, 142-148.

Costelloe, B., Finn, D., 2003. Indirect evaporative cooling potential in air–water systems in temperate climates. Energy and Buildings 35, 573-591.

Daramola, J.O., Adeloye, A.A., 2009. Physiological adaptation to the humid tropics with special reference to the West African Dwarf (WAD) goat. Tropical Animal Health and Production 41, 1005-1016.

Darcan, N., Cankaya, S., 2008. The effects of ventilation and showering on fattening performances and carcass traits of crossbred kids. Small Ruminant Research 75, 192-198.

Darcan, N.K., Cankaya, S., Karakok, S.G., 2009. The Effects of Skin Pigmentation on Physiological Factors of Thermoregulation and Grazing Behaviour of Dairy Goats in a Hot and Humid Climate. Asian-Aus-

tralasian Journal of Animal Sciences 22, 727-731.
Devendra, C., 1987. Bioclimatology and the Adaptation of Livestock (Ed. H.D. Johnson). Vol. 15: Elsevier.
Finch, V.A., Dmi'el, R., Boxman, R., Shkolnik, A., Taylor, C.R., 1980. Why Black Goats in Hot Deserts? Effects of Coat Color on Heat Exchanges of Wild and Domestic Goats. Physiological Zoology 53, 19-25.
Flamenbaum, I., Wolfenson, D., Mamen, M., Berman, A., 1986. Cooling dairy cattle by a combination of sprinkling and forced ventilation and its implementation in the shelter system. Journal of Dairy Science 69, 3140-3147.
Fournel, S., Ouellet, V., Charbonneau, É., 2017. Practices for Alleviating Heat Stress of Dairy Cows in Humid Continental Climates: A Literature Review. Animals 7, 37.
Ghassemi Nejad, J., Sung, K.-I., 2017. Behavioral and physiological changes during heat stress in Corriedale ewes exposed to water deprivation. Journal of Animal Science and Technology 59, 13.
Gomila, L.F., Roussel, J.D., Beatty, J.F., 1977. Effect of Zone Cooling on Milk Yield, Thyroid Activity and Stress Indicators. Journal of Dairy Science 60, 129-132.
Heath, A.M., Navarre, C.B., Simpkins, A., Purohit, R.C., Pugh, D.G., 2001. A comparison of surface and rectal temperatures between sheared and non-sheared alpacas (Lama pacos). Small Ruminant Research: the journal of the International Goat Association 39, 19-23.
Helal, A.E.M., Hashem, A.L.S., Abdel-Fattah, M.S., El-Shaer, H.M.J.A.-E.J.o.A., Science, E., 2010. Effect of heat stress on coat characteristics and physiological responses of Balady and Damascus goats in Sinai, Egypt. American-Eurasian Journal of Agricultural and Environmental Science 7, 60-69.
Hirayama, T., Katoh, K., Obara, Y., 2004. Effects of heat exposure on nutrient digestibility, rumen contraction and hormone secretion in goats. Animal Science Journal, 75, 237-243.
Igono, M.O., Johnson, H.D., Steevens, B.J., Krause, G.F., Shanklin, M.D., 1987. Physiological, Productive, and Economic Benefits of Shade, Spray, and Fan System Versus Shade for Holstein Cows During Summer Heat. Journal of Dairy Science 70, 1069-1079.
Kadzere, C.T., Murphy, M.R., Silanikove, N., Maltz, E., 2002. Heat stress in lactating dairy cows: a review. Livestock Production Science 77, 59-91.
Kendall, P.E., Verkerk, G.A., Webster, J.R., Tucker, C.B., 2007. Sprinklers and Shade Cool Cows and Reduce Insect-Avoidance Behavior in Pasture-Based Dairy Systems. Journal of dairy science 90, 3671-3680.
Mader, T. L., Davis, M. S., Brown-Brandl, T., 2006. Environmental Factors Influencing Heat Stress in Feedlot Cattle. Journal of Animal Science 84, 712-19.
Maia, A.S.C., daSilva, R.G., Battiston Loureiro, C.M., 2005. Sensible and latent heat loss from the body surface of Holstein cows in a tropical environment. InternationalJournal of Biometeorology 50, 17-22.
Marai, I.F.M., EL-Darawany, A.-H.A., Ismail, E.-S.A.-F., Abdel-hafez, M.A.M., 2006. Tunica dartos index as a parameter for measurement of adaptability of rams to subtropical conditions of Egypt. Animal Science Journal 77, 487-494.
Means, S.L., Bucklin, R.A., Nordstedt, R.A., Beede, D.K., Bray, D.R., Wilcox, C.J., Sanchez, W.K., 1992. Water Application Rates for a Sprinkler and Fan Dairy Cooling System in Hot, Humid Climates. Applied Engineering in Agriculture 8, 375-379.
Olsson, K., Hydbring, E., 1996. The preference for warm drinking water induces hyperhydration in heat-stressed lactating goats. Acta Physiol. Scand. 157, 109-114.
Ribeiro, N.L., Germano Costa, R., Pimenta Filho, E.C., Ribeiro, M.N., Bozzi, R., 2018. Effects of the dry and the rainy season on endocrine and physiologic profiles of goats in the Brazilian semi-arid region. Italian Journal of Animal Science 17, 454-461.
Ryan, D.P., Boland, M.P., Kopel, E., Armstrong, D., Munyakazi, L., Godke, R.A., Ingraham, R.H., 1992. Evaluating Two Different Evaporative Cooling Management Systems for Dairy Cows in a Hot, Dry Climate. Journal of Dairy Science 75, 1052-1059.
SAS (Statistical Analysis System), 2001. User's Guide: Statistics, V.S.I., NC, USA.
Seo, K., Mohanty, T.R., Choi, T., Hwang, I., 2007. Biology of epidermal and hair pigmentation in cattle: a mini review. Veterinary Dermatology 18, 392-400.
Silanikove, N., 1985. Effect of dehydration on feed intake and dry matter digestibility in desert (black Bedouin) and non-desert (Swiss Saanen) goats fed on lucerne hay. Comparative Biochemistry and Physiology Part A:80: 3, 449-452.
Silanikove, N., 2000. The physiological basis of adaptation in goats to harsh environments. Small Ruminant Research 35, 181-193.
Smith, J., VanBaale, M., Jamison, C., Rodriguez, R., Brouk, M.J., Harner, J.P., 2006. Evaluate the efficacy of heat stress audits" of your cooling system through core body temperature. Kansas Agricultural Experiment Station Research Reports.
Smith, T. R., Chapa, A., Willard, S., Herndon, C., Williams, Jr., R. J., Crouch, J., Riley, T., Pogue, D. 2007. Evaporative Tunnel Cooling of Dairy Cows in the Southeast II: Impact on Lactation Performance. Journal of Dairy Science 89, 3915-3923.
Spain, J.N., Spiers, D., 1998. Effect of Fan Cooling on Thermoregulatory Responses of Lactating Dairy Cattle to Moderate Heat Stress. Paper presented at the Chastain, J.P. (Ed.), Proceedings of the Fourth International Dairy Housing Conference. ASAE, St. Joseph, MI.
Strickland, J.T., Bucklin, R.A., Nordstedt, R.A., Beede, D.K., Bray, D.R., 1989. Sprinkler and Fan Cooling System for Dairy Cows in Hot, Humid Climates. Applied Engineering in Agriculture 5, 231-236.
Toida, H., Kozai, T., Ohyama, K., Handarto, 2006. Enhancing Fog Evaporation Rate using an Upward Air Stream to improve Greenhouse Cooling Performance. Biosystems Engineering 93, 205-211.
Turner, L.W., Monegue, H.J., Gates, R.S., Lindemann, M.D.,1997. Fan, sprinkler, and sprinkler plus fan systems for cooling growing-finishing swine. American Society of Agricultural Engineers 3.
Weissenböck, N.M., Weiss, C.M., Schwammer, H.M., Kratochvil, H., 2010. Thermal windows on the body surface of African elephants (*Loxodonta africana*) studied by infrared thermography. Journal of Thermal Biology 35, 182-188.
West, J.W., 2003. Effects of Heat-Stress on Production in Dairy Cattle. Journal of Dairy Science 86, 2131-2144.
Willits, D.H., 2003. Cooling Fan-ventilated Greenhouses: A modelling Study. Biosystems Engineering 84, 315-329.
Yousef, M.K., 1985. Stress physiology in livestock. Volume I. Basic principles. In. CRC Press, Florida, ISBN: 0 8493 5667.