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ORIGINAL RESEARCH

Effects of ventilation of the sheep house on heat stress, growth and thyroid hormones of lambs

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Abstract Twenty single male Assaf lambs were divided into two groups and housed in semi-open barns. Air temperature averaged 35°C. For 9 weeks after parturation, one group was cooled by fan between 1000 and 1600 hours and the other group was not cooled. Rectal and skin (head and testis) temperatures, respiration rate, and pulse rate were recorded twice daily. Lambs were weighed individually every week and levels of T3 and thyroxin were determined. Differences in rectal, head, and testis temperatures ($P<0.05$) and respiration rates ($P<0.01$) between the two groups were significant. Growth was affected positively by fan treatment, live weight increased by 15%, and cooled lambs had higher thyroxin levels.

Keywords Lamb · Thermal stress · Ventilation · Growth · T3 and T4 hormones

Introduction

Ventilation plays a critical role in sustaining the welfare and performance of farmed livestock, by affecting thermal exchanges between the animal's body surface and the environment and by removing aerial pollutants, which originate from animals and their excreta. In addition, it has been reported that a ventilation regimen, providing ventilation cycles during the warmest hours of the day and the night at a mean ventilation rate of 66 m^3/ewe per h, may adequately sustain the welfare and performance of lactating ewes raised in Mediterranean climates during summer (Sevi et al. 2002). Some researchers reported that poor ventilation is responsible for increased aerial concentrations of viable microbes, NH_3 and CO_2, reduced feed efficiency, and enhanced aggressive interactions in cattle, pigs, and broilers (Averos et al. 2008; Minka and Ayo 2009; Smith et al. 1996; Marrufo Villa et al. 1999). A ventilation rate of 1.22 m^3/h per kg body weight has been suggested for the maintenance of gaseous pollutants within acceptable levels in animal houses (Sevi et al. 2002). However, little information is available for sheep and goats due to the fact that extensive production systems are predominant for this species.

Thyroid hormones, thyroxin T4 or triiodothyronine T3, play an important role in the animal's adaptation to environmental changes. T4 and T3 stimulate oxygen consumption and heat production in cells, which increases the basal metabolic rate, enhances glucose utilization, and modifies lipid metabolism and stimulate cardiac and neural functions (Todini et al. 2006). The thyroid glands secrete mostly T4, which is monodeiodinated to T3, prior to interacting with the target cells. Low ambient temperatures tend to increase thyroid activity, whereas high temperatures depress it (Carpen and Martin 1989).

Due to marketing potential, all dairy ewes in the experimental research farm of Cukurova University (located East Mediterranean region of Turkey) are synchronized by Chrono-gest method for increasing feasibility and effective reproductively. Due to this manipulation, lambs are born during the warmest period of the year. Such peculiarities may contribute to minimizing the impact of

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high summer temperatures on lamb welfare. There are two main potential cooling effects of fan ventilation: (1) the removal of metabolic heat produced by the animals and its replacement with cooler external air, and (2) in some circumstances, a direct convective cooling effect if there is forced air movement close to the animal. This study was undertaken to assess the above-mentioned ventilation regime effects on growth performances and thyroid hormones (T3 and T4) of crossbred lambs during summer in a Mediterranean climate.

Materials and methods

The experiment was conducted in summer time (July to August) at the Dairy Research Experimental Farm of Cukurova University (36°59′ N, 35°18′ E). The climate characteristic of this area is typical Mediterranean (450-mm annual rainfall, an average temperature: 35°C, relative humidity: 65%, wind speed of, 1.1 km/h) Twenty lactating Cukurova Assaf (75% Awassi+25% East-Friesian) ewes were selected from dairy sheep flocks which were synchronized by Chrono-gest methods in February (Anonymous 2010). They were selected according to their ages, lactation numbers, milk yields, birth type, and gender of the lambs: thus all ewes were 3 years old, second lactations, and had had single male lambs.

The animals were housed in a semi-intensive system in semi-open barns. Water was given ad lib and feed was given twice a day. All animals were fed on concentrate (12% crude protein and 2300 kcal ME/kg.), and middle quality alfalfa hay was also offered during the experiment. Lambs were born in early July and they were divided into two groups consisting of ten lambs each. Lambs were kept with their mothers until weaning time (2.5 months old). The concentrate feed (16% crude protein and 2,500 kcal ME/kg.) and hay was also given to the lambs when they reached the age of 2 weeks. Lambs were weighed individually every week. Contrary of the control group (CG), the treated group (TG) was ventilated during the time period of 1000 to 1600 hours. Groups were housed separately in the experimental pens. The experimental pens were adjacent, facing south, away from prevailing winds and two axial fans were mounted 2.5 m from the floor (45 cm diameter) in one of the paddocks of experimental animals during the 9-week trial. Ewes and lambs could freely move within each pen, which was provided by a 4-mph fan speed. Also, automatic data loggers (Thermo-3897) were placed for recording air temperature and relative humidity in each pen (see Table 1).

The blood samples were taken twice a day (1100 and 1500 hours) twice a week throughout July and August. The blood was collected by jugular venipuncture. The samples were collected into EDTA tubes where they were analyzed for whole blood count (LH-750, Coulter Counter Beckman, Beckman Coulter, Inc., Brea, CA, USA); and blood gas analyses, and the samples were collected into heparin tubes were analyzed immediately (Nova Biomedical, Waltham, MA, USA). Immunoassay of T3 and T4 was carried out with commercial kits; minimum detectable concentration of T3 19.5 ng/dl and the intra-assay coefficient of variation was for 141 ng/dl 2.2% and for 445 ng/dl 1.5%; and minimum detectable concentration of T4 was 0.42 μg/dl and the intra-assay coefficient of variation for 6.55 μg/dl 1.3% and for 4.90 μg/dl 1.8%.

Table 1 Climatic data and THI of the experimental pens during the fattening trial

Traits	Groups	Average values
Air temperature (°C)	TG	32.4±0.2
	CG	35.1±0.2
Relative humidity (%)	TG	47.2±1.2
	CG	72.1±1.1
THI	TG	80
	CG	89

The temperature humidity index (THI; by Moran 2005) was calculated from temperature and relative humidity in order to determine the heat stress. THI table presents five comfort zones for animals: 72<no stress, 72–78 mild stress, 78–89 severe stress, 89–98 very severe stress, 98>dead animals.

The TG was ventilated 6 h a day contrary to the CG. The physiological data of lambs (rectal temperature (RT), respiration (RR) and pulse rates (PR), and skin temperatures from head (HT) and testis (TT)) were recorded in the morning (0800–0900 hours) and in the afternoon (1600–1700 hours). Rectal temperatures were measured by digital thermometer, and respiration and pulse rates were recorded using a stethoscope. Skin temperatures were measured via infrared thermometer (Testo BP-960) at a distance of 10 cm from the head and testis skin.

Statistical analysis

Body weight and hormone levels of lambs at different weeks were analyzed with Student's *t* test to determine the effect of fan treatment. Also, the data were analyzed according to variance analysis of a complete randomized block design; $\widehat{Y}_i = \mu + F_i + T_j + FT_{ij} + e_{ij}$ where, $\widehat{Y}_i$ is observation value (rectal temperature (RT), head skin temperature (HT), testis skin temperature (TT)); μ is the overall mean; F_i is the effect of the i^{th} fan treatment (1= without fan, 2=with fan); T_j is the effect of the j^{th} time (1= at 08:00, 2=at 16:00); FT_{ij} is the effect of interaction between fan and time; *eij*=residual error. DUNCAN multiple range test was then utilized to comprehend these differences (SAS 1990). Also, respiration rate (RR) and pulse rate (PR) were analyzed using Friedman test. Subsequently, any significant findings were further subjected to post-hoc pair-wise comparisons performed by Dunn's Test.

Results and discussion

Temperature-humidity index and some climatic data of experimental period were given Table 1. Silanikove (2000) and Avendano-Reyes et al. (2006) reported that the homoeothermic ability of sheep starts to be compromised when the thermal heat index (THI) exceeds 80%. According to Silanikove (2000) and Srikandakumar et al. (2003); THI is a good indicator of stressful thermal climatic conditions. THI values of 70 or less are considered comfortable, 75–78 stressful, and values greater than 78 consider extreme distress and animals are unable to maintain thermoregulatory mechanisms or normal body temperature. Based upon the THI values, the lambs were subjected to stressful conditions (i.e., 80 to 89, see Table 1) in this experiment. Thus, the fan treatment was effective in cooling inside the experimental pens.

The results related to growth performances of lambs were shown in Table 2. According to the obtained data growth rates of lambs were positively affected by the fan treatment ($P<0.05$). The lambs cooled by fan started gaining more weight starting from the third weeks after lambing and by end of the trial; they had gained almost 15% more weight than the lambs in the control group. The averages of weaning weight of hormone-treated and non-treated lambs, in mating season, were reported as 20.10 and 21.9 kg by Darcan et al. (2005). These values were obtained between April and May when the thermal stress did not have a negative effect on lambs, while the animals in the present study were assessed during a time of heat stress. Our result(s) was lower than Avendano-Reyes et al. (2006) which related to heat stress in animals. However, weaning weights of EG lambs were 14% lower than the hormone-treated lambs in the Darcan et al. (2005) study while control lambs' were 31%.

Table 2 Differences in body weight between lambs in control (CG) and treated groups (TG)

Weeks	Body weight (kg)		SEM*	Sig.
	CG	TG		
1	4.6	4.6	0.1	NS
2	5.1	5.4	0.2	NS
3	6.1 [b]	6.6 [a]	0.2	*
4	7.1 [b]	8.1 [a]	0.2	*
5	8.3 [b]	9.7 [a]	0.2	*
6	9.4 [b]	10.7 [a]	0.1	*
7	11.5 [b]	13.2 [a]	0.4	*
8	13.5 [b]	15.0 [a]	0.2	*
9	15.3 [b]	17.6 [a]	0.4	*

SEM standard errors of the means

[a,b] Means within rows with different superscripts are significantly different

*$P<0.05$

The average measurements and daily trends of physiological parameters of lambs subjected to fan (TG) were stated in Table 3. The results showed that rectal, head, testis temperatures ($P<0.05$), and pulse and respiration rates ($P<0.01$) were affected by the fan treatment and that its interaction with time ($P<0.05$) were significant. Rectal, head, and testis temperatures of TG and CG lambs were increased during the day, as expected. But TG lambs had lower rectal, head, and testis temperatures than CG lambs in both morning and afternoon measurements. Supplying air velocity around livestock in the hot season was the most effective way to alleviate heat stress. These applications related to physiological responses of animal such as decreasing body core temperature, heart rate, respiration rate, etc. TG groups had lower rectal temperature (−0.23 in morning and −0.33 afternoon); lower head temperature (−0.89 in morning and −0.99 in afternoon) and lower testis temperature (−0.92 in morning and −0.97 in afternoon) than the concomitant counterparts. Depending on the decreases in rectal temperature, the lambs may decrease maintenance cost (West 2003) and they could improve feed intake and daily gain. The data of respiration and pulse rates were also supported by the above mentioned results. Respiration rates of TG lambs were also lower than CG lambs especially in afternoon measurements (almost −15 breath per/min in morning and −18 breath per/min in the afternoon). Positive effects of evaporative cooling (wetting) on performance in lactating animals (Darcan and Güney 2008) and growing animals (Darcan and Güney 2002; Darcan and Cankaya 2008) were shown in the previous studies; however, some studies (Goncu and Ozkutuk 2003) argued that wetting the animal may increase relative humidity around the animal and/or barn and heat loss from the animal's body may be decreased due to difficulties in water evaporation in wetted animal skin under such conditions.

According to Avendano-Reyes et al. (2006), increased body temperature is a normal mechanism by which animals diffuse heat from their bodies to maintain thermoregulation in hot ambient conditions. Sevi et al. (2002) found that prolonged exposure to maximum air temperatures over 30°C and to THI values over 80, prevent lactating ewes from maintaining their thermal balance. In this response, in

Table 3 The average measurements and daily trends of physiological parameters of lambs subjected to fan treatments (TG) at different times (T)

Parameters						
	Treatment time (2400-hour clock)	RT (°C)	HT (°C)	TT (°C)	RR (per min)	PR (per min)
CG	0800–0900	39.0 [c]	33.6 [b]	33.3 [b]	64.2 [b]	84.1 [c]
	1600–1700	39.6 [a]	35.5 [a]	34.6 [a]	85.7[a]	90.0 [ab]
TG	0800–0900	38.8 [c]	32.8 [b]	32.4 [c]	48.9 [c]	85.3 [bc]
	1600–1700	39.2 [b]	33.5 [b]	33.6 [b]	68.3 [b]	91.8 [a]
SEM		0.01	0.3	0.1	2.3	0.5
	Treatment	*	*	*	**	**
Effects	Time	*	*	*	**	**
	Interaction (treat×time)	*	*	*	–	–

SEM standard errors of the means

[a, b, c] Means within rows with different superscripts are significantly different

$^*P<0.05$, $^{**}P<0.01$

the present trial, respiration rates and rectal temperatures significantly increased whenever THI exceeded 89. Under high ambient temperatures, animals benefit from ventilation directly via heat being removed from their body surface and indirectly via the lowering of air temperature, relative humidity, and gaseous pollutant levels. Thus, the failure to find an effect of the ventilation regimen during the warmest weeks of the trial might be partly ascribed to a reduction in the effectiveness of heat removed through convection mechanisms, because of a drop in the thermal gradient between ewe body surfaces and the moving air.

T hormone levels (T3 and T4) were given in Table 4. The physiological responses of the animals to environmental stress during the summer, and their energy balance, showed that seasonal heat and cold stress have profound effects on serum biochemical parameters. Thyroid hormones are known to be important modulators of developmental processes and general metabolism. Seasonal variations in the concentration of serum thyroxin (T4) and triiodothyronine (T3) of the animals have been reported (Nazifi et al. 1999). In reference to Silanikove (2000) and Todini et al. (2006), under the heat stress conditions, blood T3 and T4 concentrations were decreased (Silanikove 2000; Todini et al. 2006) as well as metabolic rates, feed intakes, growth, and milk production. In our study, T3 and T4 serum concentrations of TG and CG were found lower in afternoon than morning hours ($p<0.05$). In addition T3 and T4 levels of ventilated lambs (TG) were higher than control groups (CG) regardless of morning and afternoon hours. In control group lambs, due to rising evaporation rate after dehydration T3 and T4 levels were inhibited on the contrary of cooled lambs (TG). This finding was similar to reports of Silanikove (2000), Todini et al. (2006), and Al-Haidary (2004) who showed that the T3 and T4 levels were inhibited in Naimey Sheep under heat stress at semi-arid environments conditions. In addition, Nazifi et al. (1999) showed that the thyroid was stimulated in summer when water was available, but was inhibited after dehydration. This inhibition assists in the preservation of body water by decreasing pulmonary water loss and reducing basic metabolism.

Conclusion

Sheep are known to be one of the most heat-resistant species among farm animals. In addition, due to synchronization out of season, lambs were born in the warmest period of the year. Such peculiarities may contribute to the impact of high summer temperatures on lambs by minimizing welfare and growth performance. In the present study, ventilation systems that operated over upper critical air temperature and relative humidity were extremely effective and had high productivity in sheep farming. Our results suggest that providing ventilation during the warmest hours of the day may sustain the welfare and performance of crossbred lambs raised in Eastern Mediter-

Table 4 T3 and T4 hormone levels of experimental lambs

Traits	Observation time	Groups		
		TG	CG	SEM
T3	Morning	261.4 [a]	230.3 [b]	0.3*
	Afternoon	243.2 [a]	213.3 [b]	0.2*
T4	Morning	6.7 [a]	6.0 [b]	0.2*
	Afternoon	6.5 [a]	5.8 [b]	0.2*

[a,b] Means within rows with different superscripts are significantly different

$^*P<0.05$

ranean climates during summer. In addition, the prevention of gas accumulation would ensure improved health and reduced mortality for young animals, especially this relates to gas accumulation within barns. In the near future, it is suggested that investigations be carried out into the effects of fan use in the prevention of heat stress and the reduction of health problems in farm animals; and additionally regarding practical applications of this technology.

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