Effect of Solar Heat Load And Sex On Some Physiological Responses of Lambs

Hind A. Salih[1], Faisal El-Hag[2], Claudia Kijora[3]

[1]*University of Kordofan, Dept. of Animal Production, Sudan,*

[2]*Agricultural Research Corporation, El-Obeid Research Station, Animal Nutrition and Range, Sudan*

[3]*Humboldt-Universitat zu Berlin, Dept. of Animal Breeding in the Tropics and Subtropics, Germany*

Abstract - Forty new weaned males and females Sudan Desert lambs (Ovis aries) were used to investigate the effect of direct sunlight and sex on some physiological responses of lambs. The lambs were subjected to two housing conditions; either kept in shade or under direct sunlight. Exposure to direct sunlight showed a sharply increase ($p<0.01$) of respiration rate (RR) with a significant ($p<0.05$) increase of rectal temperature (RT). There were no sex-dependent differences on RR or RT. No significant differences in both thyroxine (T_4) and triiodothyronine (T_3) hormones were observed between shade and direct sunlight groups. T_4 and T_3 levels revealed a significant sex effect ($p<0.05$, $p<0.01$).

Keywords - lambs, rectal temperature, respiration rate, sunlight, thyroid hormones (T_4 and T_3).

1. INTRODUCTION

Sudan Desert sheep varies from sedentary systems around settlements to nomadic systems over considerable areas [1]. In North Kordofan, Sudan the average maximum temperature varies between 30 and 35°C during most of the year with peaks above 40°C during hot summer. The rainy season extends from July to October, reaching it peaks in August. The annual rainfall ranges from 75 mm in the extreme north about 500 mm in south. The average annual rainfall was estimated at 280 mm in Elobeid Agricultural Research Station and the relative humidity is uniformly low ranging between 22-25 % in the dry season [2]. Under these harsh conditions the animals suffering by climatic stress, nutritionally poor pastures, water shortages and poor livestock managements.

Sheep keeping in cotes should provide protection from solar radiation as a strategy to maintain productivity and welfare of animals, in particular during the hot season [3]. Shading improved the indexes of thermal comfort animal's physiology and production parameters [4].

Body temperature, pulse, respiration rates and thyroid activities are important physiological indicators commonly used to study adaptation to environmental stress in sheep [5].

The present study was conducted to evaluate the effect of housing conditions (shade and sunlight) and sex on some physiological parameters (RR, RT, T_4 and T_3) of Desert sheep lambs in Sudan.

2. MATERIALS AND METHODS

2.1 Study area

The experiment was carried out at Elobeid Agricultural Research Station Farm, in Sheikan Locality, North Kordofan State (Latitudes 11º: 15, to 16º: 30, N and longitudes 27º to 32º E), Sudan. The trial commenced in December, 2007 and ended in March, 2008.Table: 1 shows the weather conditions during the experimental period and at the days of sampling.

2.2 Experimental animals and procedures

Forty new weaned unshorn Sudan Desert lambs (*Ovis aries*) 4 months old, 19±0.4 kg body weight were used in this trial; twenty were males and the other twenty were females .The lambs were subjected to two housing conditions; either kept in shade or under direct sunlight. At the beginning of the experiment all lambs were treated against internal and external parasites with Ivomec administered subcutaneously at 0.5cc per head, and allowed one week adaptation period. Lambs were then divided into two equal groups. One group of males (n=10) and females (n=10) was randomly allocated to a shaded condition and the other to direct sunlight all over the period of the experiment. Shaded pens of $2\times3m^2$ each were used to accommodate two animals tethered to individual pegs and provided with individual feeding and water troughs. The lambs kept under direct sunlight were treated equally, then all lambs were received water *ad libitum* and given free access to hay and they were offered 200g of supplement per head daily until the end of the trail. The supplement was containing 49.6% sesame seed cake, 49.6% sorghum, 0.5% mineral block and 0.25% common salt.

2.3 Data records

2.3.1 Respiration rate (RR) and rectal temperature (RT)

The two groups of lambs were monitored for RR and RT every two weeks. Six measurements every two hours from 8:00a.m until 6:00p.m were taken on the same measurements day. RR was measured by counting the rate of flank movement for 20 seconds, then adjusted for 1 minute and recorded while RT was measured using a clinical digital thermometer. RR counts were performed by the same person over the whole experimental period to avoid inter-observer variations.

2.3.2 Blood sampling and processing

Blood samples were taken every two weeks from the jugular vein in vacationer tubes without anticoagulant on the same day of RR and RT measurements at 4:00 p.m, for hormonal assays. All blood samples were maintained at room temperature until clotting, and then centrifuged at 2000 rpm for 10 minutes; serum was collected and frozen at -200°C until assays. Thyroxine (T_4) and Triiodothyronine (T_3) were quantified using a commercial radio- immuno- assay (RIA) using kits method according to the protocol described in the kits (China Institute of Atomic Energy) provided by the International Atomic Energy Agency (IAEA). The radio activity of T_4 and T_3 was counted with a gamma counter .The results were expressed as ng of hormone per ml of serum. Assays were performed by Sudan Atomic Energy Commission, Institute of Radio Biology, Central and States Laboratories Department, Khartoum, Sudan.

2.4 Experimental design and statistical analysis

RR, RT, T_4 and T_3 were statistically analyzed as randomized complete block design in a 2x2 factorial arrangement of treatments, with five replications. Each replication included four lambs (2 males and 2 females). Two factors were studied; housing (shade versus direct sun light) and sex of lamb (male versus female) within sampling period and time of the day [6]. Duncan Multiple Range Test was used for mean separation. The data were analyzed using Statistical Package for Several Science (SPSS, 1997), while Microsoft Excel software program was used for graphics (MS Excel 2007).

Table-1: Meteorological data during the lambs' trial every two weeks and at the date of measurements

Period	Air temperature °C		Relative Humidity %
	Min	Max	
15. Dec.-30.Dec.	9.3	32.8	30.8
30. Dec.-13.Jan.	12.2	34.7	24.1
13. Jan.-27.Jan.	9.7	32.0	25.1
27. Jan.-10.Feb.	7.3	33.4	23.6
10. Feb.-23.Feb.	10.2	32.3	19.3
23. Feb.-9.Mar.	12.4	38.2	15.1
Date of Measurements			
15.Dec.2007	13.3	31.7	29.2
30.Dec.2007	15.5	32.5	34.5
13.Jan.2008	12.8	27.9	26.2
27.Jan.2008	11.5	23.4	21.0
10.Feb.2008	15.5	33.4	18.4
23.Feb.2008	13.0	26.8	15.9
9.Mar.2008	21.5	38.2	15.1

Source: Elobeid Agricultural Research Station-Sudan (2008).

3. RESULTS

3.1 Respiration rate (RR) and rectal temperature (RT)

Exposure of lambs to direct sunlight had resulted in a sharp increase in RR ($p<0.01$) and an elevated ($p<0.05$) RT in comparison with those under shade. RR of lambs under direct sunlight and for those under shade were 48.9 and 26.4 breathes/minute, respectively, while the respective RT for lambs under these two housing conditions were 39.1 and 38.8°C (Table- 2).

Sex of lamb exerted no significant ($p>0.05$) main effect on their RR and RT. However, males had comparatively higher RR and RT in comparison with females (Table- 2).

Table-2: Main effects of housing conditions (HC), sex and date of measurements (DM) on respiration rate (RR) and rectal temperature (RT) of Desert lambs

Factor	Respiration Rate (RR) Breaths/Minute	Rectal Temperature (RT) ^{O}C
Housing Conditions:		
Shade	26.4	38.8
Sunlight	48.9	39.1
SE±	1.20**	0.08*
Sex:		
Male	38.3	39.0
Female	37.0	38.9
SE±	1.20^{NS}	0.08^{NS}
Date of Measurements:		
15.12.07	28.5^{d}	39.9^{a}
30.12.07	37.1^{bc}	38.8^{bc}
13.01.08	30.9^{cd}	38.7^{bc}
27.01.08	19.4^{e}	38.5^{cd}
10.02.08	43.1^{b}	38.9^{bc}
23.02.08	42.7^{b}	38.9^{bc}
09.03.08	62.1^{a}	39.0^{b}
SE±	2.13**	0.15**
Interaction: SE±		
HC× Sex	1.60^{NS}	0.12^{NS}
HC×DM	3.10**	0.22^{NS}
Sex× DM	3.30^{NS}	0.22^{NS}
HC× Sex× DM	4.30^{NS}	0.31^{NS}

[a,b,c,d,e] Means in the same column under the same factor with the different superscripts are significantly different according to Duncan Multiple Range Test ([NS] Not Significant P>0.05, * Significant P<0.05, ** Highly Significant P<0.01).

Date of measurement had significant (p<0.05) main effects on RR and RT of lambs (Table- 2). RR followed air temperature (Table- 1) being highest at the maximum air temperature (38.2°C) whereas RT started at a higher level, decreased and then rose again during the last three measurements. The highest respective average daily RR and RT recorded were 62.1 breathes/minute and 39.0°C and were at the last date of measurement (Table- 2).

Interaction effects for the different factor combinations were not significant (p>0.05) on RR and RT, except for date of measurement x housing condition where lambs under direct sunlight recorded the highest RR at the last day measurement (Table- 2).

Data are summarized in Figure. 1: compare the effect between times of the day and housing conditions on RR of the two groups of lambs. No significant differences in RR were recorded between treatment groups at 8:00a.m and 6:00p.m according to the lower air temperature. However, a drastic significant (p<0.01) rising of the RR at the other times was observed in the direct sunlight group. The maximum diurnal variation was obtained between 8:00a.m and 2:00p.m with the rate of 60.5 breaths/min.

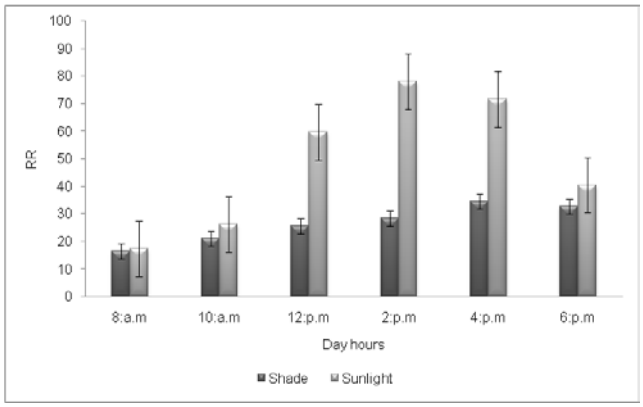

Fig. 1. Means ±SE of respiration rate (RR) of lambs as affected by housing conditions at different times of the day

The recorded every 2 hours RT of lambs under shade and direct sun light (Figure. 2) was lower at 8:00a.m, 10:00a.m and 12:00p.m with no difference between the two groups of lambs. With increasing air temperature RT had increased (p<0.01) at 2:00 pm, 4:00 pm and 6:00 pm for lambs under direct sunlight compared with those under shade. The extreme maximum value of RT recorded was 39.8°C at 2:00 pm and 4:00 pm with an extreme diurnal range of 1.8°C.

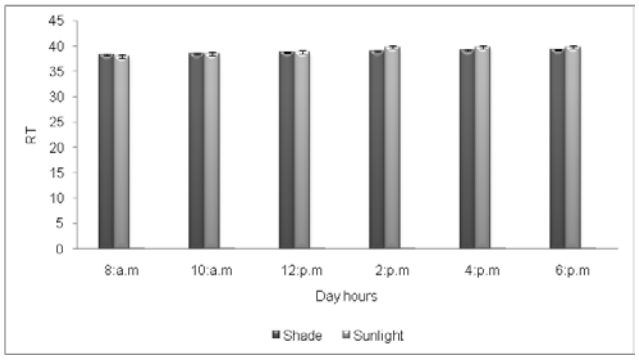

Fig. 2. Means ±SE of rectal temperature (RT) of lambs as affected by housing conditions at different times of the day

Throughout the trial period a significant difference (p<0.01) in RR was recorded between the males and females lambs at 8:00a.m, 10:00a.m and 4:00p.m when the air temperature was low (Figure. 3). Surprisingly, such a variation in RR between groups was absent either at 6:00p.m although the air temperature still low or at 12:00p.m and 2:00p.m during an increase in air temperature.

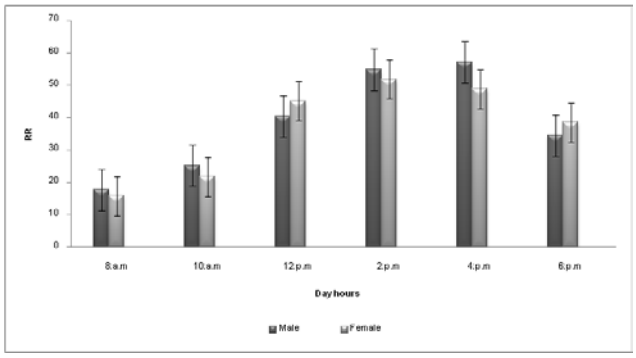

Fig. 3. Means ±SE of respiration rate (RR) of lambs as affected by sex of lamb at different times of the day

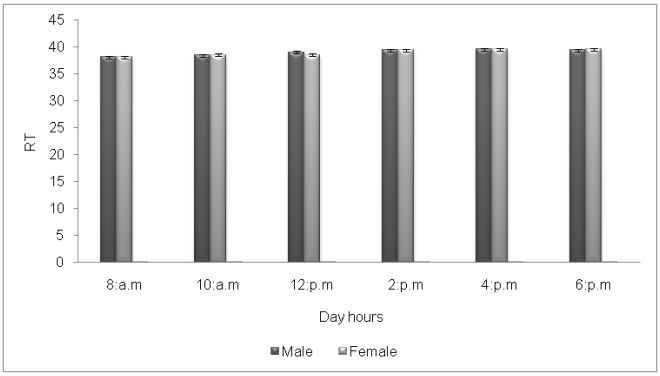

Fig. 4. Means ±SE of rectal temperature (RT) of lambs as affected by sex of Desert lamb at different times of the day

Surprisingly, such a variation in RR between groups was absent either at 6:00 pm although the air temperature still low or at 12:00 pm and 2:00 pm when air temperature was high.

All lambs exhibited similar RT values measured at the six different times of the day with no significance difference between males and females **(**Figure. 4).

3.2 Thyroxine (T_4) and triiodothyronine (T_3)

The mean serum thyroxine (T_4) and triiodothyronine (T_3) on lambs and the statistical comparison among various days within groups are shown in Table- 3. No significant differences in both T_4 and T_3 were observed between shade and direct sunlight groups, but the higher concentration of T_4 occurred in the direct sunlight group although T_3 was lower in the same group.

Analysis of T_4 level revealed a significant sex effect ($p<0.05$) with higher values for the females. On the other hand T_3 was significantly ($p<0.01$) higher in the males.

It was evident that a marked change in both T_4 ($p<0.05$) and T_3 ($p<0.01$) hormones increasing was initiated from sample 0 to sample 3 as reflected by the decrease in air temperature , but although the sample 4 showed an extreme high air temperature there was a noticeable increase in T_4 and T_3 hormones. There were no significant effects of factors interactions on T_4 and T_3, expect the effect of housing condition × sampling period on T_3 hormone.

Table-3: Main effects of housing condition (HC), sex and sampling period (SP) on Thyroxine (T_4) and Triiodothyronine (T_3) hormones concentration of Desert lambs

Factor	Thyroxine(T_4) ng/ml	Triiodothyronine(T_3) ng/ml
Housing Condition:		
Shade	38.7	0.44
Sunlight	40.0	0.41
SE±	1.57^{NS}	0.02^{NS}
Sex:		
Male	36.5	0.49
Female	42.4	0.36
SE±	1.57*	0.02**
Sampling Period:		
0 sample	32.6^{bc}	0.28ceg
1st sample	42.7^{a}	0.45^{ad}
2nd sample	40.7^{a}	0.44^{af}
3rd sample	38.8^{ac}	0.43^{bdf}
4th sample	42.4^{a}	0.52^{a}
SE±	2.33*	0.03**
Interaction: SE±		
HC × Sex	2.10^{NS}	0.02^{NS}
HC × SP	3.30^{NS}	0.04*
Sex × SP	3.30^{NS}	0.04^{NS}
HC × Sex × SP	4.67^{NS}	0.05^{NS}

$^{a, b, c, d, e, f, g}$ Means under the same column under the same factor with the different superscripts are significantly different according to Duncan Multiple Range Test (^{NS} Not significant $p>0.05$, * Significant $p<0.05$, ** Highly Significant $p<0.01$)

4. DISCUSSION

4.1 Respiration rate (RR) and rectal temperature (RT)

The results obtained in the present study indicate a significant effect of date of measurements on RR and RT due to the meteorological conditions, this is in line with [7], who reported, meteorological conditions, especially ambient temperature and relative humidity, can cause variations in physiological responses of animals; these could differ between breeds and species. In addition [8], observed that as a sheep responds to increased environmental heat, it will have an increased respiratory rate and altered depth of respiration, in response known as panting.

The normal ranges of RR and RT are 15- 40 breaths/min. and 38 - 39.5°C, respectively [9], but these ranges are 19.4 - 62.3 breaths/min. of RR and 38.5 - 39.9ºC of RT in our present results in a response to climatic conditions. On the other hand sheep are strived to maintain their body temperature within a fairly narrow range, even under adverse climatic conditions. The present data showed that RT vary between 38.5 and 39.9° C in a same trend with other researchers have been investigated RT vary between 38.3 and 39.9°C under thermo-neutral conditions [10]. RT of 42°C and above is considered as dangerous [11].

The THI during the dates of measurements was 16.7 to 22.1 and these values obtained indicate an absence of heat stress, but the last day of measurements showed an extreme severe heat stress when the THI was 25.8.

Exposure to direct sun light results in a significant effect on both RR and RT, these results are in agreement with the findings of [12], who reported that recovery of displaced core body temperature, as reflected by RT, was accomplished by utilizing several adjustments in certain thermoregulatory parameters. The increase in RR is believed to mediate an increase in the respiratory evaporative cooling, also [3] indicated that sheep exposed to solar radiation display enhanced respiration rate and increased rectal temperature compared with shaded animals.

According to the results obtained, sex of lambs had no significant effect on RR and RT; these results are agreement with [13], whom showed that there was no significant difference in physiological variables between males and females.

In the present study exposure to heat stress results in a significant increase in RR from 26.2 to 71.2 breaths/minute between 10:00a.m and 4:00p.m following an increasing in air temperature. Consistent with our observations, other investigators have shown that increased RR following heat stress in livestock, including goats [14], sheep [15] and cattle [16]. This response was further emphasized at 2:00p.m with peak ambient air temperature. The results obtained in the present study indicate a diurnal rhythm in the RT of the lambs. This finding is in agreement with the results of previous investigations into the RT of the Savannah Brown goat [17] and the West African Dwarf sheep [18]. Analogous results were also obtained in the Desert sheep [19]. The diurnal range of RT could serve as a measure of how stressful the weather is to the animal, if the diurnal range is less than 1ºC, it is established that it is not stressful, but ranges over 1°C are stressful [20], but other investigators reported that; East African sheep and goats are examples of animals with a narrow range in core temperature, i.e. they are obligatory homeotherms, and these species appear unable to increase their range of diurnal body temperature by more than 1-2°C in response to heat stress [21]. Therefore, the wide diurnal range of about 1.8°C obtained in the present study is particularly agreements with these findings.

In conclusion shading improved the indexes of thermal comfort, animal physiology and production parameters.

4.2 Thyroxine (T_4) and triiodothyronine (T_3)

Thyroid hormones (TH) are regulating the basic metabolism and play an important function in the expression of endogenous seasonal rhythms of neuro-endocrine reproductive activity in sheep, as in many species of birds [22].

In the present study there were no significant differences either in T_4 or T_3 between housing condition treatments, but it seems to be high T_4 level on lambs under direct sunlight with an inverse results of T_3; similar results were detected by [23] in chicken. [24] reported that, when the temperature ranges are not extreme (mild climate, indoor housing, shelter and the night time), the effect of photoperiod and season-depending TH profiles (mainly related to the day length changes) are predominant.

The present data indicates that T_4 was significantly higher in females, but inverse results of T_3. As far as we know others studies have been investigated that in young animals, there is no sex-dependent differences in blood TH concentrations, whereas in adult goats mean plasma TH levels were higher (significantly for T_4) in does than in bucks [25] and these findings are similar to the present results. In young cashmere goats, T_3 levels were lower in males than in females after 8 months of age, while T_4 was not affected by sex [26]. Serum T_3 and T_4 concentrations decline during the pre weaning period, are unaffected by gender (Garcia et al 2005) but, sex-related differences are reported in others mammals and are referred to several actions by sexual steroid hormones [27]. Results from the present experiment indicated that the increasing of T_4 and T_3 associated with ambient air temperatures during the sampling periods, others studies investigated the same results in sheep [28]. Except the 4^{th} sample, where an increase in TH hormones was shown although the air temperature was higher. This was in the same line of [29], who reported that, In the Sahel desert, plasma T_3 and T_4 highly significant rises was observed at the onset of the humid warm season. However, contrasting results have been reported [30]. It can be supposed that an enhanced thyroid activity during the humid warm season in such environments is functional for the animals facing the increased availability of food (quantity and quality), following the seasons characterized by food shortage.

Blood TH concentrations were high in spring (increasing day length) and low in autumn (decreasing day length), which was not fully explained by the changes in environmental temperature [24] and indicates the influence of the Photo period.

5. CONCLUSION

Little is known about TH activity in lambs so, that needs further research. Knowledge on such topics will possibly allow the monitoring and manipulation of thyroid physiology, in order to improve small ruminant's health, welfare and production.

ACKNOWLEDGEMENTS

The financial support of DAAD is gratefully acknowledged. The authors also wish to thank Dr. Mohammed Hamid, Dr. I Musa, Mr. M Suleiman and Mr.B El Fakki for technical assistance.

REFERENCES

[1] Mufarrih, M.E, "Sudan Desert sheep: Their origin, ecology and production potential", World Animal Review. 66: 23 – 31, 1991.

[2] Technoserve, "Credit component base line survey .Technoserve Inc, Agricultural Bank of Sudan" .US agency of Agricultural Development, El Obied, Sudan .204 pp, 1987.

[3] Sevi, A. Annicchiarico G. Albenzio M. Taibi L. Muscio A. Dell'Aquila S, "Effects of solar radiation and feeding time on behavior, immune response and production of lactating ewes under high ambient temperature", J. Dairy Sci. 84, 629–640, 2001.

[4] Andrade Iremar Silva Bonifácio Benício de Souza José Morais Pereira Filho Aderbal and Marcos de Azevedo Silva, "Physiological behavior and performance of lambs

Santa Inês breed submitted to different types of environmental and supplementation in grazing", Ciênc. Agrotec. Lavras, v. mar. /abr .31, n. 2, p. 540-547, 2007.

[5] Ross, T.T Goode D. and Linnerud A. C, "Effect of high ambient temperature on respiration rate, rectal temperature, fetal development and thyroid gland activity in tropical and temperate breed of sheep", Theriogenology, 24: 259-269, 1985.

[6] Steele, R.G.D., and Torrie, J.H, "Principles and Procedures of Statistics: A Biometrical Approach", (2nd Ed.). McGraw-Hill Publishing Co, New York, 1980.

[7] Mullick D. N, "Effect of humidity and exposure to sun on the pulse rate, respiration rate, rectal temperature and hemoglobin level in different sexes of cattle and buffalo", Journal of Agricultural Science, Cambridge 54, 391–394, 1960.

[8] Stockman C. A, "The Physiological and Behavioral Responses of Sheep Exposed to Heat Load within Intensive Sheep Industries", Ph. D.thesis. , Murdoch University, Western Australia, 2006.

[9] Adams, R.M., McCarl, B.A., Segerson, K., Rosenzweig, C., Bryant, K.J., Dixon, B.L., Conner, R., Evenson, R.E. and Ojima, D, "The economic effects of climate change on US agriculture. In The economics of climate change", (R. Mendelsohn and J. Neumann, eds). Cambridge University Press, Cambridge, 1998.

[10] Marai I. F. M Habeeb A. A. M Gad A. E, "Rabbits' productive, reproductive and physiological performance traits as affected by heat stress", a review. Livest. Prod. Sci. 78, 71–90, 2002.

[11] Thwaites C. J, "Physiological responses and productivity in sheep. In: Yousef, M.K", (Ed.), Stress Physiology in Livestock.CRC Press, Inc., Boca Raton, Florida, USA, pp. 25–39, 1985.

[12] Al-Tamimi Hosam J, "Thermoregulatory response of goat kids subjected to heat stress", Journal of Small Ruminant Research.71: 280-285, 2007.

[13] Stockman, C.A., Barnes, A. and Pethick, D, "Feeding sheep under high heat load did not decrease intake of feedlot rations", Department of Agriculture & Food WA. Murdoch University, Western Australia, 2007.

[14] Katamoto H. Fukuda H. Oshima I. Ishikawa N. and Kanai Y, "Nitro blue tetrazolium reduction in heat stressed goats is not influenced by vitamin E and selenium injection", J. Vet. Med. Sci. 60 (11), 1243–1249, 1998.

[15] Gadberry, M., Denard, T., Spiers, D., Piper, E, "Effects of feeding ergovaline on lamb performance in a heat stress environment", J. Anim. Sci. 81 (6): 1538–1545, 2003.

[16] Gaughan, J., Mader, T., Holt, S., Josey, M., Rowan, K, "Heat tolerance of Boran and Tuli crossbred steers", J. Anim. Sci. 77 (9): 2398–2405, 1999.

[17] Igono M.O, Molokwu E. C. I and Aliu Y O, "Body temperature response of Savannah Brown goat to the harmattan and hot – dry season", International Journal of Biometeorology 26, 225- 230, 1982.

[18] Orji B. I and Umesiobi D. O, "Behavioral and physiological responses of Nigerian Dwarf sheep to change in microenvironment of humid tropics", Proceedings of the National Conference on Small Ruminant Production, Zaria, Nigeria, pp 266-267, 1985.

[19] Ahmed M.M and Abdelatif A M, "Effect of dietary protein level on other-moregulation, digestion and water economy of Desert sheep", Small Ruminant Research 18, 51-56, 1995.

[20] Bianca W, "Heat tolerance in cattle – its concept, measurement and dependence on modifying factors", International Journal of Biometeorology 5, 5-26, 1961.

[21] Maloiy, G.M.O. and Taylor, C.R, "Water requirements of African goats and haired sheep", Journal of Agricultural Science, Cambridge 77, 203-208, 1971.

[22] Nicholls, T.J., Follett, B.K., Goldsmith, A.R. and Pearson, H., "Possible homologies between photo refractoriness in sheep and birds: the effect of thyroidectomy on the length of the ewe's breeding season", Reproduction, Nutrition, Development 28 375–385, 1988.

[23] Pietzarka, C., "Auswirkung des Genes fÜr Befiederungsrestriktion auf den Energiestoffwechsel und Thyroxinstatus in der embryonalen und adulten Phase, sowie auf die reproductive Konstitution unter variierenden Umgebungstemperaturen beim Huhn", Ph. D.thesis. , University of Giessen. Germany, 2006.

[24] Todini, L. Delgadillo J. A. Debenedetti A. and Chemineau P., "Plasma total T3 and T4 concentrations in bucks as affected by photoperiod", Small Ruminant Research 65, 8–13, 2006.

[25] Todini, L. Lucaroni A. Malfatti A. Debenedetti A. and Costarelli S. ,"Male – female differences in the annual profiles of the thyroid hormones blood level by the goat", Atti della Societa` Italiana della Scienze Veterinarie 46, 169–173, 1992.

[26] Celi, P., Seren, E., Celi, R., Parmeggiani, A. and Di Trana, A. , "Relationships between blood hormonal concentrations and secondary fiber shedding in young cashmere-bearing goats at their first moult" , Animal Science. 77: 371–381, 2003.

[27] Todini, L., "Thyroid hormones in small ruminants: effects of endogenous, environmental and nutritional factors" , Animal, 1:7, pp 997– 1008, 2007.

[28] Starling, J. M. C. Da Silva R. G. Negrao J. A. Maia A. S. C and Bueno A. R , "Seasonal variation of thyroid hormones and cortisol of sheep in tropical environment" , Revista Brasileira de Zootecnia 34, 2064–2073, 2005.

[29] Assane, M. and Sere, A. , "Seasonal and gestational variations of triiodothyronine and thyroxine plasma-concentrations in Sahel Peulh ewe" , Annales de Recherches Veterinaires. 21: 285–289, 1990.

[30] Yokus, B. Cakir D. U. Kanay Z. Gulten T. and Uysa l. E , "Effects of seasonal and physiological variations on the serum chemistry, vitamins and thyroid hormone concentrations in Sheep' , Journal of Veterinary Medicine – Series A 53, 271–276, 2006.