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Thermoregulation in Sudanese Desert Sheep under Different Environmental Conditions

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EIGHTEEN RAMS of Sudanese desert sheep were used to study the effect of type of housing and ration fed on their thermoregulation reactions (body temperature and respiration rate). Animals were divided into three equal groups of six animals each, and were housed under three different environmental conditions (closed lab. A, semishaded - B and unshaded-c). Three experiments were conducted :

Two with berseem hay (winter and summer) and one with concentrate (summer exp).

Rectal temperature and respiration rate were measured 9 times once a month (at December, May and June of each experiment) during the 24 hr, day length. The air temperature and relative humidity were recorded at the time of each test

— The sudanese desert sheep reacted differently to the climatic conditions in the three environments studed (A,B and C). These exposed to direct solar radiation (C) showed greater stress, had higher rectal temperature (103.8 °F) and more increased respiration rate (103 cyc/min), than those provided with shade, where their rectal temperature were (103.6° and 103.4 °F) and their respiration rates were (79 and 70 cyc / min) for ents A and B respectively.

Complete enclosure of the animals in the laboratory ((en—A excerted more heat stress than the other two environments (Band C) during evining, when the outdoors air temperature starts-to drop.

The amplitude of diurnal fluctuations of sheep's rectal temperature was greater in winter (1.3° - 2.3 °F) than in summer (0.8° 1.3°F). The trend of circadian rhythm was affected by air temperature and the rationd fed.

— Concentrate feeding resulted in reducing the gap between the maximum and minimum values of the rectal temperature. Rectal temperature at 8 a.m. of sheep fed concentrates was higher than of those fed berseem hay and it reached its higher values before air temperature approaches its maximum.

The majority of livestock in the Sudan is managed under a nomadic system that allows for a constant migration from north to south in search of water and grazing. During this migration animals are left to the hazards of nature, thus exposed to a severe climatic stress that can result from air temperature of more than 44° . Since no shade is provided the solar radiation undoubtely add more stress.

Recently, more interest has been directed to improve the managerial conditions under which sheep are bred. This includes, breeding them in flocks under housing systems and feeding them on concentrate rations and berseem hay before marketing to improve their bodyweight, carcass and meat quality. Thus an interest has arisen to study the thermoregulation reactions (body temperature and respiration rate) of Sudanese desert sheep kept under different types of housing. The effect of type of ration on their response to the different housing conditions was also investigated.

Material and Methods

The present investigation was carried out at the experimental farm, Animal Production Department, Faculty of Agriculture Shambat Khartoum University.

Animals

18 male Sudanese desert sheep, 1-1·5 years old were used in this study. Animals were bought from Omdurman livestock market, they were investigated against parasites and those found infected were treated. A week later the animals were ear tagged, weighed and divided according to their liveweights into three groups of six animals each. Every group was kept under one of the following environmental conditions.

Environment-A

The first group of animals was housed in animals laboratory which is made of brick walls, about 6 meters height, concrete floor and corrigated galvanized zink roof. Windows were located in the upper part of the walls.

Environment-B.

The second group was kept in a normal open yard surrounded by brick walls about one meter height and a roof made of bamboo mats which were not closely attached and thus allowed sunrays in between them.

Environment-C.

Under which the third group was kept, is a normal open yard, but without a roof or any shelter.

Maximum and minimum air temperatures were recorded every day in the three locations of the experiment. The humidity was also measured by the dry and wet bulb thermometers every day at 8 and 11 am, 2, 6 and 8 pm.

Feeding traits

Three experiments were excuted to study the effect of type of feeding on the thermal reactions of sheep to the three different environments (A,BandC).

In the first year of investigation, two experiments using berseem hay (Medicago Satival.), as the sole diet, were carried out. One during the summer *i.e.* May and June 1978 and the other in winter, December and January 1979. A third experiment using a concentrate ration instead of berseem hay was conducted on the summer of 1979 . The ration consisted of dura grains (10%) wheat bran (32%) cottonseed cake (32%), ground berseem hay (25%) and salt (1%). Concentrates were offered according to the body weight. Berseem hay was offered *ad libitum.* Water was available all the time.

Thermoregulation response

Rectal temperature and respiration rate of sheep were recorded once a month during the 24 hr day length at 8 and 10 a.m, 12 noon, 2,6 and 8 p.m., 12 midnight, 4 and 6 a.m.

Rectal temperature was tested by insertion of veterinary clinical thermometer to a depth of 3 inches in the rectum for one minute. The respiration rate was counted from the flank movement per minute. Each cycle is represented by the inward and outward movement of the flank.

Results and Discussion

1. The climatic conditions at the three housing systems

As could be seen from Table 1 the environmental conditions of the three treatments (A,B and C) were different from each other. Environment-A was characterized by a lower maximum air temperature compared to environments B and C which were higher in this respect by about 2·5 and 4·1° respectively. However, animals housed indoors were subjected to greater heat radiation from the walls of the laboratory after sunset and to a slightly higher relative humidity. The closed laboratory environment also had its own diurnal rhythm of air temperature which was different from that of the other two environments.

TABLE 1. Mean air temperature (°C) at the three housing systems during winter, summer-(1978) (berseem hay feeding) and summer II (1979) (concentrate feeding).

day time	Closed lab- A			Semi-shaded - B			Unchaded - C		
	Win.	Sum.I	Sum.II	Win	Sum.I	Sum.II	Win	Sum.I	Sum.II
8 a.m	20.0	33.0	34.0	20.5	35.0	34.5	19.5	36.3	35.0
10	24.5	37.0	35.5	26.5	40.0	36.3	26.5	42.0	37.3
12 noon	28.0	39.5	38.0	29.5	42.0	39.3	31.0	43.0	40.5
2 p.m.	28.5	40.0	34.0	31.0	43.3	41.0	31.5	45.0	42.5
6	23.5	37.0	34.0	25.5	38.5	34.0	24.5	39.0	32.5
8	22.0	35.5	34.0	22.5	36.5	32.5	21.0	35.0	32.0
12 midnight	21.0	33.0	32.5	19.5	33.5	31.0	18.0	32.5	30.0
4 a.m.	19.5	32.5	31.5	19.0	32.5	28.5	15.0	32.0	27.5
6	19.0	32.0	30.0	16.5	32.0	29.0	15.0	32.0	28.0

Environment B which was formed by utilizing a brokenshaded enclosure had a maximum air temperature of 31 ° during winter and 40°8, 42·3° during the two summer experiments. The climatic conditions in this environment were less severe than those of environment C as animals were protected here from the direct and reflected solar rays.

Environment C which was established in an outdoor enclosure with no cover whatsoever had the highest maximum air temperatures of 31·0° 42·3 and 44·8° during winter and the two summer experiments respectively. In this enclosure the animals were exposed directly to the direct solar heat and rays and to the reflected solar rays from the ground and near by material.

The greatest diurnal fluctuation in ambient air temperature was observed in environment C where air temperature at 2 p.m. was higher than that at 8 a. m. by an average of 12 and 7·9° during winter and summer experiments respectively. These variations were somewhat smaller in environment A, 8·5° and 5·4° during winter and summer experiments between the hours mentioned. Condition in environment B was intermediate in this regard as the measured difference in air temperature between 2 p.m and 8 a.m. was 10.0 and 6·9° for the winter and the two summer experiments respectively.

It was noticed also that environment C had witnessed the greatest drop in air temperature as measured at 2 p.m. and 6 p.m. followed by environments B and A in that order. Analysis of data collected during winter and summer experiments showed that the drop in air temperatures at the above-mentioned period was (5·8, 1·3 and 3·2), (5·5, 3·8 and 6·8) and (7,6 and 9·8)° for environments A,B and C and for winter and the two summer expeiments respectively.

The mean relative humidity was 68%, 54% and 35% for environments A, B and C respectively.

2· *Mean values of rectal temperatures and respiration rates of Sudanese desert sheep*

As shown from Table 2,3 and 4 the normal rectal temperature of sudenese desert sheep ranged between 101·1° to 103·8°F under air temperatures ranging between 15°-45° . Their respiration rate were 20-103 cyc./min. Kammlade (1947) considered 100·9° to 103·8°F as normal body temperature for wool breeds. Lee (1950) indicated, that the rectal temperatures in various groups of sheep (air temperature 10°-30°) varied from 101·5° to 103°F. Hafez *et al.* (1956) gave 102·2°F as mean body temperature of Egyptian fat-tailed coarse wool breed. Symington (1960) found that the rectal temperature of Native Rhadesian, Persian and Rhodesion Merino ranged between 101.·5°-103·4°F.

3· *Thermoregulation reaction to the three environments studied.*

(*a*) *During winter*

During winter experiment, the rectal temperature of sheep kept in environment-A began to increase when air temperature rose from 24° to 29°(Table 2 and Fig. 1). In case of animals subjected to environments B and C their rectal temperature started to increase at lower air temperatures (20°-25°). Due to exposure of sheep in environment-C to direct solar radiation, their rectal temperature increased from 101·1°F at 8 a.m to 103.4°F at 2 p.m, by a difference of 2·3°F. The rise in rectal temperature of sheep protected from sun-rays (environments-A and B) at the same period was only 1·5 and 1·3 °F respectively (Table 2 and Fig. 1).

The respiration rate of the desert sheep during winter experiment ranged from 20-60 breaths/min. As could be seen from fig 1 regardless of type of housing, when rectal temperature of sheep was 103°, respiration rate of animals subjected to direct solar rays was significantly higher (1·5 times) than that in animals protected from sunshine (Table 2). The magnititude and trend of changes in rectal temperature and respiration rate of sheep kept outdoors

TABLE 2. Effect of winter conditions (berseem hay feeding) and type of housing on the rectal temperature (RT) and respiration rate (RR) of Sudanese desert sheep (Mean ± SE).

Time	Closed lab- A		Semi-shaded - B		Unshaded - C	
	RT (°F)	RR(cyc) min	(RT (°F)	RR(cyc) min	RT (°F)	RR(cyc) min
8 a.m.	101.5±0.13	23±2	101.7±0.28	26±1	101.1±0.48	21±2
10	101.5±0.13	31±2	102.0±0.25	34±2	101.7±0.28	34±3
12 noon	102.7±0.12	44±4	102.6±0.16	40±1	102.9±0.22	60±7
2 p.m.	103.0±0.17	45±3	103.0±0.23	42±2	103.4±0.17	60±4
6	103.0±0.08	47±5	103.0±0.20	27±1	103.1±0.12	22±3
8	102.6±0.13	30±2	103.0±0.19	29±1	102.8±0.18	22±2
12 midnight	102 3±0.05	31±3	102.6±0.17	24±2	102.3±0.27	23±2
4 a.m.	102.2±0.05	24±1	102.2±0.20	20±1	101.8±0.2	21±2
6	101.7±0.11	22±2	101.7±0.14	20±1	101.3±0.41	22±1

(environments B and C), were greatly dependent on the fluctuations in air temperature (Fig. 1). Indoors animals (environment-A) kept their rectal temperature and respiration rate at high level for a period of 4 hr later after air temperature has decreased (Table 2 and Fig. 1).

(b) During summer

As shown from Table 3 and Fig. 2 elevation in rectal temperature of sheep kept outdours (Band C environments) began when air temperature rose from 40°to 45° while animals kept indoors (environment-A) increased their rectal temperature at the lower air temperatures of 37°-4°C. Moreover, rectal temperature of outdoors sheep reached its maximal values at 12noon, 2 hours earlier than that of sheep kept indoors, which gave their maximum readings at 2 pm. The increase in rectal temperature was 1·5°, 1.1° and 0.8°F for animals housed in environments C,A and B respectively. This could be explained by the fact that animals in environment-C were not only subjected to higher air temperatures (Fig. 2) but also to the effect of the direct and reflected solar rays. Sheep kept in semi-shaded yards were protected from the direct sunshine and had a chance to be under the favourable effect of free open air movements.

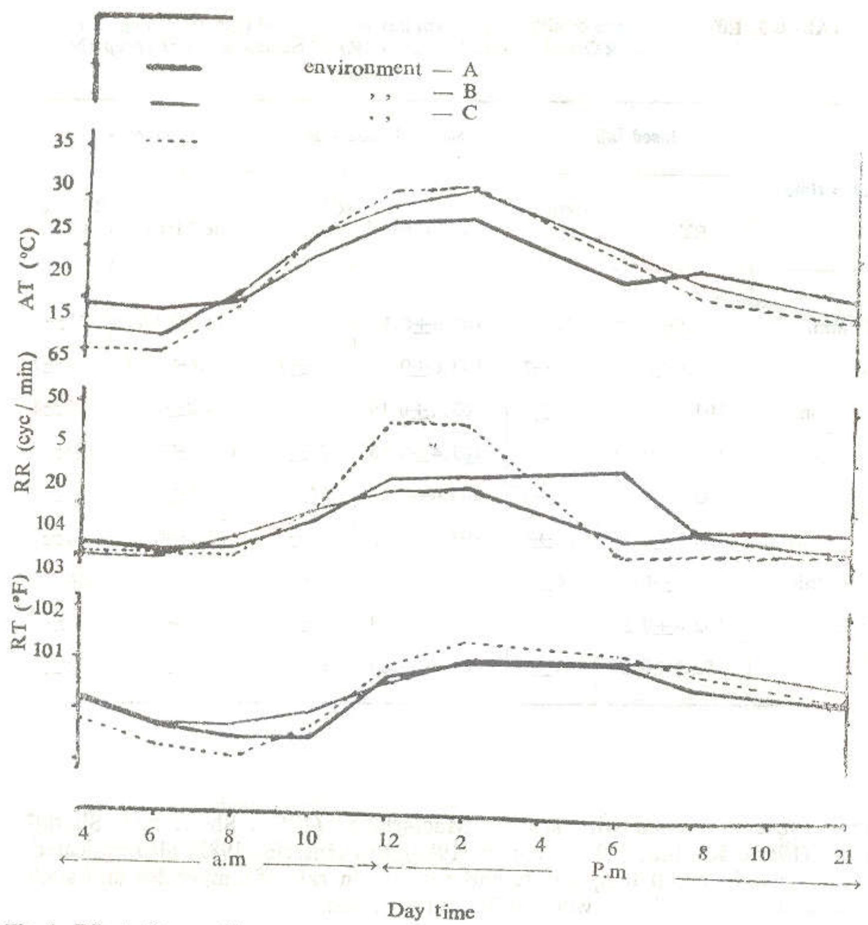

Fig. 1. Effect of type of housing and air temperature (AT) on rectal temperatur (RT) and respiration rate (RR) of sheep.
(Winter experiment-Hay).

The increase in respiration rate of all animals under any of the three environments reached its maximum at the time of maximum air temperature *i.e.* at 2 p.m. (Fig. 2). The increase was greater for sheep exposed directly to the solar-rays in environment-C than for animals in the other two environments (Table 3 and Fig. 2).

As could be expected, the desert sheep reacted differently to the climatic conditions in the three environments studied. These exposed to direct solar radiation showed greater stress, had higher rectal temperatures and more increased respiration rates of about 1·5 times during the noon and early evining,

TABLE 3. Effect of summer conditions (berseem hay feeding) and type of housing on rectal temperature (RT) and respiration rate (RR) of Sudanese desert sheep (Mean ± SE).

Day time	Closed lab-A		Semi-Shaded - B		Unshaded - C	
	RT (°F)	RR(cyc/min)	RT (°F)	RR(cyc/min)	RT (°F)	RR(cyc/min)
8 a.m.	102.5±0.18	42±3	109.6±0.15	44±6	102.3±0.17	57±5
10	102.6±0.09	58±7	102.6±0.11	53±7	102.6±0.14	78±7
12 noon	103.4±0.17	68±4	103.4±0.19	60±5	103.8±0.22	92±4
2 p.m.	103.6±0.17	79±4	103.4±0.13	70±6	103.7±0.23	103±3
6	103.1±0.16	72±4	103.0±0.15	57±6	103.2±0.16	58±7
8	103.3±0.23	63±4	103.1±0.18	58±7	102.9±0.17	48±7
12 midnight	103.1±0.19	60±7	102.9±0.13	35±4	102.6±0.16	38±5
4 a.m.	102.8±0.21	46±6	102.7±0.13	32±3	102.4±0.15	28±3
6	102.8±0.24	44±7	102.6±0.09	36±6	102.3±0.09	38 ± 6

than those provided with shade. Macfarlane (1962). Shafie and Sharaf-eldin (1965), Khalifa; (1979), Khalil (1980) and Hussein (1982) also indicated, an increase in rectal temperature and respiration rate of temperatee and subtropical breeds of sheep, when subjected to sunshine.

Respiration rate of sudanese desert sheep did not exceed 110 cyc min, even when kept at 45° air temperature and under the effect of the direct solar rays. This indicates the great tolerance of this breed to heat stress. The animals under these severe conditions never showed external symptoms of heat exhaustion and their thermoregulative mechanisms never showed signs of failure.

Results of many investigators (Lee, 1950 ; Hafez *et al.*, 1959 ; Jhonson, 1971 and Hales and Brown 1974) indicate that temperate, subtropic breeds, coorse wool or hairy coated types of sheep, increased their respiration rate to about 6 - 10 folds its initial values, while in sudanese desert sheep it was only 4 folds.

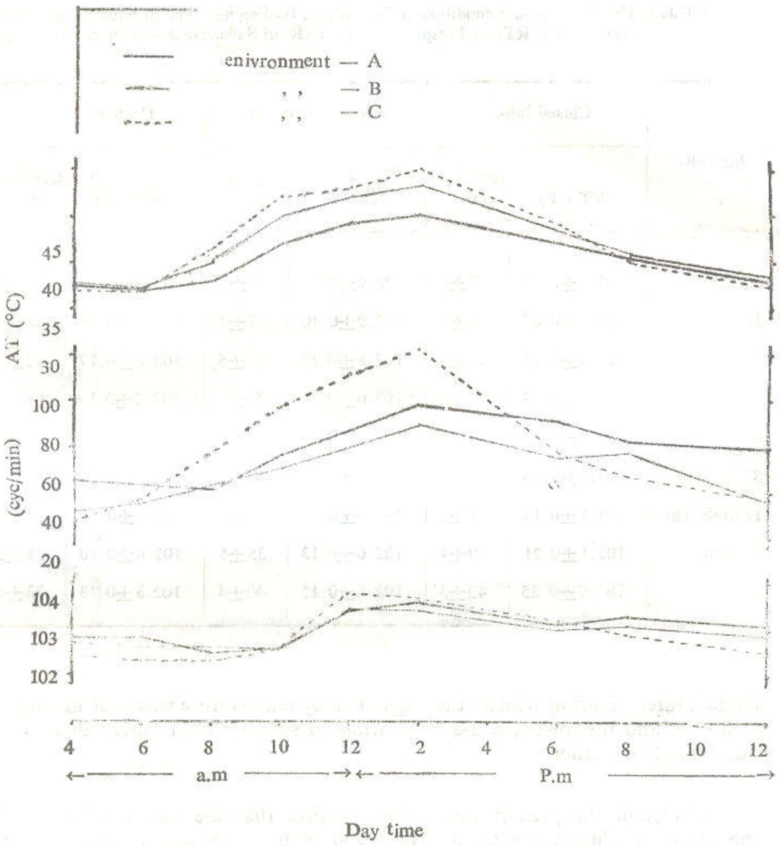

Fig.2. Effect of type of housing and air temperature (AT) on rectal temperature (RT) and respiration rate (RR) (Summer experiment-Haiy).

Diurnal rhythm of sheep rectal temperature and respiration rate

Results presented in Tables 2 and 3 indicate that the amplitude of diurnal-fluctuations was greater in winter (1·3° to 2·3°F) than in summer (0·8° 1·3°F). These differences could be related to variations in the maximum and minimum air temperatures, which was greater in winter. Seasonal rhythm was also observed in the time of maximum and minimum values of body-

TABLE 4. Effect of summer conditions (Concentrate feeding and type of housing on rectal temperature (RT), and respiration rate (RR) of Sudanese desert sheep (Mean ± S.E.).

Day time	Closed lab-A		Semi-shaded - B		Unshaded - C	
	RT (°F)	RR(cyc/min.	RT (°F)	RR(cyc/min)	RT (°F)	RR(cyc/min).
8 a.m.	103.2±0.12	57±5	102.9±0.12	49±4	102.5±0.13	51±3
10	103.1±0.07	55±4	102.9±0.10	63±5	102.7±0.14	63±4
12 noon	103.0±0.17	86±3	102.8±0.13	77±5	102.8±0.17	95±3
2 p.m.	103.2±0.13	76±3	103.0±0.16	74±5	103.2±0.19	81±5
6	103.3±0.16	69±3	103.1±0.13	53±3	102.8±0.12	48±7
8	103.4±0.16	57±7	102.9±0.12	64±6	102.7±0.09	44±4
12 midnight	103.1±0.14	51±4	102.8±0.18	40±4	102.6±0.11	31±2
4 a.m.	103.1±0.21	50±4	102.6±0.13	35±5	102.6±0.10	28±2
6	102.9±0.25	42±3	102.6±0.12	40±4	102.3±0.13	33±4

temperature. During winter, the highest body temperature was that measured at 2 p.m. and the lowest at 6-8 a.m., while in summer both these values were observed 2 hr earlier.

Results of the present study also revealed, that the ration fed modified the trend of diurnal fluctuations in rectal temperature and respiration rate of the Sudanese desert sheep (Table 4 and Fig. 3).

Circadian rhythm of sheep's body temperature was investigated by different authors (Mac farlane *et al*, 1956 ; Mendel and Raghan, 1964 ; Bligh *et al.*, 1965 ; Khalifa, 1979 and Khalil, 1980). Macfarlane, observed fluctuations of 1·5°-2·0°C in summer, while Bligh *et al.* (1965) reported only 0·95° with no obvious seasonal variations.

Similar to circadian rhythm in sheep's rectal temperature, diurnal variations in their respiration rate were also revealed (Tables 2 and 3). In the present work, respiration rate increased from (20-30 cyc/min) at 4 a.m. to

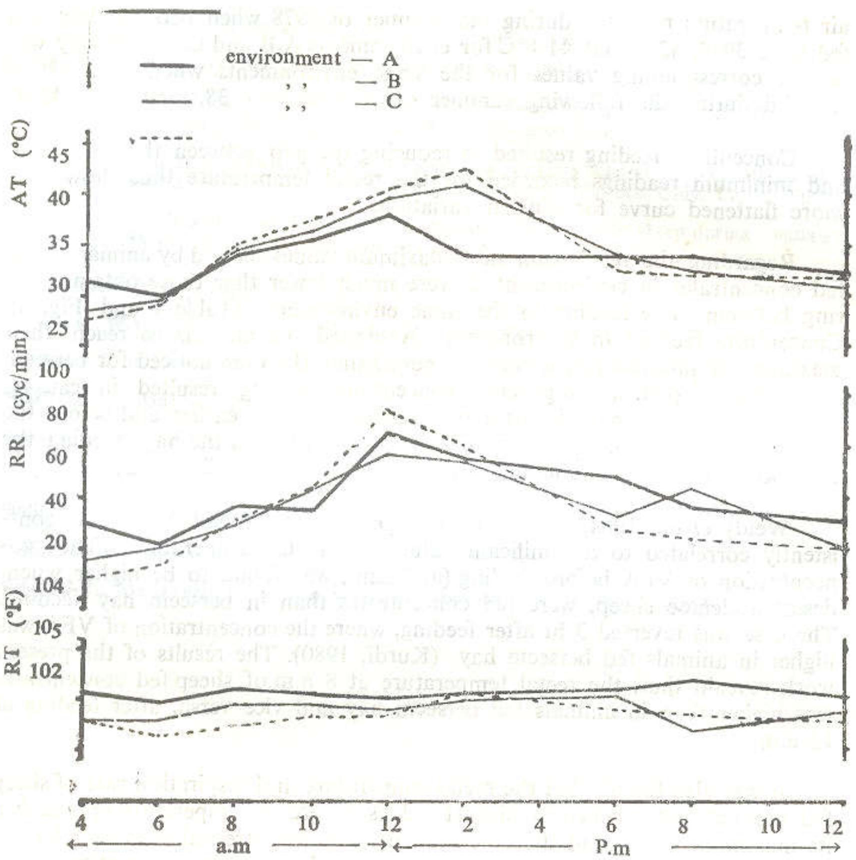

Fig. 3. Effect of type of housing and air temperature (AT) on rectal temperature (RT) and respiration rate (RR). (Summer experiment-Concentrate).

(60-105 cyc./min) at 2p.m. and this increase was more pronounced in the outdoors animals. Hafez *et al.,* (1956) Symington (1960) and Quartermain (1964) noticed such changes in respiration rate of different temperate and sub-tropic breeds.

The Effect of rations on rectal temperature and respiration rate.

It is evident from Table 1 and Figures 2 and 3 that the mean values of maximum air temperatures at the various thermal environments studied were higher when berseem hay was fed than when feeding concentrates. The high air temperaturs recorded during the summer of 1978 when berseem hay was fed were 39·8, 42·3 and 44·8°C for environments A,B and C respectively while the corresponding values for the same environments when concentrate was fed during the following summer experiment were 38, 40·8 and 42·3°

Concentrate feeding resulted in reducing the gap between the maximum and minimum readings recorded for the rectal temperature thus showing a more flattened curve for diurnal variation.

Regarding the respiration rate, maximum values showed by animals when fed concentrates in environment C were much lower than those obtained during berseem hay feeding in the same environment (Table 4 and Fig. 3). Concentrate feeding in environment A caused the animals to reach their maximum respiration rate earlier (12 noon) than the time noticed for berseem hay feeding (2 p.m.). In general, concentrate feeding resulted in causing the animals to reach their maximum respiration rate earlier and before the air temperature approached its highest values while in the hay feeding the two peaks occurred simultaneously (Table 4 and Fig. 2 and 3).

Weldy *et al.*, 1964, found that changes in total rumen VFA were consistently correlated to a significant value with rectal temperature. The concentration of VFA before feeding (at 8 a.m.) was found to be higher when, desert Sudenese sheep, were fed concentrates than in berseem hay feeding. The case was reversed 3 hr after feeding, where the concentration of VFA was higher in animals fed berseem hay (Kurdi, 1980). The results of the present work reveald that, the rectal temperature at 8 a.m.of sheep fed concentrates was higher than in animals fed berseem hay and vice versa, after feeding at 12 a.m.

It was also found, that the rectal temperature and respiration rate of sheep fed concentrates reached its highest values before air temperature approached its maximum values and thus the animals were less stressed than with hay feeding. These results indicate that it is a good management practice to feed concentrates, rather than roughages, during the hot hours of the day in order to reduce the animals load. A similar opinion was offered by a number of workers including Badr (1957), Rupel and Leighton (1957) and Scott and Moody (1960).

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التنظيم الحرارى فى الأغنام السودانية الصحراوية تحت الظروف البيئية المختلفة

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أجرى هذا البحث فى محطة التجارب الخاصة بقسم الانتاج الحيوانى بكلية الزراعة بشمبات جامعة الخرطوم بهدف دراسة تأثير نوع المسكن والغذاء على درجة حرارة الجسم ومعدل تنفس الأغنام السودانية الصحراوية .

وقد شملت الدراسة ١٨ ذكر من الأغنام السودانية الصحراوية عمرها ١ ـ ٥ر١ سنة . حيث قسمت الى ثلاثة مجاميع متساوية بكل منها ستة حيوانات ووضعت كل مجموعة فى ظروف بيئية مختلفة (حظيرة مغلقة أ ، حظيرة مفتوحة نصف مظللة ـ ب وحظيرة مفتوحة غير مظللة ـ جـ) .

وقد أجريت ثلاثة تجارب : اثنتان غذيت فيها الحيوانات على دريس البرسيم واحدة شتاء وأخرى صيفا أما الثالثة فقد غذيت فيها الحيوانات على عليقة مركزة صيفا .

وقد سجلت درجات الحرراة ومعدل التنفس ٩ مرات خلال ٢٤ ساعة (مرة كل شهر) .

وتتلخص أهم النتائج فيما يلى :

- كانت الأغنام المعرضة للتأثير المباشر لأشعة الشمس (حظيرة جـ) أكثر اجهادا حيث كانت درجة حرارة جسمها أعلى (٨ر١٠٣°ف) وكذلك معدل تنفسها (١٠٣ مرة/دقيقة) عن نظيراتها التى كانت مظللة والتى بلغت درجة حرارة جسمها ٦ر١٠٣° و ٤ر١٠٣°ف ومعدل تنفسها ٧٩ر٧٠ مرة/دقيقة فى الحظائر أ و ب على التوالى .
- أدى ايواء الحيوانات فى حظيرة مغلقة تماما (أ) الى تعرضها خلال المساء لاجهاد أكبر عن مثيلاتها فى (ب و جـ) عندما بدأت درجة حرارة الهواء الجوى فى الخارج تنخفض .
- كان الفرق بين أعلى درجة حرارة جسم الأغنام خلال الـ ٢٤ ساعة أكبر شتاء (٣ر١° ، ٣ر٢°ف) عنه صيفا (٨ر٠° ، ٣ر١°ف) .
- تسببت التغذية على عليقة مركزة الى تقليل الفرق بين النهاية العظمى والصغرى لدرجة حرارة جسم الأغنام .وكانت درجة حرارة جسم الحيوانات المغذاة على العليقة المركزة الساعة ٨ صباحا أعلى منها فى الحيوانات المغذاة على البرسيم . ووصلت حرارة جسمها أعلى قيمة لها قبل أن تصل درجة حرارة الهواء الجوى أقصاها .