THERMOREGULATORY RESPONSES OF SHEEP TO STARVATION AND HEAT STRESS CONDITIONS

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SUMMARY

The present study was carried out at Sakha Animal Production Experimental Station belonging to Animal Production Research Institute. The experiment was conducted under thermoneutral conditions (TNZ) in winter (THI < 74) and during moderate heat stress (MHS, THI 74 - <88) in summer season on 9 and 6 Ossimi rams, respectively. Body weight, thermoregulatory parameters and blood parameters were determined at the start of the experiment and after 48 and 96 hrs of starvation in each experiment. Ambient temperature (Ta), relative humidity (RH %) and Temperature-Humidity Index (THI) were measured simultaneously during the experiment.

Under TNZ, starvation had no significant effect on rectal temperature (RT), due to a significant and insignificant reduction in heat production (HP) and evaporative cooling (minute ventilation, MV), respectively. While under MHS, starvation reduced the effect of heat stress on RT by decreasing MV and respiration rate (RR), while, HP remained almost unchanged. Under TNZ, starvation caused an insignificant and significant decrease in plasma total cholesterol (Tcho.) and total lipids (Tl), respectively. Meanwhile under MHS, starvation had no significant effect on plasma Tcho. and Tl concentrations.

Before starvation, moderate heat stress caused a significant increase in RT; meanwhile, respiratory evaporation (MV) and heat production (HP) were lower than that in the TNZ. Moderate heat stress (MHS) did not affect significantly blood hematocrit (Ht) and plasma proteins (plasma total proteins (Tp), albumin (Alb) and globulin (Gl)) while it increased significantly plasma glucose concentration.

It could be concluded that starved sheep can tolerate moderate heat stress by decreasing evaporative cooling; meanwhile normal fed sheep depends on heat storage to tolerate moderate heat stress.

Keywords: Sheep, starvation, heat stress, thermoregulation, metabolic rate

INTRODUCTION

Ossimi sheep is an Egyptian native fat-tailed breed. Salem et al. (1982) reported that the Egyptian native fat-tailed sheep were shown to be more heat tolerant than the European breeds as fat-tailed sheep have lower rectal temperature and respiration rate than the European breeds under the same management and environmental conditions. Devendra (1982) stated that 43.3% of the total world populations of sheep are presented in tropical and subtropical regions. Sheep plays underestimated but
valuable role in the supply of dietary animal proteins and also socioeconomic status of several million small farmers, peasants and landless agricultural laborers.

Under Egyptian conditions, sheep, goats and camels are the main species for animal production in the desert areas. The usual watering and feeding in the desert conditions varies from one day to many days depending on the season, availability of water, feed and distance traveled between watering points. Under these conditions animals are faced with two physiological problems; namely, obtaining sufficient feed and water, and regulating their body temperature. The lack of feed and water would impose starvation and dehydration which affects productivity (body weight, fertility and milk production), thermoregulation (physiological reactions) and blood chemistry and metabolites (More et al., 1983).

In tropical and subtropical regions animal are subjected to heat stress due to high environmental temperature and relative humidity during hot season. Heat stress affects significantly the heat balance of homeothermic animals and the main thermoregulatory mechanisms are the reduction in heat production and increase in heat loss (Johnson et al., 2003). Khalifa et al. (1987), Khalifa et al. (2002), Srikandakumar et al. (2003) and Al-Haidary (2004) found that heat stress caused a significantly increase in rectal temperature and respiration rate of sheep and the effect was more pronounced in less adapted breeds (Srikandakumar et al. 2003). Mitlöchnera et al. (2001) stated that during heat stress the coping strategy of cattle is to decrease metabolic heat production by lowering feed intake, which adversely affects productivity. Many authors reported that heat production decreased under heat stress (Luiting et al., 1985 and Berman, 2003).

Bell et al. (1983) revealed that during heat stress, panting animals increase respiratory heat loss by increasing minute ventilation and when the heat stress is severe, the increase in minute ventilation includes an increase in alveolar ventilation and consequently, arterial CO2 tension (PaCO2) declines resulting in a respiratory alkalosis.

Regarding the effect of starvation on thermoregulation, Brockway et al. (1965) found that starvation for 3 to 4 days decreased total heat loss, sensible heat loss and respiratory and skin evaporation of Cheviot sheep. Also, it has been found that fasting or starvation decreased VO2, VCO2, RQ and heat production (Blaxter and Waiman, 1966, Bennet, 1972, Kelly et al., 1993 and Khalifa et al., 2003).

The objectives of the preset study were to determine the influence of feed deprivation under thermoneutral and moderate heat stress conditions on thermoregulation of native Egyptian sheep adapted to heat stress as well as to investigate the thermoregulatory mechanisms of normal and starved sheep to tolerate moderate heat stress under Egyptian conditions.

**MATERIALS AND METHODS**

The present study was carried out at Sakha Animal Production Experimental Station belonging to Animal Production Research Institute. Fifteen unshorn (wool length more than 5 cm) Ossimi Rams (9 in winter season and 6 in summer season) were selected randomly and used in these studies. They were 2.5 to 3.0 years of age. All animals were fed concentrate and hay ration according to their requirements (NRC, 1985). The feed concentrate mixture contained 12% crude protein and 50% starch value. It was consisted of 35% corticated cotton seed meal, 22% corn, 33%
wheat bran, 4% rice bran, 3% molasses, 2% lime stone and 1% salt. Fresh tap water was available ad lib. Animals were kept indoors in metabolic cages during the experimental period to determine nitrogen balance. Thermoregulatory and blood parameters were determined immediately before (0 time) and after 48 and 96 hrs of starvation.

Ambient temperature (Ta) and relative humidity (RH %) were recorded simultaneously while measuring the physiological responses. The Temperature-Humidity Index (THI) was calculated from Ta and RH according to Thom (1959) converted to °C as follows:

\[
\text{THI} = \frac{9}{5} \times ((T \times 17.778) - (0.55 - (0.55 \times RH/100))) \times (T - 14.444).
\]

Where:

- \( T \) = Dry bulb temperature in °C.
- \( RH \) = Relative humidity as %.

The experiment was carried out under thermoneutral conditions (THI< 72) in winter (according to Fuquay (1981) and Khalifa (2005) and during mild to moderate heat stress (THI 76 – 78.5) in summer season (moderate heat stress according to Fuquay (1981) and mild to moderate heat stress according to Khalifa (2005).

In both seasons, the physiological parameters were measured every 48 hrs. at midday of the highest Ta from 12.00 to 14.00. Rectal temperature (RT, °C) was determined using a clinical thermometer (0.1 °C accuracy inserted 5 cm in the rectal for 1 min.). Skin temperature (ST, °C) and ear temperature (ET, °C) were measured using the Minolta/Land Cyclops Compac 3, a portable infrared thermometer (0.95% error and 0.1 °C accuracy). Respiration rate (RR) was determined by counting the flank movements in one minute. Respiratory minute volume (MV as l/minute) was measured by Dry Gas Meter. Tidal volume (TV) was calculated by dividing MV/RR. Heat production (HP) (measured as fasting metabolic rate, kcal/BW^{0.75} per day) was calculated using the equation of Brouwer (1965). The measurement of oxygen consumption (VO\(_2\)) and carbon dioxide production (VCO\(_2\)) were made using the open-circuit technique according to Yousef and Dill (1969). Oxygen consumption was calculated from the oxygen deficit in expired air using oxygen analyzer (Servomex 570). The rate of carbon dioxide production was calculated from the CO\(_2\) deficit in expired air obtained from infrared Gas Analyzer (Model-AR-411). Calculation of % true VO\(_2\), VCO\(_2\) and volume VO\(_2\) consumption and O\(_2\) and CO\(_2\) production and Respiratory Quotient (RQ) were done using the equations of Consolazio et al. (1963) where RQ= volume of CO\(_2\) produced/volume of O\(_2\) consumed.

Blood samples were collected from the jugular vein in heparinized tubes. Hemoglobin concentration (Hb, g/l) was determined by colorimetric methods using hemoglobin kits (Drabkins reagent) and hematocrite value (Ht, %) using microhematocrite technique. Plasma total protein (TP, mg/dl) and plasma albumin (Alb, mg/dl) concentrations were determined using the kits of the Egyptian American Co. Plasma globulin (Gl, mg/dl) was calculated by subtraction. Glucose concentration (Glu, mg/dl), total cholesterol (Tcho, mg/dl), and total lipids (TL, g/dl) were measured by colorimetric method using Sentinel kits.

The statistical analysis of data was carried out using SAS program (SAS, 1990). Proc GLM of SAS (two way analysis of variance with one way repeated measurement) was used to test the effect of heat stress, starvation and their interaction. To test the effect of interaction, analysis of variance and least square
means (Proc. LS means of SAS) were used to test the effect of starvation within each temperature group and Student t test (Proc MEANS of SAS) was used to test the effect of temperature within each starvation interval.

RESULTS AND DISCUSSION

Meteorological data (Table, 1) reveal that mean ambient temperature (Ta) and relative humidity during the experimental period ranged between 23.7 to 26.2 °C and 36 to 40% in the first experiment (in winter) and 27.9 to 33.7 °C and 26 to 54% in the second experiment (in summer), respectively. The mean THI ranged between 68.4 to 71.9 and 76 to 78.5 in the first and second experiments, respectively. According to Fuquay (1981) and Khalifa (2005) sheep were under the thermoneutral zone range in winter and mild to moderate heat stress in summer.

Table 1. Ambient temperature (AT°c), relative humidity (RH %) and Temperature-Humidity Index (THI) during the experiment period

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Thermoneutral zone (TNZ)</th>
<th>Moderate heat stress (MHS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 time</td>
<td>48 hrs</td>
</tr>
<tr>
<td>AT</td>
<td>24.1</td>
<td>26.7</td>
</tr>
<tr>
<td>RH</td>
<td>40.0</td>
<td>38.0</td>
</tr>
<tr>
<td>THI</td>
<td>69.7</td>
<td>71.9</td>
</tr>
</tbody>
</table>

Fuquay (1981) stated that a THI of 72 and below is considered as no heat stress, 73-77 as mild heat stress, 78-89 as moderate and above 90 as severe, while Khalifa (2005), based on changes in body temperature, heat production and heat loss of sheep, reported that the comfort zone ranged between 20-25 °C (60-70 THI) while moderate heat stress ranged from 25 – 28 °C (70 – 85 THI) and severe heat stress occurred at Ta ≥ 28 (THI ≥85).

Effect of ambient temperature

At zero time (before starvation), moderate heat stress (MHS) caused a significant increase in RT; meanwhile, respiratory evaporation (MV) and heat production (HP) were lower than in the TNZ. The significantly lower respiratory evaporation under MHS than in TNZ was due to an insignificant decrease in RR and TV as an adaptive mechanism to compensate the reduction in HP under heat stress (Table 2). Similar trends were found after starvation for 48 hrs where RT was significantly higher under MHS than under TNZ, meanwhile, respiratory evaporation (RR, TV and MV) and gas exchange (VO2 and VCO2) were significantly and HP was insignificantly lower under MHS than under TNZ. However, after starvation for 96 hrs, MHS had no significant effect on RT and HP, while respiratory evaporative (RR and MV) was significantly lower under MHS than under TNZ.

Khalifa et al. (2002) and Al-Haidary (2004) reported that heat stress significantly increased RT, RR and ST of sheep, while, Ismail et al. (2002) found that RT did not differ significantly between summer and winter. Meanwhile, Butswat et al. (2000) stated that an increase in respiration rate appeared to be the immediate response of sheep to environmental stress. The effect of heat stress on RT and RR depends on the severity of heat stress as indicated by Lowe et al. (2002) who reported that RR and
RT were highly correlated with increasing THI. The insignificant changes in RR under MHS is in accordance with Srikandakumar et al. (2003) who concluded that the higher magnitude of increase in RT and lower magnitude of increase in RR in Omani sheep (local adapted breed) than in Merino ones (exogenous breed) during the period of heat stress suggests that this breed was less stressed than the Merino sheep with increasing heat stress. They suggested that this adapted breed of sheep can store body heat during the periods of heat stress, which can economize on the loss of water and the increased need of energy under these conditions.

Higher ST and lower ET under TNZ than under MHS (Table 2) may correspond to vasodilatation under heat stress (Turnpenny et al., 1997). Khalifa (1982) and Al-Haidary (2004) reported that heat stress significantly increased ST of sheep; however, Khalifa (1982) found that ET was also significantly higher in summer than in winter.

The insignificant decrease in HP under MHS is an adaptive mechanism to prevent respiratory alkalosis. Moderate heat stress had no significant effect on RQ although the significant reduction in both of VO$_2$ and VCO$_2$ due to the reduction in TV under MHS (Table 2) which confirm the previous conclusion that the reduction in TV under MHS is an adaptive mechanism to prevent respiratory alkalosis.

Heat stress had no significant effect on Ht value. However, Hb was significantly lower under MHS than in the TNZ but the difference was insignificant after starvation for 96 hrs due to a significant reduction in Hb during starvation under TNZ (Table 3). Srikandakumar et al. (2003) reported that heat stress decreased (P<0.01) Hb in the Merino sheep. Meanwhile, Al-Haidary (2004) reported that heat stress significantly increased Ht of Naimey sheep. Khalifa et al. (1987) indicated that the increase in Ht and Hb of sheep after exposure to solar radiation was due to the reduction in plasma volume. Accordingly, the decrease in Hb in the present results reveals that MHS did not affect plasma volume. The insignificant effect of heat stress on Hb after starvation for 96 hrs. is in accordance with Cole and Hutcheson (1985) who indicated that the degree of changes in Ht and Hb were more pronounced in ad libitum animals than in the feed-restricted animals.

Plasma TP, Alb and Gl concentrations did not differ significantly between TNZ and MHS except after starvation for 96 hrs when plasma TP and Alb were significantly lower under MHS than under TNZ due to a significant increase in TP and Alb after starvation for 96 hrs under TNZ. Macfarlane et al. (1959 and 1966) reported that plasma total protein of sheep changed little between summer and winter. However, Ismail et al. (2002) found that TP and Gl were higher in summer than in winter.
Table 3. Blood parameter of Ossimi sheep as affected by Thermoneutral zone (TNZ), Moderate heat stress (MHS) and starvation conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Thermoneutral zone (TNZ)</th>
<th>Moderate heat stress (MHS)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 time</td>
<td>48 hr</td>
<td>96 hr</td>
</tr>
<tr>
<td>Ht %</td>
<td>31.4</td>
<td>29.9</td>
<td>29.8</td>
</tr>
<tr>
<td>Hb (g/dl)</td>
<td>19.1 a</td>
<td>20.5 a</td>
<td>13.1 b</td>
</tr>
<tr>
<td>Glu. (g/dl)</td>
<td>17.0</td>
<td>14.3</td>
<td>25.8</td>
</tr>
<tr>
<td>Tp (g/dl)</td>
<td>6.71 a</td>
<td>7.87 a</td>
<td>10.47 b</td>
</tr>
<tr>
<td>Alb (g/dl)</td>
<td>3.06 b</td>
<td>4.03 b</td>
<td>4.11 b</td>
</tr>
<tr>
<td>Gl (g/dl)</td>
<td>3.65 b</td>
<td>3.84 b</td>
<td>6.36 a</td>
</tr>
<tr>
<td>Tcho. (mg/dl)</td>
<td>86.7</td>
<td>76.6</td>
<td>81.2</td>
</tr>
<tr>
<td>TL (g/dl)</td>
<td>4.64 a</td>
<td>3.25 a</td>
<td>3.37 a</td>
</tr>
</tbody>
</table>

a,b,c similar letters within each column and variable are not significant (p≤0.05).

p = Probability level for the effect of ambient temperature.
SE = Standard error of the LEAST square means.
NS = Insignificant p>0.05. *= Significant at p<0.05. ** = Significant at p<0.01.

Hb g/l = Hemoglobin concentration. Ht % = Hematocrite value.
TP mg/dl = Plasma total protein. Alb, mg/dl = Plasma albumin.
Gl mg/dl = Plasma globulin. Glu mg/dl = Glucose concentration.
Tcho mg/dl = Total cholesterol TL g/dl = Total lipids.

Plasma Glu concentration was significantly higher under MHS than under TNZ either before or after starvation for 96 hrs. Similar results were found by Samak et al. (1986) but contradict with those of Ismail et al. (2002) who reported that Glu was significantly lower in summer than in winter. Seasonal changes in Glu depend on changes in RR and HP (Shaffer et al., 1981). Opposite trends were found in plasma Tcho. and TL where they were significantly lower under MHS than under TNZ either before or after starvation (Table 3). Similar results were found by Ismail et al. (2002). The significant increase in plasma Glu concentration and decrease in plasma Tcho. and TL under MHS agree with Srikandakumar et al. (2003) who found that heat stress increased (P<0.01) plasma glucose in Merino (less adapted) but decreased (P<0.01) it in Omani (more adapted) sheep. Nazifi and Gheisari (1999) found that the concentrations of serum cholesterol, triglyceride, total lipid, HDL-cholesterol, LDL-cholesterol and VLDL-cholesterol of dromedary camels were significantly higher (p<0.05) in winter months than in summer months. Results showed that very hot and cold conditions had a considerable effect on serum lipids in dromedaries.

The present results indicate that sheep can tolerate MHS by decreasing HP and increasing heat storage (significant increase in RT) to compensate the significant reduction in evaporative cooling (due to a decrease in TV and RR) as an adaptive mechanisms to conserve water under natural MHS. Folk (1974) stated that body temperature is naturally maintained at a relatively constant level because of the balance which exists between heat production and heat loss. Starved sheep can tolerate moderate heat stress by decreasing evaporative cooling, while normal fed sheep depend on heat storage and decrease of HP to tolerate MHS.

Effect of starvation

Starvation for 96 hrs caused a significant reduction in body weight by about 4% from the initial body weight in both seasons.

Under TNZ, starvation had no significant effect on RT, but ST and ET decreased significantly which was accompanied with significant reduction in MV due mainly to
significant reduction in RR. The insignificant effect of starvation on RT was due to the significant reduction in both of evaporative cooling (MV) and HP (Table 2).

Under MHS, RT decreased significantly after starvation for 4 days which was accompanied with a significant reduction in evaporation due to significant reduction in RR, meanwhile starvation had no significant effect on TV and HP. On the other hand under TNZ, starvation affected significantly thermoregulation by decreasing HP and evaporative heat loss (Table 2).

The significant reduction in RT and RR after starvation for 4 days without significant effect on TV and HP indicate that starvation under MHS prevented the effect of HS on RT so that MV and RR decreased, while, HP remained almost unchanged. Piccione et al. (2002) stated that prolonged food deprivation is known to cause a fall in the core body temperature of homeotherms. Li et al. (2000) found that fasting decreased HP and RT (P<0.05) and Ahmed and Abdelatif (1994) stated that RT and RR were reduced by food restriction. Meanwhile, Khalifa et al. (1999a and b) found that starvation increased RT and decreased RR in both shorn and unshorn ewes under cold conditions. They explained that the significant reduction in RR of ewes in response to 2 days of starvation may be a thermoregulatory mechanism to decrease heat dissipation through panting. Finch and King (1982) attributed the reduction in RT during restriction of feed (50% of maintenance) for 3 months to the reduction in metabolic rate and that the lower metabolic demands indicate that energy reserves could be spared from rapid depletion as starvation advances.

Under TNZ, starvation caused a significant reduction in VO₂, VCO₂ and HP (Table 2). While under MHS, starvation had no significant effect, but RQ and HP tended to decrease after starvation. Under both temperatures RQ tended to decrease with starvation due to more resuction in VCO₂ than in VO₂ under TNZ and an insignificant reduction in VCO₂ with slight increase in VO₂ under MHS. The reduction in RQ during starvation under TNZ and MHS, although it was insignificant, is in accordance with Bennet (1972) and Brockway et al. (1965) who found that the RQ declined significantly in sheep as the duration of fasting increased. Kelly et al. (1993) added that O₂ consumption of ewes fed twice maintenance was higher than that of those fed maintenance ration or starved. Khalifa et al. (1999a and b) revealed that heat production, as indicated by VO₂ and VCO₂ changes, was significantly (P<0.05) decreased by starvation and duration of starvation in both shorn and unshorn ewes, reaching the lowest values at 4 days of starvation. This decrease in HP was due to the reduction in both metabolic heat production and specific dynamic action of food due to starvation. They also demonstrated that the reduction in RQ indicates that starvation caused more reduction in VCO₂ than in VO₂ due to catabolism of protein (RQ near 0.8) and fat (0.7) instead of mixed diet or carbohydrate (almost 1). As a result, after 2 days of food deprivation both shorn and unshorn ewes began to use the storage fat and body proteins as sources of energy.

Under both climatic conditions (TNZ and MHS) starvation had no significant effect on Ht value. Similar result was found in Hb under moderate heat stress, while under TNZ a significant reduction in Hb occurred after 96 hrs of starvation (Table 3). Ali et al. (1984) reported that feed restriction for 96 hr or 168 hr in male Nubian goats caused a decrease in Hb concentration, Ht and erythrocytes number. Panaretto (1964) added that undernourished decreased haematocrit value by decreasing red cell volume while plasma volume remained unchanged. Under cold conditions, Khalifa et al. (1999 a, b) detected a significant (P<0.05) decrease in the Hb concentration.
accompanied with a non significant decrease in the Ht value in the shorn and unshorn ewes at day 4 of starvation, which indicating anemia.

Starvation had no significant effect on plasma proteins (TP, Alb and Gl) except a significant increase in TP after starvation for 96 hrs under TNZ due to significant increase in Alb and Gl indicating that under TNZ starvation may cause a reduction in plasma volume. Similar results were found by Vihan and Rai (1984) who reported that TP values were significantly reduced in 5 days starved sheep and goats.

Under MHS starvation increased significantly plasma Glu as a source of energy to maintain HP at the pre-starvation level. While under TNZ, an insignificant increase in plasma glucose occurred after 96 hrs of starvation (Table, 3). Rule et al. (1985) found that plasma glucose concentration in steers increased from day 2 to day 5 of fasting where it remained at this level up to day 8 of fasting. The increase in plasma glucose level during starvation may be due to the increase in growth hormone during starvation which causes the increase in glucose by its effect on gluconeogenesis. Martin (1976) stated that growth hormone secretion increases when plasma glucose levels fall during limited periods of food deprivation. The hormone promotes glucose formation from hepatic glycogen and pyruvate; it also modifies glucogenic influences of glucocorticoids.

Under TNZ, starvation caused an insignificant and significant decrease in plasma Tcho. and Tl, respectively. Meanwhile, under MHS starvation had no significant effect on plasma Tcho. and Tl concentrations although plasma Tcho. Tended to decrease insignificantly during starvation (Table 3). The reduction in plasma Tcho. and Tl during starvation under TNZ disagrees with previous results of Khalifa et al (1986) who found that starvation increased significantly plasma free fatty acids and triglycerides of both shorn and unshorn ewes, while it had no significant effect on Tl. Also, Cole and Hutcheson (1985 &1988) found that serum cholesterol was not significantly affected by feed deprivation and that serum cholesterol levels were negatively related to the feed intake of the steers.

CONCLUSIONS

The main thermoregulatory mechanisms of starved sheep under MHS are the reduction in evaporative cooling, while in normal fed sheep heat storage is the main thermoregulatory mechanism to tolerate MHS.

Sheep can tolerate MHS by decreasing HP and increasing heat storage (significant increase in RT) to compensate the significant reduction in evaporative cooling (due to a decrease in TV and RR) as an adaptive mechanisms to conserve water under natural moderate heat stress.

Under TNZ starvation had no significant effect on RT, due to a significant and insignificant reduction in heat production and evaporative cooling (MV), respectively. While under MHS, starvation reduced the effect of heat stress on RT by decreasing MV and RR, while, HP remained almost unchanged.
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التنظيم الحراري في الأغاث المعرضة للتصويم والإجهاد الحراري

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أجريت هذه الدراسة في محطة بحوث الإنتاج الحيوي بالنيق، محافظة كفر الشيخ، معهد بحوث الإنتاج الحيوي، بهدف دراسة تأثير كل من التصميم والإجهاد الحراري على التنظيم الحراري في كيلان الأغاث الأموي المصري، تحت تأثير درجة حرارتين متوسطتين متزامنتين على عدد 15 كيلو و 600 كيلو متر من فصل الصيف هما: MHS و TNZ حيث تراوح درجة الحرارة بين 23.4 - 26.7 °C و 33.7 - 37.9 °C، وتراوح المعدل النظري للحرارة والرطوبة RH% و درجة الحرارة والرطوبة THI و درجة حرارة الجلد ST في درجة حرارة الاتصالات RQ و جهاز النفخ و جهاز التنفس RR و جهاز التنفس VCO2 و كمية الأوكسجين المستهلكة MV و مدة التربية و مدة الرعية و مدة التنفس و درجة الحرارة والرطوبة RH% و تأثير درجة الحرارة والرطوبة حرارة الاتصالات RQ و جهاز النفخ و جهاز التنفس VCO2 و كمية الأوكسجين المستهلكة MV و مدة الرعية و مدة التنفس RR و جهاز التنفس VCO2 و درجة الحرارة والرطوبة RH% و درجة الحرارة والرطوبة THI و درجة حرارة الجلد ST و درجة حرارة الاتصالات RQ و جهاز النفخ و جهاز التنفس VCO2 و كمية الأوكسجين المستهلكة MV

الميكانيكا الرئيسية للتنظيم الحراري للأغاث المعرضة للتصويم تحت الإجهاد الحراري هي خفض التبرد عن طريق التبخير في حين أن هذه الميكانيكا في الأغاث الماء فهي تنظيم الحرارة.

1- الأغاث الماء تحت الإجهاد الحراري تقوم بخفض إنتاج الحرارة و زيادة توزيع الحرارة موجهة إلى الجهاز المنزلي النظيف المستخدم في التبريد عن طريق تغذية التربة في الحالة في المنازل و ذلك للمحافظة على ميزان ماء الجسم.

2- التصميم يساهم في خفض إنتاج الحرارة عن طريق تغذية النفخ مستدام و ذلك في التوجيه مع خفض معدل التنفس و كذلك في اختراق الأنسجة المستهلكة في النفط دون تغيير الإنتاج الحراري.

3- التصميم بخفض من تأثير الإجهاد الحراري على الأغاث عن طريق خفض معدل التنفس و كذلك في اختراق الأنسجة المستهلكة في النفط دون تغيير الإنتاج الحراري.

4- التطبيق السريع في النفط دون تغيير الإنتاج الحراري.

5- تأثير الإجهاد الحراري على الأغاث عن طريق تغذية التربة في الحالة في المنازل و ذلك في التوجيه مع خفض معدل التنفس و كذلك في اختراق الأنسجة المستهلكة في النفط دون تغيير الإنتاج الحراري.

6- التطبيق السريع في النفط دون تغيير الإنتاج الحراري.

7- تأثير الإجهاد الحراري على الأغاث عن طريق تغذية التربة في الحالة في المنازل و ذلك في التوجيه مع خفض معدل التنفس و كذلك في اختراق الأنسجة المستهلكة في النفط دون تغيير الإنتاج الحراري.

8- التطبيق السريع في النفط دون تغيير الإنتاج الحراري.

9- تأثير الإجهاد الحراري على الأغاث عن طريق تغذية التربة في الحالة في المنازل و ذلك في التوجيه مع خفض معدل التنفس و كذلك في اختراق الأنسجة المستهلكة في النفط دون تغيير الإنتاج الحراري.

10- التطبيق السريع في النفط دون تغيير الإنتاج الحراري.

11- تأثير الإجهاد الحراري على الأغاث عن طريق تغذية التربة في الحالة في المنازل و ذلك في التوجي
Table 2. Thermoregulatory responses of Ossimi sheep under Thermoneutral zone (TNZ), Moderate heat stress (MHS) and starvation conditions

<table>
<thead>
<tr>
<th>parameter</th>
<th>Thermoneutral zone (TNZ)</th>
<th>Moderate heat stress (MHS)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 time</td>
<td>48 hrs</td>
<td>96 hrs</td>
</tr>
<tr>
<td>RT °C</td>
<td>39.1</td>
<td>39.3</td>
<td>39.3</td>
</tr>
<tr>
<td>ST °C</td>
<td>38.0 a</td>
<td>37.7 a</td>
<td>36.3 b</td>
</tr>
<tr>
<td>ET °C</td>
<td>36.3 a</td>
<td>33.4 b</td>
<td>32.7 a</td>
</tr>
<tr>
<td>RR (r/min.)</td>
<td>45.1</td>
<td>34.7</td>
<td>39.6</td>
</tr>
<tr>
<td>TV (ml/breath)</td>
<td>120 ab</td>
<td>157 a</td>
<td>104 b</td>
</tr>
<tr>
<td>MV (l/min.)</td>
<td>4.529</td>
<td>4.575</td>
<td>3.461</td>
</tr>
<tr>
<td>VO₂/L/d.BW⁰.⁷⁵</td>
<td>5.037 a</td>
<td>5.327 a</td>
<td>3.271 b</td>
</tr>
<tr>
<td>VCO₂/L/d.BW⁰.⁷⁵</td>
<td>4.629 a</td>
<td>4.477 a</td>
<td>2.841 b</td>
</tr>
<tr>
<td>RQratio</td>
<td>0.92</td>
<td>0.84</td>
<td>0.89</td>
</tr>
<tr>
<td>HP /day.BW⁰.⁷⁵</td>
<td>24.2 a</td>
<td>25.4 a</td>
<td>16.6 b</td>
</tr>
</tbody>
</table>

a,b,c similar letters within each column and variable are not significant (p≤0.05)

p  = Probability level for the effect of ambient temperature
SE  = Standard error of the LEAST square means.
NS  = Insignificant p>0.05.  * = Significant at p≤0.05.  ** = Significant at p≤0.01.
RT °C = Rectal temperature.  ST °C = Skin temperature.  ET °C = ear temperature.
RR r/min. = Respiration rate.  MV l/minute = Respiratory minute volume.
TV (ml/breath) = Tidal volume.  HP /day.BW⁰.⁷⁵ = Heat production.
VO₂/L/d.BW⁰.⁷⁵ = Oxygen consumption.  VCO₂/L/d.BW⁰.⁷⁵ = carbon dioxide production.
RQratio = Respiratory Quotient.