

REVIEW [REVISIÓN]

REPRODUCTIVE PERFORMANCE TRAITS AS AFFECTED BY HEAT  
STRESS AND ITS ALLEVIATION IN SHEEP

[EFECTO DEL ESTRES CALÓRICO SOBRE EL COMPORTAMIENTO  
REPRODUCTIVO DE OVINOS Y MÉTODOS PARA REDUCIR SUS  
EFECTOS]

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SUMMARY

Exposure of sheep to heat stress evokes a series of drastic changes in the biological functions which include decrease in feed intake efficiency and utilization, live body weight and impaired reproduction. The effect of heat stress is aggravated with high ambient humidity. Alleviation of heat stressed animals by physical, physiological and/or nutritional techniques, in addition to carrying out proper routine management practices at the suitable times, can help the heat stressed animals to express their genetic potentials in tropical and subtropical areas.

**Key words:** alleviation of heat stress, biochemical changes, heat stress, management practices, reproduction, sheep.

INTRODUCTION

Sheep production, as most agricultural enterprises, is affected by economic forces as well as environmental factors (Marai, 1987). Among the climatic components that may impose stress on the productive and reproductive performance traits of sheep are ambient temperature, humidity, air movement, photoperiod, solar radiation, wind, etc, of which the ambient temperature is the most important. However, the effect of ambient temperature is aggravated in the presence of high relative humidity.

Exposure to elevated ambient temperature evokes a series of drastic changes in the sheep biological functions that include depression in feed intake efficiency and utilization, disturbances in metabolism of water, protein, energy, and mineral balances, enzymatic reactions, hormonal secretions and blood

RESUMEN

La exposición de los ovinos al estrés calórico provoca una serie de cambios drásticos en sus funciones biológicas que incluyen una reducción en el consumo y eficiencia de utilización de los alimentos, pérdida de peso vivo y fallo reproductivo. El efecto del estrés calórico es agravado por la humedad ambiental excesiva. La reducción de los efectos del estrés calórico por medios físicos, fisiológicos y/o nutricionales, en conjunto con técnicas de manejo adecuadas en los momentos críticos pueden ayudar al animal estresado a expresar su potencial genético en las áreas tropicales y subtropicales.

**Palabras clave:** mitigación del estrés calórico, cambios bioquímicos, reproducción, ovejas.

metabolites. Such changes end with low live body weight and impaired reproduction, i.e. depression in age at puberty, reproductive activity and fertility (Habeeb *et al.*, 1992). Improper management such as exposure to water deprivation, nutritional imbalance and nutritional deficiency may exacerbate the impact of heat stress. However, sheep showed lower sensitivity to heat stress in comparison to cattle at maintenance feed level (Silanikove, 2000).

In the present article, ram and ewe reproductive, physiological and biochemical traits affected by heat stress, are discussed. Other animals are included whenever needed. The possible mechanisms that take place for inducing the biological changes in heat-stressed animals, are illustrated. The management practices suitable to hot climate conditions, will be discussed.

## RAM'S REPRODUCTIVE TRAITS AS AFFECTED BY HEAT STRESS

### Puberty

Puberty, the beginning of the sexual function of ram lambs is associated with a marked increase in testosterone secretion, spermatogenesis and mating behaviour (Hafez, 1987). When ram lambs reach 2.0 to 2.5 months of age at a body weight of 16 to 20 kg, the testes size increase. This coincides with the appearance of primary spermatocytes and enlargement of seminiferous tubules. At about 4 to 6 months of age with a live weight of 40 to 60 % of the mature weight, sheep copulate with ejaculation of viable spermatozoa (Hafez, 1987).

Age at puberty depends on body weight gain, which is delayed under hot conditions. In tropical conditions, the pubertal means of age and body weight are about 9.5 months (288.0±6.0 days) and 19.3 kg, respectively. However, the lambs born in the heavy rainy season (July and August) reach puberty at younger age than those born during the period of short rains or the dry season (the other months of the year). Nutrition and management affect remarkably lambs' testicular growth and puberty onset in lambs in Ethiopia, as both are related to weight gain (Mukasa-Mugerwa and Ezaz, 1992).

Sexual maturity is reached at 3 months of age in Finland ram lambs. Both Finn and Romanov ram lambs are capable to impregnate females at 5 months of age (Louda *et al.* 1981). In Scotland, ram lambs can be used in mating effectively at 7 months of age (Donald and Read, 1967).

### Libido

Rams *libido* seemed to be affected by season of the year (i.e. by ambient temperature). The highest *libido* (i.e. shortest reaction time) was recorded during winter and the longest during summer, in Ossimi, Rahmani and Ossimi x Suffolk rams (Mohamed, 1978; El-Darawany, 1999b; Abdel-Hafez, 2002), while in Awassi rams, the quickest reaction time (highest libido) was recorded in autumn and spring (15 sec) and the longest (low libido) during summer (31 sec) and winter (27 sec). Finn x Texel rams recorded significantly shorter reaction time in autumn (17 sec) than in winter and spring (27 sec), however, Finn rams showed little fluctuations in reaction time (Abi-Saab and Hamadah, 1984).

### Semen characteristics

Elevated body temperature during periods of high ambient temperature leads to testicular degeneration

and reduction in percentage of normal and fertile spermatozoa in the ejaculate (Marai *et al.*, 2002). The seminal characteristics of rams as affected by season are presented in Table 1.

*Ejaculate volume:* Ram semen ejaculate volume as determined by various workers showed a clear seasonal variation. The lowest ejaculate volume was reviewed to be in summer and winter by Hafez *et al.* (1955) and in summer by El-Darawany (1999b) in Ossimi, summer by Hafez *et al.* (1955) in Rahmani and spring and summer by Daader *et al.* (1985) and autumn and winter by Abdel-Hafez (2002) in crossbred rams (Table 1). El-Gamal (1975) reported the ejaculate volume to be low during summer and winter and high in autumn and Gunzel *et al.* (1982) confirmed that ejaculate volume tended to diminish with the increase of daylight, reaching a minimal in June (summer). Abi-Saab and Hamadah (1984) recorded ejaculate volume values as 0.65 ml during winter and early summer and 1.30 ml in autumn. Some other studies showed semen to be higher in volume in spring than in autumn season in Rahmani rams (Aboul-Naga *et al.*, 1980), or not influenced with seasonal variation (in Ossimi and Ossimi x Suffolk rams) (El-Darawany, 1999b; Abdel-Hafez, 2002).

*Semen pH:* The semen pH was significantly higher in summer and autumn compared to the winter season in Ossimi x Suffolk rams (Abdel-Hafez, 2002). Zeidan (1989) showed that semen pH to be highly correlated with environmental temperature ( $r = 0.73$  to  $0.83$  in bulls). However, other studies showed no such relationship (Osman, 1988).

*Spermatic concentration:* Sperm cell concentration showed different trends during the seasons of the year (Table 1). El-Darawany (1999b) reported that the sperm cell concentration was significantly lower under heat stress than in thermoneutral conditions. The highest sperm-cell concentration was recorded in autumn in Rahmani and Ossimi rams by Aboul-Naga *et al.* (1980), in autumn and winter in Ossimi x Suffolk rams by Abdel-Hafez (2002), late summer and autumn season in Awassi rams by Abi-Saab and Hamadah (1984) and in winter and spring in Indian Bikneri rams by Khariche (1981). With regard to the effect of month of the year, it was reported that the highest sperm-cell concentration values were observed in March, then February and April (spring) and the lowest during July-August (summer), in Rahmani x Finn sheep (Daader *et al.*, 1985).

*Spermatic motility:* A high percentage of live and progressively motile sperm is essential for accepted semen quality and high conception rates (Smyth and Gordon, 1967). Table 1 shows that sperm motility differs according to season of the year. In Ossimi, Rahmani and Ossimi x Suffolk rams, sperm motility

increased significantly in winter than in summer of Egypt (Aboul-Naga *et al.*, 1980). In Rahmani x Finn crossbreed rams, the highest live sperm percentage was recorded during spring (March to May) and autumn (September to November), in the same country (Daader *et al.*, 1985). In Galawy, Suffolk, Wicklow, Cheviot, and Dorset Horn temperate breeds, the highest live sperm percentage was observed during winter and autumn, in Ireland (Smyth and Gordon, 1967). In Bikaneri rams, the highest values were obtained in spring followed by winter, summer and autumn, respectively, in India (Kharche, 1981). Such studies indicate that live sperm percentages decrease with the increase in ambient temperature (El-Darawany, 1999b).

*Sperm abnormalities:* Sperm abnormalities are the morphological deviations from the normal sperm structure. Such abnormalities include abnormalities in head, mid-piece, tail, proximal cytoplasmic droplets (El-Darawany, 1999b) or detached acrosomes (Gunzel *et al.*, 1982), which increase in heat stressed ram semen (El-Darawany, 1999b; Table 1). The incidence

of abnormal sperm was found to be higher in summer (64.42 %; June and July) compared to winter (15.53 %; December and January) in Mutton Merino rams in a temperate environment (Naves *et al.*, 1980). The sperm abnormality percentages were 17.0, 16.5, 18.4 and 17.9 during summer, autumn, winter and spring, respectively, in Slovakian rams (Gamcik *et al.*, 1979) and 25.17, 18.42, and 14.47 during summer, winter and autumn, respectively, in Ossimi x Suffolk rams in Egypt (Abdel-Hafez, 2002), indicating that the lowest incidence of abnormal sperms was in autumn.

The highest semen quality was detected during the two periods of changing daylight, i.e. during the autumn and spring equinoxes (Abi-Saab and Hamadah, 1984). However, the seasonal differences in semen quality seemed to be attributed to both meteorological and nutritional factors (Aboul-Ela and Chemineau, 1988), as well as the sperm output and semen characteristics are adversely affected following exposure to long daylights (Ortavant *et al.*, 1985).

Table 1. Rams semen characteristics in the different seasons of the year.

Breeds	Seasons	Vol. (cc)	Motility (%)	Sperm-cell concentration (x10 <sup>9</sup> /ml)	Live sperm (%)	Abnormal sperm (%)	References
<b>Egyptian breeds</b>							
Ossimi	Summer	1.20	55.30	0.03±0.01	73.40	19.30	El- Darawany (1999b) Hafez <i>et al.</i> (1955)
	Winter	1.30	75.30	1.62±0.01	96.20	11.90	
	Spring	1.06	73.00	3.94 (10 <sup>6</sup> ul)	70.84	9.23	
	Summer	0.92	67.00	3.23 (10 <sup>6</sup> ul)	55.85	21.52	
	Autumn	0.95	73.00	3.16 (10 <sup>6</sup> ul)	64.67	12.17	
	Winter	0.87	56.00	2.81 (10 <sup>6</sup> ul)	55.07	12.41	
Rahmani	Spring	1.13	62.00	3.37 (10 <sup>6</sup> ul)	64.67	9.78	
	Summer	1.10	60.00	3.61 (10 <sup>6</sup> ul)	51.85	23.92	
	Autumn	1.29	67.00	3.38 (10 <sup>6</sup> ul)	59.92	13.18	
	Winter	1.17	54.00	2.96 (10 <sup>6</sup> ul)	54.74	17.39	
<b>Crossbreeds</b>							
¾ Rahmani x ¼ Finn	Summer	1.17	33.00	2.35±3.50	77.4	77.4	Daader <i>et al</i> (1985)
	Autumn	1.28	85.0	2.59±3.59	83.36	12.7	
	Winter	1.27	85.2	3.30±4.41	77.97	16.2	
	Spring	1.13	88.2	3.39±0.33	83.57	11.93	
1/16 Ossimi x 15/16 Suffolk	Summer	0.95	67.92	0.83±0.11	84.83	19.54	Abdel Hafez (2002)
	Winter	0.93	72.29	1.26±0.11	81.58	14.04	
	Autumn	0.93	73.50	1.24±1.13	87.27	12.73	

Vol. = Volume.

Environmental temperature influences reproductive function in the male by alteration in spermatogenesis and reduction in semen quality and male fertility (Curtis, 1983; Casu *et al.*, 1991). However, the studies on West African Dwarf rams indicated that the high environmental temperature had no adverse effect on semen characteristics (Madrid *et al.*, 1995).

In short, when mating occurs during the hot months of the year, depression in fertility occurs in rams. Particularly, rams puberty weight and age, fertility, libido and semen characteristics are deleteriously affected by exposure to elevated ambient temperatures. The greatest effect of heat stress is experienced at the 1<sup>st</sup> stage of spermatogenesis. Meanwhile, the highest semen quality was detected during the year two periods of changing daylight, i.e. during autumn and spring equinoxes. Such results may suggest the latter periods to be the most suitable periods at which collection of semen for A.I. is carried out.

#### **Scrotal measurements as indicators of spermatogenic functions following heat stress**

Scrotal circumference and testicular consistency, tone, size and weight, are excellent indicators of sperm production capacity and spermatogenic functions. Scrotal volume decreased significantly and testicular consistency and sperm quality degenerated in crossbred Moxoto-Brawn and Alpine goats with insulated scrotum with a double-walled plastic page, when exposed to heat stress (Santos *et al.*, 1998). Lowest scrotal circumference values were recorded during summer and the highest in autumn in rams (Mikelsen *et al.*, 1981). However, Hafez *et al.* (1955) reported that testes size of farm animals not to undergo marked seasonal changes. A reduction in testicular measurements (testes weight and size) by exposure to heat stress is due to the degeneration of the germinal epithelium and partial atrophy in seminiferous tubules (Chou *et al.*, 1974).

The tunica dartos muscle length which is the distance between the upper end of testes and abdominal wall, gives an indication of the magnitude of vascular heat exchange (Curtis, 1983). Muscle relaxation, i.e. dropping of the testicles away from the body area (Taylor and Bogart, 1988; El-Darwany, 1999a; Maloney and Mitchell, 1999) or separation of the testes (scrotum) and the body is necessary for cooling of the testes (3-4°C below body temperature) and facilitates spermatogenesis to proceed normally (Shelton, 2000). When scrotal (testicular) temperatures exceed the suitable values, the possibility exists at interference with sperm production. In addition, any conditions that cause high temperature in the animal such as long fleece, over condition (too fat) and lack of adaptation, are likely to have adverse effects on spermatogenesis. The amount of

wool on the scrotum interferes, particularly, with local cooling. Thus, shearing the scrotum or breeding sheep without wool on the scrotum, at least to the level of the epididymis, facilitates cooling and maintenance of sperm quality. However, animals will not be sterile at high temperatures, but a high percentage of rams could be sterile during the summer under conditions of high humidity, where local cooling is ineffective (Shelton, 2000).

Scrotal temperature of rams is regulated independently of body temperature and is performed as a result of a feedback circuit involving scrotal thermo-receptors and effectors which are related to the tunica dartos muscle and scrotum sweat gland activities. Meanwhile, this local circuit is not affected by adjustments to the general thermoregulatory control system during fever. The effect or mechanisms are found to be insufficient to maintain scrotal temperature when exposed to extreme heat or cold temperatures (Maloney and Mitchell, 1999). El-Darwany (1999a) found that the tunica dartos muscle length was the shortest when testes of rams and bulls were immersed in water at 17 and 18°C, while the maximum values were recorded at 35 and 34°C, respectively. Similarly, Abdel-Hafez (2002) found that during the seasons, the ram's tunica dartos muscle length was greater in summer and autumn than in winter.

In conclusion, testicular measurements and function are adversely affected by elevated temperature. When scrotal (testicular) temperatures exceed the suitable values, the possibility exists at interference with sperm production. In addition, any conditions that cause high temperature in the animal such as long fleece, over condition (too fat) and lack of adaptation, are likely to have adverse effects on spermatogenesis. The amount of wool on the scrotum interfere, particularly, with local cooling of the testes. Shearing the scrotum or breeding sheep without wool on the scrotum, at least to the level of the epididymis, facilitates cooling and maintenance of sperm quality.

#### **Fertility**

A satisfactory level of rams fertility, may be retained throughout the whole year, but in many instances, fertility is depressed when mating occurs during the hot months of the year (Hafez, 1987). The greatest effect is expressed during the 1<sup>st</sup> stage of spermatogenesis (Casu *et al.*, 1991). Shelton (2000) reported that under extreme conditions, the interference with sperm production can be acute, resulting in destruction of the sperm in the epididymitis and destruction of the germinal epithelium (site of sperm production). The increase of ambient temperatures up to 30°C (which is the upper temperature, for spermatogenesis) that often occurs

during summer in hot climate areas, is known to adversely affect *libido* and semen quality (Ortavant *et al.*, 1985). Pinto *et al.* (2001) reported that heat stress caused temporary interruption of sperm production and sperm motility and secondary defects seemed to be the most sensitive criteria in the Santa Ines hairy rams, in the State of Ceara, Northeast of Brazil.

A high percentage of rams could be sterile during the summer time, especially under conditions of high humidity. Exposure of the ram scrotum to approximately 40°C for 1.30 to 2.00 h caused a sharp increase in the proportion of morphologically abnormal spermatozoa 14 to 16 days later (Bradon and Mattner, 1970). Damage to spermatozoa (e.g. tail abnormalities and dead spermatozoa) (Williamson, 1974) and abnormalities (pyriform cells, midpiece abnormality and acrosomal abnormality) increased and fertility decreased (Curtis, 1983) with similar exposure although epididymal spermatozoa were unaffected (Williamson, 1974). Conception failure in ewes mated to heat-stressed ram was related to a failure to fertilize than to embryonic mortality (Curtis, 1983; Hafez, 1987). Shelton (2000) claimed that 6 weeks are required for the ram recovery after environmental conditions return to normal.

Fertility of the rams is related to several phenomena: the ability to mate, sexual desire, sperm production and viability and fertilizing capacity of ejaculated sperm (Hafez, 1987), which are influenced by elevated ambient temperatures, as well as nutritional level.

## **EWES REPRODUCTIVE TRAITS AS AFFECTED BY HEAT STRESS**

### **Age at puberty**

Puberty in ewes, i.e. age at first oestrus, is influenced by genetic and environmental factors. These factors include breed, nutritional plane, time of birth and environmental conditions (Hafez, 1987). First oestrus normally occurs in ewe lambs at 50 to 70 % of their adult live weight, which is generally 30 to 50 kg. The higher the post-weaning average daily gain (ADG), the earlier ewes will reach puberty and first parturition (Johnson, 1987). Fine wool or Merino sheep generally fail to reach puberty during the first sexual season and consequently, may be 18 to 20 months of age at first oestrus (Hafez, 1987). Early maturing breeds such as the Finnish Landrace sheep may reach puberty at 3 or 4 months of age (Maijala, 1996), while tropical and sub-tropical ewe lambs tend to reach puberty at approximately 60 to 65 % of the adult weight, i.e. at 7.1-13.1 months of age (20-22 kg). Lambs born in January-March (winter) reach puberty earlier and at lighter weight (10 months and 21 kg) than those born in June-July (summer; 11.3 months and 25 kg)

(Johnson, 1987). Such changes are mostly due to the quality of the available nutrients (forage) than due to the climate, in the different seasons, since there are a lot of farms in the tropics with good reproductive level.

### **The effect of heat stress on the breeding season**

In tropical and sub-tropical areas, the variation in daylight length is less, and indigenous ewes tend to breed throughout the year. The sexual activity may be restricted to a certain extent during summer months due to adverse effects of the high environmental temperature and lack of feed (Jainuden and Hafez, 1987).

A decrease has been observed in oestrous activity during spring in Awassi sheep in Israel (Amir and Volcani, 1965), Barbarine ewes in Tunisia (Khaldi, 1984), Egyptian local sheep (Ossimi, Rahmani, Barki and Ossimi x Suffolk) ewes (Aboul-Naga *et al.*, 1987b; Rakha *et al.*, 1988; Abdel-Hafez, 2002), Chios sheep in Greece (Avdi *et al.*, 1988) and D'man and Sardi ewes in Morocco (Lahlou-Kassi and Boukhliq, 1988). Amir *et al.* (1980) found seasonal sexual activity to extend from June to January in German Mutton Merino ewes and Amir *et al.* (1980) and Aboul-Naga *et al.* (1985) reported that it extends from August to March in Finn x German Mutton Merino in Israel and Suffolk ewes in Egypt. Curtis (1983) suggested that heat stress does not affect the occurrence of the oestrous cycle in ewes, but reduces the number of multiple ovulations.

Seasonal reproductive activity of ewes may be strongly affected by social relationships. The presence of lambs and sudden re-introduction of males (ram effect) may change oestrous and ovarian activities. Suckling causes a delay in the onset of first postpartum oestrus. Sudden re-introduction of ram after a period of complete separation induces a synchronous onset of first ovulation within a few days (Chemineau, 1987).

Seasonality is much more pronounced in ewe lambs than in adult ewes in both oestrus and ovarian activities. This may indicate the ability of older ewes to tolerate prevailing conditions (Khaldi, 1984). Table 2 shows that the onset of the breeding season in sheep begins at different times of the year in the hot climate regions, but with either decreasing and / or increasing daylight length.

Generally, it could be stated that indigenous sheep in the tropical and sub-tropical areas tend to breed throughout the year. The sexual activity may be restricted to a certain extent during summer months due to adverse effects of the high environmental temperature and lack of feed. Social relationships such as process of suckling lambs causes a delay in the

onset of first postpartum oestrus and sudden re-introduction of ram after a period of complete separation, induces synchronous onset of first ovulation within a few days.

### Cervical mucus and heat stress

Alterations in cervical mucus physiochemical properties can be used as the basis for some methods of detecting oestrus and ovulation when the ewes fail to show oestrus under heat stress conditions. In this respect, it may be useful to mention some details that may be favourable in sheep production. Cervical mucus accumulated in the vagina consists of mucin macromolecules of epithelial origin, which are

composed of glycoproteins and contain several enzymes, including glucuronidase, amylase, phosphorylase, estrase and phosphates, in addition to oviduct follicular and peritoneal fluids, and has unique biophysical characteristics, i.e. has several rheologic properties such as ferning, electric resistance, pH and viscosity (spinnbarkiet) (Hafez, 1987). These cervical mucus physiochemical properties alter during the oestrous period, under the influence of estrogen and such alterations are used as the basis for some methods of detecting oestrus, ovulation and consequent pregnancy in cattle, buffaloes and rabbits (Britt, 1977; Hafez, 1987; El-Darawany, 1994; El-Darawany and Farghaly, 1999).

Table 2. Ewe reproductive traits as affected by the breeding season.

Breeds	Time of mating	Conception rate (%)	Lambs born/ewe mated (%)	Lambs born/ewe lambed (%)	Lambs weaned / ewe mated (%)	Lambs weaned/ ewe lambed (%)	References
Marino	Spring		72.0	111.5	62.8	97.3	Aboul-Naga and Aboul- Ela (1985)
	Winter		79.5	116.5	92.3	92.3	
	Autumn		89.6	131.5	83.0	21.7	
Egyptian breeds							
Ossimi:	Winter			133.3			Ashmawi <i>et al.</i> (1984)
	summer			135.0			
	Winter	69.81					El-Fouly <i>et al.</i> (1984)
	Summer	81.63					
	Spring	61.6	67.7	109.7	54.0	87.5	Aboul-Naga and Aboul- Ela (1985)
	Winter	61.6	70.0	113.5	57.7	93.7	
	Autumn	74.1	83.5	112.6	74.6	100.6	
Rahamani	Spring	74.1		105.0			Gabr <i>et al.</i> (1989)
	Winter	84.1		114.0			
	Autumn	91.7		121.0			El-Darawany (1999b).
	Winter	80.0					
	Summer	40.0					
Crossbreds ¾Ossimi x1/4Merino	Spring	85.0		112.0			Gaber <i>et al.</i> (1989)
	Winter	83.8		119.0			
	Autumn	84.9		136.0			
Ossimi x Suffolk	Spring	75.0	90.9	121.1	81.2	108.3	Aboul-Naga and Aboul-Ela (1985)
	Winter	64.9	78.1	120.4	72.8	112.2	
	Autumn	72.2	91.7	126.9	87.9	121.2	
	Spring	44.8	48.1	101.3	39.4	87.8	Abdel-Hafez (2002)
	Winter	76.0	82.8	109.0	70.4	115.5	
	Autumn	84.8	107.9	127.2	98.0	92.7	
	Summer	33.33		100.0			
	Winter	88.89		100.0			
	Autumn	77.78		114.3			

The methods of detecting oestrus, ovulation and consequent pregnancy can be summarized as follows: When cervical mucus is spread on clean glass slide and allowed to air dry, a fern-like crystallisation (ferning arborization or ferning pattern) takes place. This fern like appearance is at a maximal during oestrogen dominance (Hafez, 1987). The ferning pattern is classified into 4 classes according to the thickness and arrangement of the fern branches as fine, intermediate and clump and no fern, respectively. The apparent width of the branches increases from fine, intermediate and clump ferning, respectively (Noonan *et al.*, 1975). Such classes were found to be correlated in descending order with the incidence of conception, respectively. In this respect, many studies confirmed that in absence of the fern pattern, conception not to occur except occasionally in some repeat breeders (Doe and Roy, 1971) and the low classes of ferning were significantly higher in silent females than in those with overt oestrus (Hafez, 1987).

Regarding the effect of season, no significant differences were found in ferning arborization during oestrus between summer and winter in Ossimi x Suffolk ewes (Abdel-Hafez, 2002; Marai *et al.*, 2004) and in Nubian x Egyptian local doe goats (El-Darawany *et al.*, 2005), under Egyptian conditions. These results were similar to those of El-Darawany and Farghaly (1999) in buffaloes. The above results suggest alteration in ferning may be considered as a basis of detecting oestrus and consequently detection of mating time (El-Darawany, 1989; El-Darawany and Farghaly, 1999; El-Darawany *et al.*, 2005).

Electric resistance (ER) of vaginal or cervical mucus has been used to detect oestrus. However, the reliability is not great enough to make such a measurement feasible. Generally, cattle conception rate values were lower in cows with high ER of the anterior vagina (Leidl and Stolla, 1976). The conception rate was estimated as 89 % when ohm reading was between 20 and 25, 78 % at 26 to 30 and 50 % at 31 to 35, in cattle (El-Darawany *et al.*, 2000). ER was found to be correlated positively with number of matings per conception, re-mating interval and gestation period and negatively with ferning pattern degrees in cervical mucus, litter size and litter weight in doe rabbits (El-Darawany and El-Syiad, 1994). Regarding the effect of season, Abdel-Hafez (2002) and Marai *et al.* (2004) found cervical mucus ER (Ohm) to be significantly higher in summer and autumn than in winter in Ossimi x Suffolk ewes. This is probably due to the significant decrease in viscosity (Abdel-Hafez, 2002; Marai *et al.*, 2004) as a result to the increase in water content in summer. However, El-Tarabany (2003) and El-Darawany *et al.* (2005) reported insignificant effect of season on the same trait, in Nubian x Egyptian indigenous doe goats.

Slightly acidic mucus (Schilling and Zust 1968) or the increase in pH during oestrus and ovulation (Hafez, 1987) is of the optimal properties for conception. Hafez (1987) reported that such changes are reversed during the luteal phase when sperm penetration in the cervix is inhibited. The pH in cervical secretion is relatively constant and ranges between 6.5 to 7.5 with average of 7.0 and decreases during oestrus, in cattle (Hafez, 1987). The changes in pH value that occur during oestrus may be due to difference in estrogen hormone level (Schilling and Zust, 1968) or to external influences. Nutritional deficiency may induce some abnormalities in the metabolic process of the genital tract ending with un-explainable infertility. Regarding the effect of season, Abdel-Hafez (2002) and Marai *et al.* (2004) recorded the cervical mucus pH to be significantly higher during warm season of the year (summer and autumn) compared to the milder conditions (winter) in Ossimi x Suffolk ewes. However, El-Darawany *et al.* (2005) reported a non-significant effect of season on the same trait, in Nubian x Egyptian local doe goats.

Viscosity can be defined as stretchability measured by either pulling the mucus from the cervix or alternatively by placing the mucus on a slide. Biochemically, the mucus contents are used as the basis for some methods of oestrous detection. It contains 98% water and becomes, thin, clear, cellular and abundant, during the oestrous period under the influence of oestrogen (Fuot, 1975; Britt, 1977 and Hafez, 1987). In the pre-ovulatory phase of the oestrous cycle, mucus is thin, watery and the intermicellar space is large enough to allow sperm penetration. After fertilization, cervical mucus becomes scant, thick, opaque, cellular and hydration decreases and the intermicellar space narrows, restricting penetration, under the influence of progesterone. Increase of cervical mucus thickness during gestation is due to its function in closure of cervix until late gestation. Before parturition, the changes in cervical mucus occur under the influence of oestrogen. Cervical mucus becomes watery, thin, clear, cellular and abundant in amount. Regarding the effect of season, Abdel-Hafez (2002) and Marai *et al.* (2004) recorded that the cervical mucus viscosity to be significantly higher in winter (mild conditions) compared to summer and autumn conditions in Ossimi x Suffolk ewes. However, El-Tarabany (2003) and El-Darawany *et al.* (2005) reported insignificant effect of season on the same trait in Nubian x Egyptian local doe goats. The high concentration of inorganic phosphate was observed in the cervical mucus of fertile animals, which might also serve as a criterion for fertility detection in the dairy cattle (Lamoth and Guary, 1970), during heat stress conditions.

In conclusion, alterations in cervical mucus physiochemical properties can be used as the basis for

detection of mating time in sheep when the ewes fail to show oestrus under heat stress conditions.

### **Oestrus, ovulation and fertilization**

Females reproductive functions are adversely affected when exposed to high ambient temperature. Length of oestrous cycle is reduced, i.e. the oestrus is suppressed and affects ovulation. Failure of ova to be fertilized and early embryonic mortality may be also due to mating of ewes during hot weather, as large numbers of ova produced are abnormal and a small number are fertilized (Casu *et al.*, 1991).

Ovulation rate in ewes is at a maximum (without breeding of ewes) in autumn and the minimum in spring (Aboul-Naga and Aboul-Ela, 1987). However, Mokhtar *et al.* (1991) reported ewes to have the highest ovulation rate when mated in October (autumn; 123.1 %), followed by those mated in February (winter; 115.4 %) and June (spring; 100 %), respectively, under Egyptian conditions, due to the change in the ambient temperature which increases in the last month.

Ossimi and Rahmani sub-tropical breeds and their crosses (Suffolk x Ossimi crossbred and different crosses between Finn) showed lower fertility and prolificacy in May (spring) than during September (autumn) and January (winter) matings under Egyptian conditions (Aboul-Naga and Aboul-Ela, 1985; Abdel-Hafez, 2002; Marai *et al.*, 2004), due to the functional problems that occur in males and females at mating during periods of thermal stress (Curtis, 1983; El-Darawany, 1999b).

### **Conception rate**

Number of days needed/conception was found to be affected by mating season when 3 matings/2years is applied, in Egypt (Aboul-Naga *et al.*, 1987a). The summer mating season showed, in general, the lowest conception rate (Table 2; Marai *et al.*, 2006a). Aboul-Naga *et al.* (1987a), El-Darawany (1999b) and Marai *et al.* (2004) found negative relationships between conception rate and ambient temperature and daylight length, in Ossimi, Rahmani and Ossimi x Suffolk ewes, respectively. Other studies showed that conception rate was the lowest for ewes mated either during the winter (El-Fouly *et al.*, 1984) or during February and June mating seasons ( Mokhtar *et al.*, 1991).

### **Embryonic mortality**

Placental development requires adequate and organized interaction of vascular growth factors and their receptors, including vascular endothelial

growth factor (VEGF) and placental growth factor (PIGF). Both VEGF and PIGF, acting through the tyrosine kinase receptors VEGFR-1 and VEGFR-2, have been implicated in playing a role in ovine placental vascular development (Regnault *et al.*, 2002).

Exposure to environmental heat stress early in placental development, could impair normal placental vascular development, since soluble VEGFR-1 (sVEGFR-1) mRNA was not detected in these tissues. These alterations in growth factor and growth factor receptor mRNA expression and alterations in VEGF, VEGFR-1 and VEGFR-2 mRNA expression during the period of maximal placental growth, may contribute to the development of placental insufficiency, and ultimately intrauterine growth restriction (Regnault, 2002). Lublin *et al.* (1984) also reported that, during hyperthermia, there was significant reduction in blood supply to the ovaries (-23 %) and to the undifferentiated uterine wall of non-pregnant or early-pregnant animals. Regnault *et al.* (1999) added that chronic heat exposure lowers circulating placental hormone concentrations as a result of impaired trophoblast cell development, specifically trophoblast migration. The impact of heat exposure during placental growth is great enough to restrict early fetal development, even before the fetal maximal growth phase (100 dpc-term). Early embryonic mortality may be due to mating of ewes during summer hot weather. In ewes subjected to high ambient temperatures, embryonic death may be related to upset of the nucleic-acid metabolism in the zygote at certain stages of development, occurrence of hormonal imbalance in progesterone, thyroid and glucocorticoid hormones (Curtis, 1983) that affect uterine environment and reduce blood supply (Sulong, 1987).

Exposure to heat stress produced fewer viable lambs in Targhee x Suffolk crossbred ewes (Brown *et al.*, 1977). Chemineau (1993) confirmed that early embryonic mortality increased and level of fecundity decreased by exposure of ewes to heat stress. Similarly, exposure to heat in the 2<sup>nd</sup> half of pregnancy also results in damage to the embryo (Casu *et al.*, 1991). The months of highest embryonic mortality were July-November in sheep in North of Cameroon (Cardinale *et al.*, 1997).

The greatest effect of heat stress on fecundity was observed to be in the first 3 days before and after ovulation (Chemineau, 1993), from a few days before to a few days after mating (Curtis, 1983) or during the first 17 days of pregnancy (Soto *et al.*, 1998). Soto *et al.* (1998) added that the use of shade was beneficial to improve the pregnancy rate of the flock. Partial or complete reproductive failure may occur as a result of genetic (anatomic, hormonal, neural, immunologic and



humoral) and environmental (seasonal, nutritional or pathologic) factors (Hafez, 1987).

### **Foetal dwarfing**

Exposure of ewes during early pregnancy to elevated ambient temperatures may be accompanied with production of dwarfed lambs, which are usually or often characterized by a hairy appearance. This is especially true for lambs of the wool breeds, but it is not clear in hair breeds. The hairy appearance is because the coat consists of the primary follicles coarse fibres and the finer secondary follicles' fibres did not appear at birth. The economic consequences of this problem which result from exposure of early pregnant ewes to elevated ambient temperature are a higher death loss among foetal dwarfed lambs and reduced growth rate for those which survive (Shelton, 2000).

Curtis (1983) reported that the deficiency in ewe's plane of nutrition during gestation may cause dwarfism. The ewe voluntary feed intake reduction during hot weather reduces the availability of nutrients for foetal growth. Further, the drop in forage quality during hot weather, aggravates such effect. Generally, the low nutritional plane and/or elevated body temperature per se seems to play a major role in foetal dwarfing in sheep. The apparent physiological explanation for foetal dwarfing is that, as temperature stress becomes a problem, there is a differential shunt of the blood supply to the lungs or superficial tissues in an attempt to dissipate the excess heat load. This apparently results in a reduction of energy supply to the internal organs, including the placenta, with a resultant undernutrition of the foetus (McCarbb and Bartolussi, 1996). When body temperatures of the ewe exceed the normal range and tissue temperatures become higher than normal, the rate of cell division may be reduced. However, foetal dwarfing may even occur in the absence of elevated body temperatures (Shelton, 2000).

### **Lambing rate**

Ovulation rate and litter size were significantly higher in September (autumn) than in January (winter) and May (spring) breeding seasons (Table 2; Gabr *et al.*, 1989). The oestrogenic compounds that may present in green fodder as in Egyptian clover (*Trifolium alexandrinum*) during winter season (Bennetts *et al.*, 1964; El-Fouly *et al.*, 1984) and elevation in ambient temperature during spring (Abdel-Hafez, 2002) may be responsible for depressing ovulation rate and number of lambs born. However, Fletcher and Geytenbeek (1970), Sefidbakh *et al.* (1980) and El-Fouly *et al.* (1984) reported the lambing rate to increase slightly in summer compared to winter matings in different breeds of sheep.

Litter size at birth / ewe mated was higher in autumn than in the other mating seasons (Table 2). The September mating surpassed the May mating season by 36 and 29% in Rahmani and Ossimi, respectively (Aboul-Naga *et al.*, 1987a). However, Abdel-Hafez (2002) and Marai *et al.* (2004, 2006a) found that the lambing rate to be insignificantly affected by breeding season of the year (summer, autumn and winter) in Ossimi x Suffolk ewes, under sub-tropical conditions.

Percentages of lambs weaned / ewe joined were lower in Merino and Ossimi ewes mated in spring and Ossimi x Merino and Ossimi x Suffolk mated in winter than in the other seasons (Aboul-Naga and Aboul-Ela, 1985). Table 2 shows that percentages of lambs weaned / ewe lambled were high in spring, autumn and winter matings. Generally, the number of lambs per litter is influenced by genotype, age of ewe and feeding regime (Johnson, 1987), ambient temperature at mating (Curtis, 1983) and mating season (Aboul-Naga *et al.*, 1987a; Gabr *et al.*, 1989; Mokhtar *et al.*, 1991).

### **Lambing interval and postpartum sexual activity**

Involution of the uterus in ewes is approximately 26 (between 24 – 30) days in ewes under mild conditions (Bhaik and Kohli, 1980). Percentages of 90 – 95 of Finn x German Mutton Merino crosses, renewed postpartum sexual activity within 90 and 95 days after summer and autumn lambings, respectively. In purebred German Mutton Merino ewes, only 40 % of the November (Autumn) lambing started new cycles within 105 days postpartum (Amir *et al.*, 1980). Generally, the major factors affecting the postpartum proestrus are nutritional status, milk yield and suckling (Johnson, 1987).

Such results indicate that lambing interval and postpartum sexual activity may vary according season of the year. In brief, mating of ewes during the hot weather may result in failure of ewes to exhibit estrus, reduction of the length of the oestrous cycle or suppression of the oestrus, failure of ova to be fertilized and early embryonic mortality, as a large number of ova produced are abnormal and only a small number of ova are fertilized. Further, age at puberty, oestrous activity, conception rate, embryonic mortality, lambing rate, lambing interval, post-partum sexual activity and lamb abnormality are affected negatively with exposure to high ambient temperatures.

### **Yield and fatty acid composition of ewe milk**

Milk yield was found to be antagonistic with heat tolerance, when examining the relationship between milk production of the Mediterranean dairy sheep and heat stress. In other words, selection only for increased

milk production will reduce heat tolerance. This is due to that Finocchiaro *et al.* (2005) found that the genetic correlations between the general additive effect of milk production and the additive effect of heat tolerance were negative (approximately -0.8) for both daily milk and fat-plus-protein yields in all periods considered.

Regarding fatty acid composition of ewe milk, it was found that exposure of lactating Comisana ewes to solar radiation resulted in higher proportions of short-chain and saturated fatty acids in milk, primarily because of increased contents of caproic, capric, lauric, myristic and stearic acids (by 3-18%), and decreased contents of oleic, linoleic and linolenic acids (by 2-9%). As a consequence, the long to short chain and the unsaturated to saturated fatty acid ratios were significantly higher by 4 and 13%, respectively, in the milk of the protected ewes compared to those of the animals exposed to solar radiation.

Provision of shade led to an increase in the 18:0 + 18:1 to 16:0 ratio, and to a decrease in the 12:0 + 14:0 + 16:0 fatty acid group, which are regarded as reliable indexes of the nutritional property of dietary fat in reducing cholesterol levels in human plasma. Feeding time had little impact on milk fat (Sevi-Agostino, 2002).

Such findings suggest that high ambient temperature may markedly modify the lipid composition of ewe milk and that provision of shade, but not feeding management, can improve the milk fatty acid profile in dairy sheep raised in hot climates (Sevi-Agostino, 2002).

## BIOLOGICAL FUNCTIONS AS AFFECTED BY HEAT STRESS

### Thyroid hormones

Thyroid hormones as affected by seasons of the year, are shown in Table 3. Triiodothyronine ( $T_3$ ) and thyroxine ( $T_4$ ) are recognized as powerful metabolic agents in farm animals (Yousef and Johnson, 1985). The major role of thyroid hormones in regulation of overall heat production lies in control of endothermic thermogenesis (Hagen, 1983). Food and ambient temperature were found to affect thyroid gland activity. However, reduction in feed intake was not the primary factor in the decrease of thyroid function during acclimation to heat (Yousef and Johnson, 1985).

$T_3$ : Alleviation of  $T_3$  level is associated with diet carbohydrate or protein contents, indicating that composition of the diet has important effect on thermogenesis (Hagen, 1983). Otten *et al.* (1980) found that feeding a high fat diet reduced  $T_3$  level.

Shalaby and Shehata (1994) reported that  $T_3$  level decreased when feeding Finn ewes 100 % NRC energy versus 80 % NRC in summer, but the differences were not significant. The same authors recorded a significant increase of  $T_3$  level with reduction of energy level to 60 % NRC. Other studies showed that  $T_3$  level in Suffolk crossbred plasma were not affected by feeding concentrate + roughage according to animal requirements or concentrates only *ad lib* during winter or summer seasons (Marai *et al.*, 1997c, 2000).

High ambient temperature seems to decrease  $T_3$  activity (Table 3) and this effect is probably initiated at the hypothalamic level (Yousef and Johnson, 1985). El-Sherbiny (1983) found that exposure of ewes to direct sunlight for 6 hours in summer and 4 hours in winter caused a reduction in  $T_3$  levels. The same authors also recorded lower level of  $T_3$  in ewes plasma during summer than during winter season in sheep. Marai *et al.* (1997d, 2000) confirmed that  $T_3$  concentration in blood plasma was significantly lower ( $P < 0.01$ ) in summer than in winter season in Ossimi x Suffolk crossbred sheep. The studies of Guerrini and Bartchinger (1983) clarified that the decrease in  $T_3$  level was correlated with the increase in rectal temperature, under hot climate conditions. However, other studies showed that  $T_3$  level remained almost unvaried, while the plasma level of thyroxine ( $T_4$ ) decreased with the increase in ambient temperature in ruminants (Kamal *et al.*, 1989).

$T_4$ : El-Sherbiny *et al.* (1983) and Marai *et al.* (1997d, 2000) showed that the levels of  $T_4$  were higher during summer than in winter season in Barki and Ossimi x Suffolk crossbred sheep. In contrast, Shalaby (1996) found that exposure of Finn sheep to direct solar radiation for 6 hours in summer caused significant decrease in  $T_4$  level.

Shalaby (1985), Yousef and Johnson (1985), Habeeb *et al.* (1992) and Shalaby and Shehata (1994) confirmed that the correlation between thyroid hormones and ambient temperature were negative. However, El-Sherbiny *et al.* (1983) found that plasma  $T_4$  level was insignificantly changed, when Barki sheep were exposed to solar radiation in summer or in winter season.

### Cortisol

Cortisol hormone plays a very important role in many physiological functions, especially energy production, thermal regulation, lactogenesis, and regulation of milk production (Abdel Samee *et al.*, 2000). Cortisol levels were found to decrease in the polygastric species exposed to high temperature (Kamal *et al.*, 1989). Other studies showed that the cortisol hormone level increased significantly under high ambient temperature (Yousef *et al.*, 1997). Marai *et al.*

(Submitted) confirmed that cortisol level in Ossimi x Suffolk ram blood plasma was higher significantly ( $P<0.05$ ) in summer than in winter and autumn seasons under Egyptian conditions. However, Abdel Samee (1991) showed that the cortisol hormone level was not correlated with either ambient temperature or temperature humidity index (THI) in Hampshire x Suffolk withers. In Beetal goats, cortisol level in blood plasma was significantly higher during hot humid than hot dry conditions (Koushish *et al.*, 1997). The increase in glucocorticoids was estimated as 38 % after 1 h and 62 % after 2 h reaching a peak of 120 % at 4 h when exposed to hot conditions, then declined gradually to values not different from normal after 48 h and remained at or below this level for the rest of exposure duration (Alvarez and Johnson, 1973).

Particularly, Lowe *et al.* (2002) reported that Romney-cross ewe lambs subjected to controlled environmental conditions showed that plasma cortisol concentrations increased in heat-stressed lambs after the rectal temperature (RT) reached approximately 40.7°C. Plasma catecholamines were only elevated in lambs when RT was greater than 42°C.

### Progesterone

Emesih *et al.* (1995) reported that pregnant doe goats exposed to heat stress showed higher plasma progesterone concentrations than in those maintained

at moderate ambient temperature. However, El-Darawany *et al.* (2005) found that the effect of the season of the year on plasma progesterone in pregnant doe goats was not significant. Particularly, Marai *et al.* (2004) found that the progesterone hormone level in urine (efficacious) in ewes at day 21 after mating was higher significantly ( $P<0.05$ ) in summer than in winter and autumn seasons.

### Testosterone

Testes testosterone content fell from 1.1 to 0.4 µg/gm and spermatic vein plasma content from 8.2 to 1.9 µg/dl, when rams were exposed for 14 days to an average environmental temperature of 30°C (Curtis, 1983). The lowest serum testosterone level was recorded during hot environmental conditions in Ossimi rams (El-Darawany, 1999b). From another point of view, short daylight stimulates the secretion of testosterone, FSH and LH in rams, while long daylight inhibits their secretion. Rams sexual activities peak occurs during the autumn breeding season and coincides with a sharp rise in plasma testosterone level. Then it declines in late winter, spring and summer (Jainuden and Hafez, 1987). However, Marai *et al.* (Submitted) found that testosterone level was insignificantly affected by season in Ossimi x Suffolk rams.

Table 3. T<sub>3</sub> and T<sub>4</sub> as affected by season of the year.

Breeds	Year seasons	T <sub>3</sub> ( ng/ dl)	T <sub>4</sub> (ug/ dl)	References
Finn	Summer:			Shalaby (1996)
	8.00h	97.2±5.9	4.5±0.3	
	14.00h	70.8±6.1	4.1±0.3	
	Winter:			
	8.00h	96.9±6.2	5.5±0.3	
	14.00h	115.8±5.9	5.9±0.3	
Egyptian breeds:	Summer:			Aboul-Naga and Aboul-Ela (1987).
	8.00h	99.0± 6.2	5.8± 0.3	
	14.00h	85.5±5.3	5.7±0.2	
	Winter:			
	8.00h	93.4±5.1	4.5±0.2	
	14.00h	96.3±5.5	5.8±0.3	
Rahmani (In north- delta)	Summer:			Aboul-Naga and Aboul-Ela (1987).
	8.00h	38.0± 4.0		
	12.00h	46.0±4.0		
	Winter:			
8.00h	70.0±4.0			
12.00h	64.0±4.0			
Ossimi (In north- delta)	Summer:			
	8.00h	29.0±4.0		
	12.00h	29.0±4.0		

Breeds	Year seasons	T <sub>3</sub> ( ng/ dl)	T <sub>4</sub> (ug/ dl)	References
Rahmani (In upper Egypt)	Winter:			
	8.00h	42.0±4.0		
	12.00h	50.0±4.0		
	Summer:			
	8.00h	15.0±4.0		
	12.00h	20.0±4.0		
Ossimi (In upper Egypt)	Winter:			
	8.00h	36.0±4.0		
	12.00h	51.0±4.0		
	Summer:			
	8.00h	16.0±4.0		
	12.00h	22.0±4.0		
Ossimi	Winter:			
	8.00h	31.0±4.0		
	12.00h	45.0±4.0		
	Summer:			
	Housing system:			Marai <i>et al.</i> (1992)
	Closed	72.1±4.12		
Mature	Semi- open	70.3±8.00		
	Closed	55.0±5.49		
Growing	Semi-open	67.2±3.90		
	Winter:			
Mature	Closed	95.2±4.05		
	Semi- open	91.9±6.18		
Growing	Closed	86.7±3.86		
	Semi- open	80.0±6.01		
Crossbreds: Ossimi x Suffolk	Summer	117.1±7.96	7.46±0.3	Marai <i>et al.</i> (1997c)
	Winter	257.4±6.90	8.40±0.26	
	Summer	27.9±18.28		Marai <i>et al.</i> (submitted)
	Winter	94.8±18.28		
Finn x Rahmani	Autumn	52.9±18.28		
	Pre- exposure	138.8±13.2	7.1±0.5	Shalaby and Shehata(1994)
	3 h exposure	74.3±12.2	7.2±0.6	
	6 h exposure	103.1±11.0	6.9±0.6	
	During the day :			
	6.00h	138.4±13.9	6.4±1.7	
	12.00h	170.4±13.5	7.4±1.8	
	18.00h	155.4±14.2	9.5±1.8	
24.00h	185.2±15.2	5.8±1.9		

### Blood metabolites

Blood plasma metabolites in sheep as affected by year seasons are shown in Table 4.

### Plasma proteins

The plasma proteins provide an efficient way of transferring the heat from inside the body to the outer surface in the skin for heat dissipation by non-evaporative process during heat stress, since it holds an adequate percentage of water in the intra-vascular fluids and maintains the viscosity of the blood (Kamal *et al.*, 1962).

Plasma protein contents were negatively correlated to environmental temperature (Kamal *et al.*, 1962). Baumgartner and Parthner (1994) confirmed that the serum total protein levels were significantly ( $P<0.05$ ) lower in summer than in winter in Karakul sheep. However, Salem *et al.* (1998) noted that the serum total protein levels were higher in hot summer than in winter in Chios lambs and Chios crosses with Ossimi lambs in upper Egypt. However, Marai *et al.* (Submitted) found that plasma total protein levels to be insignificantly affected by season in Ossimi x Suffolk rams.

The significant decline in serum proteins with rising temperature seems to be due to dilution of plasma proteins as a result of the increase in body water content, decrease of protein synthesis as a result of the depression of anabolic hormonal secretion (El-Masry and Habeeb, 1989) and the increase in the catabolic hormones such as glucocorticoids and catecholamines (Alvarez and Johnson, 1973). The decrease in serum protein may also be due to the decrease in feed nitrogen and mineral intake, which occurs under heat stress conditions.

### **Albumin**

Serum albumin level was found to be significantly ( $P < 0.05$ ) lower in summer than during winter season in Karakul and Ossimi x Suffolk sheep (Baumgartner and Parnthaler, 1994; Marai *et al.*, Submitted, respectively). The decrease in serum albumin concentration was estimated to be about 10 % (Marai *et al.*, 1996; Yousef *et al.*, 1996). However, Salem *et al.* (1998) noted that the serum albumin level was higher in summer than in winter in Chios and Chios crosses with Ossimi lambs, in Upper Egypt.

### **Globulin**

Globulin level in blood plasma was insignificantly affected by season of the year (winter, summer and autumn) in Ossimi x Suffolk rams under Egyptian conditions (Marai *et al.*, Submitted).

### **Serum total lipids**

Serum total lipids concentration decreases significantly in ruminants with prolonged exposure to high environmental temperature (Marai *et al.*, 1995, 1997a; Habeeb *et al.*, 1996; Yousef *et al.*, 1996, 1997). Such phenomenon may be due to the increase in either body water content or utilization of fatty acids for energy production as a consequence of the decrease in glucose concentration.

### **Cholesterol**

Cholesterol concentration decreases markedly with the increase in environmental temperature (Shaffer *et al.*, 1981; Abel-Samee, 1987; Marai *et al.*, 1995; Habeeb *et al.*, 1996). The marked decrease in cholesterol concentration may be due to dilution as a result to the increase in total body water or to the decrease in acetate concentration, which is the primary precursor

for the synthesis of cholesterol. The marked increase in glucocorticoid hormone level (in heat stressed animals) may be another factor causing the decline in blood cholesterol.

### **Glucose**

Results of the effect of the high ambient temperature on plasma glucose content are conflicting. Sano *et al.* (1985) found that changes, immediately after exposure to hot climate in sheep, were little in blood glucose metabolism, while Marai *et al.* (1992) found in mature Ossimi ewes that the blood glucose level was found to be significantly ( $P < 0.05$ ) higher during summer than in winter. The increase in plasma glucose during hot condition may be due to the decrease in the glucose utilization, depression of both catabolic and anabolic enzyme secretions and subsequent reduction of metabolic rate (Webster, 1976), or to the rapid panting which results in increased breakdown of glycogen into free glucose by the increase in glucocorticoid hormones (Thompson, 1973). Some other studies showed that blood glucose decreased significantly with different percentages (in Chios, Chios crosses with Ossimi rams) (Salem *et al.*, 1998) and insignificantly in Ossimi x Suffolk (Marai *et al.*, Submitted) with exposure to high ambient temperature. The decrease in glucose level by exposure to high ambient temperature was estimated to be 24 % in Friesian cow blood (Shaffer *et al.*, 1981), 13 % in Holstein, Brown Swiss and Jersey heifers (Kamal *et al.*, 1962) or 8 % in Friesian calves (Habeeb, 1987). Such change in glucose level during hot climate relates in part to the decrease in concentration of insulin which is correlated closely to the decrease in energy metabolism during hot climate (Herbein *et al.*, 1985; Habeeb, 1987), the marked dilution of blood and body fluids, the increase in glucose utilization to produce more energy required for high respiratory activity (Habeeb *et al.*, 1992), the decrease in production of propionic acid in the rumen (Kelly *et al.*, 1968), the decrease in roughage intake (Colditz and Kellaway, 1972), and/or the decrease in hepatic capacity for gluconeogenesis (Sano *et al.*, 1983). However, the studies of Patel *et al.* (1991) showed that the level of sheep blood glucose was not affected by exposure to direct sunlight from 8.30 (32.3°C) to 14.30 h (37.7°C) for three consecutive days during the last week of May (in Indian native Patanwadi and its crosses with Merino and Rambouillet sheep).

Table 4. Means ( $\pm$  S.E) of blood plasma glucose, total protein, albumin and globulin in sheep, during different seasons of the year.

Breeds	Seasons	Total proteins (mg /100ml)	Albumin (mg/ 100ml)	Globulin (mg/100m)	Glucose (mg/100ml)	References
Egyptian local Breeds						
Barki	Spring	6.56 $\pm$ 0.10	3.12 $\pm$ 0.1	3.42 $\pm$ 0.1	62.02 $\pm$ 2.9	Samak <i>et al.</i> (1986)
	Summer	6.53 $\pm$ 0.2	2.89 $\pm$ 0.1	3.65 $\pm$ 0.2	63.69 $\pm$ 3.5	
	Winter	7.20 $\pm$ 0.4	3.29 $\pm$ 0.2	3.90 $\pm$ 0.3	51.88 $\pm$ 3.4	
Rahmani	Spring	6.89 $\pm$ 0.2	3.17 $\pm$ 0.1	3.72 $\pm$ 0.2	62.98 $\pm$ 2.2	
	Summer	6.87 $\pm$ 0.1	2.97 $\pm$ 0.1	3.90 $\pm$ 0.1	60.18 $\pm$ 3.4	
	Winter	7.26 $\pm$ 0.4	3.48 $\pm$ 0.1	3.79 $\pm$ 0.3	47.37 $\pm$ 2.2	
Crossbreds						
Ossimi x Suffolk	Autumn	7.99 $\pm$ 0.6	4.17 $\pm$ 0.3	3.82 $\pm$ 0.3	110.23 $\pm$ 2.4	Marai <i>et al.</i> (submitted)
	Winter	8.65 $\pm$ 0.6	4.8 $\pm$ 0.3	3.85 $\pm$ 0.3	100.31 $\pm$ 2.4	
	Summer	6.25 $\pm$ 0.6	3.15 $\pm$ 0.3	3.10 $\pm$ 0.3	70.12 $\pm$ 2.4	

### Kidney function

**Urea-N:** Dixon *et al.* (1999) reported that the hot environment reduced nitrogen balance in Merino x Border Leicester sheep, probably due to the decrease of total DM intake and increase of panting. The decrease in blood urea-N level was estimated as 16 % in Friesian (El-Masry, 1987; Kamal *et al.*, 1989), 28 % in lactating cows (Aboul-Naga, 1987) and 30 % in calves, under heat stress conditions (Habeeb, 1987). The depression in blood urea-N associated with exposure of the animals to heat stress may be due to more resorption of the urea-N from the blood to the rumen to compensate the decrease in ruminal ammonia-N as a result of the decrease in feed intake (El-Fouly *et al.*, 1978; Yousef *et al.*, 1996) and/or the increase in urinary nitrogen excretion under severe heat stress conditions as indicated by a negative nitrogen balance (Kamal *et al.*, 1962).

**Creatinine:** Creatine is synthesized in the kidneys, liver and pancreas by two enzymatically-mediated reactions. Creatine is then transported in blood to other organs such as muscle and brain, where it is phosphorylated to high energy compound phosphocreatine. Inter-conversion of phosphocreatine is a particular feature of metabolic process of muscle contraction. Some of the free creatine in muscle spontaneously converts to its inhydrate, creatinine. Daily, between 1 and 2 % of muscle creatine is converted to creatinine (Burtis and Ashwood, 1996).

Creatinine level was found to increase significantly during summer than in winter, in Karakul and Ossimi x Suffolk sheep (Baumgartner and Parthner, 1994;

Marai *et al.*, Submitted, respectively). Other studies showed either a slight rise (in Rambouillet, Chokola, Malpura and Rambouillet x Malpura rams (More *et al.*, 1980), or a decrease by different percentages (in Bos Taurus cattle) by exposure to high ambient temperature. The decrease in creatinine concentration was estimated to be 19 % in Friesian calves (Marai *et al.*, 1995, 1997a).

### Liver function

**SGOT and SGPT:** Most studies show that serum transaminase activities change with the change in environmental temperature. Some studies showed that the overall mean serum GOT values were higher in summer than in winter, while serum GPT was insignificantly affected by season of the year in Barki and Rahmani ewes (Okab *et al.*, 1993). Other studies showed that GPT level was significantly higher in summer than in winter season in Chios and its crosses with Ossimi lambs (Salem *et al.*, 1998), and GOT level decreased significantly during summer season in Karakul sheep (Baumgartner and Parthner, 1994). Marai *et al.* (Submitted) found that SGOT and SGPT levels were insignificantly affected by season of the year (summer, autumn and winter) in Ossimi x Suffolk, under Egyptian conditions.

The increase in activities of serum GOT and GPT in the heat stressed animals may be due to the increase in stimulation of gluconogenesis by corticoids (increase in cortisol, cortisone or adrenocorticotrophic hormone; Thompson, 1973; Habeeb, 1987; Marai *et al.*, 1995).

*Alkaline phosphatase (ALP):* Alkaline phosphatase enzyme activities were found to decrease significantly ( $P < 0.05$ ) in summer than in winter in Karakul sheep (Baumgartner and Parthner, 1994) and in Ossimi x Suffolk (Marai *et al.*, Submitted). However, alkaline phosphatase activities level was found to be insignificantly affected by the increase in ambient temperature in summer, in cattle (Aboul-Naga, 1987) and in NZW rabbit males (El-Masry *et al.*, 1994)

*Lactate dehydrogenase (LDH):* Lactate dehydrogenase level increased significantly in native Patanwadi sheep and its crosses with Merino and Rambouillet when exposed to direct sunlight from 8.30 (32.3°C) to 14.30 h (38.7°C) for 3 consecutive days in the last week of May in India (Patel *et al.*, 1991). However, Marai *et al.* (Submitted) found that the LDH activity was insignificantly affected by season of the year (summer, autumn and winter) in Ossimi x Suffolk rams.

## MINERAL BALANCE

### Inorganic phosphorus

Inorganic phosphorus level in Rambouillet, Chokla, Malpura and Rambouillet x Malpura ram plasma increased during hot conditions (More *et al.*, 1980). Contrarily, Baumgartner and Parthner (1994) noted that the inorganic phosphorus level was significantly ( $P < 0.05$ ) lower during summer than in winter, in Karakul sheep. However, other studies showed that the inorganic phosphorus level was not affected by exposure to direct sunlight from 8.30. (32.3°C) for 3 consecutive days during last week of May in Patanwadi sheep and its crosses with Merino and Rambouillet, in India (Patel *et al.*, 1991), or by season of the year (summer, autumn and winter), in Ossimi x Suffolk rams, under Egyptian conditions (Marai *et al.*, Submitted).

### Zinc

In Ossimi x Suffolk rams, zinc blood plasma was insignificantly affected by season of the year (summer, autumn and winter), under Egyptian conditions (Marai *et al.*, Submitted). However, in cattle, retention of zinc reduced significantly by 24 % with exposure to high environmental temperature (32 to 39°C) (Kamal and Johnson, 1977; Aboul-Naga, 1983).

### Plasma Na<sup>+</sup>

Plasma Na<sup>+</sup> concentration increased in sheep exposed to heat stress (Ashmawy and Ibrahim, 1999).

### Plasma potassium

Plasma potassium decreased when exposure to heat stress, in sheep (Ashmawy and Ibrahim, 1999).

### Heat stress syndrome

Exposure of the animal to high environmental temperature stimulates the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite centre in the hypothalamus causing the decrease in feed consumption. Thus, fewer substrates become available for enzymatic activities, hormone synthesis and heat production, which minimize thermal load (Kamal, 1975). Exposure to more severe heat, suppresses the production of hormone releasing factors by the hypothalamic centre causing a decrease in pituitary hormonal secretion (Johnson, 1974), insulin and possibly thyroxine (Habeeb, 1987).

The metabolic pathways slow down causing drastic impairment of protein utilization due to the dramatic decrease in dry matter intake, apparent digestibility, volatile fatty acids production, rumen pH and electrolyte concentrations in rumen fluids and shortage of energy substrate, hormones and enzymes (Niles *et al.*, 1980).

Under these conditions, the protein synthesis becomes unable to counteract the protein catabolism that leads to a negative nitrogen balance. Such destruction in protein tissues is due to the increase in glucocorticoid hormones (proteolytic hormones) responsible for protein catabolism. The increase in glucocorticoid hormones may occur through the increase in gluconeogenesis which delivers the amino acids to their corresponding  $\alpha$ -keto acids (Alvares and Johnson, 1970), the hepatic capture of amino acids (Noall *et al.*, 1957) or through inhibiting oxidation of glucose that is essential for providing the energy required for peptide synthesis (Welt, 1952). The increase in catecholamines (lipolytic hormones) (Winegrad, 1962) or the decrease in insulin, responsible for protein anabolism (Habeeb, 1987) may also contribute to tissue destruction.

## MANAGEMENT PRACTICES TO ALLEVIATE HEAT STRESS

Good management should aim to well-being, comfort and maintaining high productive and reproductive efficiency of the animals. The management practices in hot climate should alleviate the heat stress effects. It should involve modification of the environment, reduction of the animal's heat production and increasing its heat loss by helping in dissipating the heat load. Alleviation of heat

stressed animals can be applied by physical, physiological and nutritional techniques (Marai and Habeeb, 1997).

### Management of sheep in hot climates

Optimal climatic conditions for sheep and goats would be something like an air temperature of 13 to 20°C, a wind velocity of 5 to 18 km/hr, relative humidity of 55 to 65% and a moderate level of sunshine. However, these factors are interrelated.

The low degree of technical skill in livestock raising is another problem in such regions. Regular training of those who are concerned, on the proper methods for animal husbandry, will help in overcoming such disadvantage. The specialized institutions spread in the country side, may play the major role in this respect.

### METHODS OF ALLEVIATION HEAT STRESS

Environmental amelioration practices are usually applied to highly intensive enterprises, of which products bring in sufficient return to warrant the expenses, e.g. dairying and/or feed-lot production. Some of the management practices to ameliorate the environment and reduce the animal's heat production, are shown above. Below, are some techniques that can be used to help sheep to dissipate the heat load and to correct the negative effects caused by heat stress. Such techniques are classified to physical, physiological and nutritional techniques as follows.

#### a. Physical techniques:

1. *Air movement:* Increasing air movement promotes evaporation, makes cooling by perspiration more effective and helps removal heat dissipated by animals, in the forms of radiation, conduction and convection. It can carry away moisture in the form of vapour. It also helps in cooling of the surroundings (bam walls and roofs, fences, earth, etc.) which in turn helps keeping the animals cooler.

2. *Air conditioning:* The air condition technique improves each of growth and milk yield and its composition in heat stressed animals. However, it has not, practically, been established as an economically feasible tool in hot weather because of the high costs of electrical power supply (Kamal *et al.*, 1972). The techniques 1 and 2 are considered as methods of modification of the environment as well and are used in the close barns.

3. *Drinking cool water:* The beneficial effect of drinking cool water in reduction of the heat load is due to the heat dissipated by conduction as a result to the difference between the drinking cool water and urine temperatures. Moreover, the increase in body water due to the increase in water intake under hot climate

helps dissipation of heat by increasing evaporative heat loss through sweating and respiration and by conduction (Aboulnaga *et al.*, 1989, Daader *et al.*, 1989; Habeeb *et al.*, 1994; Marai *et al.*, 1997b).

4. *Clipping:* Significant reduction in skin and rectal temperatures and respiratory rates have been shown by clipping animals (Bianca, 1959). In range and housed conditions, shorn animals show an increase in growth rate. However, the direct exposure of their clipped skins to solar radiation may hurt the skin. In such case, suitable covering for the skin can be obtained by partial clipping of the coats of the animals.

#### b. Physiological techniques:

1. *Diaphoretics administration:* These compounds are used to increase sweat production for increasing the evaporative cooling of the heat stressed animals (El-Fouly, 1969; Kamal *et al.*, 1972; Marai *et al.*, 1995). However, such treatments cause significant increases in each of rectal temperature and respiration rate.

2. *Diuretics administration:* These compounds are used to increase water excretion to increase the heat loss by excreting water in urine with the same body temperature and then followed by drinking water which is also of lower temperature than that of the body (Daader *et al.*, 1989).

3- *Goitrogens administration:* These compounds block thyroidal iodine uptake and consequently depress thyroid gland activity. It depress the secretion of T4 in the heat stressed animals to decrease heat production. However, this technique is not favoured under heat stress conditions, since the treated animals under such conditions may be affected seriously due to their need to more energy for greater muscular activity for the high respiratory activity, O<sub>2</sub> consumption and energy metabolism (El-Fouly, 1969; Kamal *et al.*, 1972).

4. *Hormonal substances administration:* Administration or injection of hormones can be used as a technique for alleviation of heat load on animal, since secretion of most of the hormones is depressed under heat stress conditions. However, injection of T4 for this purpose, was found to be associated with the increase of body temperature of the animals (Marai *et al.*, 1994). Similarly, insulin injection in the udder was found to show the same effect, besides it increases milk production. Injection by BST also minimized the negative effects of moderately high environmental temperatures on milk yield by increasing heat loss and minimizing the endogenous heat production and related physiological functions without any significant increase in rectal temperature and respiratory rates (Mohammed and Johnson, 1985). However, such techniques require some specific precautions and are expensive at the same time.



### c. Nutritional techniques:

Supplementing of heat stressed animals with protein, fat and/or mineral resources, is required to correct their negative balances, since heat stress induces a significant decrease in the dry matter intake and a significant increase in protein and lipids catabolism and decrease in live body weight, in addition to increase in excretion of urine and sweat containing minerals. Supplementation with ingredients that include crude protein or NPN (like urea) can be used to correct the negative nitrogen balance (Habeeb *et al.*, 1989; Marai *et al.*, 1997b). Palm oil can be used to increase the gross energy intake and consequently increase the performance. Mineral resources supplementation corrects minerals negative balances (El-Masry *et al.*, 1989). Vitamins such as vitamin C supplementation also have alleviation effect under heat stress conditions.

### CONCLUSIONS

Exposure to heat stress affects negatively the reproduction of sheep and this effect is aggravated when heat stress is accompanied with high ambient humidity. Such effect evokes a series of drastic changes in the animals' biological functions that include depression in feed intake efficiency and utilization, disturbances in metabolism of water, protein, energy, and mineral balances, enzymatic reactions, hormonal secretions and blood metabolites. Such changes result in depression of reproduction including decline in semen quality or fertility in the male, failure of the ewe to exhibit estrus, failure of ova to be fertilized in ewe, loss of the fertilized ova shortly after mating and fetal dwarfing. Such phenomena necessitate either practicing the breeding and lambing during the mild months of the year (pregnancy occurs in Egypt during the hot summer, since commonly breeding is practiced during April-June and lambing during October-November) or keeping the breeding stock, especially during the mentioned two phases under ameliorated conditions (particularly under intensive production systems) or provision of shade shelter as a practical measure under extensive conditions, in the hot climate regions. It is also useful to apply some management practices to ameliorate the environment, reduce the animal's heat production, as well as, applying some techniques that can help sheep in dissipating the heat load and to correct the negative effects caused by heat stress. Such techniques might be physical, physiological and/or nutritional.

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