GPH INTERNATIONAL JOURNAL
Research in
Biological Science
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Research Article

Paper ID #348

The Negative Effects of Heat Stress on Farm Animals during the Hot Summer Season in Tropical and Subtropical Countries and How to Reduce the Adverse Effects

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ABSTRACT

The thermal comfort region for the greatest animals is between 4° C and 25° C. When temperature surpasses 25° C, animals suffer heat stress. In severe heat stress, the profound body temperature increases, animal cells are affected and production performance is reduced. Most physiological and biochemical variations could occur to protect essential cell functions in contradiction of heat stress and to permit a fast recovery from moderate hypothermic destruction. In tropical and subtropical countries, the climatic characteristic is the major constraint on animal productivity. Production and reproduction are reduced as a result of the extreme changes in biological functions affected by heat stress. Reduction of the negative effects of heat stress can be reduced or even eliminate those losses to improve its productivity has been attempted using different techniques including physical and nutritional means.

KEYWORDS

Heat Stress, Farm Animals, Temperature-Humidity Index, Production, Reproduction, Alleviation Techniques

INTRODUCTION

Best climatic conditions for animals would be something like an air temperature of 13 to 20 ºC, wind velocity of 5 to 18 km/hour, the relative humidity of 55 to 65%, and a moderate level of sunshine, and these factors are interrelated. Ambient temperature is related to other climatic factors but the relationship with the relative humidity seems to be the most important, since the feeling of warmth under high ambient temperature increases with high relative humidity percentage. Such a relationship induced to propose a measurement of the level of severity of heat stress using the two factors and was termed the temperature-humidity index. The effect of heat stress is enlarged when the relative humidity is larger than 50% **(Wiersma 1990).** In tropical and subtropical countries, the climatic characteristic is the major constraint on animal productivity. Production and reproduction are impaired as a result of the drastic changes in biological functions caused by heat stress **(Habeeb et al. 1992)**.

According to the World Health Organization, World Meteorological Organization**,** and the United Nations Environmental Program**,** global warming would be a greater frequency and greater duration of exposure to hotter temperatures, especially, during the summer months. Typical hyperthermia sometimes occurs during severe heat in summer and as a result of hard expose to the sun throughout the world **(McMichael et al. 1996).**

Lower (LCT) and Upper Critical Temperature (UCT):

After environmental temperatures change out of the comfortable temperature (Thermo-neutral, THN), dairy cattle begin to experience either heat stress or cold stress. Both stresses require the animal to increase the quantity of energy used to continue the body temperature stable and there is less energy available to produce their products. THN region is the range of temperatures where animal normal body temperature is kept steady and heat production is at the basal level **(Berman 2005).**

The ranges of the thermo-neutral zone are from lower critical temperature (LCT) to upper critical temperature (UCT). The LCT is the environmental temperature at which animals requirements to increase metabolic heat production to continue body temperature. The UCT is the environmental temperature at which the animal increases heat manufacture as a concern of an increase in body temperature after insufficient evaporative heat loss **(Igono et al. 1985; Figure 1).** UCT for growth rates and milk production of Bos Taurus cattle are in the range 21-27°C and 24-30°C, respectively.

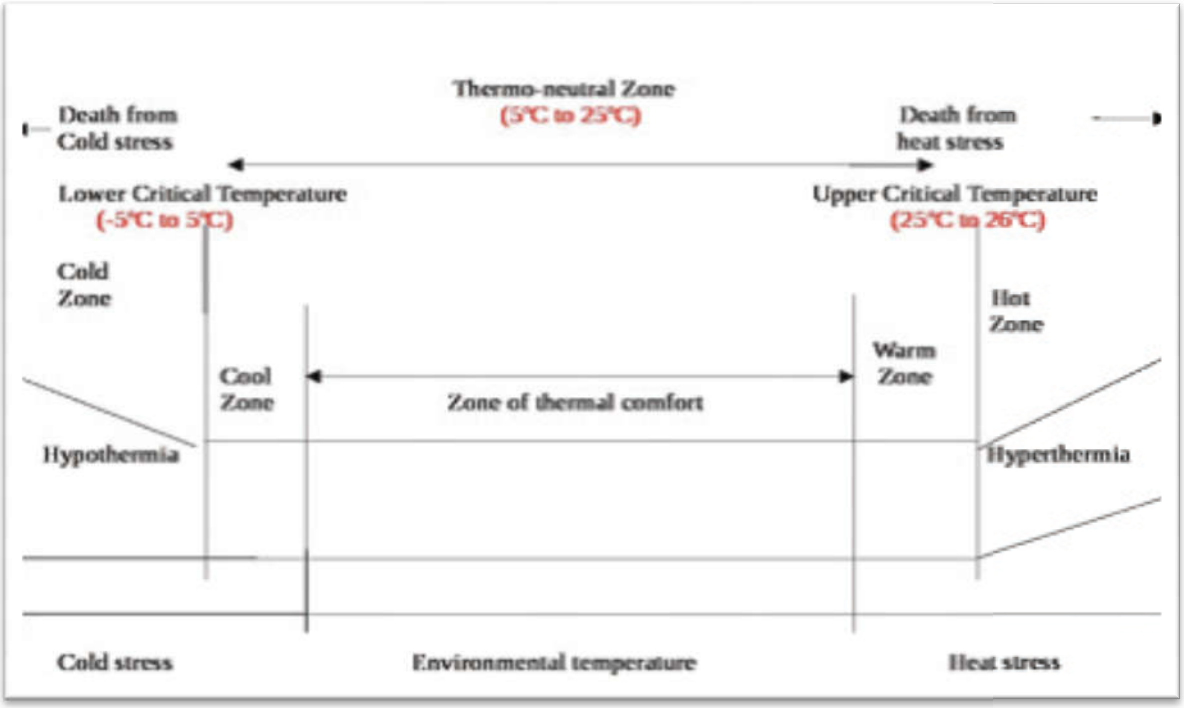

Figure 1. ***Lower (LCT) and upper critical ambient (UCT) temperatures and animal response (Igono et al. 1985).***

THN state depends on the age, breed, feed intake, diet composition, the previous state of temperature acclimatization, production, housing system, stand conditions, skin fat insulation, outside coat protection, and the activities of the animal. The UCT is given as 25-26 ºC, LCT as a range from -16 to -37 ºC for the animal **(Berman et al. 1985).** The LCT for newborn calves is 10 ºC in the dry and draught-free environment and decreases to 0 ºC by the time the calf is 1 month old **(Hamada 1971).**

Thermoregulation Mechanism

Thermoregulation income by which animal sustains its body temperature which includes the balance between heat gain and heat loss**.** The Ambient temperature within an animal's lower and upper critical temperature is considered at the zone of thermoneutrality **(Figure 2).**

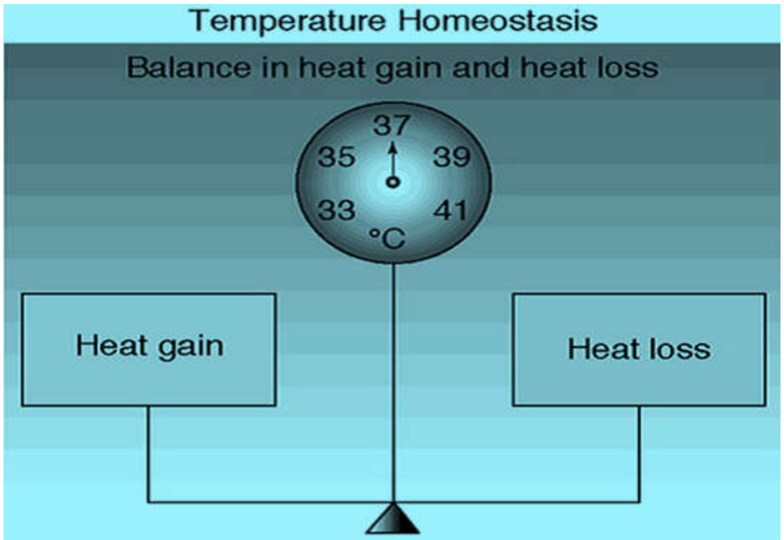

Figure 2. ***Balance between heat gain and heat loss (Wiersma 1994).***

Within this region, minimal physiological cost and maximum productivity normally are achieved. Above the upper critical temperature concomitant with decline of meat, milk and reproductive performance have been detected in farm animals, these measures usually are used to point to heat stress **(Igono et al. 1985).** Heat dissipates in animal's bodies via varying the rate and depth of blood circulation, by losing water through the skin and sweat glands, and as a last resort, by panting, when blood is heated above 98.6 °F. Sweating cools the body through evaporation. High relative humidity (RH%) delays evaporation, robbing the body of its ability to cool itself. When heat gain exceeds the level the body can remove, body temperature begins to increase, and heart-related diseases and syndromes may develop **(Figure 3)** (**Collier et al. 2009).**

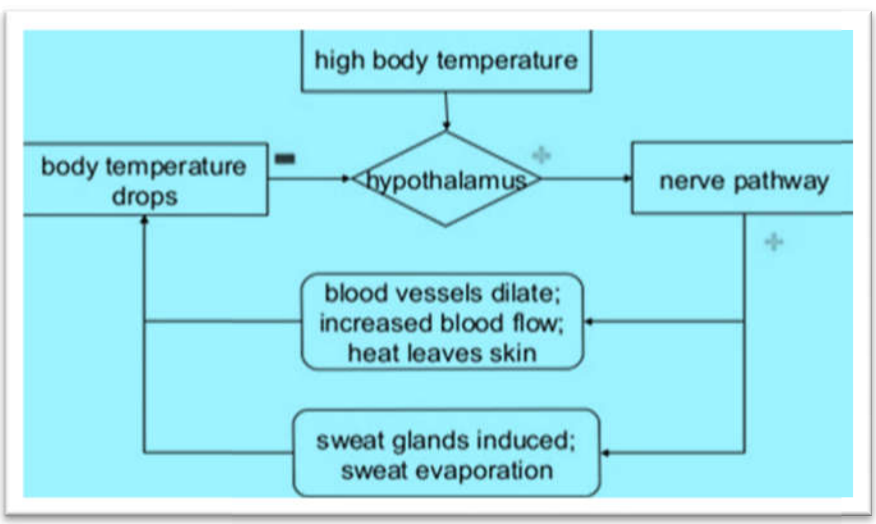

Figure 3. ***Thermoregulation in animals exposed to heat stress conditions (Collier et al. 2009)***

Animals have a sequence of mechanisms to sustain homeostasis. The THN zone is definite as the range of environmental conditions under which an animal can regulate heat loss with the lowest of effort. Changes in ambient temperature change metabolism and affect the level of heat production and heat loss. If the ambient temperature falls below the LCT, metabolism will increase in to augment heat production. If the ambient temperature rises above the evaporative serious temperature, evaporative heat loss increases and food consumption is withdrawn, decreasing metabolism and heat production **(Igono et al. 1992)**.

Heat Stress

Heat-stress is the state at which body mechanisms activate to sustain an animal's thermal balance when exposed to uncomfortable elevated ambient temperature. Heat-stress occurs when any combination of the environmental conditions causes the effective temperature of the environment to be higher than the animal's THN (comfort zone) **(Armstrong 1994).** Heat-stress when an animal misses the ability to dissipate sufficient heat to maintain thermal balance and her body temperature increases. This harms dry matter intake (DMI), production, and reproduction **(Praks 2010).** Animal experiences heat stress when an animal loses the ability to dissipate sufficient heat to maintain thermal balance and body temperature escalations. Heat-stress is defined as the state at which the animal body's physiological mechanisms activate to maintain the body's thermal balance when animals exposure to elevated temperature **(Marai and Habeeb 2010a, b).**

The summer season in Egypt,as a subtropical country, (latitude 31° 12' N to 22 ° 2' N, longitude 25 ° 53' E to 35 ° 53' E), is categorized by high ambient temperature (35-40° C), high relative humidity (50-75%) and high solar radiation (4500KJ/M^2) with extreme observed during the periods of greatest heat stress which normally extends more than 6 months from May to October. Animals under such conditions of the year become uncomfortable suffering extremely in their production and reproduction **(Habeeb et al. 2018a, b)**. Exposure of animals to uncomfortable conditions brings some sequences of risky changes in the biological functions, which include a decrease in feed intake and utilization as well as conflicts in water, protein, energy and mineral balances and blood biochemical components finale to deficiency the productive and reproductive performance and lowers natural immunity making animals more vulnerable to disease**(Habeeb et al. 2008a, b).**Heat-stress is a circumstance in which the animal body temperature has difficulties dissipating excess heat. Inadequate heat dissipation variety from general discomfort to symptoms of heat rash, heat syncope, heat cramps, heat exhaustion, and heat stroke according to the National Weather Service **(National Weather Service 2005).**

Temperature-Humidity Index (THI)

The environmental temperature, relative humidity, photoperiod, solar radiation, and wind velocity seemed to be interrelated in the subtropical climate. However, the relationship of environmental temperature with the relative humidity looks to be the most important, since the sensitivity of heat increases with increases relative humidity percentage **(Habeeb et al. 2018c).** Such association planned measurement of the level of the sternness of heat-stress using both environmental temperature and relative humidity and was called temperature-humidity index **(THI).** The expressions for describing how animals reply to thermal challenges have been defined by the International Commission for Thermal Physiology **(International Commission for Thermal Physiology 2001).**THI could be used as a sign of warm air climatic conditions. THI is a measurement by calculation from the relative humidity and the air temperature and is calculated for a specific day. The THI value is that as the relative humidity at any temperature increases and it becomes increasingly more difficult for the animal to cool itself. However, THI of 70 or lower are revealed comfortable, 75–78 are stressful and higher than 78 are excessive stresses **(Kadzere et al. 2002).**

Table (1) shows ambient temperature and relative humidity arrangements that produce mild heat stress (THI 72 to 79), moderate heat stress (THI 79 to 89), and severe heat stress (THI > 89) **(Collier et al. 2012).**

***Table 1*. Temperature Humidity Index (THI) for dairy cows.**

Themperature		% Relative Humidity																				
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	8	86	87	88
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
93	34.0	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91	92	93
94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92	93	94
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
97	36.0	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97
98	36.5	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95	96	98
99	37.0	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96	98	99
100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98	99	100
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99	100	101
102	39.0	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100	101	102
103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101	102	103
104	40.0	79	80	81	83	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101	103	104
105	40.5	79	80	82	83	84	86	87	88	89	91	92	93	95	96	97	99	100	101	102	103	105
106	41.0	80	81	82	84	85	87	88	89	90	91	93	94	95	97	98	99	101	102	103	104	106
107	41.5	80	81	83	84	85	87	88	89	91	92	94	95	96	98	99	100	102	103	104	106	107
108	42.0	81	82	83	85	86	88	89	90	92	93	94	96	97	98	100	101	103	104	105	107	108
109	43.0	81	82	84	85	87	89	89	91	92	94	95	96	98	99	101	102	103	105	106	108	109
110	43.5	81	83	84	86	87	89	90	91	93	94	96	97	99	100	101	103	104	106	107	109	110
111	44.0	82	83	85	86	88	90	91	92	94	95	96	98	99	101	102	104	105	107	108	110	111
112	44.5	82	84	85	87	88	90	91	93	94	96	97	99	100	102	103	105	106	108	109	111	112
113	45.0	83	84	86	87	89	91	92	93	95	96	98	99	101	102	104	105	107	108	110	111	113
114	45.5	83	85	86	88	89	92	92	94	96	97	99	100	102	103	105	106	108	109	111	112	114
115	46.0	84	85	87	88	90	92	93	95	96	98	99	101	102	104	106	107	109	110	112	113	115
116	46.5	84	86	87	89	90	93	94	95	97	98	100	102	103	105	106	108	110	111	113	114	116
117	47.0	85	86	88	89	91	93	94	96	98	99	101	102	104	106	107	109	111	112	114	115	117
118	48.0	85	87	88	90	92	94	95	97	98	100	102	103	105	106	108	110	111	113	115	116	118
119	48.5	85	87	89	90	92	94	96	87	99	101	102	104	106	107	109	111	112	114	116	117	119
120	49.0	86	88	89	91	93	95	96	98	100	101	103	105	106	108	110	111	113	115	117	118	120

Stress Threshold
Respiration rate exceeds 60 BPM
Milk yield losses begin
Reproductive losses detectable
Rectal temperature exceeds 38.5°C (101.3°F)

Mild-Moderate Stress
Respiration rate exceeds 75 BPM
Rectal temperature exceeds 39°C (102.2°F)

Moderate-Severe Stress
Respiration rate exceeds 85 BPM
Rectal temperature exceeds 40°C (104°F)

Severe Stress
Respiration rate 120-140 BPM
Rectal temperature exceeds 41°C (106°F)

Source: Collier et al, 2012, Arkansas University

An animal has numerous mechanisms to aid dissipate body heat. These mechanisms include conduction where the animal conducts heat to any cooler surface; convection where heat flows leave the animal's body; radiation where the animal releases heat to any cooler environment and evaporation where wetness is evaporated from the external of animal's body (sweating) and animal lungs (panting). The animal will also decrease feed intake to produce a lesser amount of metabolic heat which is a protecting mechanism **(Garner et al. 2017).** Heat stressed animals are less possible to display standing estrus and commonly exhibit signs of estrus at night when the temperature is cooler. Besides, the length of estrus is shorter for animals exposed to heat stress **(Wolff and Monty 1974; Hales et al. 1996).**Exceeding the upper critical environmental temperature related to the decline of the productive and reproductive performance of animals **(Igono et al. 1992).**

Explaining the mechanisms involved in increased heat loss when the body becomes overheated. **Guyton (1969)** listed that overheating encourages the preoptic thermostatic regionto increase the rate of heat loss from the body in three different means:

(1) By stimulating the sweat glands to cause evaporative heat loss from the skin

(2) By stimulating vasodilator nerves to the skin by this means increasing the transport of the heat by the blood to the body external.

(3) By stopping sympathetic centers in the posterior hypothalamus to eliminate the normal vasoconstrictor manner to the skin vessels and by this means let more vasodilatation.

Production and reproductive performance in animals are reduced as a result of the severe changes in biological functions which decrease about 50% from the productivity of temperate breeds when introduced to the tropical or sub-tropical countries due to heat stress **(Agarwal and Singh 2006;Habeeb 2019).** Exposure animals to high air temperature encourage the peripheral warm air receptors to transfer suppressive nerve impulses to the appetite center to decrease the feed consumption for minimizing heat load on animals. Therefore, fewer substrates are converted for hormone synthesis and heat production. Feed intake initiates to decline at air temperatures of 25-26°C in animals and reduces more speedily above 30°C and decline by as much as 40% at 40°C**(Rhoads et al. 2013),** 22-35% in goats **(Hamzaoui et al. 2012)** or 8-10% in buffalo heifers **(Hooda and Singh 2010).** Reducing feed intake is the way to decrease heat production in warm situations like the heat increment of feeding is an important cause of heat production in animals **(Kadzere et al. 2002).** As a result of the stage of negative energy balance, as a result, body weight and body condition score go depressed **(Lacetera et al. 1996).**Exposure animals to severe heat stress defeat the production of hormone-releasing factors from the hypothalamic centers to decrease the pituitary hormonal secretion and consequently lowers the secretion of the thyroid hormones final etod efficiency of production and reproduction of animals **(Habeeb et al. 1992)**. Besides, a high level of cortisol detected in the animals exposed to heat stress may be associated with depression in animal production **(Habeeb et al. 2000).** Animals commonly respond to heat stress conditions by eating less food, thus certainly controlling the increase in deep body temperature due to digestion. Respiratory rate increases and there is a manifest increase in insensible heat loss by evaporation of water from the lungs. Animals also drink at least 5 times the amount of water under temperate conditions as well as urine output increases and most mineral ions are missing **(Bray and Bucklin 1996)**.Exposure of animals to excessive environmental temperature encourages the nerve impulses to the specific centers in the hypothalamus to increase the evaporative and non-evaporative cooling systems and the adaptive mechanisms to help in preventing the increase in animal body temperature. Prolonged heat exposure suppresses the production of hormone-releasing factors from the hypothalamic centers causing reductions in pituitary hormones. These decreases in both substrate and hormones with a rise in body temperature inhibit the enzymatic activities, which decrease the metabolism and accordingly impair production and reproduction **(Marai and Habeeb2010a, b)**.

Negative Effects of Heat Stress on Animal Performance

1. Negative Effects of Heat Stress on Animal Growth

Growth is orderly genetically and environmentally by well-balanced offered nutrients, hormones, and enzymes. Most revisions presented that growth performance is impaired at elevated temperatures on temperate breeds. Growth traits in both male and female animals are impaired as a consequence of the drastic changes in biological functions including disturbances in protein, water, energy and mineral metabolism. These drastic changes depress the productivity of temperate breeds about 50% when introduced to a tropical or sub-tropical environment due to heat stress (**Habeeb et al. 1992).** The heat stress conditions of 36.0 and 32.0 °C induced a significant reduction in daily body weight gain (DBWG) of buffalo calves by 22.6 and 16.5%, respectively, when compared to mild climate conditions (18.0°C) **(Habeeb et al. 2007).**The stressful condition of hot climatic conditions induced a significant reduction in DBWG of bovine claves by 25.5% with differed from calf to another and ranged between 3.2 to 48.4% **(Habeeb et al. 2009).** The heat stress-induced a highly significant decline in DBWG of crossing calves by 14.0, 29.0, and 22.0% during the 1st, 2nd, and 3rd months of heat stress exposure, respectively **(Habeeb et al. 2011).** The heat stress conditions of the summer season induced a significant decline in DBWG of buffalo calves by 18.1, 17.41, and 8.65 % during the 1st, 2nd and 3rd months during the summer season, respectively **(Habeeb et al. 2012a).** The heat stress conditions of the hot period induced significant decreases in each of the final live body weight (FLBW) , DBWG, and total body weight gain (TBWG) decreased by 4.50, 24.76, and 24.88%, respectively as compared to under mild conditions **(Gad 2013).** The DBWG values were significantly lower in summer than in winter during the three months. The decrease values were 55.2, 60.2, and 57.4% in the first, second, and third months of the summer season, respectively **(Atta et al. 2014). DBWG** was found to be highly significantly lower in summer than in winter in both tow breeds by 52.8 and 43.3.4%, respectively as well as the stressful condition of hot summer conditions induced a significant reduction in solids body weight gain (SBWG)of bovine claves by 8.0 kg through 3 months at the rate of 88.4 g daily when compared to the absence of heat stress during the winter season and the percentage decrease due to heat stress reached to more than 33% (**Habeeb et al. 2014**).

Concerning the effect of heat-stress on solids daily body gain (SDBG), the calculated loss in SDBG due to heat-stress conditions was found to be 23% in Friesian heifers (**Kamal and Seif 1969),** 14-29% in Guernsey cattle **(Kamal and Johnson, 1971),** 51% in Friesian calves **(Habeeb 1987)** and 46% **(Marai et al. 1995).**In Friesian cows, total body solids (TBS) or dry body weight (live body weight- total body water (TBW) was found to decrease significantly from winter (126.5 kg) or spring (118.0 kg) to summer (91.0 kg), under natural hot climate (**Kamal and Seif 1969**). The TBS decreased in buffaloes and Friesian calves by 11.42% at each level of temperature, when the ambient temperature in the climatic chamber increased from 16°C, 50% RH to 32°C, 50% RH, constantly for one week **(Kamal and Seif 1969**). In Holstein's calves, heat stress caused a significant decrease (15%) in TBS (**Kamal and Johnson 1971**). In growing buffaloes, TBS was similarly lower at 32°C and 50% RH than at 18°C and 50% RH (100 and 124 kg, respectively) (**Kamal et al. 1972**). A pathway of heat stress syndrome in cattle under hot climatic conditions was suggested by **Kamal (1975)** to clarify that the production and reproduction of cattle are affected negatively by heat stress conditions **(Figure 4).**

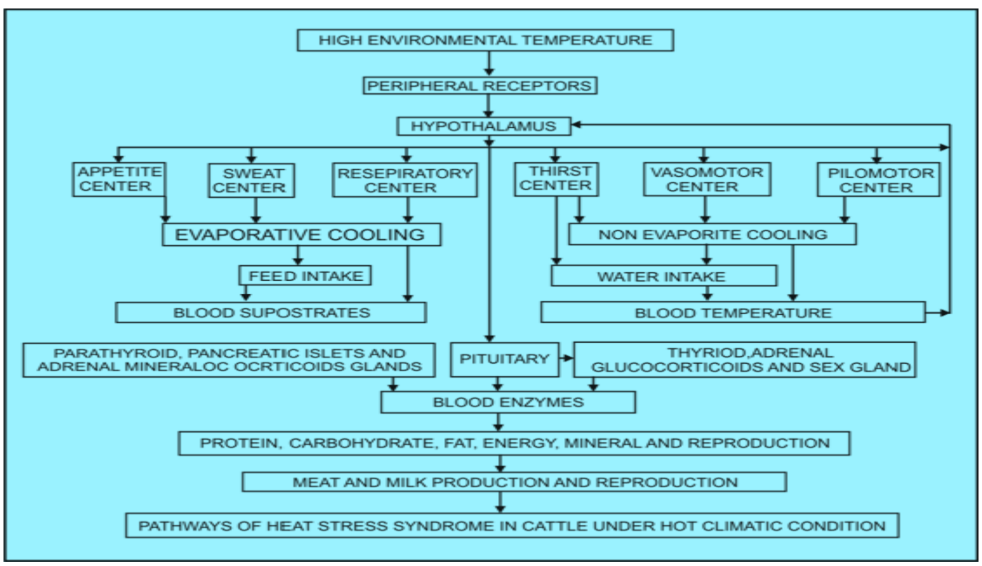

Figure 4. ***Pathways of heat stress syndrome in an animal under hot climatic conditions (Kamal 1975).***

TBS decrease from spring to summer (110.9 to 59.5 kg) and from summer combined with solar radiation (59.5 to 58.6 kg) in buffaloes (**Kamal et al. 1978).** Holstein and Friesian calves also showed similar responses under heat stress and average body solid content decreased by 16% with the increase in ambient temperature in the climatic chamber, therefore the authors suggested using the heat-induced loss % in dry body weight, i.e. total body solids as a heat tolerance index due to differentiate between animals in their heat tolerance **(Kamal 1982).** The heat stress-induced a significant decrease in TBS in both male and female Friesian calves (**Marai and Habeeb2010; Habeeb et al. 2014**).

The effects of heat stress conditions on growth performance are the products of the decrease in anabolic activity and the increase of tissue catabolism. The decrease of anabolism is essentially caused by the decrease in voluntary feed intake of essential nutrients; particularly metabolizable energy for both maintenance and gain weight and this causes loss of production per unit of food. The increase of tissue catabolism occurs mainly in fat depots and/or lean body mass (**Habeeb et al. 1992)**. The adverse effect of high ambient temperature with high relative humidity on animals may be due to a decrease in feed consumption, dehydration of animals, tissue catabolism and the low metabolically energy left for growth, since more energy is consumed by the increase in respiratory frequency that occurs in hot ambient temperature (Habeeb et al., 1992). The decrease in growth traits due to tissue damage can be estimated by total body solids losses in heat-stressed animals. This damage may be attributed to an increase in glucocorticoids and catecholamines (**Alvarez and Johnson 1973)** and decrease in insulin level (**Habeeb 1987**), T_4 and T_3 secretions and decrease in feed intake, feed efficiency, digestibility and feed utilization (**Habeeb et al. 1997 ;Bernabucci et al., 1999**). The animal tries to decrease the fed intake under heat stress as an attempt to create less metabolic heat, as the heat increment of feeding, especially, ruminants represent a large portion of whole-body heat production **(Kadzere et al. 2002).** The decrease in the substrates and hormones and the rise in body temperature inhibit the enzymatic activities, which decrease the metabolism and consequently impair daily body weight gain. Also, the decrease in thyroid hormone levels during summer may be attributed to the decrease in thyroid-stimulating hormone and/or the increase in glucocorticoid hormone or the interaction between the thyroid, and the adrenaline and noradrenaline released in response to temperature may contribute to the depression of gain either live or solids (**Johnson et al. 1988).**

Specifically, there is a reduction in body amino-N **(El-Fouly et al. 1998)** and endogenous DNA and RNA purine catabolism as a result of the increase in catecholamines and glucocorticoids. The nitrogen balance in young animals decreases significantly under high temperatures, but it does not reach the negative nitrogen balance as found in older animals. This phenomenon may be because heat-induced protein catabolism is not high enough to offset the well-known high rate of protein synthesis in young animals. High environmental temperature stimulates the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite center in the hypothalamus causing a decrease in dry matter intake. Thus, fewer substrates become available for enzymatic activities, hormone synthesis, and heat production. Besides, an exposure animal to severe heat stress conditions suppresses the production of hormone-releasing factors from the hypothalamic centers causing a decrease in pituitary hormonal secretion and consequently lowers the secretion of anabolic hormones **(Kamal 1975).**

2. Negative Effects of Heat Stress on Milk Yield and Milk Composition

The rise in temperature averages by 1.6, 3.2 and 8.8°C above normal (21 °C) results in the decrease in daily milk yield averages by 4.5, 6.8 and 14%, respectively, and a decline in the daily temperature by 7°C below normal resulted in an increase in the daily milk yield by 6.5% in dairy cattle **(Petkov 1971).** Milk production of imported pure breeds from mild climates to the humid tropics rarely exceeded 12-15 kg a day and most usually were less than 10 kg daily **(Raun, 1976).** Milk yield in early, mid, and late lactation decreased by 25, 41, and 47%, respectively, at 72 h after the beginning of heat exposure **(Bober et al. 1980).** At 30°C, the high producing animals showed a mean reduction of 2.0 kg/day compared to a reduction of only 0.65 kg/day for the low producing animals **(Vanjonack and Johnson 1975).** DMI and milk yield in domestic animals decreased and water intake increased with increasing environmental temperature (**NRC 1981).** In the hot climate (38°C), the reduction in the average milk yield in Friesian cows was lower by 30% than in the mild climate (18°C) **(Kamal et al. 1989**). Milk yield, milk total solids, milk butterfat, protein, and lactose values in lactating Water buffaloes were significantly lower in July (37.1°C) than in February (17.5°C). The depression in the overall mean of milk yield was 16.6% in 6 lactation numbers and concluded that buffaloes produced milk of better quality in winter than that attained under summer conditions (**Habeeb et al. 2000**). From the economical point of view, exposure of 6 buffaloes to Egyptian summer heat conditions, the weakly milk production decreased by 51.4 kg and 11 kg total solids loss in their milk. This means that their production benefits decreased weekly by about 100.0 Egyptian pounds according to the price of 1996 **(Habeeb et al. 2000).** Increasing air temperature, temperature-humidity index are related to decreased dry matter intake and milk yield, and reduced efficiency of milk yield **(West 2003).**

Milk constituents are also greatly affected by hyperthermia. Fat and protein percentages declined between 8 and 37°C and protein to fat ratio decreased at temperatures above 29°C, while chloride content increased above 21°C, in Friesian cows (**Rodriguez et al. 1985**). Friesian cows maintained under 38°C had lower averages of total solids, fat, protein, ash, and lactose yields than when the same animals were maintained under thermo-neutral environmental temperatures and the reduction percentages were 28, 27, 7, 22.7, and 30, respectively.

The decrease in milk yield and milk constituents of dairy cattle is a result of the depression in feed consumption which is the most important reaction to heat exposure. High ambient temperature during summer stimulates the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite center in the hypothalamus causing a decrease in feed consumption to minimize thermal load on animals. Thus, fewer substrates become available for enzymatic activities, hormone synthesis, and heat production (**Kamal 1975**). The shortage of energy, substrates, and hormonal levels in heat-stressed lactating cows may be responsible for the depression in milk yield and composition. Besides, a high level of cortisol which was observed in the animals exposed to high ambient temperature may be associated with the depression in quantity and quality of milk (**Habeeb et al. 1992**).

Further, the energy consumed during hot weather is used less efficiently for milk yield because of greater maintenance costs, which were estimated to be 20% greater when environmental temperatures were 35°C and cows use digestible energy with 35.4% less efficiency than that in an 18°C environment and the increase in respiratory and heart rate is responsible for the increased maintenance that occurs during heat stress (**West 1993**). Also, production of hormone-releasing factors by the hypothalamic center is suppressed causing the metabolic pathways to slow down, causing drastic impairment of protein utilization due to shortage of energy, substrates, hormones and enzymes, and a dramatic decrease in apparent digestibility, volatile fatty acids production, rumen pH and electrolyte concentrations in the rumen fluids (**Niles et al. 1980**). Under these conditions, protein synthesis becomes unable to counteract the protein catabolism which leads to a negative nitrogen balance. The 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 α-keto acids (**Alvarez and Johnson 1973**).

The increase in catecholamine (lipolytic hormones) or the decrease in insulin responsible for protein anabolism may also contribute to tissue destruction. Moreover, exposure animals to high environmental temperature cause disturbance in each of carbohydrates, lipids, minerals, and vitamin metabolism which leads to a negative balance in each of nitrogen, and minerals resulting in low protein turnover, less heat production, and fewer minerals for the biosynthesis of milk. The depression in some hormone levels in heat-stressed cattle such as insulin and thyroxin may also be responsible for the decrease in milk production, as well as, milk composition.

3. Negative Effect of Heat Stress on Animal Reproductive Efficiency

Negative relationships between THI and reproductive performances in animals were documented by many authors **(Habeeb et al. 2018 b&c; El-Tarabany and El-Tarabany 2015 a&b).** Heat stress define as a daily maximum THI of 72 or more from day 35 before to the day 6 after the day of breeding decreases the conception the rate of lactating dairy cows by around 30% relative to days of breeding and when maximum THI during three toone-day pre–artificial insemination values were greater than 80, conception rate decreased from 30.6% to 23.0% **(Garcia-Ispierto et al. 2007b).** Heat stress causes reproductive problems such as reduced semen quality, lower birth weights, decrease immune system, and harmed the developing embryo lead to lower conception rates and fertility **(Gantner et al. 2011).** Fertility in farm animals is well-defined as the ability of the animal to conceive and maintain pregnancy if inseminated at the appropriate time relative to ovulation (**Garcia-Ispierto et al. 2007a).**Poor estrous detection and embryonic or fetal losses are among the leading causes of poor reproductive performance. During the postpartum period, about 50% of standing periods of estrus are undetected and this failure in estrous detection can increase the average interval between successive inseminations to about 40-50 days and reduces both reproductive efficiency and profitability **(Stevenson et al. 1983).**The interval from parturition to conception during summer was 24-67 days longer than during the winter even though barns during summer were supplied with evaporative coolers**(King et al.1988).**Heat stress severely reduces pregnancy rates in farm animals and conception rates of lactating animals decreased sharply when maximum air temperature on the day after insemination exceeded 30ºC (**Stevenson et al. 1983).**In contrast, conception rates for heifers did not decline until 35 ºC. Virgin heifers had higher conception rates for all services (50%) than lactating cows (34%) and suffered only slight depression of fertility during summer months. Heifers required 1.5 services per conception compared with 2.3 for lactating cows. Conception rates decreased from 40 to 50% during months when ambient temperatures are greater and to be less than 10% during the months of the year when ambient temperatures are lesser (Badinga et al. 1985).

High temperature slow ered conception rates in cows more than in heifers since lactating cows were usually unable to maintain normal body temperature under heat stress conditions because of the high rates of lactation associated with internal heat production(**Wolfensen et al. 1995**).High erenvironmental temperature is one of the major factors responsible for reduced fertility in farm animals. Heat stress harmed reproductive events by decreasing the expression of estrous behavior, altering ovarian follicular development, compromising oocyte competence, and inhibiting embryonic development **(Mondal et al. 2017).** Heat stress after insemination reduced the weight of corporalutea and impaired concept growth **(Biggers et al. 1987).** Heat stress also increases the production of prostaglandin secretion (GF2α) in the end ometrium, leading to the early regression of corpus leuteam orthe death of embryos. The heat stress from 8 to 16 days after insemination modulated the uterine environment reduced the weight of corporalutea and impaired concept growth **(Biggers et al. 1987).** Heat stress decreases the intensity and duration of behavioral estrusso that a smaller proportion of cows are detected in estrus under heat stress conditions and increases the embryonic mortality (**Thatcher and Collier 1986).**In heat-stressed cows, the intrauterine environment is compromised which results in reduced blood flow to the uterus and elevated uterine temperature and these changes suppress embryonic development and increase early embryonic loss and minimize the proportion of successful inseminations (**Rivera and Hansen 2001).**High ambient temperature will also affect pre-attachment stage embryos but the magnitude of the effect has been reduced as embryos develop **(Ealy et al. 1993).** Holstein heifers subjected to heat stress from the onset of estrus had an increased proportion of abnormal and developmentally disturbed embryos as compared with heifers preserved at thermo-neutrality and the production of embryos by super ovulation is often reduced and embryonic development compromised in seasons when ambient temperatures are greater **(Putney et al. 1989).** Heat stress can affect endometrial prostaglandin secretion; leading to premature luteolys is a dembryoloss. However, the majority of embryo loss occurs before day 42 in heat-stressed cows (**Vasconcelos et al. 1998).** Heat stress in the period around the day of breeding was consistently associated with reduced conception rate **(Morton et al. 2007).** Abortions represent a loss of reproductive efficiency in normal bovine populations, and spontaneous abortion of dairy cows is an increasingly important problem that contributes substantially to low herd viability and production inefficiency by decreasing the number of potential female herd replacement sand lifetime milk production by increasing costs associated with breeding and premature culling**(Thurmond et al. 2005)**.

A positive relationship between heat stress during the pre-implantation period and early fetal loss in dairy cattle was found by **Lopez-Gatius et al. (2005).** Conception and pregnancy rates in pure bred Holste in cows under subtropical Egyptian conditions were significantly decreased from 31.6% and 26.3% at the lesser THI to11.5% and 9.9%, respectively, than at the greater THI. At the same time, conception and pregnancy rates were significantly reduced at either the lesser or greater THI while the embryonic loss rate was significantly increased from11.5% at the lesser THI to 22.2% at the greater THI **(El-Tarabany and El-Tarabany 2015a).** The relationship between THI and conception rate of lactating dairy cows to identify periods of exposure to heat stress relative to breeding in an area of moderate climate was studied by **Schuller et al. (2014).**The authors compared three different heat load indices related to conception rate: mean THI, maximum THI, and the number of hours above the mean THI threshold. The THI threshold for the influence of heat stress on conception rate was 73. It was statistically chosen based on the observed relationship between the mean

THI at the day of breeding and the resulting conception rate. Negative effects of heat stress were already apparent at lower levels of THI, and 1hour of mean THI of 73 or more decreased the conception rate significantly. The conception rate of lactating dairy cows was negatively affected by heat stress both before and after the day of breeding. The greatest negative impact of heat stress on conception rate was observed 21 to 1 day before breeding. When the mean THI was 73 or more in this period, the conception rate decreased from 31% to 12%. Compared with the average maximum THI and the total number of hours above a threshold of more than or 9hours, the mean THI was the most sensitive heat load index relating to conception rate. The conception rate of dairy cows rose in moderate climates and was highly negatively affected by heat stress. The relationship between temperature and breeding efficiency indicates that high environmental temperatures were associated with low breeding efficiency (**Cavestancy et al. 1985).**

Increased maximum temperature from 29.7ºC to 33.9ºC was associated with a decrease in conception rate on the first service from 25 to 7% and fetal loss rate of Holstein was significantly increased from 17.1% at low THI to 24.9% at greater THI and abortion and still birth rates were significantly increased from 3.6% and 3.8% at low THI to 7.2% and 5.9% at greater THI, respectively **(El-Tarabany and El-Tarabany 2015b).**The same authors concluded that animals had a significantly longer calving interval and days open at high THI compared with low THI. Holste in cows had a significantly longer calving interval and days open at high THI (449 and 173 days, respectively), compared with low THI (146 days) (**Bouraoui et al. 2002)**. Heat stress affects reproduction by inhibiting the synthesis of gonadotropin-releasing hormone and luteinizing hormone which is essential for oestrus behavior expression and ovulation **(Temple et al. 2015).** Further, only fewer standing heat are observed during heat stress which may ultimately lead to a decreased pregnancy rate. Body temperature greater than 39°C may harm the developing embryo from day 1-6 and lead to loss of pregnancy. Heat stress during late gestation may also lead to cows calving10-14days before their due date **(Morrill 2011).** Heat stress affects reproduction by inhibiting the synthesis of gonadotropin-releasing hormone and luteinizing hormone which is essential for estrus behavior expression and ovulation (**Temple et al. 2015).**It can be concluded that heat stress is one of the major concerns which affect the reproduction potential of farm animals almost in every part of the world. Elevated temperature and humidity as presented in THI negatively affect feed intake and altered hormonal concentrations leading to negatively affecting the reproductive efficiency of dairy cattle as presented in **Figure (5)(Thornton et al. 2015).**

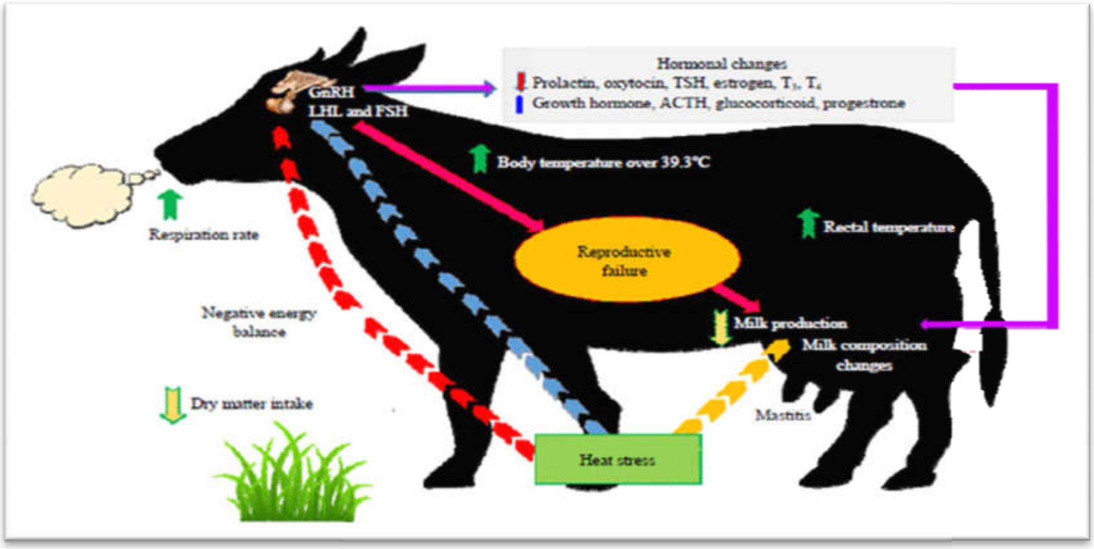

Figure 5. ***Pictorial representation of heat stress impacting reproduction in animals (Thornton et al. 2015).***

How to Reduce the Adverse Effects of Heat Stress on Farm Animals

Good management should aim to well-being, comfort, and maintaining the highly productive and reproductive efficiency of the animals. Under hot climate conditions, the major objective is to facilitate overcoming heat stress, although such criteria are sometimes difficult because of its occasional high costs, altogether with that most countries in which it occurs have severe financial constraints. Providing suitable housing, feeding, disease, and parasite control and heat stress alleviation practices, together with amelioration of the environment, can help heat-stressed animals to express their genetic potentials in tropical and sub-tropical areas **(Habeeb et al. 2018d; Sharaf et al. 2019).**

Although we cannot change the weather, we can modify the animal's environment to minimize heat stress and we can change feeding practices. Some of the management carry out to ameliorate the atmosphere and decrease the animal's heat production and some techniques that can be used to support the animal in dissipating the heat load and to correct the negative effects caused by heat stress. Such techniques are categorized into physical and nutritional techniques as follows:

First: Physical Techniques

The physical technique includes shading and cooling methods. Any cooling system that is to be effective must be into consideration the intense solar radiation, high ambient temperature, and the typically high daytime relative humidity. These challenging conditions tax the ability of any cooling system to maintain normal body temperature for the animals.

1- Reducing Sun Solar Radiation using Shading

a. Using natural shade: Trees are an excellent normal source of shade on the grass. Trees are not operative blockers of solar heat but the evaporation of moisture from leaf surface cools the immediate air.

b. Using artificial shade: Solar radiation is a major factor in heat stress. Obstructive its effects through the use of accurately built shade structures alone increase production strangely. Two options are available: permanent shade structures and portable shade structures **(Shearer et al. 2005).**

c. Using permanent shade structures: Major design parameters for permanent shade structures (orientation, floor space, height, ventilation, roof construction, feeding and water facilities, waste management system) depend on climate conditions. In hot and humid climates the alignment of the long-axis in an east-west direction achieves the maximum amount of shade and is the preferred orientation for tied animals, its north to south direction is better where animals are free to move. Space requirements are essentially doubled in a hot climate. Normal air program under the stable shade structure is affected by height and width, the slope of the roof, the size of the edge opening, etc. Painting metal roofs white and adding insulation directly under the roof will reflect and insulate solar radiation and reduce thermal radiation on animals.

d. Using portable or temporary shades: Portable shades offer some advantages in their ability to be moved to a new area in different pastures. Portable shade cloth, as well as a light roofing material, may be used on the temporary shades. Shading is one of the most important and cheapest ways to modify the cow's environment during hot weather. It is reported that cows shaded during the dry period gave birth to larger calves and had greater 100-day and 305-day milk yields than un-shaded dry cows. The shed should be placed on a top of a hill if possible, opened on all sides, and with wire or cable fences, the roof should be 3.5 to 4.0 meters high with its long dimension east-west to prevent exposure to high solar radiation. The roof slopes should be south-north to avoid vertical sun heat. The roof can be made of a 10 to 15 cm layer of hay held in place by wire above and below that realizes insulating and cool effects. Such a roof does not permit penetration of heat from the sun through to radiate into the animals, as well as, little radiant animals are reflected from its underside **(El-Sobhy 2005)**. Also, hot air under the shade can rise through the loose hay. If solid insulating material or wood shads roofs are used, the top should be painted white or shiny to reflect as much heat as possible, and the underside should be dull and dark to avoid reflecting animal heat it receives. The pens should be constructed of wire or cables to offer less resistance to air movement. The adequate surface area from shade per animal is 3.7 - 5.6 square meters for cattle and 1.86-2.79 square meters for sheep to be kept loose in the shed. Vegetation should surround the pens. Shade trees (with falling leaves during winter) should be scattered around and within the yards of the sheds, and such sheds should be scattered in the pasture or range. If livestock owners are compelled to build for housing their animals, they have to use insulating materials for the outer walls with adequate ventilation openings and the roofs should erect 60 cm more than the outer walls to protect the walls from direct sun heat. One of the first steps that should be taken to moderate the stressful effect of a hot climate is to protect the animals from direct and indirect solar radiation. It was estimated that the total heat load could be reduced from 30 to 50% with a well-designed shade **(El-Sobhy 2005)**.

2. Reducing Ambient Air Temperature for Cooling the Animal Body

a. Using air movement: Increasing air movement assists evaporation, makes cooling by perspiration more active, and aids removal of heat dissipated by animals in the form of radiation, conduction, and convection. It can transfer away moisture in the form of vapor and it also helps in cooling the surroundings (barn walls and roofs, fences, earth, etc.) which in turn helps to keep the animals cooler.

b. Using air conditioning: Air temperature of micro-environment can be lowered by air conditioning or refrigeration but the expense of such types of air cooling makes these impractical. The air condition technique improves animal productive and reproductive traits of heat-stressed animals. But, it has not practically, because of the high costs of electrical power supply.

c. Using fans and sprinklers: Several options are available. However, if you are going to put water on cows, air movement with fans is a necessity. Sprinklers should wet the animal but not the udder. Fans should move enough air to evaporate the water. Sprinklers can be controlled with timers to cycle the water on and off (i.e. 5 minutes on and 10 minutes off in a 15-minute cycle). Fans and sprinklers are usually placed near the feed bunk. The coolest place in the barn should be near the feed bunk to encourage eating. Fans, but not sprinklers, may be placed over free stalls. Fans and sprinklers should also be used in the holding area where temperatures increase rapidly when cattle are concentrated before milking. **Habeeb et al. (2001)** studied the role of niacin and sprinkling in improving milk yield composition and biochemical functions of the heat-stressed Friesian cows. The authors reported sprinkling the heat-stressed lactating cows with tap water caused a significant increase in milk yield (16.7%), milk protein (6.7%), and milk fat (6.0%) contents and a significant decrease in ash content (15.3%). The increase in daily milk yield, milk composition, and most blood components in the heat-stressed cows due to sprinkling may be attributed to that sprinkling cooled the animal's surface directly by conduction and evaporation (2427 joules dissipated per g water evaporated). The result was reducing the heating load of the summer season by increasing the heat loss through skin vaporization. This reduction in heat load improved the appetite of the animal to increase feed intake and consequently protein utilization either from feed or from digested rumen microorganisms, are increased. The increase in milk yield and composition may be also due to the role of sprinkling in alleviating the thermal hormonal alterations which depress the milk yield under heat stress, i.e., increase T_3 level and decrease cortisol level in sprinkled animals compared with not sprinkled. Consequently, the energy used for cooling processes may be spared for production functions. Moreover, sprinkling aids animals to reach a steady physiological state as indicated by restoration in blood components as well as a reduction in serum transaminases enzyme activities **(Abdel-Samee et al. 1989).**

d. Using sprinkler and fan cooling systems (Direct evaporative cooling): Sprinkling uses a large water droplet size to wet the hair coat to the skin. Cooling is accomplished as water evaporates from the hair and skin. Upper body sprinkling followed by forced-air ventilation reduces body temperature; increase feed intake and milk yield. Sprinkling the heat-stressed animals with tap water alleviates the heat stress on respiratory and cardiovascular systems resulting in significant decreases in respiration and pulse rates. Sprinkling also cooled the animal's surface directly by conduction and evaporation resulting reduction in the rectal temperature of the treated animals as compared to not sprinkled animals. The decrease in rectal temperature, respiration rate, and pulse rate and the increase in hemoglobin and packed cell volume values in the sprinkled animals may be due to increasing the heat loss through skin vaporization and at the same time, alleviating thermal hormonal alterations. The vaporization of 1ml of water requires 2.43 joules to convert into vapor and this is the amount of heat lost when 1 ml of the sweat evaporates from the skin **(Marai et al. 1997).**The importance of sprinkling in dissipating heat load is due to the high thermal capacity of water (1 cal. / g /°C) and its high heat of evaporation (580 cal. /g). Sprinkling the animal with water would help in dissipating heat from the skin of the animal through conduction and then evaporation of the water layers coating it (**Habeeb et al. 1992**).

e. Using sprayers in parlor exit lanes: Exit lane sprayers are designed to automatically spray water onto the cows as they pass through.

3- Increasing the evaporative cooling:

The evaporative cooling pad (corrugated cardboard or similar material) and a fan system that uses the energy of air to evaporate water is a more economically feasible method to cool the micro-environment.

a. Fine mist injection apparatus: Recent design of micro-environment evaporative cooling systems. This apparatus injects water under high pressure into a stream of air blown downward from above. Coolers are positioned in the roof of the shade structures or cowsheds and air is pulled through the cooler at very high rates. This system is effective in arid climates.

b. High-pressure foggers disperse: High-pressure foggers disperse is a very fine droplet of water that quickly evaporates, cooling the surrounding air and raising the relative humidity. The typical design incorporates a ring of fogger nozzles attached to the exhaust side of the fan. As fog droplets are emitted they are immediately dispersed into the fan's air stream where they soon evaporate. Animals are cooled as the cooled air is blown over their body and as they inspire the cooled air.

c. Misters: A mist droplet is larger than a fog droplet but cools the air by the same principle. These systems do not work well in windy conditions or in combination with fans in humid environments, where mist droplets are too large to fully evaporate before setting to the ground. The consequence is wet bedding and feed.

4. Enhancing the Animal's Natural Mechanism of Heat Loss:

a. Drinking cool water for cooling the animal body: Cooling in hot and humid climates emphasizes shade, wetting the skin, and moving air to enhance the animal's major mechanism for the dissipation of heat as evaporative cooling from the skin. The internal cooling technique (drinking cool or cold water) acts through the difference between the cool drinking water and warm urine execration temperature which helps in heat dissipation by conduction and also aids in evaporative cooling from the body surface **(Habeeb et al. 2012a, b).** Conclusively, drinking cool water is a method used to reduce the heat load on farm animals. The importance of drinking cool water in a hot climate may be attributed to the direct effect of the cooling process which aided animals to reach a steady physiological state concerning hemodilution normally occurring in heat-stressed animals. It is also possible that this cooling treatment improved the appetite of animals thus causing an increase in feed intake, especially, protein either from feed or from digested rumen microorganisms and consequently an increase in blood substrates, minerals, and vitamins. It is concluded that drinking cool water is an ideal means and easier technique for improving the productive performance of animals during the summer season **(Habeeb et al. 2012c)**.

The advantage of drinking cool water in the decline of the heat load is due to the heat dissipated via conduction as a result of the difference between the drinking cool water and urine temperatures. Moreover, the increase in body water due to the increase in water intake under a hot climate helps dissipation of heat by increasing evaporative heat loss through sweating and respiration and by conduction (**Marai et al. 1997**). Drinking cool water is a method used to reduce the heat load on farm animals. The importance of drinking cool water in a hot climate may be attributed to the direct effect of the cooling process which aided animals to reach a steady physiological state concerning hemodilution normally occurring in heat-stressed animals**.** It is also possible that this cooling treatment improved the appetite of animals thus causing an increase in feed intake, especially, protein either from feed or from digested rumen microorganisms and consequently an increase in blood substrates, minerals, and vitamins. It is concluded that drinking cool water is an ideal means and easier technique for improving the productive performance of animals under the summer season **(Habeeb et al. 2012b)**.

Clean water should be provided to cows where they congregate during the day and while in the holding pen and return alley from the milking parlor. The most serious nutrient needed by the animal is water. Water intake will rise by 30% or more during heat stress. Using wet feeds in the ration or adding water to the ration can also help. Water is one of the most important nutrients required for the maintenance of life and is involved in many physiological functions essential for the maximum performance of farm animals. Water requirements vary and are regulated by many factors such as intake of dry matter, environmental temperature, and loss of water from the body tissues **(Habeeb et al. 2012c**). Livestock needs a plentiful supply of good and clean water for normal rumen fermentation and metabolism, proper flow of feed through the digestive tract, good nutrient absorption, normal blood volume, and tissue requirements**.** The exposure of animals to elevated ambient temperatures induces an increase in the dissipation of excess body heat, to negate the excessive heat load. The dissipation of excess body heat is excluded by the evaporation of water from the respiratory tract and skin surface via panting and sweating **(Bewley et al. 2008)**. Drinking cool water in a hot climate maybe lead to the direct effect of the cooling process which aided animals to reach a steady physiological state with respect to hemodilution normally occurring in heat-stressed animals. It is also possible that this cooling treatment improved the appetite of animals and causing an increase in feed intake, especially, protein either from feed or from digested rumen microorganisms and consequently an increase in blood substrates, minerals, and vitamins **(Habeeb et al. 2010a, b).**

b. Shearing process: Effect of the wool shearing process during the hot summer season on some physiological, nutritional and growth performance was studied by **Habeeb et al. (2009)** and found that shearing lambs during summer season increased significantly the mean values of DM, OM, CP, CF and NEF digestibility percentages, improved significantly the nutritive values of ration (TDN and DCP), decreased significantly water intake, increased DM intake and body weight gain and improved feed conversion rate. Providing shearing resulted in reducing the adverse effects of heat stress in summer and in turn improved the metabolic media of shorn lambs to increase their productivity. Besides, providing shearing resulted in alleviating the burden of summer heat stress and consequently improved the heat tolerance of lambs raised under semi-arid conditions of the desert and resulted in decreasing the hostile effects of heat stress in summer and turn better the metabolic media of shorn lambs to increase their levels in proteins and thyroid hormones (T_4 and T_3) **(Habeeb et al. 2009;Bewley et al. 2008).**

Second: Nutritional Techniques

1. Nutritional dietary manipulation

Heat-stressed animals are required protein, fat and mineral funds to correct their negative balances since heat stress conditions induce a significant decrease in the DMI and a significant increase in protein and lipids catabolism. Besides heat stress conditions cause an increase in the excretion of urine and sweat containing minerals. Therefore, supplementation with ingredients that include crude protein or NPN (like urea) can be used to correct the negative nitrogen and minerals balance to correct protein and minerals negative balances **(Habeeb et al. 1989).** Supplementation of heat-stressed animals with protein, fat, vitamins, and mineral resources is required to correct their negative balances since heat stress induces a significant decrease in the DMI and a significant increase in excretion of urine and sweat containing minerals **(Omnisky et al. 2002).** Feeds should be administered during the coolest periods of the day, i.e. in the early morning late in the evening or by night, under hot climate conditions. On extremely hot days, it is preferred to keep the animals in the sheds. Mineral resource supplementation correct mineral's negative balances and consequently improved milk production **(Habeeb et al. 2018e; Habeeb et al. 2019).** A sharp increase in the secretion of potassium through sweat occurs during hot climate conditions so feeding diets that have a high dietary cation-anion difference improved DMI and milk yield and regulation of acid-base balance **(West et al. 1991).**

2. Ration Changes and Management: Rations need to be formulated to compensate for reductions in dry-matter. Lower fiber diets produce less metabolic heat, though care must be taken to ensure adequate fiber is still provided. Additional fat is an option when needing to increase energy while maintaining the necessary fiber. Preserve feed fresh by feeding during early morning hours and in the evening when animals have well appetites. Consider feeding only a third of the ration during the day and two thirds in the evening when temperatures are cooler. Adding a total mixture of ration preservatives will retard feed heating in the bunk. Keep bunks free of spoiled feed to maximize the animal's appetite.

3. Supplementary of Medicinal Plants to Animal Diet

The antioxidant activity is high in medicinal plants and antioxidants play an important role in inhibiting and scavenging radicals that protecting animals against infectious and degenerative diseases **(Anwar et al. 2004).** Some medicinal plant extracts and pure forms of active compounds were evaluated for their potential application as modifiers of rumen microbial fermentation to produce VFA which represents the main supply of metabolizable energy for ruminant **(Buswuet et al. 2005).**Medicinal plant extracts can be used as an antioxidant agent as it inhibited the non-enzymatic peroxidation which may increase immunity and may help the animals to tolerate the heat stress**(Awadallah 2002).**The antioxidant activity of medicinal plants was due to it acts as a scavenger of oxygen free radicals and protects hemoglobin from oxidation and lowers the production of reactive oxygen species like superoxide anions, H_2O_2 and nitrite radical generation **(Masuda et al. 2001).**Friesian calves under heat stress conditions fed diets supplemented daily with Nigella sativa seeds improved body weight gain **(Awadallah 2002)**.

4. Change in Time of Feeding:

Habeeb et al (2010a, b) showed that ewes in groups fed at 1200 and 1500h were better than ewes fed at 0900h in physiological and nutritional aspects. Respiration rate and temperatures of rectal, skin, and ear values decreased significantly while daily feed intake, dry matter intake, and water intake values increased significantly due to late feeding time under summertime. Digestibility of DM, OM, CP, CF, and NFE, as well as TDN and DCP of diet, improved significantly in ewes fed at 1200 and 1500 has compared to ewes fed at 0900h. The same authors concluded that late of feeding time decreased the heat load of the summer season on pregnant ewes and providing feed at 1200h or 1500h to the animal without adversely affecting performance under hyper thermia. **Schwartzkopf-Genswein et al. (2004)**reported that cattle fed late (21.00hr) in the day gained marginally more weight than cattle fed in the morning (0900). The lowest ADG was observed for morning fed steers, whereas the highest ADG was recorded for evening fed steers. Cattle fed in the evening also had higher significantly daily dry matter intake than morning fed cattle. These results indicate that it may be beneficial to feed in the evening from a cold climate thermodynamics perspective because the heat produced during fermentation and metabolism is shifted to the evening when cold stress is more likely to occur. Besides, in regions where heat stress is a concern, evening feeding would help decrease any additional heat load that could occur if the animals were fed during the warmest part of the day. **Simone (2010)** suggests that by altering feeding time to the afternoon or evening can help to alleviate heat stress. Heat is generated in the animal by the process of consuming and fermenting feed. Adjusting the time of feeding to late afternoon or evening will mean that additional heat generated from the feed will occur in the cooler hours of the day. Also, multiple feeding can be beneficial during hot weather by offering 20 to 40% of total feed delivery in the morning, and the remainder (60 to 80%) in the evening will help to alleviate heat stress.

CONCLUSION

Animals raised under the hot summer season of tropical and subtropical countries are suffering from severe climatic stress for almost 6 months of the year and become uncomfortable suffering extremely in production and reproduction. Exposure of animals to heat stress evokes a series of drastic changes in the biological functions ending to impairment the productive and reproductive performance Reduces the heat-stressed on animals can be applied by different techniques. The management practices concerned with hot climate involve modification of the environment, reducing the animal's heat production, and increasing its heat loss. Some techniques that can be used to help the animal in dissipating the heat load and to correct the negative effects caused by heat stress arc classified to physical and nutritional techniques.

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