

## Review Article

# Impact of Heat Stress of Hot Summer Season in Tropical and Subtropical Countries and How Reduce the Adverse Effects on Farm Animals

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## Abstract

The thermal comfort region for 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, nutritional, and physiological 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°C, 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% [1]. 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 [2]. 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 [3].

### 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 [4]. 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 animal 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 subsequent for insufficient evaporative heat loss. 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).

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°C, LCT as a range from -16 to -37°C for the animal [5]. The LCT for newborn calves is 10 °C in the dry and draught-free environment and decreases to 0°C by the time the calf is 1 month old [6].

### Thermoregulation mechanism

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

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 [7]. Heat dissipate in animals 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

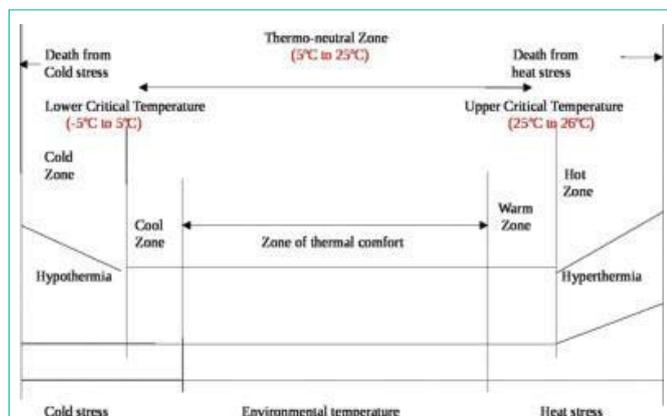


Figure 1: Lower (LCT) and Upper Critical ambient (UCT) temperatures and animal response [7].

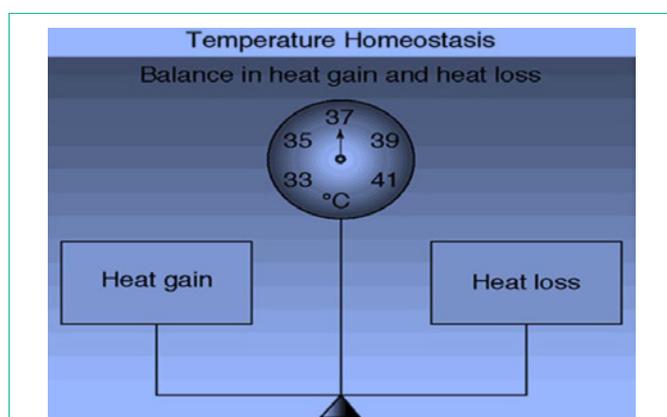


Figure 2: Balance between heat gain and heat loss [1].

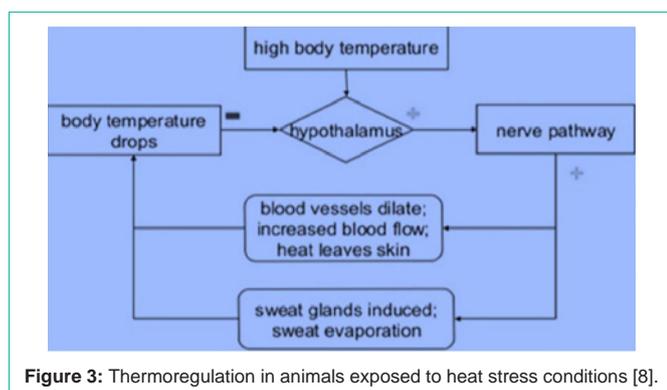


Figure 3: Thermoregulation in animals exposed to heat stress conditions [8].

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 heat-related diseases and syndromes may develop (Figure 3) [8].

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 a lowest of effort. Changes in ambient temperature change metabolism and affect the level of heat production and heat loss. If ambient temperature falls below the LCT, metabolism will increase in order to augment heat production. If ambient temperature rises above the evaporative serious

temperature, evaporative heat loss increases and food consumption is withdrawn, decreasing metabolism and heat production [9].

### 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) [10]. 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 [11]. Animal experiences heat stress when an animal loses the ability to dissipate sufficient heat to maintain thermal balance and body temperature escalations. Heat-stress 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 [12,13].

The summer season in Egypt, as a subtropical contry, (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/M2) 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 [14,15]. 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 [16,17].

### Stages of heat stress

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 [18].

**Heat rash:** Heat rash is skin irascibility affected via extreme sweating throughout hot and humid weather. Heat rash is the slightest severe heat stress that takes place once sweat blocks openings. Still, heat rash is common causes only temporary discomfort.

**Heat syncope:** Heat syncope may affect animals that are not acclimatized to hot environments. Syncope normally is the unexpected loss of consciousness due to the deficiency of sufficient blood and O<sub>2</sub> to the brain. Heat stress can reason by diverting blood to the lower body or extremities at the income of the brain.

**Heat cramp:** Heat cramp is painful muscle cramps produced by excessive sweating which usually caused by losing too much water and salt via sweating, especially, when water is replaced by drinking but not salt, particularly, potassium. Heat cramp is muscle contractions follow after strenuous movement in a hot atmosphere when the animal body becomes down of salt and water and consequences from the decreased bloodstream to the brain. Heat cramp is frequently very painful caused by electrolyte deficiencies that result from prolonged

periods of extreme sweating. This sweating reduces the body's salt and moisture levels. Low salt levels in muscles cause painful cramps.

**Heat exhaustion:** Heat collapse happens when extreme sweating in a hot situation decreases the blood volume and excessive loss of water and salt via excessively greatly sweating. Symptoms of heat exhaustion or collapse contain: heavy sweating, great weakness, dizziness, confusion, nausea, clammy, moist skin, flushed complexion, muscle cramps, raised animal body temperature, loss of appetite, hyperventilation, shallow breathing, cool moist skin, weak and rapid pulse (120-200), low blood pressure, dehydration, decreasing of blood circulation and decreased blood flow to the brain.

**Heat stroke (Hyperthermia):** Heatstroke occurs when the core body temperature rises above 40.5°C and the body's internal systems start to shut down. Heatstroke is the most serious heat-related disorder. It occurs when the body becomes unable to control its temperature: the body's temperature rises rapidly, the sweating mechanism fails, and the body is unable to cool down. When heat stroke occurs, the body temperature can rise to 106 degrees Fahrenheit or higher within 10 to 15 minutes. Heatstroke can cause death or permanent disability if emergency treatment is not given. Symptoms of heatstroke include hot, dry skin or profuse sweating and high body temperature (103°F), a distinct absence of sweating (usually); hot red or flushed dry skin; rapid pulse; difficulty breathing; constricted pupils [19].

### 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 [20]. 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 [21]. 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 [22] 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).

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 [23]. 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 [24,25]. Exceeding the upper critical environmental temperature related to the decline of the productive and reproductive performance of animals [9].

Explaining the mechanisms involved in increased heat loss when the body becomes overheated. Guyton [26] listed that overheating encourages the preoptic thermostatic region to 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 [27,28]. 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 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 [29], 22-35% in goats [30] or 8-10% in buffalo heifers [31]. 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 [22]. As a result of the stage of negative energy balance, as a result, body weight and body condition score go depressed [32]. 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 finale to deficiency of production and reproduction of animals [2]. Besides, a high level of cortisol detected in the animals exposed to heat stress may be associated with depression in animal production [33]. 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 [34]. 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 [12,13].

### Syptoms of heat stress in farm animals [1,11]

1. Reduced activity, restlessness and crowding under shade and

increased salivation.

2. Increased respiration rate: 80 to 120 bpm under moderate heat stress, 120 to 160 bpm under strong heat stress, and over 160 bpm under severe heat stress.

3. Rates of the gut and ruminal motility are reduced

4. Lethargy and decreased activity.

5. Decreased feed intake: Feed Intake (FI) decreased by >10-15% at 25-27 °C with a marked decline of 40% above 30°C. The FI of animals at 40°C is reduced by 20-40%. During heat stress, DMI, gut motility, rumination, ruminal contractions are reduced due to depressing animal appetite by having a direct negative effect on the appetite center of the hypothalamus [35].

6. Increased sweating: In animals, two types of sweating can be distinguished: both are involved in heat dissipation. The first type is insensible sweating or perspiration that leaves the body at all times unless the relative humidity is 100%. The second kind is thermal sweating occurs as the principle evaporative cooling mechanism of the animal when the environmental temperature increases [36].

7. Increased rectal temperature (>102.6 F): The normal temperature of animals is 101.5 F. Rectal temperature is an indicator of thermal balance and may be used to evaluate the adversity of the high environmental temperature. In severe conditions of heat stress the rectal temperature increase. The effect is increased when the relative humidity is greater than 50%. A rise of 1°C or less is enough to reduce performance in most animals [37].

8. Reduced heart rate: The normal panting is 35-45 breathing while under heat stress, panting increased to >80 breaths per minute. The initial increase in heart rates slows down when the heat stress persists. Reduced heart rate is more usual in the heat-stressed animal as it is concomitant with the reduced rate of heat production as a reaction to high environmental temperatures.

9. Increased water intake: Heat stress increases Water Intake (WI) by 5 times the normal level in temperate regions. Water and macro-mineral needs subjective heavily by demands to sustain homeostasis and homeothermy are changed for animals during heat stress. Lactating animals have a large turnover of water and electrolytes [38]. Warm air stress increases water and electrolyte metabolism. Extreme water intake during the hot period was at the lowest doubled from the WI under a comfortable climate. This is mainly due to lower plasma concentrations of metabolic hormones [35].

10. Increased animal water content: The Total Body Water (TBW) is estimated to range between 75 and 81% of the bodyweight for animals. Heat stress concurrently influences water metabolism (35). Under current stress, animals tend to have increased water content in the rumen as a result of a faster water turnover rate. Water loss from an animal is a continuous process; taking place all the time and increasing during the heat stress due to further evaporative water loss. WI of an animal under heat-stress increases progressively [39].

11. Reduced milk production by 10-20% or more: It is accepted that heat stress is the major cause of lost production in animals in hostile regions. Production of animals is reduced by 15%, accompanied by a 35% decrease in the efficiency of energy utilization

for productive purposes when the animal is transferred from an air temperature of 18 to 30 °C. Animal production declines as a direct result of high ambient temperatures due to the negative effects the heat stress on the secretory function of the udder [39,40].

12. Metabolic responses are reduced: Under heat-stress, metabolism is reduced due to reduced thyroid hormone secretion and gut motility, resulting in increased gut fill. Plasma growth hormone concentration and secretion rate decline with hot temperatures. Ruminal pH is normally lower in the heat-stressed animal.

13. Electrolyte balance: Great changes in dietary electrolyte balance and acid/base balance associated with heat-stress. The major electrolytes involved in dietary electrolyte balance are Na<sup>+</sup>, K<sup>+</sup>, CL<sup>-</sup> are the main ions involved in sweat [41].

14. Heavy loss of electrolytes: evaporative heat loss through sweating and panting is the primary mechanism for heat loss at great environmental temperatures. As a result of water loss from sweating, thirst is increased and more urine is excreted and the huge water flux resulting from increased water consumption also causes heavy loss of electrolytes. Potassium loss from the skin increases by 500% in heat-stressed animals and in attempts to conserve potassium, animals increase urinary excretion rates of sodium.

15. Increased panting: In high temperatures, there is panting respiration to cool the body by evaporative cooling. The rapid loss of CO<sub>2</sub> results in respiratory alkalosis. Animals compensate by increasing the urinary output of HCO<sub>3</sub><sup>-</sup>. Persistent replacement of this ion is serious to the controlling of blood chemistry. Heat stress increases dietary requirements for the key electrolytes, Na<sup>+</sup>, K<sup>+</sup>, and HCO<sub>3</sub><sup>-</sup>. Therefore dietary electrolyte balance is important in locations where environmental temperatures exceed 24 °C and are exacerbated if relative humidity exceeds 50%. Running of the dietary electrolyte balance is based on addition essential body salts and electrolytes to the drinking water and feed. It stabilizes the dietary electrolyte balance, promotes homeostasis, assists the osmoregulation of body fluids, stimulates appetite, and ensures normal skeletal development. Animal sweat contains a large amount of potassium. Mineral recommendations during heat stress include: Potassium: > 1.4% of DM, Sodium: 0.35 to .45% of DM Magnesium: 0.35 to 0.40% of DM and Chlorine: < 0.40 % of DM. Mineral alterations should be prepared several weeks before the onset of high temperatures so minerals are present in the body when needed. Several feed additives, such as Buffer and yeast culture, have shown benefits when addressing heat stress [42].

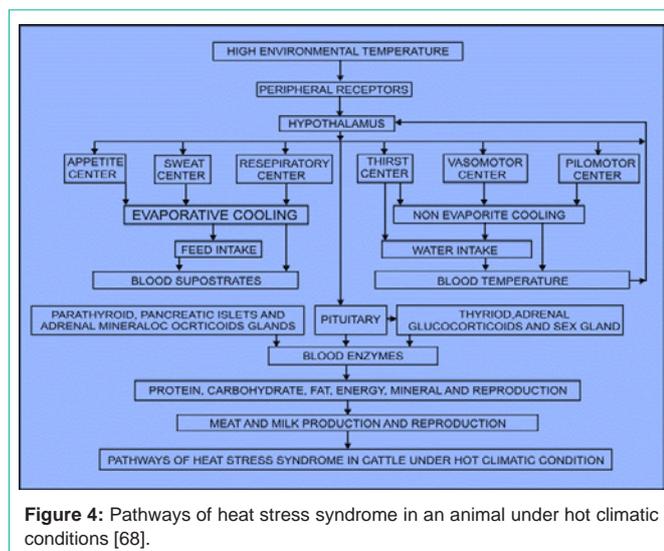
16. Oxidative stress: The terms oxidative stress, oxidative damage, free radical and antioxidant have become an integrated part of the variety of scientific discussions in issues related to chemistry, biology, and research in biosciences. Oxidative stress commonly occurs following heat stress in tropical regions and affects negatively on animal's performance. The adverse effect of heat stress harmed enzymatic activity [43]. Glutathione (GSH) is an antioxidant in animals protects cells from oxidative damages and is capable of preventing damage to important cellular components caused by reactive oxygen species such as free radicals, peroxides, lipid peroxides, and heavy metals. GSH has been mediating the initial response for acquiring tolerance to heat stress. GSH serves vital functions in animals, antioxidant defense, scavenging free radicals,

and other reactive species, removing hydrogen and lipid peroxides, preventing oxidation of bio-molecules, signal transduction, and gene expression and DNA and protein synthesis, and proteolysis. Different kinds of stress result in a reduction in the concentration of reduced GSH in animal organs. GSH synthesis is impaired under stress conditions, leading to GSH deficiency. A decrease in GSH and an increase in GSSG were found in the blood of heat-stressed cattle. Significant inhibition of total ATPase activity and cholinesterase enzymes were found in animals under heat stress conditions [44]. The DMI in heifers was negatively correlated with THI during all seasons compared to thermoneutral season and the results reveal that the heifers exhibited more signs of heat stress during hot-dry and hot-humid seasons which were reflected by higher concentrations of cortisol, superoxide dismutase and malondialdehyde and more deviation in the normal daily rhythm of various physiological functions and concluded that physiological and oxidative parameters were positively correlated with the THI [45]. Fast production of free radicals and reactive oxygen species and/or a decrease in antioxidant defense mechanisms result in oxidative stress [46]. The effect of heat stress is known to induce oxidative stress which induces the production of Reactive Oxygen Species (ROS). The high production of ROS and a decrease in antioxidant defense lead to the cause of many diseases and leading to the onset of health disorders in cattle [47]. Roles for GSH in signal transduction, gene expression, apoptosis, protein glutathione-relation, and nitric oxide metabolism are well discovered [48]. Specifically, several studies have led to the free radical theory of human diseases and to the advancement of nutritional therapies to improve GSH status under various pathological conditions [49]. Most recently, studies of GSH turnover were initiated to provide much-needed information about quantitative aspects of GSH synthesis and catabolism in the animal body and specific cell types. Adequate protein nutrition is crucial for the maintenance of GSH homeostasis in animal enteral or parenteral cystine, methionine, N-acetyl-cysteine, and l-2-oxothiazolidine-4-carboxylate are effective precursors of cysteine for tissue GSH synthesis [50]. The dietary of antioxidant nutrients is important in protecting tissues against free radical damage since free radical reactions are an integral part of normal metabolism. The antioxidant function enhances immunity by maintaining the structural and functional integrity of the immunity system. The reduction in immunity will affect animal production efficiency through increased susceptibility to diseases, thereby leading to increased animal morbidity and mortality [51]. The protection against free radical damage by the dietary of antioxidant nutrients has become very important in the studies related to ruminant production and reproduction. Antioxidant status gives complementary information about the metabolic status of the animal rather than metabolic parameters alone [52]. Oxidative stress markers can be divided into non-enzymatic antioxidants and antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase [53]. Oxidative stress commonly occurs following heat stress in tropical regions and affects animals and Glutathione protects cells from oxidative damages. The oxidative balance is affected during heat stress periods. Fast production of free radicals and reactive oxygen species and/or a decrease in antioxidant defense mechanisms result in oxidative stress [46].

### **Negative effects of heat stress on animal performance**

**Negative effects of heat stress on growth traits:** Growth is orderly

genetically and environmentally by well-balanced offered nutrients, hormones, and enzymes. Most revisions presented that growth performance are 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 of 50% when introduced to a tropical or sub-tropical environment due to heat stress [2]. 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) [54]. The stressful condition of hot climatic conditions induced a significant reduction in DBWG of bovine calves by 25.5% with differed from calf to another and ranged between 3.2 to 48.4% [55]. 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 [56]. 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 [57]. 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 [58]. 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 summer season, respectively [59]. 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 calves 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% [60]. 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 [61], 14-29% in Guernsey cattle [62], 51% in Friesian calves [63]. and 46% [64]. 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 (126.5kg) or spring (118.0kg) to summer (91.0kg), under natural hot climate [61]. 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 [61]. In Holstein's calves, heat stress caused a significant decrease (15%) in TBS [62]. In growing buffaloes, TBS was similarly lower at 32°C and 50% RH than at 18°C and 50% RH (100 and 124kg, respectively) [65]. TBS decrease from spring to summer (110.9 to 59.5kg) and from summer combined with solar radiation (59.5 to 58.6kg) in buffaloes [66]. 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 [67]. The heat stress-induced a significant decrease in TBS in both male and female Friesian calves [60]. A pathway of heat



stress syndrome in cattle under hot climatic conditions was suggested by Kamal [68] to clarify that production and reproduction of cattle affected negatively by heat stress conditions (Figure 4).

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 [2]. 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 to the low metabolically energy left for growth, since more energy is consumed by the increase in respiratory frequency that occurs in hot ambient temperature [2]. 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 increase in glucocorticoids and catecholamines [69] and decrease in insulin level [63] T4 and T3 secretions and decrease in feed intake, feed efficiency, digestibility and feed utilization [70,71]. The animal try 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 [22]. 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 in the depression of gain either live or solids [72].

Specifically, there is a reduction in body amino-N [73] 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 temperature, 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 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 the 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 [68].

**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 [74]. Milk production of imported pure breeds from mild climates to the humid tropics rarely exceeded 12-15kg a day and most usually was less than 10kg daily [75]. Milk yield in early, mid, and late lactation decreased by 25, 41, and 47%, respectively, at 72h after the beginning of heat exposure [76]. At 30°C, the high producing animals showed a mean reduction of 2.0kg/day compared to a reduction of only 0.65 kg/day for the low producing animals [77]. DMI and milk yield in domestic animals decreased and water intake increased with increasing environmental temperature [78]. 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) [79]. 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 [33]. 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 [33]. Increasing air temperature, temperature-humidity index are related to decreased dry matter intake and milk yield, and reduced efficiency of milk yield [80].

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 [81]. 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 [68].

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 [2].

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 [82]. 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 [83]. 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  $\alpha$ -keto acids [69].

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.

**Negative effect of heat stress on reproductive efficiency of dairy cattle:** Negative relationships between THI and reproductive performances in animals were documented by many authors [84-87]. 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 conception rate of lactating dairy cows by around 30% relative to days of breeding and when maximum THI during three to one-day pre-artificial insemination values were greater than 80, conception rate decreased from 30.6% to 23.0% [88].

Heat stress causes reproductive problems such as reduced semen quality, lower birth weights, decrease the immune system, and harmed the developing embryo lead to lower conception rates and fertility [89]. 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 [90]. 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 [91]. 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 [92]. 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 30°C [91]. In contrast, conception rates for heifers did not decline until 35°C. 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 [93].

High temperatures lowered 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 [94]. Higher environmental 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 [95]. Heat stress after insemination reduced the weight of corpora lutea and impaired concept growth [96]. Heat stress also increases the production of prostaglandin secretion (GF2 $\alpha$ ) in the endometrium, leading to the early regression of corpus leuteum or the death of embryos. The heat stress from 8 to 16 days after insemination modulated the uterine environment reduced the weight of corpora lutea and impaired concept growth [96]. Heat stress decreases the intensity and duration of behavioral estrus so that a smaller proportion of cows are detected in estrus under heat stress conditions and increases the embryonic mortality [97]. 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 [98]. High ambient temperature will also affect pre-attachment stage embryos but the magnitude of the effect has been reduced as embryos develop [99]. Holstein heifers subjected to heat stress from the onset of estrus had increased proportion of abnormal and developmentally disturbed embryos as compared with heifers preserved at thermo-neutrality and the production of embryos by superovulation is often reduced and embryonic development compromised in seasons when ambient temperatures are greater [100]. Heat stress can affect endometrial prostaglandin secretion, leading to premature luteolysis and embryo loss. However, the majority of embryo loss occurs before day 42 in heat-stressed cows [101]. Heat stress in the period around the day of breeding was consistently associated with reduced conception rate [102]. 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 replacements and lifetime milk production by increasing costs associated with breeding and premature culling [103]. 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. [104]. Conception and pregnancy rates in purebred Holstein cows under subtropical Egyptian conditions were significantly decreased from 31.6% and 26.3% at the lesser THI to 11.5% 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 embryonic loss rate was significantly increased from 11.5% at the lesser THI to 22.2% at the greater THI [86]. 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. [105]. 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 1 hour 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 9 hours, 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 highly negatively affected by heat stress. The relationship between temperature and breeding efficiency indicates that high environmental temperatures were associated with low breeding efficiency [106]. Increased maximum temperature from 29.7°C to 33.9°C 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 stillbirth rates were significantly increased from 3.6% and 3.8% at low THI to 7.2% and 5.9% at greater THI, respectively [87]. The same authors concluded that animals had a significantly longer calving interval and days open at high THI compared with low THI. Holstein cows had a significantly longer calving interval and days open at high THI (449 and 173 days, respectively), compared with low THI (146 days) [107]. Heat stress affects reproduction by inhibiting the synthesis of gonadotropin-releasing hormone and luteinizing hormone which is essential for oestrus behavior expression and ovulation [108]. Further, only fewer standing heats are observed during heat stress which may ultimately lead to 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 calving 10-14 days before their due date [109]. Heat stress affects reproduction by inhibiting the synthesis of gonadotropin-releasing hormone and luteinizing hormone which is essential for estrus behavior expression and ovulation [108] as presented in Figure 5.

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.

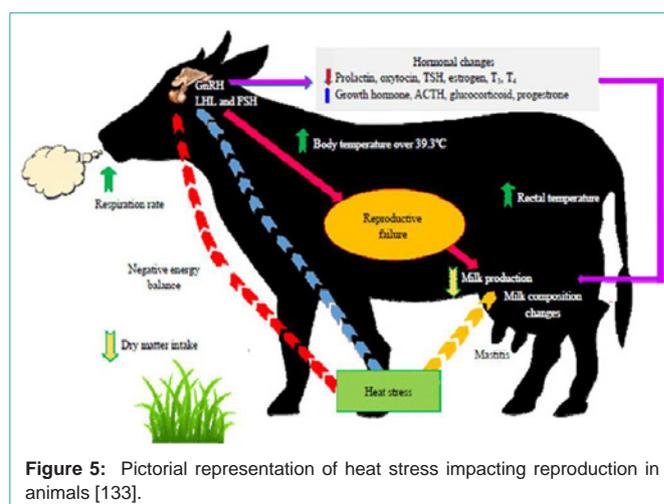


Figure 5: Pictorial representation of heat stress impacting reproduction in animals [133].

### How 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 [110,111]. 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, physiological, 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.

**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.

**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 [112].

**Permanent shade structures:** Major design parameters for permanent shade structures (orientation, floor space, height, ventilation, roof construction, feeding and water facilities, waste

Temperature		% 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	85	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	80	81	82	83	84	85	86	86	87	88	89	90	91
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	85	86	87	88	89	90	91	92	93	94	95
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	89	90	91	92	94	95	96	98	99	101	102	104	105	107	108	110
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	97	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

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

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.

**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 [113]. Also, hot air under the shade can rise through the loose hay. If solid insulating material or wood shades 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 [113].

**Reducing ambient air temperature for cooling the animal (Air movement):** Increasing air movement assistances evaporation, makes cooling by perspiration more active, and aids removal 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 animal's cooler.

**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.

**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. [114] 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 proteins 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 T3 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 [42].

**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 the 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 [64]. The importance of sprinkling in dissipating heat load is due to the high thermal capacity of water (1cal. / g /°C) and its high heat of evaporation (580cal. /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 [2].

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

**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.

**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 are pulled through the cooler at very high rates. This system is effective in arid climates.

**High-pressure foggers disperse:** High-pressure foggers disperse is a very fine droplet of water which 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.

**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.

**Enhancing the animal's natural mechanism of heat loss:** 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 excretion temperature which helps in heat dissipation by conduction and also aids in evaporative cooling from the body surface [57,115]. Conclusively, drinking cool water is a method used to reduce the heat load on farm animals. The importance of the drinking cool water under hot climate may be attributed to the direct effect of the cooling process which aided animals to reach a steady physiological state with respect 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 mean and easier technique for improving the productive performance of animals under the summer season [116].

**Drinking cool water:** The advantageous of drinking cool water in the decline of the heat load is due to the heat dissipated via 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 [64]. Drinking cool water is a method used to reduce the heat load on farm animals. The importance of the drinking cool water under hot climate may be attributed to the direct effect of the cooling process which aided animals to reach a steady physiological state with respect 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 mean and easier technique for improving the productive performance of animals under the summer season [115].

**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. [117] 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  $T_3$ ) [117,118].

**Water:** The most serious nutrient needed by the animal is water. Water intake will rise by 30% or more during heat stress. 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. 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 [116]. 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 [118]. Drinking cool water under hot climate maybe lead to the direct effect of the cooling process which aided animals to reach a steady physiological state with respect 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 [119,120].

## Second: Physiological techniques

**Diaphoretics administration:** Diaphoretics substances compounds are used to increase sweat production for increasing the evaporative cooling of the heat-stressed animals. But using these substances increased each of the rectal temperatures and respiration rates [64].

**Diuretics administration:** Diuretics 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.

**Goitrogens administration:** Goitrogens compounds block thyroidal iodine uptake and consequently depress thyroid gland activity and consequently the secretion of thyroxin hormone in the heat-stressed animals is reduced to decline heat production. But using these compounds is not favored under heat stress conditions, since the treated animals under such conditions may be affected seriously due to their need to more energy for the greater muscular activity for the high respiratory activity [65].

**Hormonal substances administration:** Supplementation or injection of hormones can be used as a method for the alleviation of heat load on animals since the secretion of most of the hormones is low under heat stress conditions.

However, injection of thyroxin for this purpose was found to be associated with the increase of body temperature of the animals. 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 respiration rates. But these methods need some specific precautions and at the same time are expensive.

### Third: Nutritional techniques

**Nutritional dietary manipulation:** Heat-stressed animals are required to protein, fat and mineral funds to correct their negative balances, since heat stress conditions induce significant decrease in the DMI and 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. 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 [121]. 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. In extremely hot days, it is preferred to keep the animals in the sheds. Mineral resources supplementation correct minerals negative balances and consequently improved milk production [122,123]. 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 [124].

**Ration changes and mangement:** 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.

**Supplemetry 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 [125]. 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 [126]. 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 [127]. 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 [128]. Friesian calves under heat stress condition fed diets supplemented daily with *Nigella sativa* seeds improved body weight gain [127].

**Change in time of feeding:** Habeeb et al. [119,120] 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 1500h as 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 hyperthermia. Schwartzkopf-Genswein et al. [129] 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 [130] 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 [131-133].

## 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 in 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, physiological, and nutritional techniques.

## References

1. Wiersma F. Department of Agricultural Engineering. The University of Arizona, Tucson. 1994.

2. Habeeb AAM, Marai IFM, Kamal TH. Heat stress, Chapter 2 In Farm Animals and Environment, edited by Philips CJC and Piggins D. Commonwealth Agriculture Bureau International, Wallingford United Kingdom. 1992; 27-47.
3. McMichael AJ, Ando M, Carcavallo R, Epstein P, Haines A, Jendritsky G, et al. Climate change and human health: an assessment by a task group on behalf of the WHO, the World Meteorological Organization, and the United Nations Environment Program. (WHO/EHG/96.7.), Geneva. 1996.
4. Berman AJ. Estimates of heat stress relief needs for Holstein dairy cows. *Journal of Animal Science*. 2005; 83: 1377–1384.
5. Berman A, Folman YM, Kaim M, Mamen Z, Herz D, Wolfenson A, et al. Upper critical temperatures and forced ventilation effects for high-yielding dairy cows in a tropical climate. *J Dairy Sci*. 1985; 68: 488-495.
6. Hamada T. Estimation of lower critical temperatures for dry and lactating dairy cows. *J Dairy Sci*. 1971; 54: 1704-1705.
7. Igono MO, Steevens BJ, Shanklin MD, Johnson HD. Spray cooling effects on milk production, milk and rectal temperatures of cows during a moderate temperature summer season. *J Dairy Sci*. 1985; 68: 979-985.
8. Collier RJ, Zimbelman RB, Rhoads RP, Rhoads ML, Baumgard LH. A re-evaluation of the impact of temperature humidity index (THI) and black globe humidity index (BGHI) on milk production in high producing dairy cows. Proceedings of the 24<sup>th</sup> Annual Southwest Nutrition and Management Conference, Tempe, Arizona, USA. 2009; 113-125.
9. Igono MO, Bjotvedt G, Sanford Crane HT. Environmental profile and critical temperature effects on milk production of Holstein cows in the desert climate. *Int J Biometeorol*. 1992; 36: 77-87.
10. Armstrong DV. Heat stress interactions with shade and cooling. *J Dairy Sci*. 1994; 77: 2044-2050.
11. Praks J. The effect of temperature stress on dairy cows. *Veterinary ruminants*. 2010.
12. Marai IFM, Habeeb AAM. Buffalo's biological functions as affected by heat stress. A review. *Livest Sci*. 2010a; 127: 89-109.
13. Marai IFM, Habeeb AAM. Review: Buffalo's reproductive and productive traits as affected by heat stress. *Tropical and Subtropical Agroecosystems*. 2010b; 12: 193-217.
14. Habeeb AAM, El-Tarabany AA, Gad AE, Atta MA. Negative Effects of Heat Stress on Physiological and Immunity Responses of Farm Animals. *International Technology and Science Publications (ITS). Agricultural Studies*. 2018a; 2: 1-18.
15. Habeeb AA, Gad AE, EL-Tarabany AA, Atta MAA. Negative Effects of Heat Stress on Growth and Milk Production of Farm Animals. *Journal of Animal Husbandry and Dairy Science*. 2018b; 2: 1-12.
16. Habeeb AAM, EL-Gohary ES, Saleh HM, El-Deeb MM. Effect of Summer Heat Stress Conditions and Feeding Protein Level on Milk Yield and Composition in Ossimi Ewes and Their Lambs Performance. *Egyptian J of Applied Sciences*. 2008a; 23: 409-429.
17. Habeeb AAM, EL-Gohary ES, Saleh HM, Aboelnaga AI. Effect of Summer Heat Stress Conditions and Feeding Protein Level on Blood Components in Ossimi Ewes and Their Suckling Lambs. *Egyptian J of Applied Sciences*. 2008b; 23: 388-408.
18. National Weather Service. Heat Index Calculator. National Weather Service Jackson, Kentucky. Heat Index Charts-National Climatic Data Centre. 2005.
19. Sawka MN, Lutzka WA, Montain SJ, Cadarette S, Kolka MA. Physiologic tolerance to uncompensable heat, Intermittent Exercise, Field vs. Laboratory. *Medicine and Science in Sports and Exercise*. 2001; 33: 422-430.
20. Habeeb AA, EL-Tarabany AA, Gad AE, Atta MAA. Negative Effects of Heat Stress on Physiological and Immunity Responses of Farm Animals. *International Technology and Science Publication*. 2018c; 2: 1-18.
21. International Commission for Thermal Physiology (ICTP). Glossary of terms for thermal physiology, 3<sup>rd</sup> edition. *Jpn J Physio*. 2001; 51: 245–280.
22. Kadzere CT, Murphy MR, Silanikove N, Maltz E. Heat stress in lactating dairy cows: A review. *Livestock Production Science*. 2002; 77: 59-91.
23. Garner JB, Douglas A, Williams A, Wales A, Marett A, DiGiacomo B, et al. Responses of dairy cows to short-term heat stress in controlled-climate chambers. *Animal Production Science*. 2017; 57: 1233-1241.
24. Wolff LK, Monty DE Jr. The physiologic response to intense summer heat and its effect on the estrous cycle of nonlactating and lactating Holstein-Friesian cows in Arizona. *Am J Vet Res*. 1974; 35: 187-192.
25. Hales JRS, Hubbard RW, Gaffin SL. Limitation of heat tolerance. In: *Handbook of Physiology (Fregly MJ, Blatteis CM, editors)*. New York, Oxford University Press. 1996; 279-355.
26. Guyton AC. *Textbook of medical physiology*. 3rd (Saunders WB. editor.), Co. Philadelphia. 1969; 985-992.
27. Agarwal A, Singh M. Impact of microclimatic modification on the production of dairy animals during summer. *Indian Dairyman*. 2006; 58: 49-59.
28. Habeeb AAM. Negative effects of heat stress conditions during the hot summer season in Egypt on rabbits productivity and alleviation of these effects using some supplementary nutrients. *International Journal of Agriculture and Biological Sciences*. 2019; 3: 1-15.
29. Rhoads RP, Baumgard LH, Suagee JK, Sanders SR. Nutritional interventions to alleviate the negative consequences of heat stress. *Adv Nutr*. 2013; 4: 267–276.
30. Hamzaoui S, Salama AAK, Caja G, Albanell E, Flores C, Such X. Milk production losses in early lactating dairy goats under heat stress. *J Dairy Sci*. 2012; 95: 672–673.
31. Hooda OK, Singh S. Effect of thermal stress on feed intake, plasma enzymes and blood biochemicals in buffalo heifers. *Indian J Anim Nutr*. 2010; 27: 122–127.
32. Lacetera N, Bernabucci U, Ronchi B, Nardone A. Body condition score, metabolic status and milk production of early lactating dairy cows exposed to a warm environment. *Riv Agric Subtrop Trop*. 1996; 90: 43–55.
33. Habeeb AAM, Ibrahim MKh, Yousef HM. Blood and milk contents of triiodothyronine (T3) and cortisol in lactating buffaloes and changes in milk yield and composition as a function of lactation number and ambient temperature. *Arab J of Nuclear Sciences and Applications*. 2000; 33: 313-322.
34. Bray DR, Bucklin R. Recommendations for Cooling Systems for Dairy Cattle. Fact Sheet DS-29. University of Florida Cooperative Extension Service, Gainesville, Florida. 1996. 32611.
35. Yasothai R. Effect of climate on nutrient intake and metabolism and countered heat stress by nutritional manipulation. *International J of Science, Environment and Technology*. 2014; 3: 1685-1690.
36. Chandrahas A, Das KS. Heat stress and ameliorative measures in buffaloes. *Livestock International*. 2005; 2: 5-8.
37. McDowell RE, Hooven NW, Camoens JK. Effects of climate on performance of Holsteins in the first lactation. *J Dairy Sci*. 1976; 59: 965-973.
38. Shalit O, Maltz E, Silanikove N, Berman A. Water, Na, K, and Cl metabolism of dairy cows at the onset of lactation in hot weather. *J Dairy Sci*. 1991; 74: 1874-1883.
39. Silanikove N. Effects of water scarcity and hot environment on appetite and digestion in ruminants: a review. *Livest Prod Sci*. 1992; 30: 175-194.
40. Silanikove N. Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livestock Production Science*. 2000; 67: 1–18.
41. Farooq U, Samad HA, Shehzad F, Qayyum A. Physiological responses of cattle to heat stress. *World Applied Sciences Journal*. 2010; 8: 38-43.
42. Abdel-Samee AM, Habeeb AAM, Kamal TH, Abdel-Razik MA. The role of urea and mineral mixture supplementation in improving the productivity of heat-stressed Friesian calves in the subtropics. Proceedings of the 3<sup>rd</sup> Egyptian-British Conference on Animal Fish and Poultry Production, Alexandria University, Alexandria, Egypt. 1989; 2: 637-641.
43. Habeeb AAM. Biosynthesis and Roles of Glutathione in heat Stressed

- Animals. *International Journal of Scientific Research in Chemistry*. 2018a; 3: 91-98.
44. Habeeb AAM. Oxidative Stress in Animals Exposed to Different Stressful Conditions. *International Journal of Nutritional Sciences*. 2018b; 3: 1027-1029.
  45. Lakhani P, Kumar P, Lakhani N, Alhussien MN. The influence of tropical thermal stress on the seasonal and diurnal variations in the physiological and oxidative status of Karan Fries heifers. *Biological Rhythm Research*. 2020; 51: 837-846.
  46. Bernabucci U, Ronchi B, Lacetera N, Nardone A. Markers of oxidative status in plasma and erythrocytes of transition dairy cows during the hot season. *Journal of Dairy Science*. 2002; 85: 2173-2179.
  47. Miller JK, Brzezinska-Slebodzinska E, Madsen FC. Oxidative stress, antioxidants, and animal function. *J Dairy Sci*. 1993; 76: 2812-2823.
  48. Jones DP. The redox potential of GSH/GSSG couple: assay and biological significance. *Methods Enzymol*. 2002; 348: 93-112.
  49. Townsend DM, Tew KD, Tapiero H. The importance of glutathione in human disease. *Biomed Pharmacother*. 2003; 57: 145-155.
  50. Guoyao Wu, Yu Zhong Fang, Sheng Yang, Joanne R Lupton, Nancy D Turner. Glutathione Metabolism and Its Implications for Health. *Journal of Nutrition*. 2004; 134: 489-492.
  51. McDowell LR. Recent advances in minerals and vitamins on the nutrition of lactating cows. *Pak J Nutr*. 2002; 1: 8-19.
  52. Castillo C, Hernández J, López-Alonso M, Miranda M, Benedito JL. Values of plasma lipid hydroperoxides and total antioxidant status in healthy dairy cows: preliminary observations. *Arch Tierz*. 2003; 46: 227-233.
  53. Zalba G, San Jose G, Moreno MU, Fortuno MA, Fortuno A, Beaumont FJ, et al. Oxidative stress in arterial hypertension: role of NAD (P) H oxidase. *Hypertension*. 2001; 38: 1395-1399.
  54. Habeeb AAM, Fatma El Teama, Osman SF. Detection of heat adaptability using Heat shock proteins and some hormones in Egyptian buffalo calves. *Egyptian Journal of Applied Sciences*. 2007; 22: 28-53.
  55. Habeeb AAM, El-Masry KA, Fatma El Teama, Gad A. The role of cyclic guanosine monophosphate and heat shock proteins in heat-stressed cattle. *Egypt. Journal of Applied Sciences*. 2009; 24: 32-56.
  56. Habeeb AAM, Gad AE, El-Tarabany AA. Effect of two climatic conditions and types of feeding on body weight gain and some physiological and biochemical parameters in crossing calves. *Zagazig Veterinary Journal*. 2011; 39: 34-48.
  57. Habeeb AAM, Teama Fatma El, EL-Tarabany AA. Effect of adding selenium and vitamin E to the diet on reproductive traits of female zaraibi goats and growth of their kids. *Isotope and Radiation Research*. 2012a; 44: 693-709.
  58. Gad AE. Effect of olive pulp levels in the diet of buffalo calves on physiological body functions and productive traits under heat stress conditions. *Isotope and radiation research*. 2013; 45: 61-77.
  59. Atta MAA, Marai IFM, El-Darawany AAM, El-Masry KA. The adaptability of bovine calves under a subtropical environment. *Zagazig Journal of Agriculture Research*. 2014; 41: 793-802.
  60. Habeeb AAM, El-Masry KAM, Atta MAA. Growth Traits of Purebred and Crossbred Bovine Calves During Winter and Summer Seasons. 4<sup>th</sup> Int. Conference Radiation Research and Applied Science Taba, Egypt. 2014; 1-10.
  61. Kamal TH, Seif SM. Effect of natural and controlled climates of the Sahara in virtual tritium in Friesians and water buffaloes. *Journal of Dairy Science*. 1969; 52: 1657-1663.
  62. Kamal TH, Johnson HD. Total body solids as a measurement of short-term heat stress in cattle. *Journal of Animal Science*. 1971; 32: 306-311.
  63. Habeeb AAM. The role of insulin in improving the productivity of heat-stressed farm animals with different techniques. Ph. D. Thesis, Faculty of Agriculture, Zagazig University, Zagazig, Egypt. 1987.
  64. Marai IFM, Habeeb AAM, Daader AH, Yousef HM. Effects of diet supplementation and body cooling on heat-stressed Friesian calves reared in high ambient temperatures in the eastern desert of Egypt. *Tropical Animal & Health Production*. 1997; 4: 201-208.
  65. Kamal TK, Kotby S, El-Fouly HA. Total body solids gain and thyroid activity as influenced by goitrogen, diuretics, sprinkling and air cooling in heat stressed water buffaloes and Friesians. *FAO/IAEA Symposium on Isotope Studies on the physiology of Domestic Animals, Athens, Greece, Proceedings Series, IAEA, Vienna*. 1972; 177-185.
  66. Kamal TH, El-Banna IM, Ayad MA, Kotaby EA. The effect of hot climatic and management on water requirement and body water in farm animals using tritiated water. *Arab Journal of Nuclear Sciences and Applications*. 1978; 11: 160-184.
  67. Kamal TH. Tritiated-water heat-tolerance index to predict the growth rate in calves in hot deserts. In: *Use of Tritiated water studies of production and adaptation in ruminants. Proceedings Research Coord. Mtg., Organized by jointly by FAO/IAEA division Nairobi, Kenya. IAEA, Panel Proc. Series, IAEA, Vienna*. 1982; 155-165.
  68. Kamal TH. Heat stress concept and new tracer methods for heat tolerance in domestic animals. In: *Peaceful Uses of Atomic energy for Scientific and Energy comm. Baghdad, Iraq*. 1975; 230-235.
  69. Alvarez MB, Johnson HD. Environmental heat exposure on cattle plasma catecholamine and glucocorticoids. *Journal of Dairy Science*. 1973; 5: 186-194.
  70. Habeeb AAM, Marai IFM, Owen JB. Genetic improvement of livestock for heat adaptation in hot climates. *International Conference of Animal Production and Health, Zagazig University, Zagazig Egypt*. 1997.
  71. Bernabucci U, Bani P, Ronchi B, Lacetera N, Nardone A. Influence of short- and long-term exposure to a hot environment on rumen passage rate and diet digestibility by Friesian heifers. *Journal of Dairy Science*. 1999; 82: 967-973.
  72. Johnson HD, Katti PS, Hahn L, Shanklin MD. Short-term heat acclimation effects on the hormonal profile of lactating cows. In: *Research Bulletin No. 1061, University of Missouri, Columbia*. 1988.
  73. El-Fouly HA, El-Masry KA, Gamal MH. Physiological studies related to some reproductive traits in Baladi cows. 2. Effect of calves sex on some reproductive traits of Baladi cows and growth performance of their Baladi and crossbred (Brown Swiss x Baladi) calves. *Zagazig. Veterinary Journal*. 1998; 26: 69-78.
  74. Petkov G. Environmental milk production of cows. *Veterinaria Shirka*. 1971; 75: 23-28.
  75. Raun NS. Beef and cattle production practices in the lowland American tropics. *Animal Review*. 1976; 19: 18-21.
  76. Bober MA, Becker BA, Valtorta SE, Katt P, Mertsching H, Johnson HD, et al. The relationship of growth hormone and thyroxine to milk production under heat in Holstein cows. *Journal of Animal Science*. 1980; 51: 261-268.
  77. Vanjonack WJ, Johnson HD. Effects of moderate heat and yield on plasma thyroxine in cattle. *Journal of Dairy Science*. 1975; 58: 507-516.
  78. National Research Council. *Effect of Environment on Nutrient Requirements of Domestic Animals*. National Academy Press, Washington, D.C. Dr. Joe West, Extension Dairy Specialist, University of Georgia. 1981.
  79. Kamal TH, Habeeb AAM, Abdel-Samee AM, Marai IFM. Milk production of heat-stressed Friesian cows and its improvement in the subtropics. *International Symposium on the Constraints and Possibilities of Ruminant Production in the Dry Subtropics, Cairo, Egypt. EAAP. Publication*. 1989; 38: 156-158.
  80. West W. Effects of Heat-Stress on Production in Dairy Cattle. *Journal of Dairy Science*. 2003; 86: 2131-2144.
  81. Rodriguez LR, McKonnen G, Wilcox CJ, Martin FG, Krienke WA. Effect of relative humidity and maximum and minimum temperature, pregnancy and stage of lactation on milk composition and yield. *Journal of Dairy Science*. 1985; 68: 973-978.

82. West JW. Interactions of energy and bovine somatotropin with heat stress. *Journal of Dairy Science*. 1993; 77: 2091-2102.
83. Niles MA, Collier RJ, Croom WJ. Effect of heat stress on rumen and plasma metabolite and plasma hormone concentration of Holstein cows. *Journal of Animal Science*. 1980; 152.
84. Habeeb AAM, Gad AE, EL-Tarabany AA, Atta MAA. Negative Effects of Heat Stress on Growth and Milk Production of Farm Animals. *Journal of Animal Husbandry and Dairy Science*. 2018b; 2: 1-12.
85. Habeeb AAM, Gad AE, Atta MAA. Temperature-Humidity Indices as indicators to heat stress of climatic conditions with relation to production and reproduction of farm animals. *International Journal of Biotechnology and Recent Advances*. 2018c; 1: 35-50.
86. El-Tarabany MS, EL-Tarabany AA. Impact of thermal stress on the efficiency of ovulation synchronization protocols in Holstein cows. *Animal Reproduction Science*. 2015a; 160: 138-145.
87. El-Tarabany MS, EL-Tarabany AA. Impact of maternal heat stress at insemination on the subsequent reproductive performance of Holstein, Brown Swiss, and their crosses. *Theriogenology*. 2015b; 84: 1523-1529.
88. Garcia-Ispierto I, Lopez-Gatius F, Santolaria P, Yaniz JL, Nogareda C. Factors affecting the fertility of high producing dairy herds in northeastern Spain. *Theriogenology*. 2007b; 67: 632-638.
89. Gantner V, Mijic P, Kuterovac K, Soli D, Gantner R. Temperature- humidity index values and their significance on the daily production of dairy cattle. *Mljekarstvo*. 2011; 61: 56-63.
90. Garcia-Ispierto I, López-Gatius F, Bech-Sabat G, Santolaria P, Yániz JL. Climate factors affecting conception rate of high producing dairy cows in northeastern Spain. *Theriogenology*. 2007a; 67: 1379-1385.
91. Stevenson JS, Schmidt MK, Call EP. Estrous intensity and conception rates in Holsteins. *Journal of Dairy Science*. 1983; 66: 275-280.
92. King VL, Denise SK, Armstrong DV, Torabi M, Wiersma F. Effects of a hot climate on the performance of first lactation Holstein cows grouped by coat color. *Journal of Dairy Science*. 1988; 71: 1093-1096.
93. Badinga L, Collier RJ, Thatcher WW, Wilcox CJ. Effects of climatic and management factors on conception rate of dairy cattle in subtropical environments. *Journal of Dairy Science*. 1985; 68: 78-85.
94. Wolfenson D, Thatcher WW, Badinga L, Savio JD, Meidan R. Effect of heat stress on follicular development during the estrous cycle in lactating dairy cattle. *Biological Reproduction*. 1995; 52: 1106-1113.
95. Mondal S, Mor A, Reddy IJ, Nandi S, Gupta PSP. Heat Stress Induced Alterations in Prostaglandins; Ionic and Metabolic Contents of Sheep Endometrial Epithelial Cells *in Vitro*. *Biomed J Sci & Tech Res*. 2017; 1: 1-5.
96. Biggers BG, Geisert RD, Wetteman RP, Buchanan DS. Effect of heat stress on early embryonic development in the beef cow. *Journal of Animal Science*. 1987; 64: 1512-1518.
97. Thatcher WW, Collier RJ. Effects of climate on reproduction. In: Morrow DA. (Editor). *Current Therapy in Theriogenology 2*. W. B. Saunders Co, Philadelphia, PA. 1986; 301-309.
98. Rivera RM, Hansen PJ. Development of cultured bovine embryos after exposure to high temperatures in the physiological range. *Reproduction*. 2001; 121: 107-115.
99. Ealy AD, Drost M, Hansen PJ. Developmental Changes in Embryonic Resistance to Adverse Effects of Maternal Heat Stress in Cows. *Journal of Dairy Science*. 1993; 76: 2899-2905.
100. Putney DJ, Mullins S, Thatcher WW, Drost M, Gross TS. Embryonic development in super ovulated dairy cattle exposed to elevated ambient temperatures between the onset of oestrus and insemination. *Anim Reprod Sci*. 1989; 19: 37-51.
101. Vasconcelos JLM, Silcox RW, Lacerda JA, Pursley GR, Wiltbank MC. Pregnancy rate, pregnancy loss, and response to heat stress after AI at 2 different times from ovulation in dairy cows. *Biological Reproduction*. 1998; 56: 140-148.
102. Morton JM, Tranter WP, Mayer DG, Jonsson NN. Effects of environmental heat on Conception rates in lactating dairy cows: critical periods of exposure. *Journal of Dairy Science*. 2007; 90: 2271-2278.
103. Thurmond MC, Branscum AJ, Johnson WO, Bedrick EJ, Hanson TE. Predicting the probability of abortion in dairy cows: a hierarchical Bayesian logistic-survival model using sequential pregnancy data. *Prev Vet Med*. 2005; 68: 223-239.
104. López-Gatius I, Santolaria P, Yániz JL, Nogareda C, López-Béjar M. Relationship between heat stress during the peri-implantation period and early fetal loss in dairy cattle. *Theriogenology*. 2005; 65: 799-807.
105. Schüller LK, Burfeind O, Heuwieser W. Impact of heat stress on conception rate of dairy cows in the moderate climate considering different temperature-humidity index thresholds, periods relative to breeding, and heat load indices. *Theriogenology*. 2014; 81: 1050-1057.
106. Cavestany D, EL-Wishy AB, Foote RH. Effect of season and high environmental temperature on fertility of Holstein cattle. *Journal of Dairy Science*. 1985; 68: 1471-1478.
107. Bouraoui R, Lahmar M, Majdoub A, Djemali M, Belyea R. The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. *Animal Research*. 2002; 51: 479-491
108. Temple D, Bargo F, Mainau E, Ipharraguerre I, Manteca X. Heat stress and efficiency in dairy milk production: A practical approach. *The Farm Animal Welfare Fact Sheet No. 12*, Farm Animal Welfare Education Centre. 2015.
109. Morrill K. Heat stress-impact on lactating cattle. *Cornell University Cooperative Extension*. 2011.
110. Habeeb AAM, Gad AE, Teama Fatma EI, EL-Tarabany AA. Means of Alleviation the Negative Effects of Summer Heat Stress on Animals. *Journal of Animal Husbandry and Dairy Science*. 2018d; 2: 37-61.
111. Sharaf AK, El-Darawany AA, Nasr AS, Habeeb AAM. Alleviation of the negative effects of summer heat stress by adding selenium with vitamin E or AD3E vitamin mixture in drinking water of female rabbits. *Biological Rhythm Research*. 2019.
112. Shearer JK, Bray DR, Bucklin RA. The management of heat stress in dairy cattle: What we have learned in Florida. *Proc. Feed and Nutritional Management Cow College, Virginia Tech*. 2005; 60-71.
113. El-Sobhy HE. Heat stress in female farm animals. *A Review JKAU: Met, Environ and Arid Land Agric Sci*. 2005; 165: 3-24.
114. Habeeb AAM, Aboulnaga AI, Kamal TH. Heat-induced changes in body water concentration, T3, cortisol, glucose and cholesterol levels and their relationships with thermoneutral body weight gain in Friesian calves. *Proceeding of the 2nd International Conference on Animal Production & Health in Semi-Arid Areas, Suez Canal University, Faculty of Environmental Agricultural Sciences, El Arish, North Sinai, Egypt*. 2001; 97-108.
115. Habeeb AAM, EL-Tarabany AA, Gad AE. Importance of drinking water temperature for heat-stressed pregnant Ossimi ewes during the summer of Egypt. *Arab J of Nuclear Sciences and Applications*. 2012b; 45: 223-232.
116. Habeeb AAM, Gad AE, EL-Tarabany AA. Effect of hot climatic conditions with different types of housing on productive efficiency and physiological changes in buffalo calves. *Isotope and Radiation Research*. 2012c; 44: 109-126.
117. Habeeb AAM, Saleh HM, Mustafa MM, Nessim MZ. Effect of a wool shearing process during the hot summer season on the physiological and nutritional performance of Ossimi lambs. *Egyptian J Nutrition and Feeds*. 2009; 12: 391-405.
118. Bewley JM, Grott MW, Einstein ME, Schutz MM. Impact of intake water temperatures on reticular temperatures of lactating dairy cows. *J Dairy Sci*. 2008; 91: 3880-3887.
119. Habeeb AAM, Saleh HM, EL-Tarabany AA, Gad AE, Mostafa MM. Impact of altered feeding time regimen under summertime environmental conditions on the physiological and nutritional performance of pregnant ewes. *Isotope and Radiation Research*. 2010a; 42: 1493-1512.
120. Habeeb AAM, Elwan KM, Marai IFM, EL-Drawany AA, EL-Tarabany AA.

- Effect of amelioration summer heat stress condition techniques on some blood hormones, vitamins and trace elements in rabbit bucks. *Isotope and Radiation Research*. 2010b; 42: 1353-1373.
121. Omnisky K, Kennedy A, Wittenberg K, Mostaghi S. Physiological and production responses to feeding schedule in lactating dairy cows exposed to short-term, moderate heat stress. *J Dairy Sci*. 2002; 85: 730-737.
122. Habib AAM, Gad AE, Mustafa MM. Improvement of Gain, Feed Efficiency and Physiological Body Functions in Native Bovine Calves during Hot Summer Season using Different Nutritional Supplements. *International Journal of Nutritional Sciences*. 2018e; 3: 1021-1028.
123. Habib AAM, El-Darawany AA, Nasr AS, Sharaf AK. Impact of some medicinal plant supplementation on pregnant rabbits diet during the hot summer season. *Research Journal of Medicinal Plants. Res J Med Plants*. 2019; 13: 145-154.
124. West JW, Mullinix BG, Sandifer TG. Effects of bovine somatotropin on physiologic responses of lactating Holstein and Jersey cows during hot, humid weather. *J Dairy Sci*. 1991; 74: 840-851.
125. Anwar UL, Gilani H, Jabeen Q, Khan MAU. A review of medicinal uses and pharmacological activities of *Nigella sativa*. *Pakistan J Biol Sci*. 2004; 7: 441-451.
126. Busquet M, Calsamiglia S, Ferret A, Kamel C. Screening for effects of plant extracts and active compounds of plants on dairy cattle rumen microbial fermentation in a continuous culture system. *Animal Feed Science and Technology*. 2005; 123-124: 597-613.
127. Awadallah IM. Effect of supplementation with niacin and *Nigella Sativa* seeds on Friesian calves under heat stress conditions. *J Agric Sci, Mansoura Univ*. 2002; 27: 791-801.
128. Masuda T, Maekawa T, Hidaka K, Bando H, Takeda Y, Yamaguchi H. Chemical studies on antioxidant mechanisms of curcumin: analysis of oxidative coupling products from curcumin and linoleate. *J Agric Food Chem*. 2001; 49: 2539-2547.
129. Schwartzkopf-Genswein KS, Beauchemin KA, McAllister TA, Gibb DJ, Streeter M, Kennedy AD. Effect of feed delivery fluctuations and feeding time on ruminal acidosis, growth performance and feeding behavior of feedlot cattle. *J Anim Sci*. 2004; 82: 3357-3365.
130. Simone H. Heat stress in beef cattle, Tech Line, Products and answers that Work, Hubbard Beef Solutions. 2010.
131. Collier RJ, Zimbelman RB, Rhoads RP, Rhoads ML, Baumgard LH. A re-evaluation of temperature humidity index (THI) and black globe humidity index (BGHI) on milk production in high producing dairy cows. *Western Dairy Management Conference*. Reno, NV. 2012.
132. Habib AAM, Gad AE, El-Tarabany AA. Effect of hot climatic conditions with different types of housing on productive efficiency and physiological changes in buffalo calves. *Isotope and Radiation Research*. 2012; 44: 109-126.
133. Thornton PK, Boone RB, Villegas JR. Climate change impacts on livestock. Working Paper No. 120, CGIAR Research Program on Climate Change, Agriculture and Food Security, Denmark. 2015.