Review Article

Deterioration Effects of Heat Stress on Farm Animals Performance in Tropical and Subtropical Regions

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Abstract

The thermal comfort region for greatest animals is between 4ºC and 25ºC and when environmental temperature surpasses 25ºC, animals suffer from heat stress conditions. Over 50% of the cattle population is located in the tropics and it has been appraised that heat causes severe economic loss in approximately 60% of the dairy farms around the world. In tropical and subtropical countries, the climatic characteristic is the major constraint on animal productivity. In severe heat stress, growth, milk yield, milk composition and reproductive traits are reduced as a result of the extreme changes in biological functions affected by heat stress. Heat stress disturbs the steady-state concentrations of free radicals, resulting in both cellular and mitochondrial oxidative damage. Although heat stress causes a decline in dry matter intake, the cow's energy and protein requirements in hot environments increase. This review provides an overview of the impact of heat stress on production and reproduction in farm animals.

Keywords: Heat stress; Animal; Growth; Milk yield; Milk composition; Reproductive traits

Introduction

Deterioration effects of heat stress on growth traits

In tropical, subtropical and arid regions, high ambient temperature is the major factor jeopardizing animal production. Heat stress reduces the metabolic rates and alters post-absorptive metabolism, regardless of the decreased feed intake. Growth, production, reproduction and health are not priorities anymore in the metabolism of heat-stressed animals and when heat stress is accompanied by high ambient humidity, the effect of high temperature is more pronounced because of the reduced heat dissipation by evapotranspiration [1]. Across the United States, heat stress results in estimated total annual economic losses to livestock industries that are between $1.69 and $2.36 billion. Of these losses, $897 to $1500 million occurs in the dairy industry and $370 million in the beef industry [2]. Sackett et al. [3] estimated the economic costs of heat stress to Australian feedlots at approximately 16.5 million (AUD) and now these estimates may not reflect the current economic impact of heat stress. Furthermore, in conjunction with climate change, these estimates are probably underestimating the economic impact of heat stress on cattle production systems. Growth is orderly genetically and environmentally by well-balanced offered nutrients, hormones and enzymes. In tropical and subtropical regions, growth traits of the animals both males and females are impaired as a result of the extreme changes in biological functions containing disturbances in protein, water, energy and mineral metabolism. These drastic changes depress the growth traits of animal temperate breeds about 50% during the summer season when introduced to a tropical or sub-tropical environment due to the heat stressful conditions [4].

Deterioration effects of heat stress Daily Body Gain (DBG)

Heat stress was shown to affect negatively animal growth performances in tropical and subtropical regions of the world. Decreased body weight, average daily gain and growth rate were in beef cattle [5]. A compensatory gain was reported in beef cattle after a mild or short period of heat stress [6]. Concerning the effects of heat stress of the summer season on DBG, Habeeb et al., [7] reported that exposed buffalo calves to high environmental temperature of 36.0 and 32.0ºC induced a significant reduction in DBG by 22.6 and 16.5%, respectively when compared to expose the animals to the low environmental temperature (18.0ºC). In bovine claves, Habeeb et al., [8] reported that the stressful condition of hot summer season induced a significant reduction in DBG ranged between 3.2 to 48.4% with an average of 25.5% when compared to the animals exposed to the winter season. In bovine crossing calves, Habeeb et al., [9] found that the heat stress of the hot summer season induced a highly significant decline in DBG by 14.0, 29.0 and 22.0% during the 1st, 2nd and 3rd months of the summer season, respectively, when compared to the animals exposed to the winter season. The same trend was observed in buffalo calves, the summer season induced a significant decline in DBG by 18.1, 17.41 and 8.65 % during the 1st, 2nd and 3rd months of the summer season, respectively, when compared to the animals exposed to the winter season [10].

Atta et al. [11] also found that DBG values were significantly lower in the summer of Egypt than in winter during the three months of the summer season and the decrease values were 55.2, 60.2 and 57.4% in the first, second, and third months of the summer season with overall decreases percentages in DBG of 52.8 and 43.3.4% in purebred and crossbred calves, respectively. Gad [12] also showed that heat stress conditions of the hot period during the summer season induced significant decreases in each of the final live body weight, DBG and total body weight gain and these parameters decreased by 4.50, 24.76 and 24.88%, respectively as compared to under mild conditions. Habeeb et al. [13] reported that the heat stress conditions of the summer season induced a highly significant reduction in DBG of

bovine calves. The authors showed that averages of DBG of purebred and crossbred bovine calves were 600±32 and 843±7.1g during the winter season and were 283±9.3 and 478±38g during the summer season, respectively, and the DBG was found to be highly significantly lower in summer than in winter in both two breeds. The reduction in DBG of bovine calves was 30kg through 3 months at the rate of 333.9g daily and the percentage reduction reached more than 45% when compared to mild climate conditions of the winter season. When comparing the two breeds, the result showed that crossing bred calves were better than purebred calves in DBG by 20.4kg with an average daily of 226.1g.

Growth Periods of heat stress are associated with reductions in growth, i.e., live weight gains and DMI [14]. As ambient heat load increases, cattle divert energy that is typically partitioned for growth towards maintaining homeostasis resulting in a reduction in growth and growth efficiency [15]. For feedlot cattle, this diversion of energy is associated with depressed growth rates, whereby heat-related decreases in weight gain are approximately 10kg, which coincides with a seven-day increase in days on feed. There is considerable variability in average DBG and feed conversion across feedlot studies [16].

In growing cattle, heat stress has decreased DMI, increased DM digestibility, decreased rate of gain partially negated by the compensatory gain [17]. The combination of the elevated humidity (80%) and high temperatures (33ºC) had a profound effect on the BWG and feed intake, both decreasing rapidly with the rise of environmental temperatures. The body weight gain at 33ºC was significantly decreased in comparison with the two other temperatures (20ºC, 28ºC). A significant decrease in BWG and feed intake and with a significant increase in DM digestibility values with the increase of temperature (33ºC) with relative humidity was set at 60% [18]. Heat stress (cyclical daily temperatures ranging from 29.4ºC to 40.0ºC)-induced reduction in feed intake by approximately 12% as dry matter appears to fully explain decreased average DBG in Holstein bull calves. Heat stress had reduced average DBG (1.24 *vs.* -0.09 kg/d when compared with the thermoneutral control group (18.0ºC to 20.0ºC) [19]. Dry matter intake and growth performance of calves and heifers are reduced during heat stress because of redistributing energy to heat regulation through a series of physiological and metabolic responses, such as elevated blood insulin and protein catabolism. Heat stress-induced alteration in rumen motility and microbiota affects the feed digestibility and rumen fermentation [20]. Heat stress exerts a negative effect on the dry matter intake and growth performance of calves and heifers. Wang et al., [20] reported that dairy calves born in summer tended to have lower average daily gain than those born in winter due to that calves in summer consume lower starter DMI than those born in winter. Broucek et al., [21] showed that calves under heat stress conditions (74.8 of THI) had reduced starter intake compared with those raised under moderate conditions (59.7 of THI). Moreover, Nonaka et al. [22] found that daily dry matter intake and ADG of pre-pubertal Holstein heifers at 33ºC environment dropped by 9% and 22%, respectively, compared to those raised at 28ºC environment.

Deterioration effects of heat stress on Daily Solids Body Gain (DSBG)

Concerning the effect of season of the year on DSBG or dry

weight gain (bodyweight-body water), the calculated loss in body solids due to heat stress conditions was found to be 23% in Friesian heifers [23], 14-29% in Guernsey cattle [24]. The loss values in DSBG in Friesian calves were 51% [25] and 46% [26]. In Friesian cows, DSBG was found to decrease significantly from winter (126.5kg) or spring (118.0kg) to summer (91.0kg), under natural hot climate [23]. The same authors confirmed that the total body solids decreased in buffaloes and Friesian calves by 11.42% at each level of temperature, when the ambient temperature in the climatic chamber increased from 16ºC, 50% RH to 32ºC, 50% RH, constantly for one week. In Holstein calves, heat stress caused a significant decrease (15%) in TBS [24]. In growing buffaloes, TBS was similarly lower at 32ºC and 50% RH than at 18ºC and 50% RH (100 and 124kg, respectively) [27]. The same was true in water buffaloes and Red Danish cattle whether the animals were heifers, pregnant or lactating [28]. The latter authors found that TBS decrease from spring to summer (110.9 to 59.5 kg) and from summer combined with solar radiation (59.5 to 58.6 kg) in buffaloes. 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 [29]. Therefore, Kamal [29] suggested using the heat-induced loss percentage in DSBG as a heat tolerance index due to differentiate between animals in their heat tolerance. Kamal and Habeeb [30] found that heat stress-induced a significant decrease in TBS in both male and female Friesian calves. Marai and Habeeb [31] showed that exposure Friesian calves to heat stress decreased significantly DSBG. Habeeb et al. [13] found that averages of DSBG of purebred and crossbred bovine calves were 217±10 and 319±9g during the winter season and were 139±4 and 222±17g during the summer season, respectively, indicating that DSBG was found to be highly significantly lower in summer than in winter in both purebred and crossbred native calves by 35.9 and 30.4%, respectively. The reduction in DSBG was 8.0kg through 3 months at the rate of 88.4g daily when compared to the absence of heat stress during the winter season with a percentage decrease of more than 33%. When comparing between the two breeds, the result showed that crossing bred calves were better than purebred calves in DSBG by 8.2kg through 3 months at the rate of 91.6g daily with best more than 50%. The authors concluded that crossbred calves are better than purebred calves under two climatic conditions.

Explanation the decrease in growth performance due to heat stress

The effects of heat stress conditions on growth performance are the products of the decrease in anabolic activity and the increase of tissue catabolism mainly in fat depots and/or lean body mass. 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 decrease in feed digestibility and feed utilization and this causes loss of production per unit of food (feed efficiency) [32]. 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. The adverse effect of high ambient temperature with high relative humidity on animals may be also due 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 [4]. The decrease in growth traits due

to tissue damage can be estimated by body solids losses in heat-stressed animals [33]. This damage may be attributed to an increase in glucocorticoids and catecholamine [34] and a decrease in insulin level, T4 and T3 secretions [35]. 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 [36]. The animal tries to decrease the fed intake under heat stress as an attempt to create less metabolic heat, as the heat increment of feeding, especially; ruminants represent a large portion of whole-body heat production [37]. The decrease in the substrates and hormones synthesis and the rise in body temperature inhibit the enzymatic activities, which decrease the metabolism and consequently impair daily body weight gain [38]. 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 [4]. The decrease in growth traits and the tissue damage estimated by body solids losses in heat stressed animals may be attributed to increase in glucocorticoids and catecholamine [34,39] and decrease in insulin level [25], T4 and T3 secretions [40] and decrease in feed intake, feed efficiency, digestibility and feed utilization [32,35]. The animal decrease fed intake under heat stress in an attempt to create less metabolic heat, as the heat increment of feeding, especially, ruminants represents a large portion of whole body heat production [37]. The decrease in the substrates and hormones and the rise in body temperature inhibit the enzymatic activities, which decrease the metabolism and consequently impair DBWG. In addition, 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 noradrenalin released in response to temperature may contribute in depression of gain either live or solids [36].

Deterioration effects of heat stress on milk yield and milk composition

Deterioration effects of heat stress on milk yield: Heat stress has become a major concern for dairy producers because of the associated decreases in milk production and large economic losses. The economic losses due to heat stress were estimated by St-Pierre et al., [2] for the major livestock industries in the United States. In the dairy and beef industries, heat stress had a negative economic impact of $897 million and $369 million per year, respectively. Heat stress results in total annual economic losses to the US livestock production industry ranging from $1.69 to 2.36 billion, of which $900 million is specific to the US dairy industry, stemming from decreased milk production, compromised reproduction, and increased culling [2]. Milk production of cows is influenced by environmental factors, especially high temperature and humidity during the summer season. The increase in environmental temperature averages by 1.6, 3.2 and 8.8°C exceeding normal environmental temperature (21°C) results in the decrease in daily milk yield averages by 4.5, 6.8 and 14%, respectively, and a decline in the environmental temperature by 7°C lower normal environmental temperature resulted in an increase in the daily milk yield by 6.5% in dairy cattle [41]. At 30°C, the high producing animals showed a mean reduction of 2.0 kg/day compared to a reduction of only 0.65 kg/day for the low producing animals [42]. Milk yield in early, mid, and late lactation decreased by 25, 41 and 47%, respectively, at 72 h after the beginning of heat exposure [43]. Schneider et al., [44] reported that dairy cattle in heat stress consumed less feed (13.6 *vs.* 18.4 kg/day and produced less milk (16.5 *vs.* 20.0 kg/day than cows in a suitable temperature zone. 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) [45]. Milk yield value in lactating buffaloes was significantly lower in July (37.1°C) than in February (17.5°C) and the overall mean depression of milk yield was 16.6% in 6 lactation numbers [39]. The same authors found that exposure of lactating buffaloes to the hot summer season, the weakly milk production decreased by 51.4kg and 11kg 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. Ravagnolo et al., [46] reported that milk yield declined by 0.2kg per unit increase in THI when THI exceeded 72. The authors concluded that THI can be used to estimate the effect of heat stress on production. Higher yielding cows are more challenged by heat stress than lower-yielding animals [47]. Lactating dairy cows have an increased sensitivity to heat stress compared with non-lactating (dry) cows, due to milk production elevating metabolism [48].

Linvill and Pardue [49] indicated that milk production only begins to decline when the THI consistently exceeds 74 during the previous 4 days and the milk yield and composition are greatly affected by the heat stress during the early lactation period (first 60 days of lactation). Moreover, a study that investigated seasonal effects on milk yield showed that the milk yield of Holstein cows decreased by 10% to 40% in summer in comparison to the milk yield in winter [50]. Kadzere et al., [37] found that milk production is reduced 15%, accompanied by a 35% decrease in the efficiency of energy utilization for productive purposes, when a lactating Holstein cow is transferred from an air temperature of 18 to 30°C. Gantner et al., [51] showed that the milk yields were significantly different between the heat-stress and non-heat-stress periods. Milk production has been reported to decline by 17-53 %, feed intake by 35-48 % and milk yield of dairy cattle decrease by 0.3kg per animal compared to each unit increase of THI value. A study by West et al., [52] showed that increasing air temperature, temperature-humidity index are related to decreased milk yield and reduced efficiency of milk yield because of the positive relationship between milk yield and heat production. The daily milk yield is highly affected by climate change and the increment of temperature and humidity leads to a significant decrease in milk production [53]. West [54] reported a decline in milk yield by Holsteins that was more rapid than for Jerseys across a range of temperature-humidity indices from 72 to 84 and increasing air temperature and temperature-humidity index above critical thresholds are related to decreased DMI and milk yield and reduced efficiency of milk yield. West [54] found that the milk yield of Holstein cows and Jersey cows decreased by 0.69kg and 0.45kg, respectively, for every unit increase in THI, indicating that a higher degree of breed selection led to a greater impact of heat stress. Per unit increase in THI beyond 72, 0.2kg reduction in milk yield was recorded in dairy cows. West et al., [52] reported that milk yield for Holsteins declined 0.88kg per THI

unit increase for the 2-d lag of mean THI, and DMI declined 0.85kg for each degree (ºC) increase in the mean air temperature. Bouraoui et al., [55] decided that for each point increase in the value of THI beyond 69, milk production drops by 0.41kg per cow per day in the Mediterranean climatic regime, besides, feed intake and milk yield decreased by 9.6% and 21%, respectively. Rhoads et al., [56] decided that feed intake remaining 65% of the reduction in milk yield is due to decreased feed intake remaining 65% reduction is due to direct physiological effect of heat stress and for every 1ºC in air temperature above thermal neutral zone (21-27 ºC) cause 0.85kg reduction in feed intake, which causes 36% decline in milk production in dairy cattle. A similarly reduced milk yield was also recorded in cattle exposed to heat stress [57]. In an experiment on Holstein cows to assess the decrease in milk yields due to heat stress in tropical conditions, a yield of 0.32kg per day was observed for the unit rise of THI above 66 [58]. Similarly, milk yields of cows decreased by 1.8kg along with per unit increment of average ambient temperature [59]. Holstein milk yield decreased during moderate and severe heat stress, whereas Jersey milk yield declined during severe heat stress. Holstein milk yield decreased from 34.8 to 32.9 kg/d in moderate heat stress and decreased further to 30.4 kg/d in severe heat stress. Jersey milk yield was not different in moderate heat stress and significantly decreased to 23.8 kg/d in severe heat stress [60]. To give a practical quantitative evaluation, Bernabucci et al., [61] reported a loss of 0.27kg milk per each temperature–humidity index unit incremental change. Chanda et al., [62] found that the averages milk yield of both Group One (G1) (Holstein-Friesian 50%×Local 50%) and Group Two (G2) (Holstein-Friesian 75%×Local 25%) were significantly higher in the cool period (14.92 and 19.54 l/d than in hot period (12.84 and 15.00 l/d for the G1 and the G2, respectively. The milk yield of the G2 group hampered more compare to the G1 due to higher THI during the hot season. Most livestock species perform well in the temperature range of 10-30 ºC, beyond this limit cattle tend to reduce milk yield and feed intake [63]. Both intakes of feed and milk production were reduced by about 15% as rectal temperatures increased from 38.8 to 39.9 ºC [64]. Osei-Amponsah et al., [65] found that average daily milk production in lactating Holstein Friesian cows was significantly dropped by 14% from low to high THI and highly significant negative correlations were obtained between THI and milk yield and feed intake.

Deterioration effects of heat stress on milk composition: Heat stress not only decreases milk yield but also affects milk content. The milk composition, especially fat and protein are significantly affected in the period of the hot environment. These studies illustrate that the performance of dairy cows in summer is greatly affected by heat stress, which is indirectly reflected in changes in feed intake, milk yield, and milk components [66]. The fat and protein content of the milk decreased significantly as a result of increased THI [51]. Also, Summer et al., [67] observed a decrease in milk fat content during summer when compared with autumn, ranging from a minimum in June-August (3.36 to 3.38 g/100 g) to a maximum in November (3.67 g/100 g). Heat stress reduced protein and fat content [68]. The fat and protein content of milk decreased by 0.012kg and 0.009kg, respectively, for each unit of increase in THI above 72 [46]. Milk constituents are also greatly affected when Friesian lactating cows are exposed to hyperthermia. Fat and protein percentages decreased at environmental temperatures between 8 and 37ºC and protein/fat ratio decreased at environmental temperatures above 29ºC

[69]. Friesian cows maintained under 38ºC had lower averages of total solids, fat, protein, ash and lactose yields than when the same animals were maintained under thermoneutral environmental temperatures. The reduction percentages were 28.0, 27.0, 7.0, 22.7 and 30.0%, respectively [39]. Kadzere et al., [37] reported that heat stress reduced milk protein, milk fat, solids-not-fat in dairy cows. The author reported that milk fat, solids-not-fat, and milk protein percentage decreased 39.7, 18.9 and 16.9% respectively and when the average THI increased from 68 to 78 (from spring to summer), the protein and fat contents of milk decreased from 2.96% and 3.58% to 2.88% and 3.24%, respectively. Further, Kadzere et al., [37] reported that milk fat, solids-not-fat, and milk protein percentage decreased 39.7, 18.9 and 16.9% respectively. Chanda et al., [62] found that the milk fat, protein and lactose were significantly higher during the lower THI period compare to the higher THI period. In another study, decreased milk protein, lactose and fat values were recorded during the summer [70]. In an experiment on Holstein heifers to heat stress, Nardone et al., [71] observed a reduction in percentages of total protein, fat, casein, lactose, lactoalbumin, short and medium-chain fatty acids, IgG and IgA for the first four lactations. Further, the elevated heat load index was correlated with a decline in lactose, protein and fat concentration in milk. Besides milk solids, fat and protein concentrations in Holstein-Friesian, New Zealand Jersey cows tend to decline for THI values of 64.3, 66.7 and 73.3, respectively [72]. Bernabucci et al., [73] reported a marked and significant decrease of milk fat during summer (3.20 g/100 g) compared with the values observed in winter (3.80 g/100 g) and in spring (3.61 g/100 g). Cowley et al., [74] did not find any significant differences for milk fat content between cows in normal conditions or subjected to heat stress but when cows are maintained in conditions of heat stress; both milk protein and casein content tend to decrease. The same authors found that cows exposed to heat stress produced milk with less protein than cows housed in comfortable temperature conditions. Cowley et al., [74] found that when cows were fed with a reduced feeding system but were not subjected to heat stress, milk protein showed intermediate values and from these results, the authors suggest that the decrease of milk protein content is mostly related to a direct effect of heat stress instead of a reduction of feed intake. In accordance, Bernabucci et al., [73] found higher milk casein content in winter (2.75 g/100 g) and spring (2.48 g/100 g) concerning the summer season (2.27 g/100 g). Smith et al., [60] found that Holstein milk fat percentage was less during moderate and severe heat stress compared with milk fat percentage during mild heat stress and Holstein fat-corrected milk yield decreased from 36.7 to 34.8 kg due to heat stress. Smith et al., [60] found also that milk protein percentage declined in Holstein cows during heat stress from 3.2 to 3.1% and from 3.6 to 3.5% for Jersey cows while milk protein percentage in milk from Jersey cows decreased in moderate heat stress from 3.7 to 3.6%. Milk protein percentage from Holstein cows decreased also in moderate heat stress from 3.2 to 3.1% [60]. Percentages of milk fat and protein are often lowered (~0.5 and 0.2 percentage units, respectively) during the times of heat stress and the summer season and there is a decrease in potassium content in the milk of cows exposed to greater heat stress [64]. Hu et al., [75] suggested that a change in milk composition may be more useful to assess cows in immediate heat stress. The heat stress adversely affects both the quantity and quality of milk during the first 60 days of lactation and highly yielding breeds are more susceptible

than the low yielding breeds [76].

Deterioration effects of heat stress on hormonal levels

Heat stress can cause changes in hormone profiles like prolactin, thyroid hormones, glucocorticoids, growth hormone, adrenocorticotropic hormone, oxytocin, estrogen and progesterone [77]. Any changes in prolactin concentration during the dry period can harm the subsequent lactation. Changes in the prolactin secretion during heat stress were correlated with body temperature changes with increased rectal temperature reducing the prolactin concentration [78]. The increased cortisol concentration in heat-stressed dairy cattle was found to be associated with reduced milk production and this could be attributed to the fact of deviation of available energy for coping up mechanisms to heat stress challenges [79]. Further, heat stress can also decrease the secretion of estradiol and luteinizing hormone and a lower concentration of estradiol in the follicular fluid of dominant follicles was estimated during the summer season [80]. The reduced estradiol concentration may lead to a reduction in milk production by bringing about reduced reproductive efficiency in dairy cattle. Plasma T3 and T4 levels are found to be decreasing during heat stress than in normal thermo-neutral conditions. During heat-stress, concentrations of T3 and T4 were found to be decreasing by up to 25% [79]. The reduced plasma thyroid hormone concentration may lead to reduced milk production by causing reduced feed intake. The reduced feed intake may lead to negative energy balance making energy level not sufficient for normal milk synthesis. Further, a decline in growth hormone was also observed for THI values beyond 70 in dairy cattle. This decline in growth hormone was attributed to the suppressed hormone production to counter metabolic heat in dairy cows. It has been observed that long-term heat stress can decrease the circulating levels of growth hormone thereby reducing milk production by causing negative energy balance [54].

Explanation of the decrease in milk yield and milk constituents due to heat stress

The production of milk is directly related to the level of feed consumption. 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 [81]. When a cow becomes heat stressed, an immediate coping mechanism is to reduce Dry Matter Intake (DMI), causing a decrease in the availability of nutrients used for milk synthesis [56]. In hot weather, the animal generally reduces their feed intake and it has been estimated that at 40ºC, feed intake (on a dry matter basis) is only about one half that eaten by cows living in their optimum temperature range [82]. DMI starts to decline, and energy used for maintenance starts to increase, when environmental temperatures exceed 25ºC and when ambient temperatures exceed 32.2ºC, the DMI of cows might drop by 8-12%, and milk yield may fall by 20-30% [83]. Milk production may decrease as much as 50% when ambient temperatures exceed 32.2ºC [84]. 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 [81].

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 in the animals exposed to high ambient temperature may be associated with the depression in quantity and quality of milk [4]. The energy consumed in heat-stressed animals is used less efficiently for milk yield due to greater energy costs for maintenance (20%) and digestible energy (35.4%) when environmental temperatures were 35ºC less efficient than that in an 18ºC. The increase in respiratory and heart rate is responsible for the increased maintenance that occurs during heat stress [85]. Further, the manufacture of hormone-releasing factors in the hypothalamic center is suppressed due to heat stress conditions causing the slowdown of metabolic pathways and initiating drastic impairment of protein utilization. Due to a shortage of energy, substrates, hormones and enzymes, and a decrease in apparent digestibility, volatile fatty acids assembly, rumen pH and electrolyte concentrations in the rumen fluids and consequently protein synthesis becomes unable to counteract the protein catabolism [4]. Besides, the destruction in protein tissues due to the increase in glucocorticoid hormones (proteolytic hormones) is responsible for protein catabolism [86]. The increase in glucocorticoid hormones may occur through the increase in gluconeogenesis, which delivers the amino acids to their corresponding α-keto acids [34]. The increase in catecholamine (lipolytic hormones) or/and the decrease in insulin level in heat-stressed animals are also responsible for protein catabolism and contribute to tissue destruction. The disturbance in carbohydrates, lipids, minerals, and vitamin metabolism in animals exposed to high environmental temperature 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 [4]. Heat stress reduces DMI and milk yield and increases the maintenance costs of the cow. Animals try to decrease DMI to maintain homeothermy through reduced metabolic heat production. A study by Robinson et al., [87] showed that heat production increases with an increase in ambient temperature, resulting in a concomitant increase in the body temperature of the cow, this leads to lower milk production [37,51]. As ambient temperature increases in the summer months, and as body temperature concomitantly increases, cows decrease their feed intake to mitigate heat stress, thereby leading to a gradual decline in milk production and a change in milk content [88]. Feed intake of dairy cows begins to decrease when the ambient temperature reaches 25ºC, and sharply decreases when the ambient temperature exceeds 40ºC, after which feed intake is approximately 20% to 40% lower than the normal intake, the combination of decreased feed intake and increased ambient temperature gradually result in lower milk yield [5]. A study of 22 Holstein and eight Jersey cows found that THI negatively affected feed intake, where a THI >72.1 resulted in a decrease in the feed intake of Holstein and Jersey cows by 0.51kg and 0.47kg, respectively, for each unit of increase in THI [52]. Also, Xue et al., [89] found that the DMI increased from 18.5 to 19.8 kg/d when THI increased from 42 to 68, but decreased from 19.8 to 15.8 kg/d when the THI increased from 68 to 80 and this indicates that DMI responds to THI in a biphasic manner, where DMI increases slowly with an increase in THI until a critical point, after which it decreases sharply with an increase in THI when the THI value is higher. Therefore, cows gradually enter a state of heat stress when THI exceeds 68, and DMI decreases gradually with increasing heat stress.

Bouraoui et al., [55] explained that a part of the adverse effects of heat stress on milk production could be attributed to reduced nutrient intake and decreased nutrient uptake by the portal drained viscera of the cow. The redistribution of the bloodstream away from the gastrointestinal tract to peripheral tissues for cooling functions may alter nutrient absorption and metabolism, and contribute to lower milk yield during hot weather. Apart from reducing milk production, heat-stress can also reduce the quality of milk. Internal metabolic heat production during lactation can further reduce the resistance of animals to high ambient temperature, resulting in altered milk composition and reduction in milk yield. Heat stressed cattle may try to reduce the body heat through thermoregulatory mechanisms which in turn affect feed conversion efficiency and lead to decreased milk production [90]. Decreased nutrient absorption, alteration in rumen function and hormonal imbalance are other factors that contribute to reduced milk production during heat stress [61]. Further, heat stress causes a decline in the level of non-esterified fatty acids and hepatic glucose leading to a reduced supply of glucose to the mammary glands, which in turn negatively affect lactose synthesis leading to reduced milk yield in Holstein cows [91].

Global warming will have significant economic impacts for producers and consumers and in the case of dairy cows; climate change has an important effect on milk organic and inorganic composition [92]. Rhoads et al., [56] demonstrated that reduced nutrient intake accounts for about 35% to 50% of the decrease in milk synthesis and milk yield from heat-stressed lactating cows and the remaining portion is a direct result of heat. Kadzere et al., [37] reported that heat stress leads to a decrease in feed intake of dairy cows and thereby leading to a reduction in milk production. Cattle that are affected by heat-stress show reduction in feed intake and milk yield and shift metabolism, which in turn reduces their milk production efficiency [54]. Nardone et al., [71] reported that elevated temperature and humidity can reduce the ability of cattle to dissipate excess heat which can ultimately lead to heat stress and associated physiological changes such as reduced milk fat and protein.

Cowley et al., [74] reported that the decline in protein concentration during heat stress could be attributed to the specific down thermoregulation activity of mammary protein synthesis. Hammami et al., [72] reported that heat stress can increase body temperature which may affect the fat synthesis of the mammary gland. Internal metabolic heat production during lactation can further reduce the resistance of cattle to high ambient temperature, resulting in altered milk composition and reduction in milk yield [64]. Cows exposed to significant heat stress are more susceptible to ruminal acidosis. Ruminal pH may be lowered because of reduced buffering of the rumen and a reduction in the number and intensity of ruminal contractions and only intensive management can reduce the influence of heat stress on the quantity of milk production and profitability [62].

Temperature above 35ºC may activate thermal stress in animals directly reducing the feed intake of animals thereby creating a negative energy balance, which ultimately affects the synthesis of milk [93]. Further, heat-stress can also cause endocrine disbalance such as altering the levels of prolactin, thyroid hormones, glucocorticoid, growth hormone, estrogen, progesterone and oxytocin, which

ultimately affects the milk production [76]. Accordingly, Cowley et al., [94] reported that cows subjected to heat stress reduced their ingestion and produced less milk when compared with cows raised in normal climate conditions. In recent years, global warming is a major concern for the agricultural sector. Heat stress impairs the welfare and productive performance of dairy and beef cattle and different climate conditions have important effects on the organic and inorganic components of milk. Heat stress also impacts the mammary glands and the changes can be visualized through histological changes in the udder and heat stress can increase body temperature, which affects the fat synthesis in the mammary gland [95].

Deterioration effects of heat stress on reproductive efficiency

Reproductive metrics conception rate, oocyte quality and pregnancy loss are all affected by elevated temperatures and these characteristics are determined retrospectively and thus only indicate that the animal was in heat stress at the time of, or surrounding, breeding [96]. Heat stress affects most aspects of both male and female reproduction function, such as the pregnancy rate, estrous activity, embryonic mortality, sperm motility as well as spermatozoa mortality and abnormalities [97]. Heat stress harmed reproductive events by decreasing the expression of estrous behavior, altering ovarian follicular development, compromising oocyte competence, and inhibiting embryonic development [98]. Heat load impairs numerous functions associated with establishing and maintaining pregnancy, including altered follicular development and dominance patterns, corpus luteum regression, impaired ovarian function, impaired oocyte quality and competence, embryonic development, increased embryonic mortality and early fetal loss, endometrial function, reduced uterine blood flow and reduced expression of estrus and estrus behaviors, i.e., mounting [99]. Heat stress has adverse effects on the health and biological functioning of dairy cows through reduced reproductive performance [48]. The decline in the performance of reproductive traits such as service period, conception rate and pregnancy rate of farm animals with respect to increasing in THI was found by Dash et al., [93] indicating that heat stress increased feeding costs by reducing reproduction efficiency [66].

Deterioration effects of heat stress on conception rate

Conception Rate (CR) is the proportion of services that result in pregnancy in lactating dairy cows. The relationship between THI and CR of lactating dairy cows was studied by Schuller et al., [99]. 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 and found that the THI threshold for the influence of heat stress on conception rate was 73 and observed a relationship between the mean THI at the day of breeding and the resulting CR. Garcia-Ispierto et al., [100] reported that heat stress decreases the CR of lactating dairy cows by around 30.6% relative to days of breeding and when THI is greater than 80 for three to one-day pre artificial insemination CR decreased from 30.6% to 23.0%. The possibility of successful inseminations might be curtailed by heat stress because of altering the intrauterine environment therefore CR drastically drops during heat stress [101].

El-Tarabany and El-Tarabany [102] found that the CR of lactating dairy cows was negatively affected by heat stress both before and after

the day of breeding and the greatest negative impact of heat stress on CR was observed 21 to 1 day before breeding and when the mean THI was 73 or more in this period, the CR decreased from 31% to 12%. Heat stress causes harmed the developing embryo lead to lower CR and fertility [51]. High temperatures lowered CR 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 [103]. In contrast, CR for heifers did not decline until 35°C wile virgin heifers had higher CR for all services (50%) than lactating cows (34%) and suffered only slight depression of fertility during summer months [104]. The latter authors found that heifers required 1.5 services per conception compared with 2.3 for lactating cows and CR decreased from 40 to 50% when ambient temperatures are greater and to be less than 10% when ambient temperatures are lesser. Heat stress severely reduces CR in lactating animals and decreased sharply when maximum air temperature on the day after insemination exceeded 30°C [105]. CR in purebred Holstein cows under subtropical Egyptian conditions was significantly decreased from 31.6% at the lesser THI to 11.5% than at the greater THI and CR was significantly reduced at either the lesser or greater THI [102]. The decrease in CR during the hot season can range between 20-30% as compared to the results obtained in the winter months [84].s

Dash et al., [106] reported that the CR in dairy cattle was found decreased above THI 72 while a significant decline in CR of buffaloes was observed above threshold THI 75. The CR of lactating dairy cows was negatively affected by heat stress both before and after the day of breeding [107]. The greatest negative impact of heat stress on CR was observed 21 to 1 day before breeding and when the mean THI was 73 or more, CR decreased from 31% to 12% [108]. CR was reduced when Holstein-Friesian cows were exposed to a high heat load from the day of service to 6 days after service, and in weak one and heat loads in weak-3 to weak-5 were also associated with reduced CR [109]. The CR in Holstein cows was found lowered following services performed in hot months [110]. The authors observed that CR of lactating dairy cows during the hot period (July to September) was significantly lower with 29.5% as compared to the CR of 38.2% during the cool period (October to June). The decrease in CR during summer seasons can range between 20 and 30%, with evident seasonal patterns of estrus detection [48]. Heat stress in the period around the day of breeding was consistently associated with reduced CR [109]. Additionally, CR from artificial insemination varies from 55% to less than 10% during the months of low and high temperatures and humidity, respectively [111]. The reductions in CR in hot periods are due to the combined effects of environmental heat, which produces an alteration in the synthesis of reproductive hormones [112]. As heat load intensity increases there is a continuous decline in CR in lactating cows [113]. CR can be influenced by a heat load event during the month preceding breeding to two weeks following breeding [108]. Decreased luteinizing hormone, estradiol and gonadotropins due to heat stress disturb the normal estrus cyclicity, depress follicular development, hence the drop in CR [114].

Deterioration effects of heat stress on the estrus cycle

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 [115]. 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 [105]. During high ambient temperatures, the dominant follicle develops in a low LH level reduced estradiol secretion and leads to prolonged follicular dominance, delayed ovulation and expression of estrus is poor. A higher incidence of silent heat and an-estrus is most often in cows during high ambient temperatures. Besides, the duration and intensity of estrus are reduced and there is a markedly reduced quality of oocytes [84]. Heat stressed cows are less likely to exhibit standing estrus and often only exhibit signs of estrus at night when temperatures are cooler, but when they are less likely to be observed. Also, the duration of estrus is shorter for cows subjected to heat stress [84]. There is an increasing trend in incidences of silent estrus, the decline in reproductive activity and conception of buffaloes due to an increase in air temperature during the summer season [106]. Elevated environmental temperatures negatively affect the cow's ability to display natural mating behavior, as it reduces both the duration and intensity of estrous expression [116]. Hansen and Arechiga [117] reported reduced estrous behaviors in heat-stressed dairy cows and additional evidence that estrous mounting behaviors in beef cattle are markedly decreased in total time and frequency during the summer compared with winter months. Moreover, shorter durations of estrus have been documented when European breeds are moved to tropical areas [118]. 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 [119].

In a study conducted in Florida about 76-82 %, undetected estrus events are recorded during summer months than the average of 44-65 % from October-May. Reduced concentration of Estradiol hormone is responsible for estrus expression was observed for an ambient temperature of 41C due to the reduced expression of 17 hydroxylase during heat stress [120]. A reduction in estrous behavior has been argued to be the result of reduced DMI and the subsequent effects on hormone production [121]. Shorter durations of estrus have been documented when European breeds are moved to tropical areas, with differences attributed to temperature, nutrition, and parasites [118]. A study on non-lactating Japanese Black cows indicated that their estrus cycle was significantly longer in summer than in winter and the estrus and conception rates decreased when THI exceeded 72 [122]. Heat stress affects reproduction by inhibiting the synthesis of gonadotropin-releasing hormone and luteinizing hormone, which is essential for oestrus behavior expression and ovulation [123].

Deterioration effects of heat stress on follicular development

Heat stress has been shown to exert a direct effect on follicular development in dairy cows [124]. Wolfenson et al., [103] showed that the number of dominant ovarian follicles in a heat-stressed group of dairy cows began to decline earlier than in the cooled group during the first follicular wave. The number of large follicles (diameter ≥10mm) was significantly higher in the heat-stressed group than in the cooled group resulting in 53% more large follicles in the heat-stressed group during the first follicular wave. Moreover, during the

second follicular wave, the numbers of small and medium follicles were higher in the cooled group than in the heat-stressed group, and the number of medium follicles was significantly lower than that in the first follicular wave. Also, Wolfenson et al., [103] reported that the dominant ovarian follicles appeared earlier and were fewer in number than in the cooled group, indicating that heat stress can affect the development of follicles in dairy cows However, Wilson et al., [125] showed that the dominant ovarian follicles in the heat-stressed group were equal in size to or smaller than those of the thermoneutral group during the second follicular wave and that the percentage of cows having two follicular waves in the heat-stressed group and the thermoneutral group was 18% and 91%, respectively. The day of functional luteolysis (defined as serum progesterone <1 ng/mL) was delayed in four out of 11 heat-stressed cows (day 29.1±2.4) in comparison to that of the thermoneutral cows (day 20.4±2.4 [125]. However, Al-Katanani et al., [126] suggest that cooling cows for 42 days did not alleviate the impact of heat load on oocyte competence. Related studies reported that heat stress negatively affects the development of bovine oviduct and oocyte quality [126]. Besides, heat stress also affects follicular development [127]. Besides, heat stress might depress follicular development by impairing follicle selection, delaying follicular wave, reducing follicular dominance and compromising follicular steroidogenesis, eventually leading to the poor quality of oocytes [128]. Collectively, these studies all indicate that follicular development is adversely affected by heat stress.

Deterioration effects of heat stress on pregnancy

In conjunction with climate change, the impact of hot weather on reproduction on reproduction may probably become more pronounced. Heat load is also associated with smaller conceptus size, which may influence maternal recognition of pregnancy and maintenance of corpus luteal function. Furthermore, heat load has been associated with compromising gestation during the per-implantation period, where there is an increased risk in early fetal loss between days 21 to 30 of gestation [129,130]. Heat load is also associated with a reduction in uterine blood flow, which may also influence the availability of nutrients and hormones to the uterus and as embryonic development progresses; there is an increase in embryonic thermotolerance [109]. Heat stress also has a serious impact on pregnancy in dairy cows, the pregnancy rates were 39.4% (THI <72.0), 38.5% (72.0 to 73.9), 36.9% (74.0 to 75.9), 32.5% (76.0 to 77.9), and 31.6% (>78.0). This indicates that the pregnancy rate of dairy cows decreases in a THI-dependent way, when THI was great than 72.0, with a decrease in pregnancy rate of 1.03% per unit increase in THI [131]. The effects of heat stress on pregnancy rate were explored in another study involving 1,199 crossbred dairy cows for 30 days before and after insemination. The results showed that the pregnancy rate in the heat stress-heat stress group (20.5%) was significantly lower than those of the thermoneutral-thermoneutral (32.6%) [132]. These studies show that the pregnancy rate of dairy cows was decreased in response to heat stress and that the influence of heat stress was enhanced by increased duration and intensity. However, another study showed that the pregnancy rate was significantly higher after embryo transfer than that after artificial insemination (day 21, 47.6% *vs.* 18.0%; days 45 to 60, 29.2% *vs.* 13.5% [133]. Dash et al., [106] reported that pregnancy rate in dairy cattle was found to decreased above THI 72 while a significant decline in reproductive

performances of buffaloes was observed above threshold THI 75. The pregnancy rate in purebred Holstein cows under subtropical Egyptian conditions was significantly decreased from 26.3% at the lesser THI to 9.9% than at the greater THI and the pregnancy rate was significantly reduced at either the lesser or greater THI [102]. Lower conception rate, the duration and intensity of estrus are reduced and there is a markedly reduced quality of oocytes and reduced pregnancy rates [84]. However, the decline of pregnancy rate after artificial insemination may be due to the decreases in oocyte quality and oviductal function in response to heat stress [134].

Deterioration effects of heat stress on fertility and breeding efficiency

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 [129]. Higher environmental temperature is one of the major factors responsible for reduced fertility in farm animals. Higher environmental temperature is one of the major factors responsible for reduced fertility in farm animals. Fertility is a very broad term that is influenced by various factors including genetic, nutritional, hormonal, physiopathology, management and environment, or climate. The fertility traits in dairy animals show a very low heritability value, and this indicates that most of the variations in fertility are determined by non-genetic factors or environmental effects. The main natural physical environmental factors affecting the livestock system include air temperature, relative humidity, solar radiation, atmospheric pressure and wind speed [129]. All these environmental factors are pooled to produce heat stress on animals, which is defined as any combination of environmental variables producing conditions that are higher than the temperature range of the animal's thermoneutral zone [106]. Heat stress reduces the expression of estrous behavior [101], alters follicular development [103] and the growth and functions of the dominant follicle [135], compromises oocyte competence [90] and inhibits embryonic development. Consequently, heat stress reduces the fertility of female and male cattle, resulting in reduced reproductive performance. Heat stress is perceived as a major factor contributing to low fertility of dairy cows inseminated in the late summer months and low fertility was recorded in both first and second parties during the months of low and high temperatures and humidity [136].

High ambient temperature will also affect pre-attachment stage embryos but the magnitude of the effect has been reduced as embryos develop [137]. Holstein heifers subjected to heat stress from the onset of estrus had an increased proportion of abnormal and developmentally disturbed embryos as compared with heifers preserved at thermo-neutrality and the production of embryos by superovulation is often reduced and embryonic development compromised in seasons when ambient temperatures are greater [138]. 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 [139]. The relationship between temperature and breeding efficiency indicates that high environmental temperatures were associated with low breeding efficiency [140]. Heat stress compromises the uterine environment with decreased blood flow to the uterus and increased uterine temperature, which can lead to implantation failure and embryonic mortality. The Higher ambient temperature during the

summer has been associated with reduced fertility in dairy cattle through its deleterious impact on oocyte maturation and early embryo development [90]. There are several possible mechanisms by which heat stress can prevent the growth of oocytes. The foremost is the reduction in the synthesis of the pre-ovulatory surge in luteinizing hormone and estradiol. Hence, there is poor follicle maturation and this leads to ovarian inactivity in cattle [141]. Heat stress also delays follicle selection, reduces the degree of dominance of the dominant follicle, and decreases blood progesterone concentration, which is a major cause for abnormal oocyte maturation, implantation failure and finally early embryonic death in dairy cattle [142]. During heat stress, the intrauterine environment of the cow is compromised. Hence, there is a decrease in blood flow to the uterus and elevated uterine temperature. These changes increase the chances of early embryonic loss and suppress embryonic development [116]. Heat stress can affect the function of tissues and organs in dairy cows and hinder the synthesis of some proteins and hormones, which can in turn lead to low fertility by affecting the synthesis of proteins and hormones associated with the reproductive organs. Heat stress in animals has been associated with reduced fertility through its deleterious impact on oocyte maturation and early embryo development [106].

Deterioration effects of heat stress on abortions and fetal loss

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 [143]. 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., [144]. The 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 [145]. The same authors concluded that animals had a significantly longer calving interval and days open at high THI compared with low THI. Bouraoui et al., [55] found that 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). Body temperature greater than 39°C may harm the developing embryo from day 1-6 and lead to loss of pregnancy and heat stress during late gestation may also lead to cows calving 10-14 days before their date [146]. 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 [147]. Further, only fewer standing heats are observed during heat stress, which may ultimately lead to a decreased pregnancy rate [123]. Heat stress not only affects the whole reproduction stage of heifers from estrous to calving period but also generates a lasting effect on newborn calves. The duration and intensity of estrus are reduced by Heat stress, resulting in the silent heat or weak estrus expression thus the difficulty in breeding [148]. The embryonic loss rate was significantly increased from 11.5% at the lesser THI to 22.2% at the greater THI [102]. Heat stress increases embryonic mortality [119]. The embryonic loss rate was significantly increased from 11.5% at the lesser THI to 22.2%

at the greater THI [102]. The reproductive proficiency of lactating dairy cattle is greatly diminished. Dry cattle whose last 3 months of gestation occurred during hot weather had calves with smaller birth weights and more metabolic problems after calving and they also produce 12% less milk in the next lactation [84]. The service period in cattle is affected by the season of calving for which cows calved in summer had the longest service period [106]. Increased maximum temperature from 29.7°C to 33.9°C was associated with a decrease in CR on the first service from 25 to 7% [145].

Heat stress could increase the Adrenocorticotropic Hormone (ACTH) secretion, which was reported to block estradiol-induced sexual behavior, and cortisol secretion, which could inhibit the Gonadotropin-Releasing Hormone (GnRH) and Luteinizing Hormone (LH) secretion and affect the hypothalamic-hypophyseal ovarian axis. These increased secretions could lead to hindered luteolysis, altered follicle dominance and disrupted ovulation [142]. Heat stress after insemination reduced the weight of corpora lutea and impaired concept growth. Heat stress also increases the production of prostaglandin secretion (GF2α) in the endometrium, leading to the early regression of corpus leuteam 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 [149]. 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 [150].

Conclusion

Heat stress in tropical and sub-tropical countries is considered the major concern which affects the production and reproduction potential of farm animals. Elevated environmental temperature negatively affects feed intake and altered hormonal concentrations leading to negatively affecting the reproductive efficiency of dairy cattle.

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