Journal of Animal Husbandry and Dairy Science
Volume 2, Issue 1, 2018, PP 1-12

Negative Effects of Heat Stress on Growth and Milk Production of Farm Animals

Habeeb, A. A. M., A. E. Gad , A. A. EL-Tarabany and M. A. A. Atta

Biological Applications Department, Radioisotopes Applications Division, Nuclear Research Center, Atomic Energy Authority, Inshas, Cairo, Egypt

Corresponding Author: *Habeeb, A. A. M, Biological Applications Department, Radioisotopes Applications Division, Nuclear Research Center, Atomic Energy Authority, Inshas, Cairo, Egypt, dr_alnaimy@yahoo.com, alnaimy252011@gmail.com.*

ABSTRACT

Optimal climatic conditions for cattle, buffaloes, sheep goats, rabbits and poultry would be something like an air temperature of 13 to 20 ºC, a wind velocity of 5 to 18 km/hr, relative humidity of 55 to 65% and a moderate level of sunshine and these factors are interrelated. In tropical and subtrobical countries, climatic characteristic is the major constraint on animal productivity. Growth, milk production and reproduction are impaired as a result of the drastic changes in biological functions caused by heat stress

The summer in Egypt is characterized by high ambient temperature, intense solar radiation and high relative humidity. Therefore, farm animals raised to such a sever climatic stress for almost 6 months of the year. Exposure of animals to heat stress evokes a series of drastic changes in the biological functions, which include a decrease in feed intake, feed efficiency and utilization, disturbances in water, protein, energy and mineral balances, enzymatic activities, hormonal secretions and blood metabolites ending to impairment the productive and reproductive performance.

Keywords: *Farm animals, heat stress, growth, milk yield.*

INTRODUCTION

According to 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 sun throughout the world. In animals and humans, some physiological and biochemical adaptations could occur to protect essential cell functions against heat stress and to permit a rapid recovery from moderate hypothermic damage (McMichael *et al.*, 1996).

Summer in Egypt (latitude 31º 12' N to 22 º 2' N, longitude 25 º 53' E to 35 º 53' E) are quite hot (30-40 ºC at noon) accompanied by high humidity in and near the costal area and very dry in the desert. Solar radiation is high throughout the year and for all Egyptian zones, with extremes observed during summer especially in June, July and August particularly in desert areas (Marai *et al.*, 2002). The summer in Egypt, is characterized by high ambient temperature (35-40^{o} C) and high relative humidity(50-75%). Solar radiation is high (4500KJ/M^2) throughout the year and for all Egyptian zones, with extermes observed during summer, especialy, during the periods of greatest heat stress which normally extends from mid-June to mid-September. Therefore, farm animals raised to such a sever climatic stress for almost 8 months of the year and become uncomfortable suffering extremely in production and reproduction (Habeeb *et al.*, 1992). Exposure of animals to heat stress evokes a series of drastic changes in the biological functions, which include a decrease in feed intake, feed efficiency and utilization, disturbances in water, protein, energy and mineral balances, enzymatic activities, hormonal secretions and blood metabolites ending to impairment the productive and reproductive performance. Heat stress also lowers natural immunity making animals more vulnerable to disease (Habeeb *et al* 2008).

The Thermal Comfort Zone for most animals is between 4° C and 25° C. When temperature exceeds 25° C animals suffer heat stress. In severe cases of heat stress the deep body temperature rises, animal cells are affected and production performance is reduced. The effect is increased when the relative humidity is greater than 50%. In tropical and subtrobical countries, climatic characteristic is the major constraint on animal productivity. Growth, milk production and reproduction are impaired as a result of the drastic changes in biological functions caused by heat stress and the productive traits of animals are deleteriously affected by the disturbance in the normal physiological balance (Kamal and Habeeb et al., 1999). Ambient temperature is related with 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 relationship induced to propose a measurement of the level of severity of heat stress using the two factors and was termed temperature–humidity index (Wiersma, 1990 and Livestock and Poultry Heat Stress Indices, Clemson University, 1990).

Review of Literature

Heat Stress

Heat stress when animal looses the ability to dissipate sufficient heat to maintain thermal balance and her body temperature rises. Marai and Habeeb (2010) defined heat stress as the state at which the animal body physiological mechanisms activate to maintain the body's thermal balance, when exposure to elevated temperature. This has a negative effect on many factors such as dry matter intake, reproduction, and milk production. Animal will also reduce feed intake to produce less metabolic heat, which is a protective mechanism. Animals typically react to heat stress conditions by eating less food, thus naturally controlling the rise in deep body temperature caused by digestion. Respiratory rate rises and there is a marked increase in insensible heat loss by evaporation of water from the lungs. They also drink at least 5 times the amount of water they would under temperate conditions, urine output increases and many mineral ions are lost. In addition, 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. In addition, duration of estrus is shorter for cows subjected to heat stress (Hales, *et al.*, 1996). Some responses of animals to heat stress are including (Wiersma, 1990):

- Increased body temp. (>102.6F), the normal body temperature of a dairy cow is 101.5F.
- Increased respiratory rate, panting >80 breaths per minute (35-45 normal)
- Reduced activity
- Reduced feed intake (>10-15% reduction)
- Reduced Milk Yield (10-20% or more)
- Increased peripheral blood flow and sweating.
- Reduced fertility levels
- Increased mortality

Thermoregulation Mechanism

Thermoregulation means by which animal maintains its body temperature which involves a balance between heat gain and heat loss. Ambient temperature within an animal's lower and upper critical temperature is regarded at the zone of thermoneutrality (Figure 1).

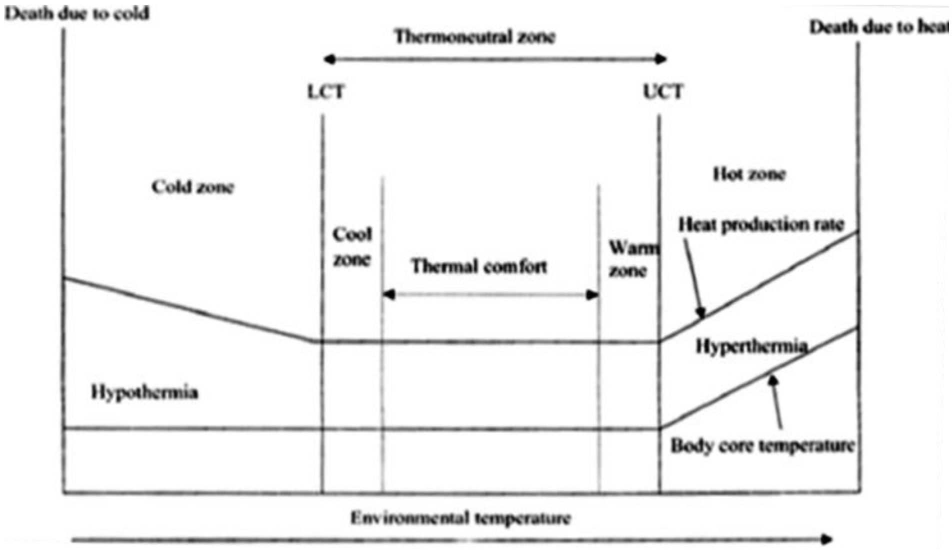

Figure1. *Lower (LCT) and upper critical ambient (UCT) temperatures and animal response (Igono et al., 1985).*

Within this zone, 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 observed in farm animals, these measures traditionally are used to indicate heat stress (Igono *et al.*, 1985). Mammals have a series of mechanisms to maintain homeostasis. The thermo neutral zone is defined as the range of environmental conditions under which an animal can regulate heat loss with a minimum of effort. Changes in ambient temperature alter metabolism and affect the level of heat production and heat loss. If ambient temperature drops below the lower critical temperature, metabolism will increase in order to enhance heat production. If ambient temperature rises above the evaporative critical temperature, evaporative heat loss increases and food intake is inhibited, reducing metabolism and heat production (Mount, 1974).

Animal has several mechanisms to help dissipate body heat, these include:

- Conduction, where the cow conducts heat to a cooler surface.
- Convection, where thermal currents leave the cow's body
- Radiation, where the cow radiates heat to a cooler environment, such as the cool night air.
- Evaporation, where moisture is evaporated from the surface of her body (sweating) and from her lungs (panting).

Explaining the mechanism involved in increased heat loss when the body becomes overheated. Guyton (1969) stated that overheating stimulates the preoptic thermostatic area increased the rate of heat loss from the body in three different ways:

- By stimulating the sweat glands to cause evaporative heat loss from the skin
- By stimulating vasodilator nerves to the skin thereby increasing the transport of the heat by the blood to the body surface.
- By inhibiting sympathetic centers in the posterior hypothalamus to remove the normal vasoconstrictor tone to the skin vessels and thereby allows more vasodilatation.

Under hot climate conditions, normal thermo regulatory reactions, i.e. respiration, sweating and rectal temperature are increased causing disturbances in the metabolism of water (increase water intake and body water content), protein, energy and minerals (negative nitrogen, energy and mineral balances). These disturbances also occur in enzymatic reactions e.g. an increase in transaminase enzymes activities and in hormonal secretion where insulin, T_4, T_3 and aldosterone decrease and cortisol increases. Such disturbances lead to depression in some of the blood metabolites, i.e. glucose, total protein, total lipids, cholesterol, etc. The final result of these changes is impairment of appetite, feed intake, feed efficiency, food utilization, growth milk yield and reproduction (Habeeb *et al.*, 2000). Particularly, exposure to high ambient temperature stimulates the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite centre in the hypothalamus causing a decrease in feed consumption to minimize thermal load on animals. Thus, less substrate become available for hormone synthesis and heat production. Exposure to severe heat also suppresses the production of hormone releasing factors from the hypothalamic centers causing a decrease in pituitary hormonal secretion and consequently lowers the secretion of the thyroid hormones. Such changes result in impairment of reproduction and production performances.

The following diagram illustrates the mechanism proposed by Kamal (1975) which brings about the adverse effect of hot climate on animals. High environmental temperature stimulates the peripheral receptors and core region receptors, including blood veins, abdomen, hypothalamus, midbrain and spinal cord to transmit nerve impulses to the specific centers in the hypothalamus, which call upon their defensive evaporative and non evaporative cooling systems as well as adaptive mechanisms causing the reaction observed in the heat stressed animals to help preventing the rise in body temperature. If all these defensive mechanisms fail to stop the rise in body temperature the animal succumbs to heat stroke (Fig.2).

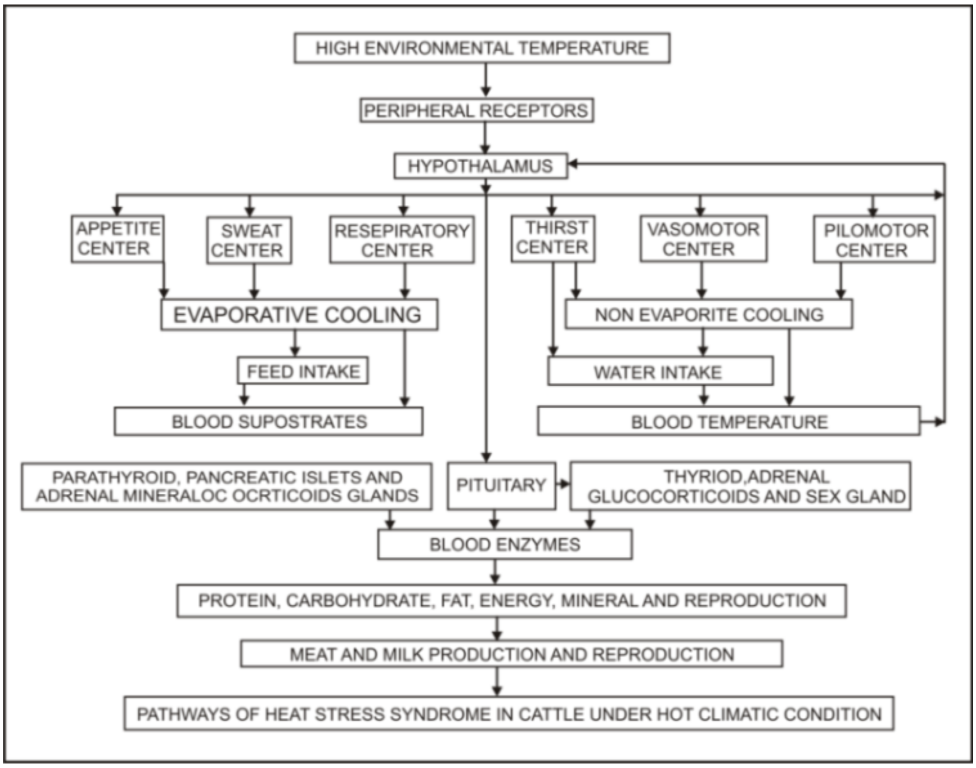

Figure2. *Pathways of heat stress syndrome in animal under hot climatic conditions (Kamal, 1975).*

Exposure of farm animals to high environmental temperature stimulates the nerve impulses to the specific centers in the hypothalamus (the defensive evaporative and non-evaporative cooling systems, appetite centre and the adaptive mechanisms that cause such reactions) to help in preventing the rise in body temperature. Prolonged heat exposure suppresses the production of hormone releasing factors from the hypothalamic centers causing reductions in pituitary prolactin, somatotropin, thyrotropin and leutinizing hormone, insulin and possibly parathomone. The decrease in the substrate and hormones and the rise in body temperature inhibit the enzymatic activities, which decrease the metabolism and consequently impair milk production, growth and reproduction (Habeeb et al., 1992). In addition, the shortage of energy, substrates and T_3 hormone may be responsible for the depression in milk yield and composition. In addition, high level of cortisol observed in the buffaloes exposed to high ambient temperature may be associated with the depression in quantity and quality of milk. Animals typically react to heat stress conditions by eating less food, thus naturally controlling the rise in deep body temperature caused by digestion. Respiratory rate rises and there is a marked increase in insensible heat loss by evaporation of water from the lungs. They also drink at least 5 times the amount of water they would under temperate conditions, urine output increases and many mineral ions are lost (Bray and Bucklin, 1996).

Negative Effects of Heat Stress on Growth Traits

Summer in Egypt is characterized by long season of 6 months from April to September, where ambient temperature exceeds 32°C for about 10 hours daily. In the newly reclaimed desert lands, hot waves of 50°C and intensive direct and indirect solar radiation (500 k cal/m²/hr) are very common in summer .Such severe climatic stress is expected to induce a vast array of physiological and biochemical changes, increase in metabolic heat production and difficulty in heat loss which impair the animal health and depress their productivity (Habeeb *et al.*, 1989). Growth, milk production and reproductive performance in both male and female animals are impaired as a result of the drastic changes in biological functions including disturbances in protein, energy and mineral metabolism, which depress with about 50% productivity of temperate breeds introduced to a tropical or sub-tropical environment caused by heat stress (Habeeb *et al.*, 1992).

Growth is controlled genetically and environmentally by well balanced available nutrients, hormones and enzymes. Most studies showed that growth performance, i.e., growth rate, daily gain weight, dry body weight (total body solids), solids daily gain and live body weight are impaired at elevated temperatures in temperate breeds.

Concerning the effect of season of the year on daily body weight gain (DBWG), Habeeb *et al.* (2007) reported that the average daily body weight gain of buffalo calves decreased significantly as a function of the severe heat stress and heat stress conditions when compared to either thermo neutral or mild climate conditions. Habeeb *et al.* (2007) found that heat stress conditions of 36.0 and 32.0°C induced significant reduction in DBWG of buffalo calves by 22.6 and 16.5%, respectively, when compared to mild climate conditions (18.0°C). Exposure to elevated ambient temperature is associated with decrease in DBWG in cattle (Habeeb *et al.*, 2009). Habeeb *et al.* (2009) showed that the stressful condition of hot climatic conditions induced significant reduction in DBWG of bovine claves by 25.5% and mentioned that there were individual variations in the amount of DBWG which decreased due to exposure of the calves to stressful conditions of summer season and concluded that the percentage heat induced change in DBWG were differs from calf to another and ranged between 3.2 to 48.4%. Habeeb *et al.*, (2011) reported that the heat stress induced a highly significant decline in DBWG of crossing calves by 14.0, 29.0 and 22.0% during 1st, 2nd and 3rd months of heat stress exposure, respectively (Table 1).

Table1. *Daily body weight gain of crossing calves as affected by climatic conditions (Habeeb et al., 2011)*

Climatic conditions	Daily body weight gain (DBWG), g		
	DBWG during 1st month	**DBWG during 2nd month**	**DBWG during 3rd month**
Mild climate	715 ± 20	858 ± 30	887 ± 30
Hot climate	615 ± 20	608 ± 30	692 ± 30
Change%	-14.0	-29.0	-22.0
Significance	0.01	0.001	0.001

Habeeb *et al.* (2012a) reported that the heat stress conditions of summer season induced significant decline in DBWG of buffalo calves by 18.1, 17.41 and 8.65 % during 1st, 2nd and 3rd months during summer season, respectively (Table 2). Gad (2013) also showed that heat stress conditions of hot period induced significant decreases in each of final live body weight, daily body weight gain and total body weight gain. Under hot conditions, these parameters decreased by 4.50, 24.76 and 24.88%, respectively as compared to under mild conditions (Table 3). Similar results were obtained by Bernabucci *et al.* (1999) in cattle who observed that heat stress conditions decreased significantly DBWG. Atta *et al.* (2014) reported that the DBWG values were significantly higher in crossbred than in purebred calves during the three months. The increase values were 44.9, 31.8 and 55.2% in the first, second and third months, respectively. Concerning the effect of season of the year, 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, respectively (Table 4). Habeeb *et al.* (2014) showed that averages of live DBWG of purebred and crossbred bovine calves were 600±32 and 843±7.1 g during winter season and were 283±9.3 and 478±38 g during summer season, respectively. The live 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. The same trend was found in solids DBWG. Averages of solids DBWG of purebred and crossbred bovine calves were 217±10 and 319±9 g during winter season and were 139±4 and 222±17 g during summer season, respectively (Table 5).

Table2. *Daily body weight gain of Buffalo calves as affected by climatic conditions (Habeeb et al. 2012a)*

Climatic conditions	Daily body weight gain (DBWG), g		
	DBWG during 1st month	**DBWG during 2nd month**	**DBWG during 3rd month**
Mild climate	925 ±20	1120 ±24	1050 ±21
Hot climate	845 ±22	925±23	860 ± 20
Significance	0.05	0.01	0.01

Table3. *Live Body weight, total and daily body weight gain in buffalo calves as affected by different climatic period of the year (Gad, 2013).*

Climatic Conditions	Live Body Weight (LBW)		Total gain, Kg(60d)	DBWG, gm
	Initial LBW	Final LBW		
Mild climate	311.0± 7.7	362.3±10.4	51.3±3.5	856. 0 ±32
Hot climate	307.4± 8.7	346.0 ±8.4	38.6±4.1	643. 0 ±30
Change, %	-1.16	-4.50	-24.76	-24.88
Significance	0.60 NS	0.04	0.001	0.001

Habeeb *et al.* (2014) reported that the heat stress conditions of summer season induced highly significant reduction in live total body weight gain (TBWG) of bovine calves by 30 kg through 3 months at the rate of 333.9 g daily when compared to mild climate conditions of winter season. The percentage reduction reached to more than 45%. From another point of view, when expressed TBWG as solids, the results showed that the stressful condition of hot summer conditions induced significant reduction in solids TBWG of bovine claves by 8.0 kg through 3 months at the rate of 88.4 g daily when compared to absence of heat stress during winter season and the percentage decrease due to heat stress reached to more than 33%. When comparing between the two breeds, the result showed that crossing bred calves were better than pure bred calves in live TBWG by 20.4 kg with daily of 226.1 g and at the same trend, crossing calves were better than pure calves in solids TBWG by 8.2 kg at the rate of 91.6 g daily with best more than 50% (Table 5).

Table4. *Least square means of daily body weight gain as affected by breed type and season of the year at month intervals in young bovine calves (Atta et al., 2014).*

Items	Daily body weight gain (g/d)		
	1^{st} month	2^{nd} month	3^{rd} month
Breed type effect			
Purebred	477.7±14	506.3±16	430.6±19
Crossbred	692.1±14	667.4±16	668.4±19
Change %	$+44.9^{***}$	$+31.8^{***}$	$+55.2^{***}$
Season effect			
Winter	807.6±22	839.5±23	770.8±23
Summer	362.2±22	334.2±23	328.2±23
Change % and sign.	-55.2 P<0.001	-60.2 P<0.001	-57.4 P<0.001

Table5. *Comparison between purebred and crossbred bovine calves in live and solids daily body weight gain during winter and summer seasons (Habeeb et al., 2014)*

Items	Live body weight gain, g/daily				Solids body weight gain, g/daily			
	Winter season		Summer season		Winter season		Summer season	
	Pure bred	Cross bred	Pure bred	Cross bred	Pure bred	Cross bred	Pure bred	Cross bred
X ±SE	600±32	843±7.1	283±9.3	478 ± 38	217±10	319 ± 9	139 ± 4	222 ± 17
Change% due to season			-52.8^{***}	-43.3^{***}			-35.9^{***}	-30.4^{***}
Change% due to breed	$+243^{***}$ g		$+195^{***}$ g		$+102^{***}$ g		$+83^{***}$ g	

***= *P<0.0001*

Concerning the effect of season of the year on solids daily body gain (SDBG), The calculated loss in body solids due to heat stress conditions was found to be 23% in Friesian heifers (Kamal and Seif, 1969), 14-29% in Guernsey cattle (Kamal and Johnson, 1971) The loss values in SDBG in Friesian calves were 51 % (Habeeb, 1987) and 46% (Marai *et al.*, 1995). In Friesian cows, TBS were found to decrease significantly from winter (126.5 kg) or spring (118.0 kg) to summer (91.0 kg), under natural hot climate (Kamal and Seif, 1969). The same authors confirmed that the total body solids (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. In Holstein calves, the heat stress caused a significantly decrease (15%) in TBS (Kamal and Johnson, 1971). In growing buffaloes, TBS were similarly lower at 32°C and 50% RH than at 18°C and 50% RH (100 and 124 kg, respectively) (Kamal *et al.*, 1972). The authors suggested using the heat–induced loss % in dry body weight, i.e. TBS as a heat tolerance index to differentiate between animals in their heat tolerance. The same was true in water buffaloes and Red Danish cattle whether the animals were heifers, pregnant or lactating (Kamal *et al.*, 1978). The later 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 response under heat stress and average body solid content decreased by 16% with the increase in ambient temperature in the climatic chamber (Kamal, 1982). Kamal and Habeeb (1999) found that heat stress induced significantly decrease in TBS in both male and female Friesian calves. Marai and Habeeb (2010) showed that exposure Friesian calves to heat stress decreased significantly TBS. Habeeb et al. (2014) found that the solids DBWG 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 (Table 5).

Concerning the importance of crossing process on DBWG, Saxena and Singh (1983) reported that growth traits of the crossbred calves were higher than those of the parent purebred. These results are explained that the increases of growth performance in crossbreds are due to heterosis in growth rate of the offspring (Habeeb et al., 2002). Nigm et al. (1982) reported that genotype crossing that influences growth performance of cattle. Nasr et al. (1997) showed that the highest values in LBW at birth and weaning were reported by grading up native cows (Baladi) with Friesian or Brown Swiss bull and that superiority mainly due to heterosis in growth rate of the offspring. In another study, birth weight, weaning weight and average DBG were improved in crossing Spanish, Nubian, or Angora with Boer goats (Brown and Machen, 1997). El-Fouly et al. (1998) showed that crossing resulted significant improvement in calves BW and DBWG and attributed that superiority due to the heterosis in growth rate of the offspring. The same author found that crossing between Brown Swiss bull and Baladi cows resulted highly significant improvement in BW at birth, 4 (at weaning), 10 and 12 months of age, whether in male or female calves and concluded that crossbreeding between Brown Swiss bull and Baladi cows successes in increasing BW at birth and weaning as well as at 12 months of age and considered crossing with Brown Swiss bull has effective for improving low producing native cattle. Similar results obtained also by Haque et al. (2011) in cattle and Rodriguez et al. (2011) in sheep and Ahuya et al. (2002) in goats. Norris et al. (2002) reported that DBWG were higher in all the crosses than in the purebred Brahman animals and attributed the high growth rates observed in the crosses were probably due to both heterotic and additive gene effect for growth and adaptation characteristics. In this respect, Habeeb et al. (2002) reported that genotype of crossbred (Brown Swiss bull x Baladi cow) calves is more favorable than those found in purebred (Baladi) calves because cross calves have a good structure and type of genes that collected in pure Brown Swiss bull and transported into native calves. From the nutritional point of view, El-Fouly et al. (1998) reported that brown Swiss x Baladi calves were more efficient in metabolism and adsorption process of nutrients and utilizing less energy intake to produce one kilogram BDG than Baladi calves. Concerning the adaptability, Molee et al. (2011) found that Holstein crossed with local breeds in the tropics and subtropics perform better than the purebred Holstein and were also resistant to heat stress. Finally, Habeeb et al. (2014) found that live and solids DBWG were found to be significantly higher in crossbred than in purebred calves by 243.0 and 102.0 g in winter and 195.0 and 83.0 g in summer, respectively indicating that crossbred calves are better in live and solids daily gain than purebred calves under two climatic conditions (Table 4).

The effects of elevated temperature on growth performance are the products of the decrease in anabolic activity and 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. This causes loss of production per unit of food under heat stress conditions (Morrison and Lofgreen, 1979). The increase of tissue catabolism occurs mainly in fat depots and/or lean body mass (Habeeb *et al.*, 1992). Specifically, there is a reduction in body amino-N (El-Fouly *et al.*, 1998) and endogenous DNA and RNA purine catabolism (El-Fouly and Kamal, 1979) as a result of the increase in catecholamines and glucorticoids. 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 due to the fact that 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 centre in the hypothalamus causing the decrease in feed consumption, i.e., dry matter intake. Thus, fewer substrates become available for enzymatic activities, hormone synthesis and heat production (Kamal, 1982). In addition, 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 (Habeeb et al., 1989). 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 (Habeeb et al., 1992). The decrease in growth traits and the tissue damage estimated by TBS losses in heat stressed animals may be attributed to increase in glucocorlicoids and catecholamines (Alvarez and Johnson, 1973 and Habeeb *et al.*, 2000) and decrease in insulin level (Habeeb. 1987), T_4 and T_3 secretions (El-masry, 1987) and decrease in feed intake, feed efficiency, digestibility and feed utilization (Habeeb et al., 1997 and Bernabucci *et al.*, 1999). 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 (Kadzere et al., 2002). The decrease in the substrates and hormones and the rise in body temperature inhibit the enzymatic activities, which decrease the metabolism and consequently impair 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 (Johnson *et al*., 1988).

Negative Effects of Heat Stress on Milk Yield and Milk Composition

The rise in temperature averages by 1.6, 3.2 and 8.8°C above normal (21 °C) results in the decrease in daily milk yield averages by 4.5, 6.8 and 14%, respectively, and a decline in the daily temperature by 7°C below normal resulted in an increase in the daily milk yield by 6.5% in dairy cattle (Petkov, 1971). Milk production of imported pure breeds from mild climates to the humid tropics rarely exceeded 12-15 kg day and most usually was less than 10 kg day (Raun, 1976). Bober *et al.* (1980) reported that milk production in early, mid and late lactation decreased by 25, 41 and 47%, respectively, at 72 h after the beginning of heat exposure. At 30°C, the high producing animals showed a mean reduction of 2.0 kg / day compared to a reduction of only 0.65 kg / day for the low producing animals (Vanjonack and Johnson, 1975). NRC (1981) studied the effect of environment on nutrient requirements of domestic animals and found that decrease in DMI and milk yield and increase in water intake with increasing of environmental temperature (Table 6).

Table6. *Relative changes in expected dry matter (DMI) and milk yield and water intake with increasing environmental temperature*

Temperature	Expected intakes and milk yields		
	DMI	Milk yield	Water intake
(°F)	(lb)	(lb)	(gal)
68	40.1	59.5	18.0
77	39.0	55.1	19.5
86	37.3	50.7	20.9
95	36.8	39.7	31.7
104	22.5	26.5	28.0

Source: *National Research Council. 1981. Effect of Environment on Nutrient Requirements of Domestic Animals. National Academy Press, Washington, D.C. Dr. Joe West, Extension Dairy Specialist, University of Georgia*

Rodriguez *et al.* (1985) demonstrated that 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. Kamal *et al.* (1989) found that in the hot climate (38°C), the reduction in the average milk yield in Friesian cows was lower by 30% than in the mild climate (18°C) (Kamal *et al.*, 1989).

Habeeb *et al* (2000) studied the effect of lactation number and ambient temperature on T_3 and cortisol levels in milk and blood and milk composition of lactating Water buffaloes. The data showed that milk yield besides milk fat, protein and lactose were significantly lower in July (37.1°C) than in February (17.5°C). The same authors showed that averages of weekly milk yield in buffaloes exposed to 37.1°C during July month were significantly lower than those obtained from buffaloes exposed to 17.5°C during February month in all lactation numbers. From the overall mean of the 6 lactations, it was found that exposure of animals to high environmental temperature caused a depression in milk yield by 16.6%. Habeeb *et al*. (2000) showed that the buffaloes produced milk of a better quality in winter (at February) than that attained under summer conditions (at July). The higher ambient temperature of July month caused a significant decrease in milk total solids, butter fat, protein and lactose contents. From the economical point of view, it is concluded that due to exposure of 6 buffaloes to Egyptian summer heat conditions, the weakly milk production decreased by 51.4 kg and 11 kg total solids loss in their milk. This means that their production benefits decreased weekly by about 100.0 Egyptian pounds according to the price of 1996 (Habeeb *et al.*, 2000). West (2003) added that increasing air temperature, temperature-humidity index are related to decreased dry matter intake and milk yield and to reduced efficiency of milk yield . Milk constituents are also greatly affected by hyperthermia. Friesian cows maintained under 38°C showed lower averages of total solids, fat, protein, ash and lactose yields than when the same animals were maintained under thermoneutral environmental temperatures (Habeeb *et al.*, 1989). The reduction percentages were 28, 27, 7, 22.7 and 30, respectively. Similar reduction values in milk constituents were reported by Habeeb *et al.* (1993, 1996).

Upper critical temperatures for growth rates and milk production of Bos Taurus cattle are in the range 21-27°C and 24-30°C, respectively. The decrease in milk yield and milk constituents of dairy cattle is a result to the depression in feed consumption which is the most important reaction to heat exposure. High ambient temperature during summer (35-40ºC) stimulates the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite centre in the hypothalamus causing a decrease in feed consumption to minimize thermal load on animals. Thus, fewer substrates become available for enzymatic activities, hormone synthesis and heat production (Kamal, 1975). The shortage of energy, substrates and hormonal levels in heat stressed lactating cows may be responsible for the depression in milk yield and composition. In addition, high level of cortisol which was observed in the animals exposed to high ambient temperature may be associated with the depression in quantity and quality of milk (Habeeb *et al.*, 1992). Further, the energy consumed during hot weather is used less efficiently for milk yield because of greater maintenance costs, which were estimated to be 20% greater when environmental temperatures were 35°C and cows use digestible energy with 35.4% less efficiency than that in an 18°C environment and the increase in respiratory and heart rate is responsible for the increased maintenance that occurs during heat stress (West, 1993). In addition, production of hormone releasing factors by the hypothalamic centre is also suppressed causing the metabolic pathways slow down, causing drastic impairment of protein utilization due to shortage of energy, substrates, hormones and enzymes, and a dramatic decrease in apparent digestibility, volatile fatty acids production, rumen pH and electrolyte concentrations in the rumen fluids (Niles *et al*., 1980). Under these conditions, the 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 gluconeogenisis which delivers the amino acids to their corresponding α-keto acids (Alvarez and Johnson, 1973). The increase in catecholamines (lipolytic hormones) or the decrease in insulin responsible for protein anabolism may also contribute to tissue destruction. M0reover, exposure animals to high environmental temperature causes disturbance in each of carbohydrate, lipids, minerals and vitamins 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 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.

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