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Optimizing Animal Productivity under Heat Stress Conditions Using Conventional and Recent Technologies

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Abstract

When the animals exposed to the high environmental temperature most of the physiological and biochemical parameters are disturbances. The heat-induced changes in each of thermoregulatory parameters as well as water, protein turnover or balances and hormonal levels may be used for evaluation the animal's adaptability to hot climate. Detection of such phenomena in the animals could be achieved by different indices. Most of indices which may be used for detecting the heat adaptability in animals are reviewed in this article paper.

Keywords: Animal Productivity, Heat Stress Conditions, Conventional and Recent Technologies.

INTRODUCTION

Heat is the major constraint on animal's productivity in sub-tropical arid zone regions. Growth, milk production and reproductive performance in both male and female animals are impaired as a result of the drastic changes in biological functions caused by heat stress (Habeeb et al., 1989, 1992, 1993 and 1997). The average milk yield and growth of the European cattle are adversely affected reaching in some cases, one-half when transferred to tropical and subtropical countries (Kamal, 1982 Kamal, et al., 1989 and Marai and Habeeb, 1998). The most adaptable animals to such conditions are those which manifest the least deviations in their traits when introduced to such conditions. However, there are individual differences in these changes between breeds and within bread. The difference in the response of such animals under hot climatic conditions is due to their difference in heat adaptability measured by heat tolerance which is the ability of the animal to express its inherited production potential during its life-time when raised under the hot conditions (Kamal, 1982). The heat tolerance indices may be used for selection the heat tolerance animals within or between breeds. Heat adaptability indices for predicting the productive animals under hot conditions are based on production level, water balance, protein balance, thermal response and heat induced changes in hormonal levels (Habeeb, et al., 2007 and 2008).

In tropical and subtropical countries, animal breeders raising European breeds select the animals which maintain high body weight gain or high fertility under hot climate. However, using the production level as an indication of adaptability is a rather time-consuming, since it takes 15-16 months to measure the mature body weight and 30 months or more to estimate the fertility and milk efficiency of doe. Besides, culling of such expensive animals because of their failure to hold their high level of production is a big loss of money. Moreover, body weight gain of heat stressed animals is a misleading index of heat adaptability, since it may be due to the increase in water retention and not to the increase in body protein and fat (Kamal and Johnson, 1971). In other words, a unit of body weight gain in one animal may be due to the increase in body water at the expense of body tissue loss, while in the other, may be due to the increase in body solids. Therefore, it is erroneous to consider the first animal as adapted to heat as the second animal, though both had similar apparent body weight gain. It is concluded that using the production level in estimating the heat adaptability in farm animals is impracticable but using some techniques in estimating the heat tolerance in farm animals is easily, quickly and more available as shown in this article paper.

Providing with suitable housing, feeding, disease and parasite control and heat stress alleviation practices, together with amelioration of the environment, can help heat stressed animals to express their genetic potentials in tropical and sub-tropical areas. This is in addition to carrying out properly routines managerial practices at the suitable times. Alleviation of heat stressed animals can be applied by physical, physiological and nutritional techniques. In tropical and sub-tropical countries, climatic heat is the major constraint on animal productivity. Growth, milk production and reproduction arc impaired as a result to the drastic changes in biological functions caused by heat stress (Habeeb et al., 1992 and Marai et al., 1995 & 1997). The decreases in growth and milk yield of the European cattle may reach one-half when introduced to tropical or sub-tropical environment (Habeeb et al., 2000& 2008 &2009). Generally, good management should aim to well-being, comfort and maintaining high productive and reproductive efficiency of the animals. Under hot climate conditions, the major objective is to facilitate overcoming heat stress, although such criteria is sometimes difficult because its occasional high costs, altogether with that most countries in which it occurs have severe financial constraints. The managemental practices concerned in hot climate, which will be the subject of the present article involve modification of the environment, reducing the animal's heat production and increasing its heat loss.

Buffalo's reaction to hot climate

The heat stressful conditions induce a vast array of biological changes 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 (Kamal 1975; Habeeb, et al., 1992 and Marai, et al., 1995).To overcome such unfavorable conditions, it is needed to ameliorate such environment and select more adaptable livestock.

Selection of desirable stock of hot climates should be for animals physiologically equipped to withstand heat and drought. This could be achieved by selection according to the morphological characteristics that could assist to adapt to hot climate and/or according to the actual ability to maintain expression of the inherited potentials that is estimated by change in either thermal, water or nitrogen balance, after testing the animals under hot climatic conditions.

Among the climatic components that may impose stress on animals are temperature, humidity, air movement and radiation, of which the temperature is the most important. In tropical and subtropical conditions, animals are faced with many problems that relate to hot climate, particularly heat stress, poor quality postures, diseases and parasites, of which heat stress is the most important. In such conditions, animals are exposed to direct and indirect solar radiation (estimated by about 4200 Kj/h /square meter of body surface, in Egypt), increase in metabolic heat production and difficulty in heat loss.

The disturbance in protein metabolism occurred as a result of the depression in appetite and consequently less feed intake as well as the decrease secretion of anabolic hormones, especially thyroxin under hyperthermal conditions, may be responsible for the decrease in blood serum proteins in buffalo calves under SHS and HS. The depression in protein biosynthesis in heat stressed calves may also lead to the pronounced increases in concentrations of the end products of proteins catabolism, i.e. serum urea-N and creatinine (Habeeb et al., 1992).

a. Physiological and biochemical changes:

Under hot climate conditions, normal thermoregulatory 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., 1992).

Among the most important non-genetic factors affecting both quantity and quality of milk in dairy animals are lactation number, season of calving and stage of lactation. These factors may alter the animal responses to high environmental heat. Milk hormones depend mainly on a continuous supply of hormones from the blood to the mammary glands. This transportation of the hormones may be affected by exposure of animals to high ambient temperature. Most of pituitary, thyroid and adrenal hormones in both plasma and milk were affected by heat exposure (Habeeb et al., 1992). 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 and T_3 either in milk or in blood besides milk fat, protein and lactose were significantly lower in July (37.1°C) than in February (17.5°C) while the opposite trend was noted for cortisol levels either in milk or in blood. 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) found that T3 concentrations in both plasma and milk and their ratio in buffalo were significantly affected due to increase of ambient temperature from 17.5° to37.1°C. The overall mean of the 6 lactations showed that plasma T3 decreased by 17.2%. However, this change was inconstant in all lactations. In the 6th and the 1st lactations which characterized by the lowest milk yield, the percentages of decline were highest and reached 20.9 and 22.5%, respectively. While at the 3rd and the 4th lactations which were characterized by the highest milk yield, the plasma T3 was not affected due to increase of ambient temperature.

Habeeb et al (2000) found that plasma T3 values either under 17.5 or 37.1°C was higher at the 1st lactation and exhibited a marked reduction with increasing milk yield until the 4th lactation followed by a rapid increase reaching the highest values in the 6th lactation. It seemed that distribution curves of plasma T3 as affected by lactation number had an opposite trend of milk yield curves. A negative correlation between T3 level in blood and milk yield was found in buffaloes. The decline in plasma T3 in the 3rd and the 4th lactation number may be due to higher utilization of plasma T3 which supply the accelerated process of milk synthesis. Milk T3 concentration declined significantly due to exposure of animals to high ambient temperature in hot summer as compared to mild winter season. The lowest values were in the milk of the 4th or the 3rd lactation and the highest values were in the milk of the 6th and the 1st lactations. These changes through 6 lactations, in general, were comparable to the alterations of plasma T3 (Habeeb et al., 2000). The authors reported that the decline in T3 content in secreted milk as a result of increasing ambient temperature could be related to a reduction in the same hormone content in plasma. Plasma T3/milk T3 ratio decreased significantly due to increase of ambient temperature. This indicates that the decline in plasma T3 was more than in milk T3. In addition, T3 was higher in plasma (5- 6 times) than in milk at all temperature conditions and at all lactation numbers (Habeeb et al., 2000).

Habeeb et al (2000) found that cortisol hormone levels increased significantly either in' plasma or in milk in all lactation number due to increase in ambient temperature from 17.5°C to 37.1°C. The overall mean of plasma cortisol values of the 6 lactations were 9.07 and 12.53 ng/ml during February and July, respectively. The corresponding values for milk cortisol were 1.53 and 2.51 ng/ml. The percentage of increase in cortisol due to heat exposure was higher in milk (64%) than in plasma (38%). Therefore, plasma/milk ratio decreased significantly as ambient temperature increased. The same authors added that plasma cortisol varied in parallel to the changes in milk yield along the 6 lactation numbers. The highest and lowest values were at the 3rd and the 6th lactations, respectively. Therefore, it is reasonable to suppose that with increasing milk yield, the increased concentrations of plasma cortisol were associated with the increased demand of the mammary glands for cortisol for milk synthesis. Cortisol was higher in plasma (2 to 10 times) than in milk at all both temperature degrees and lactation numbers.

Habeeb et al (1992) reported that cortisol level did not consistently increase when animals were exposed to moderate heat. Acute heat will significantly increase cortisol whereas prolonged heat is accompanied by slight declines in plasma level of cortisol. Plasma cortisol increased significantly in each of acute, chronic and prolonged heat. This contradiction in response of cortisol levels to change in ambient temperature may be attributed to the difference between animals in their heat tolerance. In addition, physiological state, production level, type of production, heat exposure period and blood sampling time also may be affect cortisol levels. Habeeb et al (2000) decided that the decline in T3 and the increase in cortisol in the heat stressed buffaloes during July month may be responsible for tire decline in milk components under such conditions. The relatively high total solids (fat, protein and lactose) percentage observed during February can be ascribed to the fact that those animals faced the favorable conditions of the mild winter season in Egypt. 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.

Habeeb et al. (2007) showed that the stressful conditions induced significantly increases in heat shock proteins as well as urea-N and creatinine concentrations and significantly decreases in the levels of thyroxin and testosterone hormones as well as total protein concentration. The severe heat stress and heat stress conditions induced significantly decreases in the average daily body weight gain of buffalo calves when compared to either thermoneutral or mild climatic conditions. The same authors found that the percentage changes, due to stressful condition, in daily body weight gain were highly significantly correlated with the percentage change in each of heat shock proteins, thyroxin and testosterone and concluded that heat shock proteins or thyroxin or testosterone may be used, any one, as heat tolerance index to predict the heat adaptability of buffalo calves to reared in upper Egypt like Toshka area.

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 (Hales, et al., 1996 and McMicael et al, 1996).

High ambient temperature during summer 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. The shortage of energy, substrates and T3 hormone may be responsible for the depression in milk yield and composition. In addition, high level of cortisol which was observed in the buffaloes exposed to high ambient temperature may be associated with the depression in quantity and quality of milk. 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).

b. Thermoregulation in buffaloes:

Animals maintain their heat balance through vasomotor control by regulating the amount of blood flowing through the cutaneous vessels by either vasodilatation or vasoconstriction. Vasodilatation stimulates the pilomotor centre to flatten the hair cover to allow better heat dissipation through conduction, convection and radiation (sensible means). In addition, some heat is lost by evaporation through the lungs and also from the surface of the body as a result of diffusion of water through the skin as insensible perspiration (Marai and Habeeb, 1997).

When ambient temperature increases, the amounts of water lost by insensible perspiration are increases slightly until active sweating starts. The circulation of blood transfers heat from the core to periphery. Excess heat is dissipated by evaporation of sweat as a protective mechanism of the body against overheating. At the same time, respiration rate or panting increases and becomes shallower to permit an efficient ventilation of the upper respiratory tract, without undue overventialation of the lungs themselves (Shafei and Abdelghany, 1978).

When the animal cannot sustain homoeothermic, it reduces the heat production using internal physiological means to help in re-establishment of the thermal balance. Feed consumption and thermogenic hormone secretion decrease to lower the basal metabolism resulting in a decline in productivity. If all these physiological mechanisms fail to balance the excessive heat load, the body temperature rises and the animal enters the acute phase of heat stress that normally occurs within a few days of the animal encountering the high temperature and is accompanied with a rapid decline in productivity. If these systems still fail to stop the elevation in body temperature, the animal succumbs with heat stroke and dies (Habeeb et al., 1992).

c.Adaptation to hot climate:

When exposing the animals to less severe hot conditions following more severe one or two intermittent heat stress between day and night and/or between seasons an acclimation to such renditions takes place and better productivity eventually stabilizes at a level greater than that observed before, but lower than the normal level. Some of these changes occur, rather rapidly (days), whereas others may require a longer period (weeks). When more favorable climatic changes occur, the performance is improved and a compensatory response occurs quite often resulting in a return to productive levels above the normal ones (Ames and Ray, 1983).

Adaptation or the complex of processes by which an animal adapts itself to the hot environment (in which it has to live) depends upon either increasing heat loss, reducing heat production by decreasing the body's metabolic rate and/or increasing tolerance of its tissues to more fluctuating and high body temperatures by varying the body temperature, varying the tolerance to concentrations of salt in drinking water and decreasing water turnover by concentration of waste products in the urine in order to conserve body water, and to conserve nitrogen by recycling urea to adapt to lack of forage in the dry season. Yousef (1985) indicated that the physiological adaptations in the large part are due to changes in hormonal activity, particularly the decrease in thyro-adrenal activity. However, some physiological adaptations vary between species, between breeds within species and between individuals within breeds (forming the basis for the development of a new adapted breed). Natural selection for physiologically adaptive features with some assistance by man helped in manifestation such adaptations. Changes in the behavior of livestock are important in assisting adaptation. In the tropical environment, Livestock become more sluggish in their movements, thus reducing muscular heat production, besides that poultry hold their wings slightly separated when standing and adopt an extended position when lying down. Temperate type cattle seek shade more often during the day and graze at night and all livestock drink and use more water, under the same conditions. Intermittent heat stress helps adaptation than more moderate continuous one, although it is difficult for the temperate breeds to adapt themselves to environments where the mean annual temperature is above 18°C (65°F).

Generally, the heat tolerant animals are those which manifest the last changes in most of the physiological functions when subjected to hot climate, and the good management is that aims to facilitate adaptation

Selection for adaptation of animals in hot climates

Selection of desirable stock for the tropics or sub-tropics should be for animals physiologically equipped to withstand heat and drought, this could be achieved by selection according to morphological characteristic that can assist to adapt to hot climate and/or according to physiological parameters such as the actual response or adaptability to hot climate after testing the animals under the hot climate conditions.

1. Selection based on the morphological characteristics:

The morphological characteristics preferred to the hot climate breeds should include large skin area in relation to live weight, shielded eyes, pigmented skin and eyelids (to lessen susceptibility to eye cancer) and short sleek light colored hair. The ability of animals to shed their coats early in spring, to walk long distances, to adjust to low water intake, high intake of salts either in drinking water or in forages, to poor quality food and to harsh treatment and to resist ticks (animals with long or woolly coats pick up a larger number of larval ticks than animals with short sleek coats) and other pests, must be involved.

With such information in mind, the breeds carrying bos indicus blood could be classified for different cattle areas in tropical and subtropical regions as follows:

- Brahman for the extreme and very severe hot wet ticky regions.
- Santa Gertrudis for ticky fairly severe hot wet and mixed (hot wet and hot dry) regions.
- Africans for ticky hot dry regions.

Regarding the European breeds (Bos Taurus), those with permanent short coats can be used in fairly hot rather humid regions and those with heavy coat, but shed early and decisively in the spring can be used in regions that are fairly hot and humid in summer.

However, the spread of breeds to new areas may often be either a matter of chance or just trial and error, owing to the great complexity of the environment and the unexplained idiosynerasis of breed in respect to things like terrain.

2- Selection based on physiological parameters:

Proper and more accurate selection could be based on the ability of the animals to maintain expression of their inherited functional potential during their life-time when raised under the hot conditions (which is the typical definition of adaptability or heat tolerance). The relative changes in production, thermal, water and/or nitrogen balances of the animals in the conditions under which they have to live could be used in estimating parameters for detection of their adaptability. Such measurements are estimated following testing the animals in hot climates as shown below.

Parameters based on changes in thermal balance:

1. Iberia heat tolerance (IHT; Rhoad, 1944): The test is carried out by keeping the animal in a cattle chute exposed to direct sunlight on a bright calm summer climate for three consecutive days with ambient temperature in shade between 29 and 35°C. the averages of daily rectal temperatures (RT) and respiration rates (RR) measured at 10.00 and 15.00h are calculated. The IHT is estimated by the following equation:

IHT = 100 - 10 (RT - 101) where 101 = the average normal °F of rectal temperature in cattle. If two groups show the same coefficient, the one which has lower RR is considered higher in heat tolerance. Lee and Phillips (1948) made an improvement in IHT test by using a heat chamber to obtain standard conditions of temperature and humidity at which the animals are exposed for 6h. Bonsma (1955) opposed that between breeds there are significant differences in the standard temperature of the body fixed by Rhoad as 101°F and indicated that IHT is valuable in selection within breed for heat tolerance.

2- Benezra index (BI; Benezra, 1954): The test is carried out by using RT and RR as shown in the following equation:

BI = RT/38.3+RR/23 The values obtained above or below 2 represent lower or higher respectively, heat adaptability than normal.

3. McDowell et al. (1955) used RT and RR response during 6h hot room test in estimating the relative response in cattle. The trapezoidal mean RT or RR during a 6h period (Tm) = $(0.5\ t_0 + t_1 + t_2 + t_3 + t_4 + t_5 + 0.5\ t_6) / 6$ where t_1, t_2, t_3, t_4 and t_5 =RT **or** RR recorded after 1, 2, 3.... etc, h. of exposure.

4. Bianca (1963) used the average final RT as heat tolerance coefficient (HTC) as follows:

HTC = 100 - 18 (Tr-38.3) where Tr = (average RT at comfort + Average RT at hot temperature)/ 2. In this index, the decrease in the final RT is accompanied with the increase in heat adaptability. Brown et al. (1969) indicated that the rate of RT rise is definitely related to heat sensitivity, and multiple measurements could be used as a test for heat sensitivity of individual animals.

Parameters based on productive responses:

1- Milk yield, magnitude of rectal temperature and feed energy intake: Milk yield (M), magnitude of RT and feed energy intake (F) could be used as an index for productive adaptability (PA) according to Johnson et al. (1988) as follows:

PA = % increase in RT (% decrease in M + % decrease in F). Negative heat adaptability indicates heat sensitivity and is shown when percentage increase in RT is 2.4 or more and percentage decrease in M is 28 or more, while positive heat adaptability indicates heat tolerance and is shown when percentage increase in RT is 1.2 or less and percentage decrease in M are 8 or less. The PA index is more accurate estimation for the relative level of production potential in adverse hot climates and can provide a scientific basis for the establishment of improved strains for adverse climatic zones.

2- Daily body weight gain (DBWG): Habeeb et al. (2007) showed that the stressful condition of severe heat stress (SHS) and heat stress (HS) induced significant reduction in DBWG of buffalo calves by 22.6 and 16.5%, respectively. The authors observed that there were individual variations in the amount of DBWG which decreased due to exposure of the calves to SHS or HS and consequently the percentage heat induced change differs from calf to another. Consequently, the heat adaptability (100- heat induced %) ranged between 83.9 and 31.4. Therefore, the first calf is the best calf while the second calf is the worst one. In this respect, Habeeb et al. (1992) and Kamal and Habeeb (1999) reported that the heat tolerant animals are those which exhibit the lesser changes in most of the physiological functions when subjected to hot climate. According to Kamal and Habeeb (1999) it can be concluded that first animal was more heat tolerant than second animal or the first animal is the most heat stressed calf because it lost more than 2/3 growth rate when reared under stressful conditions whereas the second calf is tolerated the heat better as it lost less than 1/6 of growth rate only.

Habeeb et al. (2009) showed that the stressful condition of hot climatic conditions induced significant reduction in DBWG by 25.5%. Habeeb et al. (2007) found that exposed the buffalo calves to heat stress conditions of 36.0 and 32.0 ºC induced significant reduction in DBWG by 22.6 and 16.5%, respectively, when compared to mild climate conditions (18.0 ºC). There are individual variations in the amount of DBWG which decreased due to exposure the calves to stressful conditions of summer season. The percentage decrease values ranged between 3.2 to 48.4. Consequently the heat adaptability (100- DBWG decrease %) differs from calf to another, so the percentage heat induced change in calf was 96.8 while in another calf was 51.6. This indicates that first animal growing under stressful conditions more than second one which showed more response to high temperature exposure. The authors concluded that the first calf was best while the second calf was worst one in the heat adaptability coefficient.

Parameters based on changes in water balance:

1- Total body water: Habeeb (1981) used the percentage increase in total body water (TBW) due to heat exposure as index for HTC as follows:

HTC - 100 - [(TBW2-TBW1) x 100 /TBW1 where TBW1 = TBW under comfort and TBW2 = TBW under hot conditions. The most heat tolerance animals are those with the highest values. Kamal (1982) and Kamal and Habeeb (1999) found a significant positive correlation between this index and the percentage increase in body weight gain during hot summer climate.

2. Total evaporative rate: Yeck and Kibler (1958) used the ratio of total evaporative rate (TER) as index for HTC as follows:

HTC = TER at 26.7°C: TER at 10°C. The most tolerant animal is that shows the highest ratio, since evaporative is considered the sole mean of dissipating body heat at high ambient temperatures.

3- Water turnover rate (water input or water intake**):** Kamal et al. (1978) used the percentage increase in water turnover rate (WTR) in estimating HTC as follows:

HTC = 100 - [(WTR_2 – WTR_1) x 100 / WTR_1] where WTR_1= WTR under comfort and WTR_2 = WTR under hot conditions. WTR= Total body water (tritiated water space) x (0.693/ T½ x 24 h of day). The T½ (biological half-life time of tritiated water, ^{3}TOH or ^{3}HOH) = the time needed in days, to remove half total exchangeable body water pool and 0.693 = the tritiated water exponential disappearance rate constant. The most heat tolerant animals are those with the highest values, and that index has proved to be more accurate in determination of adaptability of animals than total vaporization.

4. Biological half-life time of tritiated water (T½): Abdel-Samee (1982) used the percentage decrease in biological half-life time (T½) of tritiated water space (^{3}HOH) due to hot conditions as an HTC index because T½ in animals depends on WTR, i.e. WTR increases and T½ decreases as the ambient temperature increases.

HTC = 100 - [(T½1 - T½2) x 100 / T½$1_{]}$.

Where T½1 of ^{3}HOH under comfort and T½2 of ^{3}HOH under hot conditions.

Parameters based on changes in protein balance

1. Nitrogen retention (NR): Kamal et al. (1962) used the percentage decrease in nitrogen retention [NR = (N intake x digestion coefficient) - N excretion] as HTC index as follows:

HTC = 100 – [(NR_1 - NR_2) x 100 / NR_1] where $NR_1$and NR_2 are nitrogen retention under comfort and hot conditions, respectively. The most heat tolerant animals are those with the highest values.

2. Lean mass: Kamal and Johnson (1970) used the loss in lean mass estimated by the loss in the amount of radioactivity naturally occurring in ^{40}K in the body as a simple index for heat adaptability. The amount of ^{40}K is counted for few minutes in the whole body counter before and after 3 days of heat exposure. From the ^{40}K loss, the amount of lean mass loss can be known.

HTRC = 100 - [Body ^{40}K under comfort - Body ^{40}K under high temperature) x 100 / Body ^{40}K under comfort]. The animal which loses less lean mass at high ambient temperature is considered as a heat tolerant.

3. Total body solids (Live body weight - total body water): Kamal and Johnson (1971) used the loss in total body solids (TBS) that include lean body mass and body fat as heat tolerance index. Total body water is determined before and after three days of heat exposure and each value is subtracted from the corresponding live body weight to obtain TBS under comfort and under hot climate.

HTC = 100 - [(TBS at comfort - TBS at high temperature) x 100 / TBS at comfort]. The most heat tolerance animals are those with the highest values.

4. TBW/ TBS ratio: TBW is determined before and after heat exposure and total body solids was determined by subtracting total body water from the corresponding live body weight to obtain TBS at TN and HS climates. TBW was divided by TBS under each of mild and hot conditions and the heat induced changes in TBW, l / TBS, kg was considered as heat tolerance index. This heat tolerance was found had significantly negative correlated with body weight gain (DBWG) in farm animals as follows:

DBWG = 920.4 – 252.2 x TBW, l / kg TBS [$r = - 0.8925$, $P < 0.002$](Kamal and Habeeb, 1999 and Habeeb et al., 2001).

5. Protein catabolism: El-Fouly and Kamal (1979) used urea entry rate (urea pool size x ^{14}C-urea exponential disappearance rate) in blood as indication for protein catabolism in heat-stressed animals and as index for heat adaptability, since these values increase with different percentages in heat-stressed animals. Kamal (1976) used 15N-urea as an indication to protein catabolism instead of hazardous urea. Such method is quicker and more accurate than nitrogen retention method.

Parameters based on changes in Blood volume and red blood cells volume: Shebaita and Kamal (1973) showed differences in heat tolerance between species and breeds due to differences in changes in blood volume and red blood cells volume in hot climate using radioactive sodium cremate.

Parameters based on changes in DNA bases:

Habeeb et al. (2009) used the heat induced changes in cyclic Guanosine MmonoPhosphate (cGMP) as heat tolerance index. The authors showed that heat-induced significant decrease in cGMP in plasma of animals as a function of heat stress. The averages cGMP concentrations during comfortable and hot climatic conditions were 100.8 and 76.8 fmol / ml, respectively. The result showed that increase the ambient temperature from 24 to 36°C is followed by significantly increasing levels of the cGMP in plasma of calves by 23.34%. The percentage heat induced decrease differs from calf to another and ranged between 9.1 to 55.0. Consequently, the heat adaptability varied between 90.9 which is the best calf and 45.0 which is the worst one. The heat adaptability index using cGMP had a highly significant positive correlation with DBWG and it can be concluded that cGMP is a good index for heat tolerance in growing animals. Habeeb et al. (2009) found that the highest value in the heat induced change in cGMP was observed in the animal which hade the lowest daily body weight gain.

Parameters based on changes in protein fractions:

1. Heat induced changes in total proteins:

Habeeb et al. (2007) found that plasma total proteins values were 7.33 and 7.71 mg/dl in buffalo calves exposed to SHS (36oC) and HS (32oC) conditions and 8.32 and 8.50 g/dl when the calves exposed to comfortable conditions, respectively. The heat induced changes due to stressful conditions of SHS and HS as compared with comfortable conditions were 14.3 and 9.50%, respectively. Habeeb et al., (1992) clarified that the disturbance in protein metabolism occurred as a result of the depression in appetite and consequently less feed intake as well as the decrease secretion of anabolic hormones, especially thyroxin under hyperthermal conditions, may be responsible for the decrease in blood serum proteins in buffalo calves under SHS and HS. Habeeb et al. (2007) reported that plasma total proteins in buffalo calves decreased significantly during summer season of Egypt and the percentage decrease were 14.3 and 9.50 due to exposure the calves to 36 and 32 ºC, respectively, as compared to 18 ºC. The same authors found that the correlation total proteins and each of DBWG and HSP70 was not significant.

Habeeb et al. (2007) reported that globulin values were 4.48 and 3.77 mg/dl in bovine calves exposed to comfortable and hot climates, respectively. The average heat induced decrease in the globulin due to stressful conditions was 15.85%. The percentage decrease values ranged between 1.81% and 36.78% and the percentage heat adaptability values ranged between 98.19% and 63.22, respectively. The percentage heat adaptability using globulin values had positive significant correlations with the percentage changes in each of DBWG.

2. Heat induced changes in Heat shock proteins (HSP): Habeeb et al. (2007) showed that the stressful conditions of 36.0 and 32.0 ºC during summer season of Egypt induced significantly increases in HSP70 concentration in the plasma of buffalo calves and the percentage increase was highly significantly correlated with the percentage change in DBWG (0.971). Habeeb et al. (2007) showed that heat-induced heat shock (HSP70) protein expression in plasma as a function of heat stress. The authors showed that increase in the ambient temperature is followed by significantly increasing levels of the HSP70 in serum of buffalo calves. When considered mild climate as comfortable condition, the heat induced significantly increase in HSP70 by 494, 210% due to exposure of the calves to SHS and HS, respectively. The percentage heat induced change also differs from calf to another. Consequently, the heat adaptability (1000- heat induced %) may be used as the heat adaptability index or a god index for heat tolerance of growing buffalo calves.

The heat-induced HSP70 protein expression in plasma as a function of heat stress was studied also by Habeeb et al. (2009). The predominant HSP70 protein band migrating under comfortable climatic condition is compared to that those under hot climatic condition in bovine baladi animals. The results showed that increase the ambient temperature from 24 to 36°C is followed by significantly increasing levels of the HSP70 in plasma of bovine baladi calves by 17.5% with differs from calf to another. The percentage increase was 3.35 % in calf while it was 58.29% in another calf and consequently, the heat adaptability was 96.65% in the first calf and was 41.71 in the another one, i.e. the first calf is the best while the second is the worst one. The heat adaptability index using HSP70 was parallel with that obtained by daily body weight gain (DBWG) and had a highly significant positive correlation with DBWG (0.797) and it can be used HSP70 as good index for heat tolerance in growing animals.

Habeeb et al. (2009) showed that heat-induced HSP90 protein expression in plasma as a function of heat stress. The predominant HSP90 protein band migrating under comfortable climatic condition is compared to that those under hot climatic condition in animals. The results indicated that the increase the ambient temperature from 24 to 36°C is followed by significantly increasing levels of the HSP90 in plasma of calves by 19.62%. The percentage heat induced increase was 1.34% in calf while it was 50.82% in another calf and consequently, the heat adaptability was 98.66% in the first calf and was 49.18 in another calf. The heat adaptability index using HSP90 had a highly significant positive correlation with DBWG (0.867) and may be using HSP90 is a good index for heat tolerance in growing calves.

Parameters based on changes in hormonal level:

1. Heat induced changes in Thyroid hormones: Habeeb et al. (2007) showed that the stressful condition of SHS and HS induced significantly decreases in T_4 levels by 30.8 and 18.2 %, respectively. The percentage heat induced changes were 25.0 and 70.0 and consequently, the heat adaptability was 75.0 in the first calf (the best calf) and was 30.0 in the worst calf. The lower levels of T_4 in the heat stressed calves may be associated with the decreased animal heat production under hot conditions in order to maintain homeostasis (Habeeb et al., 1992).

The heat-induced changes in both T_3 and Cortisol hormones were significantly correlated with daily body weight gain (DBWG) in heat-stressed animals (Habeeb et al., 2001). The two equations as follows:

DBWG = 997.8 – 12.5 x ng / dl decrease in T3 [r = - 0.881, P< 0.003]

DBWG = 978.5 – 88.3 x ng/ ml increase in Cortisol [r = 0.7945, P < 0.01].

Therefore, Habeeb et al. (2001) used the heat induced changes in each of the two hormones as heat adaptability index for predicting the growth rate of animals under heat stress conditions. The highest values in the heat induced changes in each of T_3 (ng/dl) and Cortisol (ng/ml) were observed in the animals which have the lowest daily body weight gain.

2. Heat induced changes in Testosterone hormone:

Habeeb et al. (2007) reported that the stressful condition of SHS and HS induced significantly decrease in testosterone levels by 33.1 and 21.5 %, respectively. The percentages heat induced changes were 10.0 and 93.3 and consequently, the heat adaptability percentages were 90.0 and 6.7. The lower levels of testosterone in the heat stressed calves may be associated with the decrease of gonadotropin releasing hormone secretion from the pituitary gland of heat stressed animals (Habeeb et al., 1992).

Management of livestock in hot climates:

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

In view to breeds of animals suitable for the tropics or sub-tropics, some areas or countries are favored with their own indigenous breeds, where there is stability in the sense that the stock survive and reproduce despite the climatic rigours, but with, generally, a low level of production Other areas have had to rely entirely or partially on introduction of higher productive tropical or temperate type breeds, that can be raised as purebreds or crossed with the native stock. In the latter case, deliberate measures must be taken to select and breed animals specially fitted for each difficult region as mentioned by Habeeb et al. (1997). In addition, the possibility of a breed to fit in a certain region can be evaluated by constructing climographs (Wright 1946 and 1954) using climate data collected from both the original and new environments by plotting the mean monthly air temperature against the mean monthly relative humidity. Similarity of position, shape and area of the two patterns so formed after joining the twelve points, indicates such possibility. However, disease and parasite criteria, the feed situation, prices of inputs and products and the market situation also, have to be considered, in this respect.

The selected breed for a certain region should manifest the least changes in most of the physiological functions and consequently in die productive and reproductive traits, under the new environment. In addition, when importation of the breed into a new environment is contemplated, a large number of animals of the same breed but from different areas or countries must be included, to give more chance as much as possible genotypes for reaction with the environment. The sires selected should be of high productivity and imported from different herds or countries to avoid inbreeding that occurs inevitably in the small populations. In addition, each sire should be used for mating a group of unrelated females for one year, and then shifted rotationally to the other groups for the same reason. Such practice could be carried out up to the three generations at least, before the use of each sire or it's off springs with its original group. Transport of that breed from its original homeland should be carried out during the mild weather of the year in the new locality, i.e. during winter, in order that the animals can habituate gradually with the onset of summer hot climate. It is also preferred to locate that breed in areas with the mildest climate in the new country and to arrange achieving parturitions of the animals during the mild climate season of the year to avoid summer sanitary problems for the youngest.

With regard to housing, shade is the simplest and a relatively inexpensive tool for combating heat**.** A shed should be placed on a top of a hill if possible, open on all sides and with wire or cable fences, the roof should be 3.5 to 4.0 meters high with its long dimension east-west to prevent exposure to high sun radiation. The roof slopes should be south - north to avoid vertical sun heat. The roof can be made of a 10 to 15 centimeters layer of hay held in place by wire above and below that realizes insulating and cool effects (Marai et al., 1992 and Yousef et al., 1996 & 1997). Such roof do not permit penetration of heat from the sun through to radiate into the animals, as well as, little radiant heat from the animals is reflected back from its underside. In addition, hot air under the shade can rise up through the loose hay. If solid insulating material or wood shade roofs are used, the top should be painted white or shiny to reflect as much heat as possible, and the underside should be dull and dark to avoid reflecting animal heat it receives. The pens should be constructed of wire or cables to offer less resistance to air movement. The adequate surface area from shade per animal is 3.7 - 5.6 square meters for cattle and 1.86 - 2.79 square meters for sheep and hogs to be kept loose in the shed. Vegetation should surround the pens. Shade trees (with falling leaves during winter) should be scattered around and within the yards of the sheds, and such sheds should be scattered in the pasture or range. If livestock owners are compelled to build for housing their animals, they have to use insulating materials for the outer walls with adequate ventilation openings and the roofs should erect 60 centimeter more than the outer walls to protect the walls from direct sun heat. This is in addition to application of all that mentioned in establishing the sheds.

Regarding feeds and feeding, proper requirements should be offered to animals all the year round. Protein content often averages 2-4 percent in deceptively lush-looking grown in there areas. Such forage is usually mature and dry out with a high stem: leaf ratio (due to falling of the leaves while drying).- Digestion of highly lignified fibrous feeds increases the heat output and heat load at a time the animal is already under considerable heat stress. Animals efficient in feed conversion have more ability to withstand heat stress effects, since they produce less heat while digestion of such feeds. Arranging feeding with minimum lignified feeds and / or containing ingredients with low fiber-high energy content produces less metabolic heat is beneficial in such areas (Beede and Collier, 1986). As a general rule, feeds should be administered during the coolest periods of the day, i.e. at early morning, late in the evening or by night, under hot climate conditions. In extremely hot days, it is preferred to keep the animals in the sheds.

With regard to drinking water, ample fresh cool water must be found within each shed. The water troughs and the animals while watering should be shaded by a suitable shelter from the direct sun heat, and the water pipes should be placed at 20 - 25 centimeters depth from the ground surface to keep the water cool in the hot climate. Internal and external parasites, fungi and disease vectors that prevail in high ambient temperatures and humidities require rotational treatments for prevention and adequate facilities for treatments when the animals are infested. This is in addition to application of the known sanitary measures.

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

Methods for alleviation the heat stress conditions on animals:

Environmental amelioration practices arc usually applied to highly intensive enterprises, of which products bring in sufficient return to warrant the expenses, e.g. dairying, feed-lot production or poultry keeping. Some of the management^ practices to ameliorate the environment and reduce the animal's heat production, are shown above.

Below, arc some techniques that can be used to help the animal in dissipating the heat load and to correct the negative effects caused by heat stress. Such techniques arc classified to physical, physiological and nutritional techniques as follows.

a. Physical techniques:

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

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

3- Sprinkling (spraying). The importance of sprinkling in dissipating heat load is due to the high thermal capacity of water (1 cal / gm /°C) and its high heat of evaporation (580 cal/gm). Sprinkling the animal with water would help in dissipating heat from the skin of the animal through conduction and then evaporation of the water layers coating it (Kamal et al., 1989 and Marai et al., 1995 & 1997).

4. Drinking cool water: The beneficial effect of drinking cool water in reduction of the heat load is due to the heat dissipated by conduction as a result to the difference between the drinking cool water and urine temperatures. Moreover, the increase in body water due to the increase in water intake under hot climate helps dissipation of heat by increasing evaporative heat loss through sweating and respiration and by conduction (Habeeb et al., 1994 and Marai et al., 1997).

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

b. Physiological techniques:

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

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

3- Goitrogens administration: These compounds block thyroidal iodine uptake and consequently depress thyroid gland activity. It depresses the secretion of T4 in the heat stressed animals to decrease heat production. However, this technique is not favored under heat stress conditions, since the treated animals under such conditions may be affected seriously due to their need to more energy for greater muscular activity for the high respiratory activity, O2 consumption and energy metabolism (El-Fouly, 1969 and Kamal et al., 1972).

4. Hormonal substances administration: Administration or injection of hormones can be used as a technique for alleviation of heat load on animal since secretion of most of the hormones is depressed under heat stress conditions. However, injection of 74 for this purpose was found to be associated with the increase of body temperature of the animals (Marai et al., 1994). Similarly, insulin injection in the udder was found to show the same effect, besides it increases milk production. Injection by BST also minimized the negative effects of moderately high environmental temperatures on milk yield by increasing heat loss and minimizing the endogenous heat production and related physiological functions without any significant increase in rectal temperature and respirator v rates (Mohammed and Johnson, 1985). However, such techniques require some specific precautions and arc expensive at the same time.

c. Nutritional techniques:

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

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