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REVIEW [REVISION]

BUFFALOES' REPRODUCTIVE AND PRODUCTIVE TRAITS AS AFFECTED BY HEAT STRESS

[CARACTERES PRODUCTIVOS Y REPRODUCTIVOS DEL BUFALO EN CONDICIONES DE ESTRES CALÓRICO]

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SUMMARY

The reproductive traits of buffaloes are affected by climatic changes. In some areas of the world, buffaloes breed throughout the year, but more so in some seasons and a little less in other seasons. In other areas, buffaloes are considered seasonal breeders, since the majority of animals come into oestrus during certain season. Ambient temperature and relative humidity showed a direct effect on breeding efficiency. Heat stress reduces the intensity and duration of oestrus at temperature-humidity index (THI) >25 in hot and <25 in cold seasons. Contrarily, there is a tendency for better performance during the cool months. Generally, it seems that a number of factors, singly or in combination, cause the marked seasonal breeding behaviour. Management, housing and photoperiod may be of the factors that change the manner of manifestation of oestrous symptoms during summer months. The present article reviews buffalo reproductive and productive traits as affected by heat stress: under hot climate conditions. Other animals are included whenever needed.

Key words: buffaloes; heat stress; reproductive and productive traits

RESUMEN

Los caracteres reproductivos del buffalo son afectados por cambios climaticos. En algunas áreas del mundo los bufalos se reproducen todo el año y con un pequeño efecto estacional. En otras áreas, los bufalos son considerados de reproducción estacional. La temperatura ambiente y la humedad relativa tienen un efecto directo sobre la eficiencia reproductiva. El estrés calórico reduce la intensidad y duración del estro a un índice de temperatura y humedad >25 en la época de calor y <25 en la época de frío. Contrariamente, existe una tendencia para un mejor comportamiento animal en las épocas frías. Generalmente, un gran número de factores, aislados o en conjunto, pueden ser considerados como la causa de la conducta estacional. El manejo, alojamiento y fotoperíodo son de los factores que modifican la manifestación del estro en los meses de verano. La presente revisión es acerca de los caracteres productivos y reproductivos del bufalo en condiciones de clima cálido y el efecto del estrés calórico. Otras especies fueron incluidas cuando fue necesaria la comparación.

Palabras clave: Bufalos; estrés caloric; caracteres reproductivos y productivos.

INTRODUCTION

Origin

Bubalus bubalis (The water buffalo), i.e. all types of domestic river and swamp buffaloes: are the domestic form of the wild progenitor Bubalus arnee of India, in southern Asia and possibly the wet areas of western Asia (Brock, 1989), representatives of which are still found in the jungles of Assam.

Bubalis arnee is originated of the Genus Bubalis, Group Bubalina of the Sub-family Bovidae.

The Genus Bubalis surpasses the cattle Genus Bos in its ability to adapt to the hot, humid areas of muddy and swampy lands, since it thrives in the very hot areas of the tropics and subtropics, i.e. in the swamps of Southeast Asia, the marshes of southern Iraq and the valleys of flooding rivers in the Indian subcontinent, as well as, near the River Nile in Egypt.

The water buffalo species, Bubalus bubalis, is divided into two types, the swamp buffalo and the riverine (river) buffalo.

The swamp buffalo (the largest concentration is found in the rice-growing countries of Southeast Asia) is not as adaptable as the river buffalo, since the former is found only in swampy and marshy areas and in hot climates. It is a semi-aquatic animal, spending the hottest part of the day (10.00 to 16.00 h) partly submerged in natural swamps or self-made wallows, i.e. it must have almost unlimited access to water to keep cool. Swamp buffaloes are light in weight (mature weight is approximately 700 kg for males and 500 kg for females) and have a lower milk production capacity (430 to 620 kg of milk / lactation) (Webster and Wilson, 1980). These buffaloes are used mainly for draught power in rice cultivation in the paddy-fields of Southeast Asia.

The riverine buffalo is heavier (mature weight is approximately 1100 kg for males and 550 kg for females). Their milk production capacity is far higher than that of swamp buffaloes, ranging from 1000 to 2000 kg per lactation and varying among strains and countries. The river buffaloes are adaptable to a large range of environmental conditions. The best milk breeds of buffaloes are essentially of the river type and are mostly confined to areas where the summer temperature rises above 46 °C and the winter temperature may fall below 4 °C, in India (India possesses more than half of the world's buffalo population) and Pakistan.

Distribution

Buffaloes are found only in certain regions in the world; principally Asia, some Mediterranean countries, some countries in Eastern Europe and recently in many countries in Latin America. However, although such regions are widely different in the geographical conditions, but no other domestic animal can thrive and be similarly useful and economical.

Particularly, the buffalo is a milk producing species in nearly 25 countries and contributes with a major part of the local milk production [the. milk is white in colour with high fat and solids not fat (SNF) contents as compared to local or imported cattle] in six of these countries, although the buffalo population in these countries is smaller than the cattle population. These countries are India, Pakistan, Thailand, the Philipines, Nepal and Egypt.

In addition, it serves as an economically important source of meat (in Egypt, buffaloes produce about 66 and 43% of the national milk and meat production, respectively; FAO, 1996).

Adaptability

Buffaloes are perfectly suited to the hot and humid climates and muddy terrain, although they exhibit signs of great distress when exposed to direct solar radiation or when working in the sun during hot weather. Such phenomena are due to morphological, anatomical and behavioural characteristics.

Morphologically, buffaloes have a good coat of soft hair like that of cattle at birth and during early calfhood. The hair on the body becomes sparser and almost devoid of hair as the animal grows. The amount of hair coat retained varies considerably, depending on the breed, season and housing practices and because of its exposure to water and mud. The colour of the hair may be black, dun, creamy yellow, dark, light grey or white. Series of B (Brown), C (Albino), D (Dilute) and E (Extension) genes are present in buffaloes, while only A (Agouti), B, C, D, E and P (Pink eye) genes are found in cattle (Searle, 1968).

Anatomically, buffalo skin is covered with a thick epidermis and the basal cells which contain many melanin particles that give the skin surface its characteristic black colour (Shafie, 1985). The melanin particles trap the ultraviolet rays and prevent them from penetrating through the dermis of the skin to the lower tissue. These rays are abundant in solar radiation in the tropics and subtropics, and excessive exposure of animal tissue could be detrimental, perhaps even resulting in skin tumors. This beneficial characteristic is reinforced by well-developed sebaceous glands, with greater secretary activity than in cattle (Shafie and Abou El-Khair, 1970). These glands secrete the sebum, a fatty substance emerges on the skin's surface and covers it with a lubricant, making it slippery for water and mud. This greasy sebum, along with the thick hornified top layer of skin, prevents water and the solutes in it from being absorbed into the skin. In this way, the animal is protected from the harmful effects of any deleterious chemical compounds in the water. Moreover, the sebum layer melts during hot weather and becomes glossier to reflect many of the heat rays, thus relieving the animal from the excessive external heat load. However, although buffaloes are perfectly suited to their environments, but they suffer in the sun, since they exhibit signs of great distress when exposed to direct solar radiation or when working in the sun during hot weather. This is due to that their bodies absorb a great deal of solar radiation because of their dark skin and sparse coat or hair, in addition to that they possess a less efficient evaporative cooling system due to their rather poor sweating ability (although this ability is more efficient than in cattle). Controlled field studies with Egyptian buffaloes revealed that their thermoregulatory mechanism, function efficiently in the shade and these are more effective than those of cattle when the speed of recovery from the effect of stress is taken a measure of efficiency (Mullick, 1960). Pandy and Roy (1969) confirmed these results in their studies on the seasonal changes in body temperature, cardio-respiratory and haematological characteristics, body water content and electrolytic status of buffaloes under conventional farm management.

Particularly, it was found that buffaloes have less physiological adaptation to extremes of heat and cold than the various breeds of cattle. Body temperatures of buffaloes are actually slightly lower than those of cattle, but buffalo skin is usually black and heat absorbent and is only sparsely protected by hair. Also, buffalo skin has one-sixth of the density of sweat glands that cattle skin has, so buffaloes dissipate heat poorly by sweating. If worked or driven excessively in the hot sun, a buffalo's body temperature, pulse rate, respiration rate and general discomfort increase more quickly than those of cattle. Failure to appreciate this caused many buffalo deaths in northern Australia when the animals were herded long distances through the heat of the day as if they were cattle. This is particularly true in young calves and pregnant females. During a trial in Egypt, 2 hours exposure to sun caused temperature of buffalo to rise 1.3 °C, whereas temperatures of cattle rose only 0.2 – 3 °C. Milk production was found to be higher by about 200 kg in more heat-tolerant buffaloes, and with 161 kg in those possessing higher sweat gland density and sweating volume coefficient (Nagareenkar and Sethi, 1981).

Regarding the behavioural characteristics, buffaloes wallow or roll in mud during hot or even cold seasons, due to that sweating process is less efficient. This type of behaviour is more efficient than keeping in low temperature housing, although an artificial wallow becomes fouled by excreta unless the water is continually flowing (Cockrell, 1974). Ragab *et al.* (1953) reported that sprinkling adult females for two hours showed an average fall of 0.9oC in body temperature. Cockrell (1974) added that the body temperature of buffaloes in the hot sun could only be kept normal by wallowing or by quasi-continuous application of water, preferably with air draft or wind to dry it off. Frequent and massive application of such practice is more helpful. Takkar *et al.* (1980) confirmed that the body surface of buffaloes should be kept cool by allowing them to wallow or by sprinkling water at least 4-5 times in a day, during summer months. Experimental evidence has indicated that for maintaining proper homeothermy, the buffalo has to be provided with wallows or showers in the summer months and be protected from cold draughts during the winter months preferably by housing them.

HEAT STRESS

Climatic factors such as air temperature, solar radiation, relative humidity, air flow and their interactions, often limit animal performance (Sharma *et al.*, 1983a, b), of which air temperature is the most important. The relationship between high ambient temperature and increased animals' rectal temperature and the subsequent impact on feed and energy intakes are well known and the effects of heat stress on animal reproduction and production are well established.

Elevated body temperature is due largely to a reduction in the temperature gradient between skin surface and the environment. The effects of exposure to ambient elevated temperature are controlled by the external environment through a chain of reactions involving thermoreceptors, photoreceptors, sensor capacities, the hypothalamus, central nervous system, endocrine glands and gonads.

Heat stress is the state at which the mechanisms activate to maintain animal's body thermal balance, when exposure to elevated temperature.

In cows, heat stress is cyclic in nature, being, generally, at the peak by mid afternoon and cooling somewhat in the evening and early morning hours. Cows may exhibit a respiratory alkalosis in the afternoon, but respiratory may actually overcorrect such a case in the evening so that when cows become cool in early morning a metabolic acidosis occurs. During the day, cows in an unshaded environment have higher rectal temperatures and respiratory rates than shaded cows, but at night both measures were lower for cows with no shade (Blackshaw and Blackshaw, 1994).

The environmental factors associated with heat stress which affect the physiological systems governing thermal regulation and the maintenance of positive heat loss, are primarily ambient temperature, relative humidity (RH) and radiant energy. In tropical and sub-tropical areas, high ambient temperature is the major constraint on animal productivity (Marai *et al.*, 1995, 1997a, b, 2000, 2002, 2007, 2008; Shelton, 2000). The effect of heat stress is aggravated when heat stress is accompanied with high ambient humidity (Marai *et al.*, 1997a, b, c, 2000, 2002, 2007; 2008).

Exposure of buffaloes to the hot conditions evokes a series of drastic changes in the biological functions that include depression in feed intake, efficiency and utilization, disturbances in metabolism of water, protein, energy and mineral balances, enzymatic reactions, hormonal secretions and blood metabolites. Such changes result in impairment of reproduction and production performances. The effect of heat stress is aggravated when heat stress is accompanied by high ambient humidity (Marai *et al.*, 2009, Marai and Habeeb, 2010).

In the shade, buffaloes thermoregulatory mechanisms function efficiently and this mechanism may be more effective than in cattle. At the same time, the buffalo has a greater tolerance to cold weather than are commonly supposed due to its exposure to cold stress in some of the cold areas in which it exists in the world. However, there are no studies available on tolerance of buffaloes to cold stress.

THE BREEDING SEASON

The buffalo has maintained a fine natural conformity with the annual climatic cycles of temperature, humidity, rainfall, sunshine, solar radiation, etc. (which in turn induce the annual vegetation cycle, whether natural or cultivated). The indirect effect of climate on the vegetation pattern seems to be the most influential in the buffalo's natural reproductive-productive pattern. The water buffalo's natural conformity has been reported in several geographical regions, including China, the Philippines, Thailand, Malaysia, Indonesia, India, Pakistan, Iraq and Egypt.

Seasonal high environmental temperatures were found to be associated with low breeding efficiency, when estimating the relationship between ambient temperature and breeding efficiency (Cavestany *et al.*, 1985).

In some areas of the World as in Egypt and Iraq, buffaloes breed throughout the year, but more so in the spring and a little less in autumn. In Japan, however, incidence of normal oestrous cycle (17-26 days) tended to decrease during the spring months (March-June) compared with the other seasons, in swamp buffaloes (Kanai and Shimizu, 1983). In Indian buffalo, Misra and Sengupta (1965) explained that the sex vigour of the buffalo declines during the hot summer and improves with the onset of the colder season, although.Gill and Rurki (1985) reported that regularity of oestrus is not affected by the dry and humid hot seasons, in good management system. On the other side, Beg and Toty (1999) mentioned that buffaloes are seasonal breeders, since the majority of animals come into oestrus during winter and fail to exhibit signs of oestrus during summer, under some tropical climatic areas.

In general, the reproductive traits of buffaloes are affected by climatic changes. However, although some degree of seasonal variation in breeding efficiency is usual with most domestic livestock, the variation is more marked in buffaloes. Particularly, ambient temperature and relative humidity showed a direct effect on breeding efficiency (Roy *et al.*, 1968). Pranee *et al.* (1996) showed that heat stress reduces the intensity and duration of oestrus at temperature-humidity index (THI) >25 in hot and <25 in cold seasons. Contrarily, there is a tendency for better performance during the cooler months. However, it seems that a number of factors, singly or in combination cause the marked seasonal breeding behaviour. Management (Marai *et al.*, 2009), housing and photoperiod may be of the factors that change the manner of manifestation of oestrous symptoms during summer months,

MALES' REPRODUCTIVE TRAITS AS AFFECTED BY HEAT STRESS

Scrotal traits

Socrtal circumference and testicular consistency, tone, size and weight, which are excellent indicators of sperm producing capacity and spermatogenic functions, decrease in hot summer in the sub tropics to the extent that they become lower than those of the same breeds reared under temperate environmental conditions (Fields *et al.*, 1979; Finch, 1986; Yarney *et al.*, 1990). In this connection, Mikelsen *et al.* (1981) recorded the highest scrotal circumference values in the month of October. The reduction in testicular measurements (testes weight and length) by exposure to heat stress is due to degeneration in the germinal epithelium and to a partial atrophy in the seminiferous tubules (Chou *et al.*, 1974). This is reflected in the adverse effects on the average number of testicular cells, especially the secondary spermatocytes and spermatids of types B, C and D, the ratio of steroli cells to other cells and the diameter of the seminiferous tubules (El-Sherry *et al.*, 1980). However, Habeeb *et al.* (2007) reported that farm animal's testes size do not undergo marked seasonal changes.

Testes histological examination suggests that only spermatogenic elements disappear and that interstitial material remain unchanged or increase in number and volume as a function of exposure to heat stress (Gomes *et al.*, 1971).

The local cooling caused by tunica dartos muscle relaxation, i.e. dropping of the testicles away from the body area (Taylor and Bogart, 1988; El-Darawany, 1999; Maloney and Mitchell, 1999) or separation of the testes (scrotum) and the body is necessary for cooling of the testes (3-4 °C below body temperature) and facilitates spermatogenesis to proceed normally (Shelton, 2000). Therefore, the tunica dartos muscle length which is the distance between the upper end of testes and abdominal wall, gives an indication of the magnitude of vascular heat exchange (Curtis, 1983). When scrotal (testicular) temperatures exceed the suitable values, the possibility exists at interference with sperm production. In addition, any conditions that cause high temperature in the animal such as long hair cover, over condition (too fat) and lack of adaptation, are likely to have adverse effects on spermatogenesis. The amount of hair on the scrotum interferes, particularly, with local cooling. Thus, shaving the scrotum or breeding bulls without hair on the scrotum, at least to the level of the epididymis, facilitates cooling and maintenance of sperm quality. However, animals do not become sterile at high temperatures, but a high percentage of bulls could be sterile during the summer under conditions of high humidity, where local cooling is ineffective (Shelton, 2000).

Scrotal temperature of bulls is regulated independently of body temperature and is performed as a result of a feedback circuit involving scrotal thermo-receptors and effectors which are related to the tunica dartos muscle and scrotum sweat gland activities. Meanwhile, this local circuit is not affected by adjustments to the general thermoregulatory control system during fever. The effect or mechanisms are found to be insufficient to maintain scrotal temperature when exposed to extreme heat or cold temperatures (Maloney and Mitchell, 1999). El-Darawany (1999) found that the tunica dartos muscle length was the shortest when testes of bulls and rams were immersed in water at 17 and 18 °C, while the maximum values were recorded at 35 and 34 °C, respectively. Similarly, Marai *et al.* (2006) found that during the seasons, the tunica dartos muscle length was greater in summer and autumn than in winter, in rams.

Spermatogenesis

High temperature usually affects inversely the processes of spermatogenesis and metamorphosis of sperms, that cause semen degeneration (Coser *et al.*, 1979). Accordingly, impairment of each of fertility power of spermatozoa and their ability to produce viable embryos, are expected with heat elevation (Wildeus and Hammond, 1993). Particularly, Sahni and Roy (1967) reported that maximum and minimum temperatures for optimum spermatogenesis were 29.4 and 15.6 °C, respectively. Seasonal differences, with minimal spermatogenesis occurring during summer months that is usually referred to as "summer sterility" (Akpokodje *et al.*, 1985), are attributed to reduction of steroidgenic function of the testes and to the decrease of the blood flow through the testes (Setchell, 1970).

Despite the thermoregulatory mechanism of the testes, sexual desire (libido) is negatively affected by high environmental temperature. Such phenomenon, altogether with the adverse effects on ejaculate volume, live sperm percentage, sperm concentration, viability and motility (Gamcik *et al.*, 1979), reduce conception and fertility rates of the male, i.e. reduce the male's fitness.

Reaction time (libido)

In buffaloes, 75 percent of the services occur during the 4 months of the mildest period during the year that constitute the breeding season (November - February), and the bull is used at least three times a week during this period, in Egypt (Asker and El-Itriby, 1958).

The reaction time (libido) was reported to be generally shorter in summer season than during the other seasons. The shortest time (9.4±0.6 minutes) was recorded during summer and the longest (15.9±1. 5 minutes) in autumn. Values of 10.5±0.7 and 14.7±1.1 minutes were recorded in spring and winter, respectively (El-Saidy, 1988). However, El-Sherbiny (1987) mentioned that it was significantly longer in summer season than in the other seasons of the year.

The optimum climatic conditions for sexual activity were found to be either during autumn or spring season (Hafez, 1968; Ziedan, 1989) and the lowest sexual activity was shown in summer season (Zeidan, 1989)

Physical characteristics of semen

The quantity and quality of semen vary with season of the year, although the degrees of response (to seasonal effects) vary according to species, breed and locality.

Season of the year effect was significant on ejaculate volume. However, the data in the literature showed that the influences of high environmental temperature on semen-ejaculate volume were conflicting. The studies of Zeidan (1989) and Marai *et al.* (1996) showed that semen-ejaculate volume decreased, while studies of Fawzy (1982) showed remarkable increase with heat elevation. The highest mean value (3.7±0.1 ml) was recorded in winter and the lowest (2.4±0.1 ml) in spring. Mean values of 2.9±0.2 and 2.6±0.1 ml were recorded in summer and autumn, respectively.

The effects of season on motility of spermatozoa were also conflicting. Some studies showed that the initial motility of spermatozoa decreased in hot climate conditions (Ax *et al.*, 1989; Zeidan, 1989). Other studies indicated that motility of spermatozoa either increased (Oloufa *et al.*, 1959; El-Azab, 1980) or did not show any change due to season of the year or elevation of temperature (Zeidan, 1989; Silva *et al.*, 1991).

Percentage of live spermatozoa differed significantly between seasons. The averages were 87.5±0.5, 76.2±0.8, 74.5±1.5 and 85.8±0.6% during spring, summer, autumn and winter, respectively (Zeidan, 1989). Everett *et al.* (1978) recorded the highest total sperm-output during summer season.

Spring and summer seasons were characterized by the highest percentage of ejaculates with white milky (47.4%) and opaque creamy (28.5%) appearance, and by the lowest percentage with greyish soapy (14%) and transelucent watery (10%) appearance. In contrary, autumn showed the highest percentage of bad semen appearance. In other words, the highest percentage (47.4%) of ejaculates showed a white milky appearance, whereas (28.5%) was opaque creamy, 14% greyish soapy and 10% transelucent white watery. Generally, semen appearance varied from opaque creamy to transelucent watery.

The above confliction in the results may be due to type and duration of heat exposure, intensity of environmental heat and differences in species, breed and age of the experimental animals.

Chemical characteristics of semen

Seminal plasma contains many organic compounds which are not found elsewhere in the body at such high concentrations. Such compounds are fructose, total phosphorus, total nitrogen, citric acid, sodium, potassium, calcium, sorbitol and spermine. These substances are produced by various accessory glands in response to testosterone. Their estimation in ejaculated semen or directly in the glands can be used as an index of the accessory gland functions.

Initial fructose concentration shows seasonal, as well as, monthly variations. Some studies revealed that fructose concentration decreased (Wildeus and Hammond, 1993), while others recorded either an increase (El-Shamaa, 1983; Zeidan, 1989) or no significant change by exposure to high environmental temperature (Dojeseva *et al.*, 1979). Total phosphorus concentration in semen was found either to decrease significantly (Fawzy, 1982; El-Shamaa, 1983) or increase significantly (Oloufa *et al.*, 1959), during summer season. El-Keraby *et al.* (1980) found that the highest value of total nitrogen in semen was in spring and the lowest in autumn.

Citric acid concentration was found to decrease significantly as a result to exposure to high environmental temperatures (Amir and Volcani, 1965). Sodium and potassium cation concentrations were found either to decrease in summer than in winter season (El-Shamaa, 1983; Zeidan, 1989), or to be significantly higher during summer than in the other seasons of the year (Fawzy, 1982). Total calcium concentration in seminal plasma was found either to increase (Marai *et al.*, 1991) or decrease (El-Azab, 1980) in summer than in winter or not significantly affected (El-Keraby *et al.*, 1980) by season of the year. Zeidan (1989) reported that the highest calcium concentration was found in spring and the lowest in winter season. Hydrogen ion concentration (pH) in semen differs significantly between seasons of the year (Kapoor, 1973; Zeidan, 1989), but with high correlation coefficients with environmental temperatures (0.73 to 0.83). However, some studies showed no such significant correlations (Gili *et al.*, 1974; Osman, 1988).

Generally, elevation of ambient temperature affects male reproductive functions deleteriously. Such phenomenon leads to testicular degeneration and reduces percentages of normal and fertile spermatozoa in the ejaculate of males. The ability of the male to mate and fertilize is also affected.

The biological backgrounds of such phenomena include disturbances in each of sexual activity, endocrine and testes functions, spermatogenesis and physical and chemical characteristics of semen.

Most of anabolic and thermogenic hormones such as thyroxine, triiodothyronine, insulin, growth hormone, cortisol and aldosterone decrease appreciably under hot climatic conditions in an attempt by the animal to decrease its endogenous heat production to tolerate heat. The adrenal function is also reduced in heat-stressed animals and this may allow the animal to cope with the environment because of the calorigenic actions of glucocorticoids (Gwazdauskas, 1985).

Regarding male sex hormones, Gomes *et al.* (1971) and Rhynes and Ewing (1973) estimated the decrease in testosterone concentration with one-third of that of the control after 2 weeks of exposure to high ambient temperature.

In artificial insemination, Stott *et al.* (1972) identified the first 4 to 6 d post-insemination as the most critical. However, Ingraham *et al.* (1974) claimed that for optimal conception rate, heat stress must be minimized at least 12 d prior to breeding. Heat stress also adversely affected the sperm and the ovum in the reproductive tract and early embryo development (Burfening and Ulberg, 1968), and may alter the hormonal balance of the dam (Stott *et al.*, 1972; Thatcher, 1974). Most data on the influence of high environmental temperature on reproduction in dairy caws are reported by Monty and Garbareno (1978) and Wise *et al.* (1988).

FEMALES' REPRODUCTIVE TRAITS AS AFFECTED BY HEAT STRESS

Age at first calving (AFC)

Indian buffaloes AFC was found to be either affected significantly (Kanaujia *et al.*, 1974; Cady *et al.*, 1983; Misra *et al.*, 1986), or insignificantly (Tomar and Tomar, I960; Johari and Bhat, 1979; Reddy and Mishra. 1980; Khosla *et al.*, 1984; Reddy and Taneja, 1984; Dutt and Yadav, 1987) by season and / or month of birth. In Egyptian buffaloes, the studies showed that there were no significant effects of season of birth on AFC (El - Sheikh and Mohamed, 1965; Mourad, 1978; Ashmawy, 1981; Eid, 1988; Ibrahim, 1989; Rashad, 1989; Zaki. 1989; Alim, 1991). Regarding the effect of month of calving, El-Sheikh and Mohamed (1965) found that calving for the first time occurred at a younger age in heifers born in October, November and December than in those born in any other months of the year in the same type of animals, but the differences were not significant.

Weight at first calving was found to be affected significantly in primiparous Egyptian buffaloes and the heifer buffaloes which calved in winter were lighter in weight as compared to those calved in summer and autumn (Rashad, 1989; Zaki, 1989). Other studies showed that body weight at calving was insignificantly affected by month and season of calving in Egyptian (Ragab and Abdel - Salam, 1962; Eid, 1988) and Indian buffaloes (Johari and Bhat, 1979; Chourasia *et al.*, 1984; Reddy and Taneja, 1984; Singh *et al.*, 1984).

Oestrus

During the day, onset of oestrous behaviour was found to take place during the cool periods of the morning and the evening, but the peak was in the morning. El-Wardani (1995) and El-Wardani and El-Asheeri (2000) observed that the buffaloes exhibited the signs of oestrus in the early morning (3.00 to 9.00 h) and in the evening (15.00 to 21.00 h) with a peak in early morning (about 37 %), while the lower percentage was at noon (about 12 % of oestrous cases started during the period from 9.00 to 15.00 h).

In the hot season, buffaloes display the most remarkable sexual activity in the morning (6.00 h) and midnight (24.00 h) and the lowest activity at noon time (12.00 h), although Rife (1959) claimed that practically, there was no incidence of oestrus during the hot months and the oestrous symptoms were not pronounced during the adjacent periods. In the mild season where the ambient temperature goes extremely down, particularly at night (24.00 h), buffaloes might modulate their physiological function to display most of their sexual behaviour at the time of the day where the ambient temperature is moderate.

Comparison between seasons of the year shows that ovarian activity decreases in hot summer and increases during winter and spring, i.e., when ambient temperature decreases. Oestrous cycle is suppressed (Williamson and Payne, 1971), as well as, anoestrum is produced (Bond *et al.*, 1960), during heat stress. The observed cases of oestrus were more frequent and stronger in the milder season, accompanied by changes in the seasonal pattern of sex hormones (Shafie *et al.*, 1982; Barkawi *et al.*, 1989). The number and amplitude of the luteinizing hormone (LH) pulses was greater in the colder season (Aboul-Ela and Barkawi, 1988). However, Shafie *et al.* (1982) reported that almost equal incidence of ovulation in the hot (May-October) and the milder (November-April) seasons, were observed in a herd of buffaloes in Egypt.

Concurrently, the decline in feed intake and in the quantity and quality of feed available, especially with respect to: protein, vitamin A and phosphorus, aggrivate the negative influence on the adenohypophysis. Less gonadotrophic hormone release results in weak heat and/or anoestrum (El-Sawaf *et al.*, 1979). Incidence of anoestrum due to increase in plasma corticoids and progesterone (Abily, 1974) and shortening of duration of oestrus and decrease in intensity of oestrous expression (Bianca, 1985) with exposure to heat stress, could be another explanation for these phenomena. Gwazdauskas *et al.* (1981) and Drost and Thatcher (1987) reported that slight elevation in each of proestrous estradiol, progesterone and corticoid concentrations during the luteal phase were detected in heifers and cows upon exposing to heat stress. The differences in both proeostrous estadiol/progesterone ratio and luteal progresterone concentrations may be correlated with the quality of the developing pre-ovulatory follicles, the intensity of oestrous behaviour and subsequent microenvironment of the oviduct and uterus (Drost and Thatcher, 1987).

Such phenomena could also be attributed to reduction in ovarian function (El-Sawaf and Schmidt, 1962) and immense irreparable damage (El-Sawaf *et al.*, 1979) which result in complete ovarian inactivity in heat-stress.

Oestrous cycle length

Length of oestrous cycle and degree of expression of oestrus in buffaloes are affected by various factors, such as season, climate, photoperiod, temperature and nutrition (Beg and Toty, 1999). Hafez (1953), Shalash (1957) and Salama *et al.* (1967) confirmed that season of the year affected buffalo oestrous cycle length. The longest cycles is associated with the hot season in Egyptian (Salama *et al.*, 1967; Barkawi, 1981) and underfed Murrah buffalo cows in India (Kaur and Arora, 1982). Shalash (1957) explained that the longest duration (23.33 days) occurred during May (hot climate) and the shortest (20.29 days) during October (less hot) in Egyptian buffaloes. The same author added that the difference was highly significant. Contrarily, Badr (1993) reported that Egyptian buffaloes calved in the hot season showed a shortened oestrous cycle length in cows as indicated by the length of the luteal phase. However, Hashem (1996) showed that length of regular progesterone cycles for buffaloes calved during the hot season was 23.15±1.14 days, while that in buffaloes calved during mild season was 23.19±2.74 days. Singal *et al.* (1984) reported that thermal stress increased the ACTH / cortisol level, which caused a change in the endocrine secretion resulting in anoestrus. This inactivity of ovaries associated with thermal stress may in part be avoided by applying some physical alleviation techniques during the hot dry period.

Nutrition and management are considered the main factors affecting frequency of oestrus in buffaloes in the humid tropical Amazonian climate, in Brazil (Vale *et al.*, 1991). In Egypt, Marai *et al.* (2009) confirmed the latter conclusions.

Silent heat

Season of the year to exerted a significant effect on occurrence of silent heat, since Barkawi (1981) showed that percentages of silent heat were 85 and 56 for hot and mild seasons, respectively, and Badr (1993) found that incidence of the silent heat was higher in the buffaloes calving during the hot season (35.7 %) than in those calving in the mild season (27.3 %). However, in buffalo heifers, season of the year seemed to exert a non significant effect on occurrence of silent heat (El-Sheikh and EI-Fouly, 1971).

Anoestrus resulting by thermal stress (Singal *et al.*, 1984) may be the reason in the heat silent in buffaloes. The ovarian activity as monitored through rectal palpation or changes in blood progesterone concentration decreases during the more hot period during the year than during winter and spring (October-March, mild period) (EI-Fouly *et al.*, 1976b).

The level of estradiol hormone was significantly lower in more hot season (March-May) at all stages of the oestrous cycle compared to the corresponding stages in the mild season (October-November), while significant reverse trend was observed for progesterone level in Egyptian buffalo cows (Shafie *et al.*, 1982). Shafie *et al.* (1982) suggested that the decrease of estradiol level in the hot season particularly on the day of oestrus may depress the intensity of oestrus manifestation resulting in higher incidence of quiet ovulation in buffaloes.

The ovarian activity delay, high incidence of quiet ovulation and high percentage of sustained anoestrus by hot month calvers, are most probably due to the effect of hot conditions which cause decrease of pituitary gland responsiveness to GnRH and consequently depress the ovarian activity (El-Fouly *et al.*, 1976a; Aboul-Ela *et al.*, 1983).

Pregnancy rate

Buffaloes can calve at any season of the year in Egypt with no detrimental effect on their productive efficiency if the buffaloes are kept all time under suitable conditions of feeding and management (Ashmawy, 1981).

Most of the calvings (63%) occur during the milder seasons of the year (autumn and winter) (El-Sheikh, 1987), which are characterized by optimum temperatures and an abundance of nutritious pasture fodder for the lactating buffalo and offspring, in Egypt.

Thermal stress adverse effects on the conceptus and dams subsequent post-partum performance are pronounced during the initial stages of gestation, as well as, during late gestation. High summer temperature above the thermoneutral zone drastically reduces conception rate (CR) and presumably increases embryonic loss, in cattle (Gwazdauskas *et al.*, 1981).

At time of insemination or during the days after breeding, the adverse effects of heat stress affected CR in Florida, since CR between 10 to 15% were recorded following artificial insemination during heat stress (Gwazdauskas *et al.*, 1973; Badinga *et al.*, 1985). Gwazdauskas *et al.* (1975) showed that rising ambient temperature from 12.5 to 35 °C was accompanied by decline of CR in cattle from 40 to 31%. Particularly, an increase in rectal temperature of 1 °C at 12 h post-insemination was found to be associated with a decrease of CR in cattle (45 vs 61%) (Ulberg and Burfening, 1967). Likewise, increase in uterine temperature of 0.5 °C on the day of, and day after insemination, was associated with decline in CR of 13 and 7%, respectively (Gwazdauskas *et al.*, 1973). Particularly, Gwazdauskas *et al.* (1975) also found that when solar radiation increased from 300 to 800 langleys (langley = 19 calorie per square centimetre), CR dropped from 39.5 to 26.0%.

Particularly, CR drop significantly and do not recover until November, in lactating dairy cows, during summer months in subtropical regions such as Florida (Thatcher and Collier, 1986). The highest first service CR was shown by females inseminated in winter (Azzam *et al.*, 1989).

The cow and bull contribute in the low CR in the subtropics, but the female was the major contributor (Stott *et al.*, 1972).

The high adverse effects in females are shown on the ova, their fertilization and consequent development of embryos (Neville and Neathery, 1974). Drost and Thatcher (1987) reported that, since the temperature of the blood is cooler than that of the uterus, the consequent reduction in blood flow to the uterus allows the uterine temperature to rise. The decrease in estrogen concentration as a function of heat stress and, consequently, the sufficient alteration of environment in the follicle suppresses normal maturation of the egg, in addition to, depression or postponing of the "ovulatory spurt" of LH. However, Drost and Thatcher (1987) reported that fertilization rates may be normal in heat-stressed cows, but embryonic death may increase in either the zygotes or in the early developing embryos when the embryos are still in the oviduct or after they arrive in the uterus, i.e. before maternal pregnancy recognition (days 15 to 17).

Early embryonic development and survival are affected when exposed acutely to high environmental temperature during the period of rapid conceptus development and maternal recognition of pregnancy (Dutt and Jabaro, 1976). Conceptus size and weight are reduced with exposure to heat stress (Biggers *et al.*, 1987). Such phenomenon may be explained by that the conceptus metabolic rate, nutrients uptake and growth are altered by elevated uterine temperature. The increase in conceptus metabolic rate, as well as, the possible decrease in nutrient secretion by the uterus may result in retarded conceptus development. The increase in body temperature accompanied with low progesterone concentration may also alter endometrial secretion, forming an unfavorable environment for conceptus growth (Thatcher *et al.*, 1985). Conclusively, depression of reproductive efficiency through reduced CR caused by an unfavourable thermal environment may be related to the direct effect of the increase of uterine temperature on embryo development or indirectly through a modification in the endocrine of the dam.

In general, Biggers *et al.* (1987) reported that seasonal variations in CR were closely correlated with climatological factors such as temperature, humidity, solar radiation, atmospheric pressure, perspiration and day length.

In summary, high environmental temperature suppresses oestrus resulting in periods of anoestrus which interfere with ovulation. Hyperthermia can also interrupt early pregnancy by causing death and resorption of embryos and abortion of well grown foetuses. Oestrous cycle length, duration of oestrus, incidence of abnormalities in the ova, embryonic mortality, fetal death rates, gestation length, fetal size, incidence of oestrus with weak signs, percentage silent heat, ovulation failure, interval from parturition to conception and the number of services per conception, may increase. The frequency of ovulatory oestrus, fertilization rate and neonatal survival may decrease as a function of heat stress. Heat stress also causes loss of libido and reduction in ovarian activity and CR.

Days open

Environmental heat stress during late gestation has pronounced effects on the conceptus (growth) and dams subsequent post-partum performance.

Days open, the period between parturition and successful mating was found to be affected significantly ($P<0.001$) by season of birth (Kirrella, 1977; Alim and Taher, 1979; Marai *et al.*, 2009). The lowest length of days open was found to be during summer and autumn (Kirrella, 1977; Alim and Taher, 1979; Marai *et al.*, 2009). The THI values were 32.1 and 26.4 during summer and autumn, respectively, indicating exposure to very severe heat stress during summer and autumn seasons, with the highest THI value during summer (Marai *et al.*, 2009).

The length of the days open depends on restoration of normal post-partum uterine function. Restoration of normal post-partum uterine function which is a prerequisite for normal cyclicity is affected by pre-partum environmental influences (Lewis *et al.*, 1984).

In cows exposed to heat stress pre-partum, the rate of uterine involution and post-partum peripheral plasma concentration of PGF2a increase and corpous leteum (CL) diameter reduces (Lewis *et al.*, 1984). Oxytocin also induces a rapid increase in luminal and myometrial secretion rates of PGF by endometrium in heat-stressed pregnant cows, as well as, in endometrial tissue of cyclic cows (Oyedipe *et al.*, 1984), although an attenuated increase exist in secretion of prostaglandins in response to oxytocin during early pregnancy in cattle (Lafrance and Goff, 1985; Gross *et al.*, 1988). The decrease in CL size may be due to heat-induced partial regression of CL attributed to greater uterine secretion of PGF2a (reflected by greater concentrations of systemic PGF) in heat-stressed animals, since maintenance of the luteal function is associated with decease in endometrial PGF2a secretion. The increase in endometrial protaglandin secretion rate in response to heat stress may compromise CL function, initiate partial or complete luteal regression and contribute to pregnancy failure.

Lactation length

Lactation length was affected significantly by season of birth in Egyptian buffaloes (Alim, 1978; Alim and Taher, 1979; Ashmawy, 1981; Mostageer *et al.*, 1981; Mourad *et al.*, 1990; Mohamed, 2000; Marai *et al.*, 2009). The shortest length of lactation length was reported in summer and the longest in spring (Mourad, 1978; Mostageer *et al.*, 1981; El-Khaschab *et al.*, 1984; Mohamed, 2000).

Dry period

Season of birth was found to affect the dry period of Egyptian buffaloes significantly by Alim (1978) and insignificantly by Ashmawy (1981), Mourad *et al.* (1990), Mohamed (2000) and Marai *et al.,* (2009). The shortest length of the dry period was reported in spring and the longest in summer (Mohamed, 2000).

Calving interval

Calving interval was affected significantly by season of birth in Egyptian (El - Sheikh and Mohamcd, 1965; Kirrella, 1977; Alim: 1978; Alim and Taher 1979; Mourad *et al.*, 1989, Rashad, 1989; Zaki, 1989; Khalil *et al.*, 1990; Marai *et al.*, 2009) and Indian buffaloes (Singh *et al.*, 1958; Bhatnagar *et al.*, 1961; Venkataratnan and Venkayya, 1964; Sharma and Singh, 1974; Basu *et al.*, 1978; Roy *et al.*, 1981; Cady *et al.*, 1983; Singh *et al.*, 1987).The lowest length of calving interval was during summer and autumn (El-Khaschab *et al.*, 1984; Marai *et al.*, 2009).

Particularly, exposure of buffaloes to heat stress evokes a series of drastic changes in the biological functions that include depressions in feed intake efficiency and utilization, disturbances in metabolism of water, protein, energy, and mineral balances, enzymatic reactions, hormonal secretions and blood metabolites. Such changes result in depressions in live body weight, growth rate and total body solids and daily body solids gain weight averages and impairment of reproduction (Marai and Habeeb, 1998; Marai *et al.*, 2007).

PRODUCTIVE PERMANCE TRAITS AS AFFECTED BY HEAT STRESS

Thermal stress adverse effects on the conceptus and dams subsequent post-partum performance traits, are pronounced during initial, as well as, late stages of gestation.

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Growth traits

Growth, i.e. the increase of live matter or cell multiplication, is controlled genetically and environmentally by well balanced available nutrients, hormones and enzymes. In mammals, growth is the change in live body weight during the different stages of life.

Growth

Body weights at birth, weaning and at first service, and daily gain weights from weaning to first service and from weaning to first service were found to be affected significantly by season of birth.

At birth, such effects were detected in Egyptian (Ragab and Abdel-Salam, 1963; Fahmy. 1972; Sadek, 1984; Eid, 1988; Osman, 1989; Zaki, 1989; Mohamed, 2000; Marai *et al.*, 2009), Indian (Basu *et al.*, 1978; Johari and Bhat, 1979; Krishnamoorthy *et al.*, 1979; Gogoi *et al.*, 1985) and Iraqian (Thapan and Alrawsi, 1984) buffaloes. However, other studies showed no significant effect in Egyptian (Alim, 1964, 1991), Indian (Gudi *et al.*, 1971; Singh *et al.*, 1984) and Italian (Roy Choudhury, 1971) buffaloes. The birth weight was the heaviest in winter (Fahmy. 1972; Alim and Taher. 1979) or in spring (Asker and Ragab, 1952; Sadek, 1984) and the lightest in summer (Eid, 1988; Zaki. 1989 and Marai *et al.,* 2009), in Egyptian buffaloes. In cattle, birth weight of calves was also found to be lower during hot summer months than during cool winter months with 6 kg in Holstein, in the subtropical environment of Florida (Collier *et al.*, 1980). This is in addition to the low weight of the foetal membranes collected within 24 hours of parturition during July and August (from Holstein and Jersey cows) than of those collected during the remaining months of the year (Head *et al.*, 1981). Particularly, the calf birth weight of heat-stressed cows was found to be associated with a lower mean prepartum concentration of estrone sulfate in maternal plasma which may be an indication of reduced conceptus function during thermal stress, since estrone sulfate is produced by the foetal placenta (cotyledon) (Thatcher and Collier, 1986).

At weaning, the summer born calves were lighter significantly than those born during the other seasons, in Egyptian buffaloes (Zaki, 1988; Osman, 1989; Mohamed, 2000; Marai *et al.*, 2009). However, no significant effect was found by Alim (1964, 1991) in Egyptian buffaloes and by Singh *et al.* (1984) and Chawla and Tripathi (1994) in Indian buffaloes. Aman *et al.* (1984) and Peeva and Vankov (1994) reported similar results in other types of buffaloes.

Weight at first service was lighter significantly in summer born calves than in those born during the other seasons, in Egyptian (Zaki, 1988; Osman, 1989; Mohamed, 2000; Marai *et al.*, 2009) and Indian (Rathi *et al.*, 1973) buffaloes. However, no significant effect was found by Ragab and Abdel-Salam (1962), Tantawy (1984), Eid (1988), Galal *et al.* (1992) and Mohamed (2000) in Egyptian buffaloes and by Aman *et al.* (1984), Singh *et al.*, (1984) and Chawla and Tripathi (1994) in Indian buffaloes.

Daily body gain weight from birth to weaning as affected significantly by season of birth was detected in Egyptian (Fahmy, 1972; Tantawy, 1984; Marai *et al.*, 2009) and Murrah and Surti Indian buffaloes (Bhavsar *et al.*, 1974). However, Tantawy and Ahmed (1955) and Basu and Rao (1979) found no significant effect of season of birth on daily gain from birth to weaning. The lowest daily weight gain value between birth and weaning was in summer-born calves. Such phenomenon may be attributed to suffering of the foetei from the adverse effects resulting from exposure of their dams during late pregnancy to moderate to very severe heat stress (THI= 22.8 to 32.8; during summer, Marai *et al.*, 2009). El-Masry and Marai (1991) reported that the hot conditions caused disturbance in the normal physiological balance of the dam.

Daily body gain weight from weaning to first service as affected significantly by season of birth was detected in Egyptian buffaloes (Fahmy, 1972; Tantawy, 1984; Marai *et al.*, 2009). Vankov *et al.* (1967) in Bulgarian buffaloes and Bhavsar *et al.* (1974) and Johari and Bhat (1979) in Indian buffaloes reported that the calves born in the hot months, gained less weight than in those born in the cold months. However, Marai *et al.* (2009) found that the lowest average daily gain value was in winter births in the Egyptian buffaloes. Basu and Rao (1979) in Indian buffaloes found that the summer-born calves excelled the calves born in the other seasons, in daily gain between weaning and first service. The low daily gain weight between weaning and first service during winter may be due to the inadequate managerial conditions received up to first service in winter births.

Growth rate, dry body weight (total body solids; TBS) and solids daily gain (and live body weight) in cattle, were also found to be impaired at elevated temperatures in Brown Swiss, Holstein and Jersey calves (Kamal *et al.*, 1962), Holstein and Hereford calves (Thompson *et al.*, 1963), Friesian calves (Habeeb, 1981, Marai *et al.*, 1995, 1997c), Friesian heifers (Kamal and Seif, 1969) and 2-year old buffalo heifers (Moss, 1993). The calculated loss in TBS due to heat stress conditions was found to be 17% (Habeeb, 1987) and 10.0% (Marai *et al.*, 1995) in Friesian calves, 23% in Friesian heifers (Kamal and Seif, 1969), 14.0-29.0% in Guernsey cattle (Kamal and Johnson, 1971) and 15.7 and 16.1% in 6 and 12 months old buffalo calves, respectively (Nessim, 2004). In solids daily gain, the loss values were 51 % (Habeeb, 1987) or 46% in Friesian calves (Daader *et al.*, 1989 and Marai *et al.*, 1995). The percentage daily change in growth due to stressful conditions, i.e. in daily body weight gain was significantly ($P<0.01$) correlated with the percentage change in each of heat shock proteins (change in protein molecular structure due to exposure to heat stress), thyroxine and testosterone levels (Habeeb *et al.*, 2007).

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 (Morrison and Lofgreen, 1979), particularly metabolizable energy for both maintenance and gain weight. The increase of tissue catabolism occurs mainly in fat depots and/or lean body mass (Kamal and Johnson, 1971). Specifically, there is a reduction in body amino-N (El-Fouly *et al.*, 1978) and an increase in endogenous DNA and RNA purine catabolism (El-Fouly and Kamal, 1979) as a result to the increase in catecholamines and glucorticoids. In this respect, although the nitrogen balance in young animals decreases significantly under high temperature, but it does not reach the negative nitrogen balance 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. Particularly, it could be stated that the adverse effects of the elevated temperature during summer on growth traits may be due to that the exposure to heat stress evokes a series of drastic changes in the biological functions. Such changes result in depression of live body weight, growth rate and TBS and daily body solids gain weight averages and impairment of production and reproduction (Marai and Habeeb, 1998; Marai et al, 2007). Other studies showed no appreciable change in live body weight (Habeeb, 1981) with rising temperature.

The contradictory response of changes in live body weight under heat stress may be due to the interaction between tissue destruction and water retention. The increase in total body water could be less than, equal to, or more than the loss in TBS, thus resulting in a decrease, no change or increase in live body weight, respectively.

Feed intake

Feed consumption depression is the most important reaction to exposure to elevated temperature, in tropical and sub-tropical conditions (Marai *et al.*, 1994, 2002).

Under heat stress conditions, as the quantity of consumed nutrients declines, dry matter (DM) intake including crude protein declines and a negative nitrogen balance may occur (West, 1999). DM digestibility and protein/energy ratio were also found to decrease in heat stress conditions (Moss, 1993). In lactating Murrah buffaloes, digestibility coefficient values for each of DM and crude protein were significantly lower in summer (43.0 and 50.50 ± 0.7, respectively) than in winter (68.31 and 66.83±0.05, respectively) (Verma *et al.*, 2000). Digestion and metabolism of non-pregnant female buffaloes declined with exposure 2-3 hours to solar radiation at air temperature of 42 °C (Zhengkang *et al.*, 1994). Nitrogen retention decreased significantly under heat stress conditions (35 °C) when compared with the comfort conditions (10 °C), in Jersey, Brown Swiss and Holstein heifers. The percentage decline ranged between 25.4 and 49.0 (Kamal *et al.*, 1962). In Holstein breed, the nitrogen balance was positive in calves and negative in cows (Kamal *et al.,* 1970). In heat-stressed sheep, significant negative nitrogen balance was also observed as a result to protein catabolism (EI-Fouly, 1974).

Water intake

Water contained in food varies from as low as 5% in dry grains to as high as 90% in green pasture especially in the first cut of clover. For dry rations such as hay and grain, cattle ordinarily obtain about 1.0 L per day of water in 10 kg dry feed consumption. While the water obtained from 40 kg green clover per day is about 35.0 L water intake.

Particularly, chronic heat exposure of 6 and 12 months old buffalo calves was accompanied with highly significant ($P<0.01$) increases in total water intake (28.5 and 48.3%), TBW (total body water) content (8. 5 and 9.6%), free water intake (25.2 and 56.4%), urine excretion (24.8 and 108.0%) and evaporative water loss (51.2 and 69.4%). Significant respective decreases were recorded in 6 and 12 months old buffalo calves in metabolic (which is derived from oxidation of fats, carbohydrates and proteins) (20.8 and 16.8%) and fecal water excretion (36.4 and 8.5%). Dietary water intake decreased (16.3%) due to chronic heat exposure in 12 months old calves (Nessim, 2004).

The consumed water may replace the lost TBS. by heat stress, since it was found that a net total body solids loss of 10 kg, in three days of elevated heat exposure was replaced by extra body water retained during these three days without a significant change in body weight, in cattle, (Kamal and Johnson, 1971).

Ambient relative humidity showed no significant effect on water consumption in cattle (Mullick, 1964). However, Mishra *et al.* (1963) showed that a drop in dietary water intake took place as ambient temperature increases, in buffalo cows. Particularly, a significant positive correlation between temperature and water consumption and non significant negative correlation between relative humidity and water consumption were found when temperature was held constant, in lactating and non-lactating dairy cows (Harbin *et al.*, 1958)

Concerning the mechanisms underlying water intake, water intake at low or high ambient temperature was blocked when urine excretion was inhibited by ADH administration in cows. This indicates that water retention caused by ceasing urination might block thirst (Kamal *et al.*, 1959).

MILK YIELD AND ITS CONSTITUENTS

It is difficult to quantify direct environmental effects on milk production, since milk production is also strongly affected by other factors such as nutrition and management (Fuquay, 1981), that may or may not be directly linked to environmental factors.

Milk yield

Differences in the physiological responses of cattle due to the form and duration of heat stress have been reported, and reflection of such responses has also been noted in productive (and reproductive) performance traits. Johnson (1976) attributed 3 to 10% of the variance in lactation milk yield to climatic factors.

Season of calving affected significantly milk yield in Indian (Roy Chaudhury and Deshmuykh, 1975) and Egyptian buffaloes (Mourad, 1978; Mohamed, 2000; Marai *et al.*, 2009). The highest milk yield was recorded during spring and winter (by calving during the mild period) and the lowest in summer (by calving during the hot period), in Egyptian buffaloes (El Khashab *et al.*, 1984). Other studies showed insignificant effect of season of calving on milk yield in Egyptian buffaloes (Alim, 1967; Marai *et al.*, In Press). The insignificant difference in total milk yield due to season of calving may be an evidence for the availability of adequate managerial conditions all the year round. Decline in milk yield as a direct result of high environmental temperatures had been reported by many authors (Thatcher, 1974; Johnson, 1976; Marai *et al.*, 2009).

Between 20 °C (18.2 kg) and 35 °C (16.7 kg), the reduction in milk yield was estimated to be 9%. Particularly, 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. On the other side, the decline in the daily temperature by 7 °C below normal resulted in an increase in daily milk yield by 6.5% in dairy cattle (Petkov, 1971).

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).

In the hot climate (38 °C), the reduction in the average milk yield in Friesian cows was lower by 30% than in the mild climate (18 °C) (Kamal *et al.*, 1989). Milk 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. Particularly, Bianca (1965) estimated a 33% reduction in milk production by breeds of cows from temperate climates exposed continuously to high (35 °C) ambient temperatures. Meanwhile, cows maintained under similar temperatures during the day but at <25 °C at night, did not show decrease in milk yield beyond that normally expected under temperate conditions (Richards, 1985).

In this respect, it is also important to state that the point on the lactation curve at which the cow experiences heat stress affects its total lactation yield. In other words, the reaction of the lactating cows to hot environments seemed to be related to stage of lactation (Bober *et al.*, 1980). At the initiation of lactation, heat stress negatively impacts the total milk yield. Sharma *et al.* (1983a) confirmed that climatic conditions appeared to have maximum influence during the first 60 days of lactation. During this stage, cows seemed to be less able to cope with heat stress. This is due to that during that stage of lactation, cows undergo physiological changes that make them very sensitive to environmental conditions. Of such physiological changes, the milk produced during that stage of lactation is higher than that in any other stage of lactation and is associated with a resultant high metabolic heat production. At the same time, the high producing cows become in negative energy balance as a result to the catabolic processes which are associated with metabolic heat production over and above that already induced by high nutrient intake, that induce them to make up for the deficit by mobilizing body reserves. Under Mediterranean climatic conditions, summer calvers produce less milk per lactation than winter calvers (Barash *et al.*, 1996; Maltz *et al.*, 1999) due to that summer temperatures in that region are above the thermoneutral zone of dairy cows and result in heat stress that affect early lactation.

Generation of metabolic heat affects negatively feed and energy intake (which is thought to be a protective mechanism). 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. Reduction in digestible energy efficiency was estimated as 35.4% at 35 °C than at 18 °C ambient temperature (McDowell *et al.*, 1976) or as 35% and milk yield was reduced with 15%, in lactating Holstein cows transferred from an air temperature of 18 to 30 °C (McDowell *et al.*,1976). The increase in respiratory and heart rates, is responsible for the increased maintenance that occurs during heat stress (West, 1993).

The decline in milk yield due to elevation of ambient temperature is due to the reduction in DM intake. Each 0.5 °C increase in body temperature above 38.6 °C resulted in 1.8 and 1.4 kg decreases milk yield and TDN intake, respectively (Johnson *et al.* , 1963). The secretary function of the udder may be actively affected by heat stress (Silanikove, 1992).

Milk constituents

Milk constituents are greatly affected by hyperthermia. In lactating Holstein cows transferred from an air temperature of 18 to 30° C, milk fat, solids-not-fat, and milk protein percentages decreased with 39.7, 18.9 and 16.9%, respectively, (McDowell *et al.*, 1976). 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. The reduction percentages were 28, 27, 7, 22.7 and 30, respectively (Habeeb *et al.*, 1989). Similar reduction values in milk constituents were reported by Habeeb *et al.* (1993, 1996), Yousef *et al.* (1996) and Marai *et al.* (1997a, b). 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. Averages of phosphorus and magnesium values were also found to be less in summer. Citric acid and calcium contents decreased during early lactation, while potassium decreased in all lactation stages at high temperatures (Kamal *et al.*, 1962).

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.

COMPARISON BETWEEN BUFFALOES AND CATTLE

The wide distribution of buffaloes in the world indicates that buffaloes are more adaptable than cattle to a large range of the environmental conditions.

Particularly, the buffaloes (Mediterranean and Swamp breeds) showed their exceptional adaptability to flood areas, in the Amazon. Buffalo productivity surpassed that of cattle, with males reaching 400 kg in 30 months on a diet of native grasses. The advantage of water buffaloes over Holstein, Brown Swiss, and Criollo cattle was demonstrated in a test at Delta Amacuro, Venezuela, when the cattle developed serious foot rot in the wet conditions of the Orinoco Delta and had to be withdrawn from the test. The area of Venezuela is flooded 6 months of the year and creates constant problems for cattle, yet the buffalo seems to adapt well. High humidity seems to affect buffaloes less than cattle, since buffaloes may be superior to cattle in humid areas, if shade or wallows are available. In southern Brazil, comparison between buffaloes and cattle on subtropical riverine plains have also favoured the buffaloes. This work was carried out on native pastures, mostly in the State of San Paulo.

Buffaloes' adaptability to the sub-tropical environment of Egypt was found to be better than for Friesians. The estimated values of adaptability were 89.1 and 82.9% for buffaloes and Friesians, respectively (Marai *et al.*, 2009). In this respect, it could be stated that improvement of adaptability for the hot climate conditions may be carried out by selection of the (high productive) buffaloes or cattle which show the least changes in their performance traits, under such conditions.

HEAT STRESS SYNDROME

The high environmental temperature stimulates the peripheral thermal receptors to transmit suppressive pulses 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, 1975). Production of hormone releasing factors by the hypothalamic centre is also suppressed causing decrease in pituitary hormonal secretions (Johnson, 1974), insulin (Habeeb, 1987) and thyroxine (El-Masry, 1987; El-Masry and Habeeb, 1989; Habeeb *et al.*, 1989). 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, 1970) or in the hepatic capture of blood amino acids (Noall *et al.*, 1957) or through inhibiting the oxidation of glucose which is essential for providing the energy required for peptide synthesis (Welt *et al.*, 1952). The increase in catecholamines (lipolytic hormones) (Winegrad, 1952) or the decrease in insulin responsible for protein anabolism (Habeeb, 1987) may also contribute to tissue destruction.

CONCLUSIONS

Buffaloes are perfectly suited to the hot and humid climates and muddy terrain, although they exhibit signs of great distress when exposed to direct solar radiation or when working in the sun during hot weather. Elevation of ambient temperature affects male reproductive functions deleteriously. Such phenomenon leads to testicular degeneration and reduces percentages of normal and fertile spermatozoa in the ejaculate of males. The ability of the male to mate and fertilize is also affected. Thermal stress adverse effects on the conceptus and dams subsequent post-partum performance traits, are pronounced during initial, as well as, late stages of gestation.

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