Egyptian J. Anim. Prod., 59, Suppl. Issue, January (2022):57-62

DOES HEAT STRESS INFLUENCE ANIMAL PERFORMANCE?

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SUMMARY

In tropical and subtropical regions, high environmental temperature, relative humidity, solar radiation and thermal stress are the most crucial constraints on animal welfare, health, survival ability, reproduction and productive performance. Animal welfare is an imperative worry for farmers, customers and stakeholders in the production process. Therefore, the aim of this review was to point out to the impact of heat stress on animal performance. The risky impacts of heat stress on animal growth, production, reproduction and immune status will be anticipating growing to be one of the forthcoming issues due to the continuous increase of the environmental temperature. Heat stress appears if there is dissimilarity between internal body heat release and its dissipation. High producing animals are more vulnerable to heat stress owing to the negative genetic association between production and heat tolerance. In addition, selection procedures for milk production reduce the thermoregulatory competence of the dairy animal. So, the researchers trying to alleviate and reduce this hazard effect by selecting for high tolerant genetic makeup with crossbreeding.

Keywords: Heat stress, production performance, cow and buffalo, reproductive performance

INTRODUCTION

Dairy business plays a role on society economic growth and development as it is providing an employment especially in developing countries. They were 750 million people included in milk industry with other jobs associated with it such as transportation, processing and marketing of dairy products. For each 100 L of milk production, up to five jobs are available especially in East Africa and the Near East with up to one billion jobs worldwide. Globally, the milk represents approximately 9% of all agricultural products in 2010 (FAO, 2015, IDF, 2013). Animals' welfare and production may be harshly compromised in hot climates, especially in subtropical and tropical zones due to the regular exposure to high ambient temperature and/or relative humidity for long times (Nienaber and Hahn 2007). Heat stress (HS) is defined as the heat accumulation from the surroundings and the inability of animal to dissipate heat, consequently is linked with a malfunction of the animal's production and physiological status (Bernabucci and Mele, 2014). Temperature humidity index (THI) is an appropriate index to calculate heat stress in dairy farms (Soumya *et al*., 2016). It is classified to mild (72-80), severe (80-85) and deadly stress sectors (>85) (Kohli *et al*., 2014).

Hansen (2004) and Lees (2016) stated that heat load and heat stress can be used to depict the animal's distress under hot environments. Stress is the biological reactions caused by contact to an undesirable environment. Moreover, the undesirable environmental condition is called "stressors" (Selye, 1973). Heat load is a sign of the levels of factors that are providing the environmental waves on the animal, while heat stress is how the animal reacts. Heat stress influences animal bioenergetics (Scharf 2008; Young and Hall, 1993) particularly fast-growing beef cattle and high milk producing animals for the reason that their necessity for high feeding level and the considerable heat increment originated from rumen fermentation (Nienaber and Hahn, 2007). Cattle react to HS via increasing heat dissipation (Scharf, 2008). through the physiological and behavioural thermoregulatory procedures (Farooq *et al*., 2010; Young, 1993). These procedures include amplified heat dissipation via sweating and peripheral circulation, increased respiration rate, panting concurrently with decreasing feed intake (Farooq *et al*., 2010).

In homeotherms stage, the initial thermoregulatory reaction is to sustain and re-establish the constant body temperature, through heat dissipation from the body via insensible and sensible (convection conduction, and radiation) heat exchange (Silanikove, 2000). The Thermo-Neutral-Zone is the zone at which the animal body neither gains nor loses heat. Buffaloes are highly susceptible to heat stress due to low number of sweat glands and black coat color causing reduction of feed intake, feed efficiency and utilization, consequently impairment in their productive and reproductive competence (Das *et al*., 2014; Upadhyay and singh 2008). High environmental temperature is the foremost distress which confronts the animal's capability to sustain energy, thermal, water, hormonal and mineral balance (Silanikove, 1992).

Impact of heat stress on growth:

Heat stress had a detrimental effect on animal growth performance. It reduced growth and daily weight gain (Das *et al*., 2016). The reduction may reach to 6-12% (Pragna *et al*., 2018). This may be owned to a) the decline in feed intake, digestibility and utilization competence (Hirayama and Katoh 2004; Popoola *et al*., 2014), b) stimulation of hypothalamus–pituitary–adrenal axis (HPA) that reduces the production of growth hormone and consequently reduces the growth performance (Popoola *et al*., 2014), c) down-regulation of growth-related gene expression (Angel *et al*., 2018), d) reduce the release of thyroid, triiodothyronine and thyrotropin releasing hormone (Johnson, 1985; Sivakumar *et al*., 2010), that decrease the metabolic rate and heat production (West, 1999). Also, environmental change disturbs animal agriculture via decreasing pasture, water, feed and fodder availability. Decreasing pasture availability and grazing areas caused a noticeable decrease in livestock production (Thornton *et al*., 2009).

Impact of heat stress on production:

There was a positive polynomial correlation between temperature and the reduction of milk yield (Ogundeji *et al*., 2021). Heat stress decreased milk quantity and quality in cow and buffalo (Marai *et al.*, 2009; Salama et al., 2012). Milk production of cows and buffaloes was decreased when they exposed to stressful condition (THI more than 80) (Upadhyay and Singh, 2008), particularly in high producing animals (high genetic merit). There was 2kg/day reduction of milk yield on high producing animals, while it was 0.65kg/day in low producing animals at 30°C (Vanjonack and Johnson , 1975). This may be related to that high producing animals were more sensitive to thermal stress (Berman, 2005). Milk yield was reduced by 21% when animals kept at THI ranged from 68-78 (Bouraoui *et al*., 2002). Milk production reduced by 0.20-0.41kg/cow/day for each point increase in the THI values above 69-72 (Aggarwal and singh 2006; Ravagnolo and Misztal 2000). Moreover, the daily milk yield and milk composition of cows were decreased by increasing the environmental temperature with 36% increase of the SCC (Nasr and El-Tarabany, 2017). Also, high temperature reduced milk yield and days to attain peak milk yield of crossbred Egyptian and Italian buffalo by 200 kg and 6 days, respectively. Severe hot weather decreased the peak milk yield in pure Egyptian buffalo and their crosses with the Italian one (Nasr, 2016).

The phase of lactation is also an imperative factor influencing dairy cows' reactions to heat. Animals in mid-lactation were more sensitive to heat stress that of early and late phases of lactation (Johnson *et al*,. 1998). at which the milk decreased by 38% approximately. Also, the milk reduction based on the season of lactation order, the reduction was 10-30% in first parity and 5-20% in second and third parity in Murrah buffaloes (Upadhyay and Singh, 2008). Moreover, there was a decrease in the lactation length of animals kept under heat stress condition (Gaafar *et al.*, 2011). In buffaloes, the shortest lactation length was reported in summer (Marai *et al*., 2009). Not only heat stress reduced milk yield, but also reduced milk constituents (fat, solids-not-fat and milk protein reduced by 39.7, 18.9 and 16.9%, respectively) (Kadzere *et al*., 2012). These findings were supported by Bouraoui *et al*., 2002) who detected lower milk fat, protein, casein, lactalbumin, IgG and IgA in the summer season, particularly if THI was more than 72. Also, buffaloes revealed similar reduction (Aggarwal and Singh, 2006).

The adaptation process involves an elevation of heat dissipation with a reduction of metabolic heat production via peripheral vasodilatation and lowered food intake. These procedures required energy, consequently animals adjust their energy from the productive pathways towards the adaptive pathway to preserve life-sustaining activities (Aleena *et al*., 2018; Sejian *et al*., 2018). In spite of this, the effect varied based on the genetic make-up, lactation phase and nutritional availability during the period of HS (Granado *et al*., 2014; Silanikove and Koluman, 2015). The endocrinological alterations play a decisive responsibility in the metabolic reaction to HS by neural and glandular hormones secretion (Sejian *et al*., 2013). The release of antidiuretic hormone (El-Nouty *et al*., 1980), prolactin (Wettemann and Tucker, 1974). glucocorticoids and catecholamines were increased (Alvarez and Johnson 1973). with a reduction of aldosterone (Collier *et al*., 1982). during the acute heat stress. This will lead to a decrease in the concentration of electrolytes and water balance, as a result of panting and sweating (Beede and Collier, 1986). Also, at dry period thermal stress lowered the proliferation of mammary cell and consequently, decreases the milk yield in the following lactation season (Tao and Dahl, 2013).

Impact of heat stress on reproduction:

Universal warming has a crucial effect on the reproductive performance of animals. It has increased the surface temperature by 0.7°C since the early 20th century. Heat stress has a negatively effect on animal reproductive performance. The conception rate has decreased in dairy cows and buffaloes kept at THI higher than 72-73 and 75, respectively (Dash, 2013; Dash *et al*., 2015; Morton *et al*., 2007; Schuller *et al*., 2014). The conception rate of Murrah buffalo was decreased by 19% in hot season when compared with cold one (Zicarelli, 2010). Heat stress increased the days open in buffaloes by 61 days when compared with cold season in Murrah buffaloes (Das *et al*., 2016). Buffaloes calved in cold season had a better reproductive performance than that calved in hot season (Zicarelli, 2010). Heat stress prolonged the calving interval, high incidence of metritis, increased the number of services/conception and lower the rate of pregnancy in Egyptian buffalo and their crosses with the Italian buffalo (Nasr 2016, 2017a,b). Also, the conception rate declined by 19% in F_1 (50% Brown Swiss and 50% Holstein) and by 18% in BC (Back cross; 25% BS and 75% HO), while the pregnancy % declined by 17% with an increase of embryonic losses by 10-16% (El-Tarabany and Nasr, 2015).

Heat stress caused poor expression of estrus signs with shorter length in buffaloes that increased the calving interval (Bachalaus *et al*., 1979). The reduction of reproductive performance may be owed to a) the lower circulating levels of progesterone, estradiol and luteinizing hormone causing poor follicle maturation and ovarian inactivity (Hansen *2004*; Rao and Pandey, 1982). b) amplified blood supply in the proximity of the superficial vessels rather than the deep vessels, which reduced the blood flow and nutritive supply to the uterus and ovaries interrupting their normal physiological status (Grunert *et al*., 2005), c) harmful effect on oocyte maturation and early embryonic development by delaying follicle selection and decreasing the dominance level of the dominant follicles causing an abnormal oocyte maturation, failure of implantation and finally early embryonic death (Wolfenson *et al*., 2000) d) failure of fertilization at high temperatures during the mating time (Kleemann and Walker, 2005).

There was an influence of heat stress on the survival and growth of the embryo. It caused embryonic death that attributed to a) obstruct protein synthesis of the embryo (Edwards and Hansen, 1996). b) oxidative cell damage (Wolfenson *et al*., 2000), c) decreasing the release of interferon-tau that help in pregnancy detection (Bilby *et al*., 2008), d) apoptosis (Fear and Hansen, 2011). e) low progesterone level that constraint the endometrial function and embryonic growth (Khodaei-Motlagh *et al*., 2011; Wolfenson *et al*., 2000), f) reduced the development of blastocyst (Ealy *et al*., 1993) and g) teratology (Wolfenson *et al*., 2000).

Impact of heat stress on immune status and health:

Universal environmental alterations change the ecological construction that initiates both the geographical and phonological shifts (Slenning, 2010) with interference of pathogen transmission and raise their levels in the hosts (Brooks and Hoberg, 2007). This increased the vulnerability of animals to be infected and diseased. Hot weather increased the incidence of external parasites (Dhakal *et al*., 2013). The immune system is the most important body protection systems to safeguard and survive with environmental stressors. Thermal stress changed the heamatological parameters (white blood cells (WBCs), red blood cells (RBCs), hemoglobin (Hb), packed cell volume (PCV), glucose and protein values. Thermal stress increased WBC by 21-26% and PCV (Abdel-Samee, 1987). with a reduction of RBC by 12-20% (Habeeb, 1987). interleukin 18, tumor necrosis factor and interferon (Rashamol *et al*., 2019). The high level of PCV was an adaptive procedure to supply the required water for evaporative cooling practice (Al-Haidary, 2004). Heat stress released the plasma cortisol that down-regulates L-selectin expression on the neutrophils surface (Burton and Ronald, 2003), consequently reduced neutrophils function and its ability to attack the pathogens (Kansas, 1996). Moreover, heat stress reduced the immunoglobulin, caused an impairment of the immune system and animals were more vulnerable to parasitic infestation (Carroll *et al*., 2012). Hirakawa *et al*. (2020) stated that heat stress decreased lymphocytes synthesis with destruction of the leukocyte's phagocytic actions. The incidence of mastitis was increased by increasing the THI (Jingar *et al*., 2014), which may be due to hot environment help the survival and increase the pathogens carrier fly. Surplus heat load not only has a detrimental impact on animal welfare but also causes animal death (Vitali *et al*., 2009). Finally, this review concluded that heat stress influenced animal performance, reproduction, immune status and health but the effects vary among different species.

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هل الإجهاد الحراري يؤثر على أداء الحيوان؟

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في المناطق الاستوائية وشبه الاستوائية، تعتبر درجات الحرارة البيئية المرتفعة والرطوبة النسبية والإشعاع الشمسي والضغط الحراري أهم معوقات رعاية الحيوان وصحته وقدرته على البقاء والتكاثر والأداء الإنتاجي. رعاية ورفاهية الحيوان هي مصدر قلق للمربيين والمستهلكين في عملية الإنتاج. لذلك، كان الهدف من هذه الدراسة هو معرفة مدي تأثير الإجهاد الحراري على أداء الحيوان. من المتوقع أن تكون الآثار المحفوفة بالمخاطر للإجهاد الحراري على نمو الحيوانات وإنتاجها وتكاثرها وحالتها المناعية واحدة من القضايا القادمة بسبب الزيادة المستمرة في درجة حرارة البيئة. يحدث الإجهاد الحراري إذا كان هناك اختلاف بين حرارة الجسم الداخلية المنتجة وفقدانها. الحيوانات عالية الإنتاج أكثر عرضة للإجهاد الحراري بسبب الارتباط الجيني السلبي بين الإنتاج وتحمل الحرارة. بالإضافة إلى ذلك، فإن إجراءات الانتخاب للحيوانات عالية إنتاج اللبن يؤثر بالسلب على كفاءة التنظيم الحراري لهذه الحيوانات. لذلك، يحاول الباحثون التخفيف من هذا التأثير الخطير وتقليله من خلال اختيار التركيب الجيني عالي التحمل للحرارة واستخدام التهجين بين السلالات المختلفة.