Physiological and Behavioural Adjustment of Livestock to Climate Change: Coping Mechanisms

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Abstract

Livestock species have varied greatly in the degree to which they demonstrated coping mechanisms through adjustment of various physiological and behavioural activities. Therefore, this paper focused to highlight various physiological and behavioural adjustments upon which animal is used as a coping mechanism to excessive change of climate condition. Physiologically, ruminants have demonstrated high adaption to heat load through enhanced respiratory, sweating rates, shift in body temperature, vasodilation of skin capillary bed to enhance blood flow to the skin periphery for facilitating heat transfer to the surrounding, secretion of corticotropin-releasing hormone (CRH) from hypothalamo-pituitary-adrenal axis (HPA axis), adjustment of haemoglobin levels, shifting of some antioxidant enzymes and formation of heat shock proteins to protect enzyme systems for the animals retain their original thermal set points. Among the most profound behavioural changes seen in heat stressed animals in an attempt to ameliorate thermal stressed animal is shade seeking, reduced feed intake, increasing water intake, increasing standing and decreasing lying time, pattern and orientation of lying or standing. It could be concluded that animals employed different coping mechanism through physiological and behavioural changes to adapt heat load to some degree without caretaker assistance.

Key words: Behavioural, Physiological-Adjustment, Livestock, and Climate Change

Introduction

Climate change associated heat stress is the most significant factor which negatively influences animal production. This can cause a severe economic burden to livestock farmers who rely heavily on these animal populations for securing their livelihoods. Therefore, this could lead animal to exhibit several adaptive mechanisms in an effort to cope with the adverse environmental conditions. Indu and Pareek [1] states that animals initiate compensatory and adaptive mechanisms like behavioural and physiological changes to re-establish homeothermy and homeostasis which promote welfare and favour survival in a specific environment. All animals possess a thermal comfort zone, within which their physiological functions would be beneficial. During daytime, the livestock animals maintain their body temperature in the range of ±0.5ºC [2]. Further the temperature exceeds the upper critical levels, the animal is said to be in heat stress condition.

Heat stress affect animals' performance in different ways this include not limited to growth performance [3], milk production [4], reproductive performance [5], meat production [6] disease occurrences [7].

Animal have developed coping mechanisms to minimize the impact of these environmental stressors on their biological systems. These responses are termed acclimation, acclimatization, and adaptation. Acclimation is defined as the coordinated phenotypic response developed by the animal to a specific stressor in the environment [8] while acclimatization refers to a coordinated response to several simultaneous stressors (example temperature, humidity, and photoperiod; [9]. Adaptation involves genetic changes as adverse environments persist over several generations of a species. Acclimation and acclimatization are induced by the environment and are considered phenotypic and not genotypic change and the responses decay, if the stress is removed. Acclimation and acclimatization act to improve animal fitness to the environment. In many cases, the response is induced by sudden environmental change, such as heat or cold stress.

Physiological adjustment on hot climate as coping mechanisms

When animals were exposed to excessive heat stress the following physiological adjustments would be employed to serve as a coping mechanism to stabilized body:

Enhanced respiratory: Respiration rate is the most consistent and first reaction of all the physiological responses when animals were exposed to environmental temperature above the thermoneutral zone. Therefore, increase in respiratory frequency may be used an index of discomfort in large animals [10]. Kumar state that respiration rate was indicator of heat stress in the hot environment and gave significant correlation with circulating corticoids concentration [11]. Respiration rate increased when environmental temperature increased [12] reported a very high positive correlation between the respiration rate and ambient temperature and it even rose up to 0833 when humidity was constant in buffaloes.

An evaporative heat loss from the respiratory tract is regarded as one of the primary mechanisms for maintenance of heat balance [13]. This respiratory response arises from direct heat stimulation of peripheral receptors which transmit nervous impulses to the thermal centre in the hypothalamus. The cardio-respiratory centre is then stimulated to send impulses to the diaphragm and intercostal muscles for further respiratory activity [14]. A high respiratory rate in most cases did not necessarily indicate that the animal is successful in keeping its body temperature constant, but rather indicated that it is already overheated and trying to restore normal heat balance [13]

Sweating rates: Sweat is a very complex aqueous mixture of chemicals. Although sweat is mostly water and Nacl, it also contains a mixture of other solutes in varying concentrations [15-17] and some of the micronutrients (electrolydstes Na, Cl, Vitamin K and other trace minerals) and non-micronutrients present in sweat (Products of metabolism, Proteins, amino acids and toxicants). Sweat evaporation from the skin surface plays a critical role in human and animal thermoregulation and this is most apparent when the ability to sweat is compromised during periods of strenuous physical labour and/or exposure to hot environment [18]. It is well-established that the primary physiological function of sweating is heat dissipation from body temperature regulation.

Body core temperature rises sharply with exercise-heat stress, which can lead to heat exhaustion or heat stroke if other means of cooling are not provided. Thermal sweating is mediated predominantly by sympathetic cholinergic stimulation. Sweat production is therefore stimulated through the release of acetycholine from non-myelinated class C sympathetic postgangalionic fibres, which binds to muscarinic (Subtype 3) receptors on the sweat gland [15]. Eccrine sweat glands primarily respond to thermal stimuli, particularly body core temperature [19]. Due to the fact that heat is transferred from the air to the body when ambient temperature is greater than skin temperature; with sweating, heat is transferred from the body to water on the surface of the skin. The latent heat of vaporization of sweat is 580kcal of heat per 1kg of evaporated sweat (2426J per gram of sweat [20].

Shift in body temperature: When animals exposed to high ambient temperature there should be rapid shift in body temperature which will eventually lead to condition called hyperthermia. Certain species dissipate the heat through increases in sweating while rabbit are homoethermic animal and are very sensitive to high air temperature conditions because they cannot perform thermoregulatory sweating

[21], thereby limiting their ability to eliminate excess body heat. These inability of rabbit of dissipate heat via sweat is attributed to the fact that rabbit have few functional sweat gland. Therefore, rabbit tend to have a constant internal body temperature so heat production must be coped the losses to maintain the body temperature constant.

Secretions of corticotropin-releasing hormone: Hormones, specifically those produced from the adrenal and thyroid glands, are recognized as having a significant role in thermoregulation and metabolism. The hypothalamo-pituitary-adrenal axis (HPA axis) acts as one of the principal endocrine regulators of the stress responses. The products of HPA axis which control stress pathway in animals are corticotrophin-releasing hormone (CRH), ACTH and Cortisol. The activation of the HPA axis may lead to enhanced production and release of cortisol into circulation; cortisol is the primary stress hormone of ruminants [22].

In vertebrates, an important mechanism for coping with stressors begins with adrenally-derived glucocorticoid hormones: Corticosterone in amphibians, reptiles, and birds, or cortisol in fish and many mammals. These molecules drive gluconeogenesis, suppress reproductive processes, alter movement and feeding rates, impact immune functions, and generally help an individual enter a ''state of emergency'' when environmental stressor induces their release [22]. Several studies in various livestock species clearly established higher plasma cortsisol level in ruminants during heat stressed condition [23-24]. Severe dehydration may lead to increased secretion of antidiuretic hormones (ADH) through activation of renin-angiotensin-aldosterone system. High levels of circulating ADH hormone level were reported in crossbred goats under severe dehydration [25]. The ADH hormone regulates the blood osmolarity by increasing the water absorption in the kidneys, which also assists the excretion of concentrated urine in animals suffering from heat stress [25].

Elevation of haemoglobin levels: Because of the essential role that Hb plays in the oxygen transport system, and the direct link between temperature changes and oxygen solubility, Hb expressed a coping mechanism to hyper-thermal stress in the studied population of some aquatic species [26-27]. There are several reports which showed a varying trend to total blood haemoglobin (Hb) with an increase in environmental temperature.

Okoruwa, [28] observed an elevated value of Hb in thermal stressed southern Nigeria dwarf goats and the observed change may be attributed to higher Hb requirement in the animal to meet the increased oxygen circulating during panting. Haptoglobin is one of the most commonly used acute phase proteins to assess the health and inflammatory response of animals [29] reported rise of plasma heptoglobin in dairy cows during high ambient temperature.

Changes of some antioxidant enzymes: Antioxidants are those nutrients which are required to cleanse cells of reactive oxygen species and are divided into 3 major groups: Enzymatic (SOD, Catalase (CAT), GPX), non-enzymatic (Albumin, L-Cysteine, homocysteine and protein sulfhydryl groups) and non-enzymatic low molecular weight antioxidants (ascorbic acid, glutathione, uric acid, α-tocopherol, β-carotene and retinol [10].

Several researchers have reported changes in the levels of various antioxidants in different classes of animals during period of thermal discomfort. Such as increases in SOD and GPx concentration in prepartum cows during summer month reported by Bernabucci et al [30]. Significantly (317±0.13 U/ml) SOD activities were reported in Egyptian buffaloes compared to winter (3.8±0.16 U/ml) season. Kumar [31] observed a significant positive correlation of temperature humidity-index (THI) with the erythrocyte CAT activity in murrah buffalo and cattle. The erythrocyte thiobarbituric acid reactive substance (TBARS) concentration increased in heat exposed cattle and buffalo [32]. Chaudhary et al. reported a significantly higher level of plasma Malondialdehyde, SOD and GPx activities in Surti buffaloes during hot humid periods and hot dry periods indicating an increased free radical production during periods of heat stress [33].

Behavioural adjustment on hot climate as coping mechanisms

Animal exhibit various behavioural activities as coping mechanism to thermal stress which involves the following:

Shade seeking behaviour: One of the most quick and profound behavioural changes seen in heat stressed animals is shade seeking. The stressed animals attempt to ameliorate the negative effects of direct heat load by using shade whenever they can access to it. Research clearly shows that dairy cattle use shade in warm environments, and that the frequency of this behaviour was found to increase with higher air temperature and solar radiation [34]. During warm summer conditions, cows which used shade showed lower core body temperature and lower respiration rates when compared to those without shade [35-36].

Reduced feed intake: Recent studies established lower feed intake in various farm animals including cattle, sheep, and goats during summer [37-38] Lower feed intake in warm conditions is identified as an adaptive response to regulate the thermal metabolic heat production in heat stressed animals.

Increasing water intake: Water is an important nutrient during heat stress and the properties of water are an important factor for the transfer of heat from the body to environment [39]. The body heat is preserved by the high heat capacity of water and it acts as insulation during cold stress. Therefore, the increased consumption of water is used to dissipate heat and for cooling the recticulo-rumen [40]. Of course water requirements of livestock varied greatly based on the species and water consumption rate can also vary based on several factors like age, rate of gain, pregnancy, lactation, activity, type of diet, feed intake, environmental temperature, eating pattern, access of watering area, water temperature, water given in a trough or bowl and cow dominance if water bowl or trough are shared and others. However several scientific studies indicated that high environmental temperature triggers and increased water intake. Frequency and increased water intake were reported for various livestock species during summer [41][38]. A research carried out by Devendra reported that water consumption by livestock would increase by 20-30% during severe weather conditions [42]. The daily average temperature was established to be responsible for an observed variation in water consumption by 25.7% in cows [43]. In sheep, Markwick reported that during hot weather conditions sheep use more water for evaporative cooling because shearing increases the heat load so consumption of water will increase by 78% during hot conditions [44].

Increasing standing and decreasing lying time: increased standing and decreased lying time was also reported to be associated with higher ambient temperatures [45][46]. Generally, heat stressed animals tend to spend more time standing so that they can reorient themselves in different directions to avoid direct solar radiation and ground radiation. In addition, the standing position also obstructs the conductive heat transfer into the animal body due to the presence of a layer of air adjacent to the skin, and also facilitates the dissipation of body heat load to the surrounding by increasing the amount of skin exposed to air flow or wind.

Conclusion

It could be concluded that various species of animal employed various physiological and behavioural mechanism to coped excessive thermal stress.

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