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Review Article
Significance of Metabolic Response in Livestock for Adapting to Heat Stress Challenges

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Abstract
The animals possess various inherent mechanisms to cope up with the changing environmental conditions. It has been observed that the ability of the animals to adjust with these climatic extremes is related to their level of adaptation and this is inversely correlated with their production potential. In depth understanding of metabolic response of livestock adaptation might pave way for developing more viable adaptive measures to cope up livestock production system to climate change. Hence, this review is an attempt to cover the significance of metabolic response to animal adaptation during heat stress. In animals, less feed intake helps to reduce the internal heat production by minimizing the metabolic processes to adapt the heat stressed condition. Thyroid glands and thyroid hormones are mainly known to have a very important role in the thermoregulation and homeostasis of energy and protein metabolism. Further, the histological sections of the thyroid gland of livestock subjected to heat stress indicates pathological changes of less thyroglobulin in the thyroid cells reflecting a significant decrease in thyroid activity. Changes in the concentration of thyroid hormones in the blood reflect the metabolic and nutrient status of the body. Thyroid hormones play a critical role in thermogenesis and therefore are an important reflection of adaptation to heat stress in livestock species. The roles of metabolic regulators are crucial in assessing the physiological response to heat stress through various enzymes governing the metabolic reactions in blood. The decreased level of non-estrified fatty acid (NEFA) during heat stress condition in livestock is attributed to enhance the glucose burning as a presumable strategy to reduce metabolic heat production in the animal body. In addition, alteration in the levels of both aspartate aminotranspharase (AST) and alanine aminotranspharase (ALT) are correlated to adaptive potential of livestock to environmental challenges. Based on this review, it was concluded that metabolic response is one of the primary means by which the animals tries to cope up with heat stress challenges. The animal reduces their metabolic activities in an effort to reduce the metabolic heat production to cope up with outside environment heat stress condition.

Key words: Adaptation, ALT, AST, livestock, metabolic response, NEFA, thyroid hormone

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INTRODUCTION

One of the most important and critical consequences of the climate change is increasing surface temperature all over the world. The elevated temperature resulted from increased amount of greenhouse gas (such as CO_2, CH_4 and N_2O etc.) concentration in the atmosphere is detrimental both to humans as well as animals. Increase in temperature cause decrease in both fodder availability and quality. Hence, during dry season grazing animals particularly in the tropical region are exposed to multiple stresses, which include heat stress, nutritional stress and walking stress[1,2].

The animals possess various inherent mechanisms to cope up with the changing environmental conditions[3]. The adaptive mechanisms may include morphological, anatomical, physiological, biochemical and behavioural changes in the body which help them to survive in a particular environment. It has been observed that the ability of the animals to adjust with these climatic extremes is related to their level of adaptation and this is inversely correlated with their production potential. For example, high productive and less adaptive Holstein cows showed more reduction in milk yield (13.7%) compared with low productive and high adaptive indigenous cows (4.1%) when they are exposed to same heat load[4]. The animals show various metabolic and hormonal responses for adapting to the increased heat load which include reduced feed intake, more water intake and also changes associated with blood metabolites[5,6]. The decreased productivity during heat stress condition is mainly attributed to their decreased feed intake[7]. Further, thyroid hormone plays a very important role in animal's adaptation to temperature changes[8]. The less feed intake along with lower thyroid hormone levels in livestock during heat stress results in low metabolic rate in an effort to adapt to the situation which ultimately leads to their reduced productivity[9]. Further, according to Sejian *et al.*[10] metabolic enzymes like acid phosphatase (ACP) and alkaline phosphatase (ALP) reduced significantly in goat when they are exposed to heat stress and other environmental stresses.

Since climate change results in increased temperature and this proved to be the most detrimental factor influencing both animal survival and production, efforts are needed to understand the underlying biological mechanisms of livestock adaptation to climate change. These types of efforts will help scientific study to develop appropriate coping strategies to climate change impact on livestock production. In depth understanding of metabolic response of livestock adaptation might pave way for developing more viable adaptive measures to cope up livestock production system to climate change. Hence, this review is an attempt to cover the significance of metabolic response to animal adaptation during heat stress. Efforts will be made to review in detail the process of metabolic adaptation in livestock during heat stress in an attempt to establish the significance of metabolic response as the primary pathway for livestock adaptation to climate change.

SIGNIFICANCE OF LIVESTOCK ADAPTATION

Even though climate change is a global phenomenon, its ill effects are experienced mostly by the poor people in developing countries due to their heavy dependence on the natural resources[11]. The extensive housing system practiced in the country makes the animal more vulnerable to the climate change and the heat stress in particular[12]. The increased temperature during summer season has caused a significant barrier to livestock production by decreasing both the water and feed availability[13,14]. Therefore to maintain the constant productivity in the changing climate scenario, the animal should be well adapted to the extreme conditions. Adaptability of an animal can be defined as the ability of an animal to survive and reproduce within a defined environment[15-17].

Animals show a number of physiological mechanisms to adjust with the changing environmental temperature. For example, when they are exposed to a small increase in temperature they start to dissipate the heat through conduction and convection if the temperature rose above Lower Critical Temperature (LCT) they maintain the body heat through evaporative loss and peripheral vasodilatation[18,19].

When the cows are exposed to a higher temperature than Thermal Neutral Zone (TNZ), they show various responses such as increased respiration rate, increased rectal temperature, decreased pulse rate, panting and profuse sweating and reduced feed consumption[20]. Reduction in the feed intake results in less available energy in the animal body during heat stress[21,22]. Utilisation of this energy for the adaptive mechanisms further reduces the growth and development of the animal. But according to Das *et al.*[23] and Baumgard and Rhoads Jr.[24] the energy produced through feed intake is not used for adaptive mechanisms, instead the animal has the inherent capability to release energy from the alternate sources, which include the production of the glucose from lipid and protein. In such adapted animals, the energy produced through digestion is exclusively used for the growth and production. In most of the cases, livestock adapts to increased temperature and this is aided by the availability of other factors like feed and water. But in extremely hot conditions when food and water are not available their survivability will be questioned which may further lead to death if the extreme condition persists relatively for a longer period[4,25].

The vulnerability of the animal to the heat stress depends on the magnitude of the heat load to which the animal is exposed and the inherent genetic potential of the animal to cope up with the temperature[26,27]. It has been observed that the indigenous low producing cows are more adaptable to heat stress than the high producing exotic ones[28]. In a comparison of three studies Staples and Thatcher[29] demonstrated the different response of high and low producing cows to the heat stress. The high producing cows showed more reduction in milk (4.7 kg day^{-1}) compared to the less producing (2.7 kg day^{-1}) species. Similarly, decreased milk productions in the Holstein cows compared with the low producing breeds were reported when they were exposed to moderate heat stress. All these findings indicate the sensitivity of high producing cattle breeds to heat stress condition. In addition, 20% reduction in reproductive rates is also recorded in high latitude milk yielding cows[4]. According to Finch[30] beef cattle having strictly regulated body temperature showed greater productivity than those having varying body temperature. Under high heat loads, *Bos indicus* breeds and their cross breeds showed greater thermoregulation mechanisms through differences in metabolic rate, food and water consumption, sweating rate, coat characteristics and colour compared to *Bos taurus* breeds[31]. Similarly in India, resting metabolic heat production of Haryana breeds were less compared to the Holstein, which resulted in low body heat in the former one establishing the superior adaptive capability of indigenous breeds[32]. Sheep are better adapted to heat stress than cattle. Less water loss in desert sheep breeds than the arid and humid region shows its better adaptability to the heat stress[33]. Heat stress also affects the quality and quantity of production in poultry[34]. Thus to improve or sustain production in the changing climate scenario the animal must be well adapted to the heat stress. The well-adapted animals require less energy to cope up with the temperature increase. In addition, increased feed conversion rate was also reported in adapted animals compared to the less adapted ones leading to increased profitability in rearing the adapted breeds in the fluctuating environmental conditions.

IMPACT OF HEAT STRESS ON FEED INTAKE

The environmental conditions affect the level of voluntary feed intake and the utilisation of the metabolisable energy in the livestock[35]. Exposure of the animals to high environmental temperature triggers the efforts to release the excess heat from the body through amplified respiration rate, increased consumption of water and lesser feed intake[20]. In Indian sub-continent livestock species are vulnerable to heat stress during summer[36] and particularly the grazing animals are more affected than intensively managed[37]. In animals, less feed intake helps to reduce the internal heat production by minimizing the metabolic processes to adapt to the heat stressed condition[38,39]. In most of lactating cows, the less feed intake during heat stress condition leads to negative energy balance[38,40]. Animals which are more adapted to the high ambient temperature show less reduction in feed intake compared to the susceptible[41-43]. Table 1 describes the levels of feed intake reduction in different livestock species as a result of heat stress.

There are reports which established reduced level of feed intake and milk production in dairy cattle during heat stress condition[23,37,38]. For example, in an experiment conducted in holstein cows decreased voluntary dry matter intake (upto 61.9%) was established when they were provided with *ad libitum* feed in the increased temperature condition[44]. Genetic variation in the cattle also determines the adaptability of the animal to heat stress. High producing dairy cattle are generally more susceptible to heat stress compared to the indigenous species since most of the high yielding breeds were originated from the cold regions[32,38]. According to Yasothai[37], *Bos indicus* cattle are more heat tolerant than *Bos taurus* because of their smaller body size, less metabolic activity and further they showed less reduction in feed intake throughout the heat stress condition. Further, a significant decrease in feed intake was reported in Jersy cows during high ambient temperature[37]. In an experiment Pereira *et al.*[45] compared reduction in the feed intake of three cattle species (Mertolenga, Alentejana and Limousine) in the heat stress condition, in which Mertolenga species showed more adaptation to heat stress with 2% feed intake reduction

Table 1: Reduction percentage of feed intake in heat stress condition

Species	Reduction percentage of feed intake in heat stress condition (%)	References
Holstein cows	61.9	Lamp *et al.*[44]
Alentejana cows	10	Pereira *et al.*[45]
Limousine cows	9.6	Pereira *et al.*[45]
Mertolenga cows	2	Pereira *et al.*[45]
Buffalo heifer	8.0-10	Hooda and Singh[46]
Indian goats	13	Kaliber *et al.*[49]
Murciano-Granadina dairy goats	27	Hamzaoui *et al.*[50]
Afshari lambs	17.5	Mahjoubi *et al.*[54]
Gilt pigs	47.1	Pearce *et al.*[57]
Laying hens	47.9	Mashlay *et al.*[58]
New Zealand white rabbit	42.4	Ondruska *et al.*[59]

followed by Alentejana and Limousine species with a decrease of 10 and 9.6%, respectively. The decreased feed intakes in all the three breeds were not severe and they attributed this smaller reduction in feed intake to less severity of heat stress and access to easily digestible and degradable food during the experiment. However, in buffalo heifers 8-10% dry matter intake decrease was recorded during high temperature (40°C) condition[46]. Verma *et al.*[47] and Marai *et al.*[48] attributed this decreased feed intake to the direct effect of the increased temperature on setitic centre of the hypothalamus to reduce the metabolic heat production in the animal body. In an experiment, Kaliber *et al.*[49] recorded reduced feed intake up to 13% during compared heat and water stress condition. Similarly decreased feed intake (upto 27%) was also reported in Murciano-Granadina dairy goats[50] and they attributed decreased level of feed intake to reduce metabolic heat production in the animal body to cope up with the heat stress condition. Similar reports were recorded in sheep insisting the significance of feed intake control to maintain heat balance[51-53]. Likewise in Afshari lambs, 17.5% reduced dry matter intake was recorded in the heat stress condition[54]. Similarly, decreased feed intake was also recorded in Malpura ewes during increased temperature condition[53-56]. Pearce *et al.*[57] established 47.1% decline in feed intake on crossbred gilt pigs during heat stress condition. Reduced in feed consumption rate of 47.9% were observed in commercial laying hens during heat stress condition[58]. In an experiment Ondruska *et al.*[59] recorded 42.4% decrease in the feed intake in New Zealand white rabbits during heat stress condition.

ROLE OF THYROID GLAND IN LIVESTOCK ADAPTATION

Thyroid glands and thyroid hormones are mainly known to have a very important role in the thermoregulation and homeostasis of energy and protein metabolism[13,60,61]. Appropriate functioning of the thyroid gland is essential to sustain the productivity in the domestic animals[41]. Changes in the concentration of thyroid hormones in the blood reflect the metabolic and nutrient status of the body. The difference in the bioactivity of these hormones helps to maintain the metabolic balance in the stress condition particularly in grazing animals since they are vulnerable to the fluctuating environmental changes[62]. Thyroid gland lies in the upper part of the trachea. The embryonic origin of the thyroid gland is from pharyngeal endoderm. The thyroid gland consists of two lobes, one on each the lateral side of the trachea. The thyroid gland plays a very important role in maintaining the metabolic rates in the animals which in turn helps to overcome the stress conditions in their body[63]. The predominant hormone produced by the thyroid gland is thyroxine (T_4). But it acts as a prohormone to more biologically active triiodothyronine (T_3)[64]. Its production into the blood is regulated by hypothalamus/anterior pituitary gland[60]. These hormones determine the basal metabolic rate in the body and show a positive correlation with the growth gain. Apart from these two hormones thyroid gland also secretes calcitonin hormone. Its function is to regulate the blood calcium levels. The two important factors which determine the thyroid activity in the animal's body are environmental temperature and quantity of feed intake[65]. The activity of the thyroid gland is regulated by Thyroid Stimulating Hormone (TSH) from the anterior pituitary. The production of TSH is influenced by Thyrotropin Releasing Hormone (TRH) released from the hypothalamus[66]. The activity of TRH is influenced by a change in the environmental temperature which in turn affects the thyroid hormone production and metabolic rate in the animal body[67]. The response of thyroid gland to the heat stress is very slow and it takes more time to make hormone concentrations in the blood to get steady[31]. It has been observed that the concentration of thyroid hormones in the blood plasma is less during summer than in winter. Further, according to Farooq *et al.*[31] decreased the activity of the thyroid gland is observed in the cattle species acclimated to hot environmental conditions. However in cold conditions, increased activity of the thyroid gland is observed in ram lambs[68], Malpura lambs[36] compared to the normal condition along with decreased concentration of T_3 and T_4 in the blood plasma. Figure 1 describes the impact of heat stress on the metabolic response in livestock.

The thyroid gland is highly sensitive to the ambient heat variation[69]. Appropriate thyroid gland function and activity of thyroid hormones are considered crucial to sustain productive performance in domestic animals[62]. When the animals start to suffer due to heat, food ingestion is reduced and metabolism slows down, causing a hypo-function of the thyroid gland. The thermogenic effect of thyroid hormones is closely linked to increased appetite and lipogenesis to ensure fuel availability and avoid wasting[62,69].

HISTOLOGICAL CHANGES IN THYROID GLAND DURING HEAT STRESS

The thyroid gland activity is known to be influenced by factors such as change in ambient temperature which in turn would result in metabolic adjustments in the animal's body to the altering environmental conditions[70]. The proper functioning of the thyroid gland is necessary for all species to

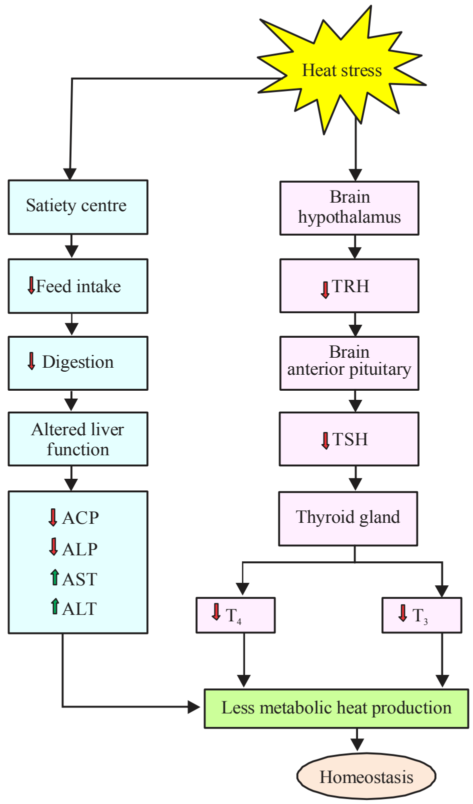

Fig. 1: Pictorial representation of heat stress impacting metabolic activity in livestock

adapt to the changing environment[62]. The increased and decreased activity of the thyroid gland is observed with cold and hot environmental conditions, respectively[65]. The depressed activity of the thyroid gland shows less concentration of the thyroid hormones in the blood plasma during the heat stress condition[69]. Analysis of the thyroid gland of cattle subjected to heat stress indicated that 15% of the thyroid cells showed pathological changes in the heat stress condition along with significant decrease in thyroid activity[65]. Similarly in ostrich, reduced size of the thyroid follicles was recorded during summer indicating less activity of the thyroid gland during heat stress condition[71]. It has been established is sheep that the decreased function of the thyroid gland during heat stress condition was a metabolic adaptation to reduce the heat production in the body[10]. There are evidence which also show that the increased ambient temperature can directly affect the hypothalamic pituitary axis and reduce TSH secretion in the body[27,69]. The decreased TSH production can also contribute to less thyroid gland function and reduced T_3 and T_4 level in the animal blood during the heat stress condition[67].

HEAT STRESS IMPACT ON THYROID HORMONE CONCENTRATIONS

Thyroid hormones play a critical role in thermogenesis and therefore are an important reflection of adaptation to heat stress in livestock species[9]. In general, it is well established that heat stress is associated with reduced thyroid activity and decreased thyroid hormone concentrations[69,72]. According to Rasooli *et al.*[69], there was a significant decrease in the concentration of T_3 and T_4 were recorded in the Holstein cows when they were subjected to heat stress condition. Further, these researchers also established that compared to T_4 and T_3 showed significant correlation with the environmental temperature. Similarly, Pereira *et al.*[73] recorded reduced the T_3 level of 18.3, 16.0, 22.0 and 14.4% in Alentejana, Frisian, Limousine and Mertolenga cattle species, respectively during the heat stress condition. In the same experiment, the researchers also observed a decline in the T_4 level of 15.3, 15.0, 23.8 and 21.7%, respectively in Alentejana, Frisian, Limousine and Mertolenga species in the increased temperature condition. In an experiment Kahl *et al.*[74] recorded a decreased level of TSH, T_4 and T_3 in steers upto 40, 45.4 and 25.9%, respectively when they are subjected to heat stress for 3 days. The decrease in TSH, T_3 and T_4 concentration in blood plasma is a clear cut indicator of suppressed pituitary thyroid axis during the heat stress condition. Likewise, Horowitz[75] stated that in the cow plasma thyroid hormone levels have been observed to decline under heat stress as compared to thermo neutral conditions. In addition, Kumar *et al.*[76] also reported a significant decrease of T_3 and T_4 level in blood plasma of black Bengal goat. According to Marai and Haeeb[77], the maximum concentration of thyroid hormones was found in winter followed by spring and least during the summer season in both buffaloes and Friesians. In male Friesian calves, acute heat exposure induced a decrease in plasma[78] T_3 and T_4. In an experiment in young (aged 6 months) and old buffalo calves, Nessim[79] recorded 35.25 and 17.59% reduced T_3 and T_4 production in heat stress condition. Likewise, in an experiment in Malpura ewes when they were subjected to heat stress, Sejian *et al.*[72] recorded significant reduction in the concentration of thyroid hormones (T_3 and T_4). In their experiment, they also reported a high level of thyroid hormone production in sheep at 23°C than those in the thermoneutral condition (30-35°C). The reduced thyroid hormone production in sheep during heat stress condition could be attributed to the efforts of these animals to generate less metabolic heat production in the body to cope up with the elevated ambient temperature[62,80]. Significant increase level of thyroid hormone production in cold condition (23°C) indicates this effect is mediated to increase the metabolic heat production in cold stress conditions[10]. In an experiment, Abdel-Fattah[81] found a change in T_3 production from 1.68 and 1.88-0.94 ng mL^{-1} and 1.06 ng mL^{-1} in Balady and Damascus goats, respectively with a decrease of 44.05 and 43.62% in heat stress compared to the normal conditions. Likewise, he also recorded 41.52 and 25.52% reduced T_4 production in Balady and Damascus goats respectively in increased temperature condition. Similarly, significant decline in T_3 and T_4 level was observed in Damascus goat species during short and long exposure to constant solar radiation[82]. Likewise, Hooda and Upadhyay[83] showed a significant decrease in T_3 and T_4 production in kids of Alpine x beetle cross when they were exposed to 40°C ambient temperature. However, they also observed that the subsequent decrease in T_3 and T_4 were not significant when these animals were exposed to 42 and 44°C temperature. Further, there are also studies indicating that thyroid hormones are considered as the indicator of nutritional status of the body[13,62,83]. Similarly, significant decrease of thyroid hormones was observed in black Bengal goats[84] and in female aardi goats[85] under high environmental temperature condition.

IMPACT OF HEAT STRESS ON OTHER BLOOD METABOLITES

The role of metabolic regulators is crucial in the physiological response to heat stress which can be assessed through various enzymes governing the metabolic reactions in plasma or serum. There are reports which established a deacreased level of non-esterified fatty acid (NEFA) during heat stress condition in livestock[35,24,86,87]. Baumgard and Rhoads[24] attributed this decreased production of NEFA during heat stress to enhance the glucose burning as a presumable strategy to reduce metabolic heat production in the animal body. In contrast, Shehab-El-Deen *et al.*[88] recorded an increased production of NEFA during summer as compared to winter and they attributed this to maintain the energy balance during summer. Further, in pigs during heat stress condition, Upah *et al.*[89] reported increased level of NEFA only during the first three days heat stress exposure. However, during subsequent days they established a negative correlation between NEFA production with environmental temperature.

In an experiment, Alberghina *et al.*[90] recorded a significantly increased production of haptoglobin in the blood plasma during heat stress condition. Similarly increased the concentration of haptoglobin was also reported in dairy cows by Wenz *et al.*[91] during summer. The level of enzymes in the blood regulates the metabolic activity in the animal exposed to stress[92]. Hooda and Singh[46] reported a significant decrease in the Alkaline Phosphatase Activity (ALP) in the buffalo heifers on exposing them to heat stress and they attributed this decrease in ALP to the dysfunction of the liver during elevated temperature. Sejian *et al.*[13] also recorded significantly lower levels of ALP and ACP in the sheep during the increased temperature condition. The varying concentrations of these metabolites show the metabolic shift in the stressed livestock species to adapt the changing environmental conditions. Further in an experiment, Nazifi *et al.*[93] observed decreased the level of creatine kinase and lactate dehydrogenase in Iranian fat-tailed goats during the summer season. Banerjee *et al.*[94] reported in an experiment conducted on Indian goat higher level of both aspartate aminotranspharase (AST) and alanine aminotranspharase (ALT) in cold adapted breeds. In contrast, Nazifi *et al.*[93] recorded increased concentration of AST and ALT during summer in goats. Further in an experiment on crossbred dairy cows, Alameen and Abdelatif[95] recorded an increased level of AST and decreased the level of ALT during summer compared to winter. In addition, Helal *et al.*[82] recorded a decreased activity of ALT and lactic dehydrogease (LDH) in Damascus goat when they were exposed to high ambient temperature and they attributed this decline to the decreased activity of thyroid gland during heat stress. However, Sharma and Kataria[96] did not found any significant difference in AST level in Marwari goats after exposing them to heat stress condition.

ALTRATION OF METABOLIC RESPONSES IN LIVESTOCK DURING HEAT STRESS

Heat stress brings about changes in post-absorptive metabolism of animal independent of decreased feed intake and energy balance[24]. Heat stress upregulates the secretion of leptin and adiponectin where leptin stimulates the hypothalamic axis and causes reduction in feed intake and adiponectin changes the feeding behaviour by peripheral and central mechanisms. Heat stress down regulates the protein synthesis at the transcriptional level which results in lower protein deposition. Further, heat stress depresses RNA content, proteolytic rates and muscle protein turnover particularly acute heat stress increases protein catabolism. Increased protein catabolism under chronic heat stress is likely to produce glucose through the gluconeogenesis pathway. The inability of heat stressed animals to utilize glucose sparing mechanisms to prioritize milk synthesis results in inflexibility of metabolism[54]. Further, mild heat stress increases intramuscular glycogen phosphorylase and pyruvate dehydrogenase without affecting the intramuscular concentrations of glucose 6-phosphate, lactate, pyruvate, acetyl-coenzyme A (acetyl-CoA), creatine, phosphocreatine or ATP. Chronic heat stress reduces the level of circulating glucose levels in spite of the increased glucose absorption, renal glucose reabsorptive and enhanced hepatic glucose output. The increased reduction of fatty acid oxidation during chronic heat stress makes the heat-stressed animals to highly dependent on glucose for their energy needs for production which is declined and results into a state of negative energy balance. Heat stress affects the protein metabolism and causes lower milk crude proteins and caseins as the effect of impaired phosphorylation and energy deficiency[9]. Further, heat stress directly affects protein metabolism by increased skeletal muscle breakdown to afford amino acids which are necessary for energy metabolism[39]. The cows are not much responding to the NEFA during heat stress as a result of elevated levels of cortisol, norepinephrine and epinephrine which are catabolic and initiate lipolysis and adipose tissue mobilization. Moreover, heat stress downregulates lipolytic enzyme activities but the blunted lipolytic activity of the adipose tissue is an adaptation to limit heat generation in heat-stressed animals. Although lipolytic enzyme activity is decreased in heat stress, the activity of the lipoprotein lipase in the adipose tissue is increased which allows the hyperthermic animals for better storage capability of intestinal and hepatic triglycerides[86].

CONCLUSION AND FUTURE RECOMMENDATION

Climate change is seen as a formidable challenge for livestock survival. To achieve an optimum return from the livestock sector, it is very essential to develop breeds with high thermo-tolerance. The animals need to possess extreme adaptive capability to a particular environment in order for them to produce normally. Hence, improving livestock adaptability based on developing a suitable breeding program using genetic markers is the need of the hour. It is very essential to understand the basics of adaptive mechanisms exhibited by these animals to survive in adverse environmental condition. The metabolic response is considered one of the primary adaptive mechanisms of ruminant livestock which favour survival and promotes welfare when an animal is subjected to heat stress condition. This pathway can lead to yield suitable biological markers for quantifying heat stress condition in livestock species. Accordingly, heptaglobin, NEFA, T_3, T_4, ALT and AST are considered important markers for assessing the metabolic adaptation in livestock. Based on this review, it was concluded that metabolic response is one of the primary means by which the animals tries to cope up with heat stress challenges. The animal reduces their metabolic activities in an effort to reduce the metabolic heat production to cope up to outside environment heat stress condition.

Efforts are needed to conduct whole tanscriptome analysis of thyroid gland during heat stress condition. This is a possibility with advancement in techniques in molecular biology. These efforts might yield confirmatory cellular and molecular markers for metabolic adaptation in livestock species. These markers can be incorporated in breeding programs through marker assisted selection program. This will help to develop thermo-tolerant breeds which can cope up to heat stress and deviate the energy towards production pathway.

SIGNIFICANT STATEMENTS

Climate change is seen as a most important threat to the survival of livestock species. Hence, developing appropriate coping strategies is the hour of need to sustain livestock production in the changing climate scenario. In order to develop appropriate adaptation strategies, sufficient study efforts are needed to understand in detail the hidden intricacies of livestock adaptation. Among the various adaptive mechanisms, metabolic response alteration is one of the primary means by which livestock copes up to increased heat stress challenges. Understanding in detail the metabolic response of livestock adaptation might pave way for developing more viable adaptive measures to cope up livestock production system to climate change.

Highlights

- The metabolic response is considered one of the primary adaptive mechanisms of ruminant livestock which favour survival and promotes welfare when an animal is subjected to heat stress condition
- In depth understanding of metabolic response of livestock adaptation might pave way for developing more viable adaptive measures to cope up livestock production system to climate change
- Heptaglobin, NEFA, T_3, T_4, ALT and AST are considered important markers for assessing the metabolic adaptation in livestock

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