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Mitigating Cold Stress in Livestock by Nutritional Interventions: A Comprehensive Review

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ABSTRACT

Climate change has been the major threat to livestock systems sustainability globally. This climate change has provoked many stressors, for instance, cold, heat, humidity, rain, ice and wind, that can directly or indirectly exert influence on the endocrine system and impact the performance of an animal including their production potential, reproductive system and regular estrous cycle. Also, the environmental stressors can contribute to the amenability of animals to infections; it is therefore, vital to understand how stressors alter the animal's adaptive capacity and efficient methods in coping stress. This review aims at the scientific evidences regarding challenges due to cold stress and its potential mitigation by nutritional interventions. The cold is amongst the most potential environmental stressors which can adversely affect production potential as well as the growth of animals. Under cold stress the animals' dietary intake increases, but the production capacity declines, furthermore, it can also culminate in physiological fluctuations, behavioral shift, tissue and intestinal impairment and soaring death rate. Maintenance of animal in its thermoneutral zone is important, otherwise any deviation from it proves life threatening. So, to cut back on the economic losses timely course of action must be taken to prevent the damages ascribed to the stressor. To maintain the production performance along with profitability, it is thus recommended to adapt scientific feeding regimens and also incorporate feed supplements (especially vitamins and minerals) to combat the devastating effects of cold stress.

Key words: Cold stress, Endocrine changes, Feeding strategies, Livestock, Thermoneutral zone.

In India livestock sector alone contributes well to the agricultural GDP, with a share of around 25.6% (Anonymous, 2020). There are about 303.76 million bovines (cattle, buffalo, mithun and yak), 74.26 million sheep, 148.88 million goats, 9.06 million pigs and about 851.81 million poultry as per 20th Livestock Census in the country (PIB, 2023). But extreme climatic condition affects adversely to the production potential of the livestock species. The rapid change in climate throughout the last few decades have negatively impacted the potential of animals (Fig 1). The change in climate now-a-days is a prime menace to the efficiency of livestock systems all over the globe (Maurya *et al*., 2007). Every animal has a haven when tied in with its physiological state, within which the animal has minimal energy expenditure, but outside of this haven, the animal encounters stress to maintain homeothermy. When an animal spends a medium/long time span out of its comfort zone, it initializes means of acclimatization, considering population of animals encountering appreciable climatic changes can alter by genetic adaptation, amending genetic and phenotypic attributes over generations (Nardone *et al*., 2006).

The change in climate modifies the outlines regarding the rate of precipitation, quality, quantity and rainfall distribution, snow melting affects flow of rivers and ground water renew structure and eventually affecting the water availability. The elevated global temperatures amend the composition of species, along with the ecological arrangement of grasslands and forage production system (Giridhar and Samireddypalle, 2015). The deficiency of water supply to animal affects the core physiological homeostasis of body, which leads to decline in body weight and body condition, decreased reproductive efficiency and

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declined resistance to diseases (Naqvi *et al*., 2015). The climate change adds on to flare up the episode and emergence of numerous diseases that are vector borne, which in turn shackle the livestock economy.

Thermoneutral zone

The thermoneutral zone can be elucidated as the range of ambient temperatures wherein the body can sustain its core temperature merely by regulating dry heat loss, *i.e*., cutaneous blood flow (Fig 2). A living body can only support its core temperature when heat generation and heat dissipation are balanced. It suggests that heat transfer from inner body to outer body must be comparable to heat transfer from skin to the environment (Kingma *et al*., 2012). While rectal temperature of cattle drops below 28°C (82°F), they are unable to restore normal temperature without assistance (Graunkle, 2011). The thermoneutral zones of different animals are mentioned in Table 1.

Stress

Stress is interpreted as any deviation from the optimum state. There are numerous climate allied stressors, for instance, cold, heat, humidity, rain, frost and wind that can alter the potential of an animal including the reproductive system, endocrine system and regular estrous cycle of animals (Gaughan, 2015). A variety of stress like environmental, physiological, nutritional and managemental, are depicted in Table 2. Stress can be categorized as acute or chronic based on the amount of unveiling to drastic temperature changes (Rincker *et al*., 2011).

In the current review we are concerned with the impact of cold stress against the production performance of livestock species and their mitigation measures through nutritional intervention.

Cold stress

The time when environmental temperatures twitch to drop in winter, especially closer to 0°C (32°F), it is the actual period to ponder about its effect on animals' efficiency and productivity (Tarr, 2013). Within the range of thermoneutral zone, animals do not need to spend any additional energy to uphold their body heat. At the inferior end of this range, normal metabolic processes contribute enough heat to sustain body core temperature. Within the thermoneutral

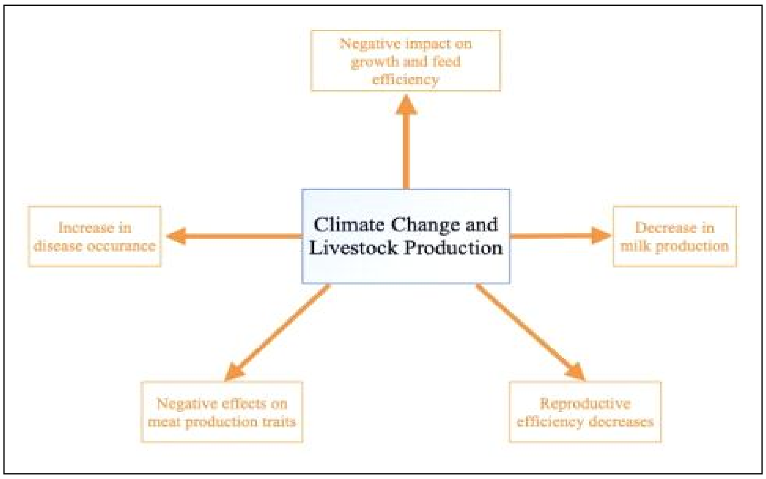

Fig 1: Effect of climate change on livestock production potential.

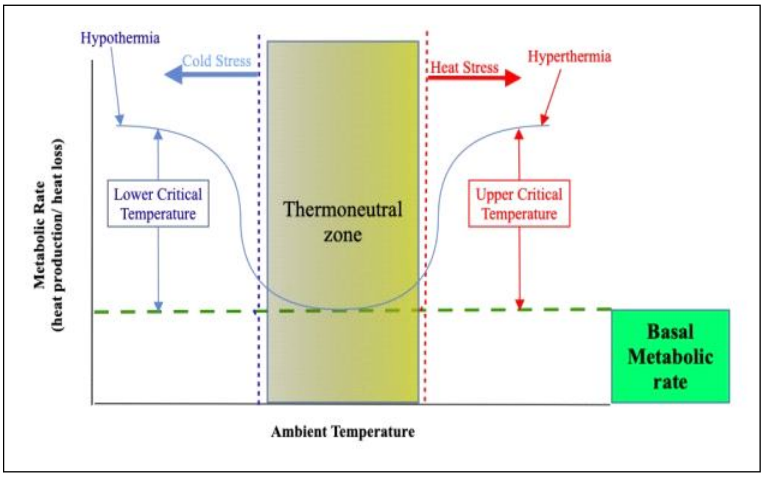

Fig 2: Thermoneutral zone.

zone, animals may alter their behaviour, for instance, seeking refuge from wind and respond eventually by growing a dense hair coat for winter, without influencing their nutrient requisites. Regardless of how, below the lower limit of thermoneutral zone, there is the "lower critical temperature," where animal undergoes cold stress. To strive against cold stress, the animal must expand its metabolic pace to furnish more body heat (Tarr, 2013). This enhances dietary requirements, explicitly for energy. Winter cold stress is a crucial environmental factor impacting livestock production in temperate climatic conditions. The impact of chronic cold stress on the important biological actions in animals can aid to develop efficient mitigation methods (Wang, 2023).

The process of metabolism continuously generates heat within the animal body and there is a continuous net loss of heat from the body surface by the process of conduction, convection and radiation. However, the balance between heat generated and heat loss must be synchronised so that the core body temperature of the animal remains relatively constant (Monteith and Mount, 1974; Robertshaw, 1974). The thermal demand of the surrounding environment controls the net rate of heat loss and the resistance of the outer shell or covering of body to the heat flow (thermal insulation). The lower critical temperatures, expressed in terms of effective dry still-air temperatures, can be easily forecasted from an animal's rate of heat production and outer insulation (Blaxter, 1962; Webster *et al*., 1970; Monteith and Mount, 1974; Young, 1975b; Mount, 1976). A drift or drove of pigs, for example, has a several degrees below lower critical temperature than that of a single pig (Close *et al*., 1971). The pigs show huddling behavior at lower critical temperatures, that lowers the exposed surface for heat loss and in turn the heat drain to the environment is reduced. Wind and moisture both shows supplementary effects by which the insulation value of animal's outer hair coat is compromised and increase the surface heat loss. A wet body coat from rain or snow reduces the insulative value of animals' outer thermal insulation.

Table 1: Thermoneutral zones of different livestock species (Elischer, 2021).

Animal	Thermoneutral zone (in °F)
Cattle (beef)	32-77
Cattle (dairy)	41-77
Goat	50-68
Sheep	70-88
Horse	40-80
Swine	50-70
Rabbit	60-65
Poultry	60-75

Animals' response to cold stress

Cold stress is a notable facet related to the laggard growth and surged fatality of animals, resulting in hefty financial losses to livestock globally, especially in the long and cold northern hemisphere winter (Hu *et al*., 2021). In homeotherms among all the environmental stressors, cold stress is high priority and energy demanding which results in oxidative stress (Qureshi *et al*., 2018) which leads to tissue injury, poor health with low economic returns. The way animal engages with cold stress is presented well in Fig 3.

Erstwhile studies have disclosed that exposing animals to long-term or clement cold circumstances physiological adaptations can occur, including amplified calorie creation, appetite and basal metabolic potency, along with changes in digestive function (Young, 1983). The long-term exposure of animal to cold conditions contribute to hypothermia, which arises when the core body temperature downgrades from normal. The stages of hypothermia are presented in Fig 4. But, when the rectal temperature of cattle drops below 28°C (82°F), they are unable to restore to normal temperature without aid like providing warmth and the dispensation of warm intra-vascular fluids (Graunkle, 2011). As hypothermia advances, physiological and metabolic activities decelerate, what's more, blood gets drawn away from the extremities towards the central pool so as to shield the internal organs. Due to these low temperature conditions, organs like teats, testes and ears are apt to get frostbite. While in extremes conditions, there is bradypnea and bradycardia, animals lose sentience and collapse (Tarr, 2013).

Factors affecting animal's ability to withstand cold

• Acclimation

The animal can acclimatise to the colder environmental conditions by growing a thick and longer hair coat, that provides added insulation against cold weather conditions.

Table 2: Different categories of stress.

Environmental	Physiological	Nutritional	Managemental
Toxic metal pollutant	Cold stress	Acidosis	Handling
Chemical fertilizers	Heat stress	Bloat	Transportation
Pesticide contamination	Advance pregnancy	Hypocalcemia	Seasonal changes
	Dehydration	Ketosis	
		Hypomagnesaemia	
		Mycotoxins	
		Plant toxins	

The body coat must be dirt-free and dry to maximize the protection against cold to the animal. Any trace of dirt or moisture on the coat reduces the insulation capability dramatically.

• **Fat layer**

Animals with a thick fat layer and in good health condition withstand the cold comparatively better than the thin animals. The extra fat layer works as additional insulating layer between the animal's core and the environment.

• **Metabolic rate**

Animals also upsurge their metabolic scale to increase the heat production and help to maintain their core body temperature. This results in increasing the demand for dietary energy and thus appetite is typically increased during cold conditions and animal consumes more (Tarr, 2013).

Neuro-endocrine response

When an animal is put through ambient cold, various hormones are let out to advance catabolic pathways that endorse body thermogenesis. Some constant physiological changes occur to manage with diverse environmental situations, which activates neuroendocrine responses. Any form of physical or external stress can lead to the triggering of physiological mechanisms mandatory to maintain homeostasis (Moberg and Mench, 2000). Both categories of stress *i.e.*, acute or chronic, can initiate neuroendocrine channels that alter physiological actions so as to sustain homeostasis to safeguard viability of the animal (Rincker *et al*., 2011). The stress hormones generated in exchange for altered environmental temperature, induces various sequelae in animals like mustering of energy for alimentation of muscular and neural functions, increased glucose transport to brain, advances in cardiorespiratory functions, immune system modulation, diminished reproductive efficiencies and loss of appetite (Funston *et al*., 2012). Stress encourages numerous neuroendocrine responses which comprise initiation of a few hormonal axis and generate tropic hormones which arbitrate the adaptive and behavioral responses in animals.

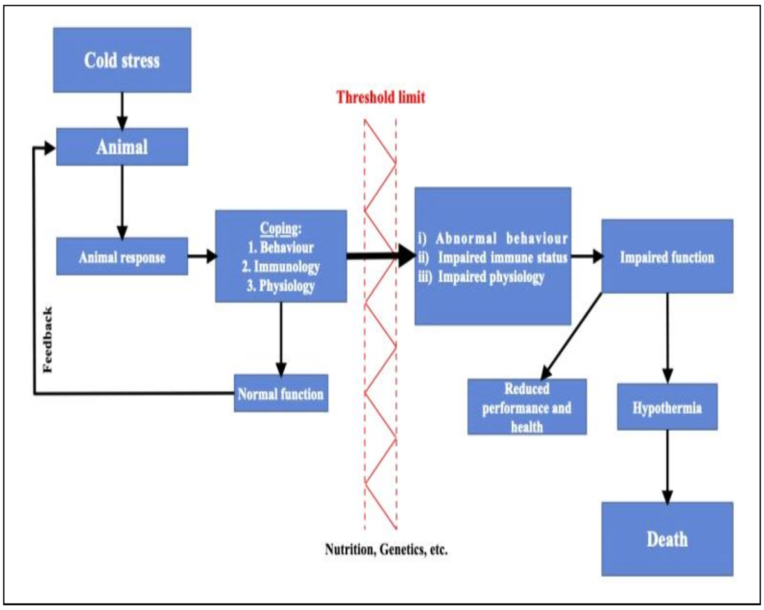

Fig 3: Response of animal to cold stress.

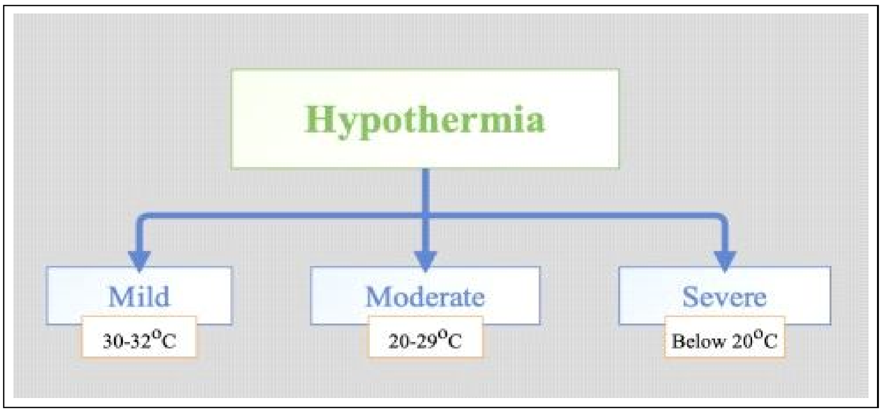

Fig 4: Types of hypothermia (Tarr, 2013).

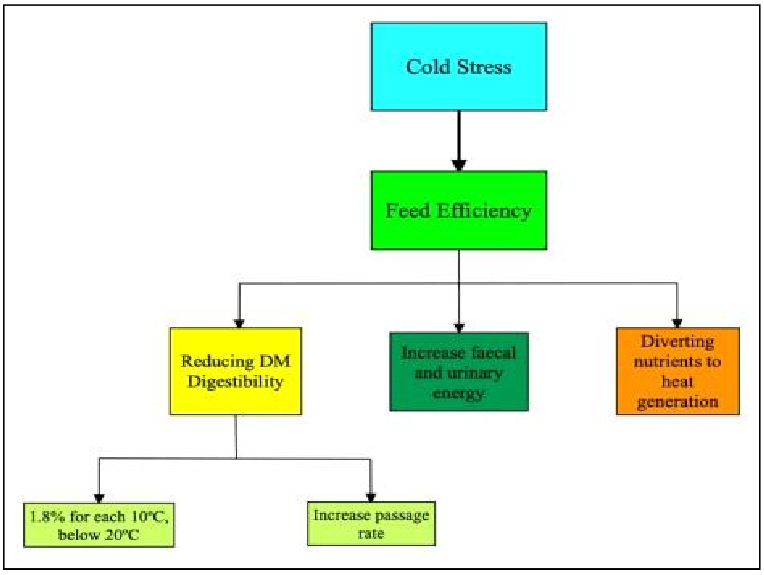

Fig 5: Outcome of cold stress on feed efficiency.

It has been documented that low-temperature stress initiates the hypothalamic-pituitary-adrenal axis and leads to the generation of glucocorticoid hormone in vertebrates. Cold exposure triggers animals to convert carbohydrate metabolism, which is tempered by hormones essentially insulin and glucagon. The metabolic thermogenesis endorsed by a rise in T_3 secretion occurs during cold stress, owing to acute secretion of catecholamines and stimulation of hypothalamic-pituitary-adrenal axis (Duddy *et al*., 2007). Exposure to cold brings about inhibition of responsiveness of the juxtaglomerular apparatus, favouring water elimination (Kim *et al*., 2010). The generation of LH and FSH was lesser in the cool surrounding, suggesting that, as in adult animals, adverse environmental conditions may diminish reproductive hormone generation in the infant. Consequently, generation of pituitary LH and FSH may serve as a biochemical index of stress (Bhimte *et al*., 2018).

The hypothalamus-hypophyseal portal system is a way through which corticotropic releasing hormone reaches anterior pituitary, which activates the synthesis and secretion of adrenocorticotropic hormone (ACTH) into the blood stream. This ACTH stimulates the part of adrenal cortex (zona fasciculata) to secrete cortisol into blood to employ its physiological actions on focussed tissues (muscle, adipose and liver) (Carlin *et al*., 2006). Cortisol belongs to the family of steroid hormones, whose precursor is cholesterol. As it has low solubility in blood, thus it is transported through special proteins *i.e*., corticosteroid binding globulin (CBG) to recipient tissues, while only 10% of it is found in its free form. Various studies have demonstrated that animals subjected to external stress shows increase in concentrations of circulating CBG and free form of cortisol. This specifies that the cortisol secretion is among the chief hormonal responses to stress (Mader *et al*., 2010). It also assists to reinstates the compromised energy balance by provoking glycogenolysis, proteolysis and lipolysis in the animal under stress. Some animals show aggressive demeanour with an increase in the concentration of cortisol in serum (Chen *et al*., 2006).

The pineal gland secretes melatonin during night, or particularly the dark phase of light cycle. This gland is thought to be a neuro-endocrine transducer of photocyclic input, which is accountable for the seasonal alterations in the reproductive aptitude of different animal species. Aforementioned gland is also known to counter the stress conditions in mammals and birds. Glucocorticoids have shown to stimulated the pineal cells (pinealocytes) to release the melatonin hormone in stressed animals in order to mitigate the thermal-stress. There are various biochemical reactions that increase with high temperature; thus, it is very common to notice raised body temperature, enhanced generation of reactive oxygen species (ROS) or free radicals via hastened metabolic reactions at the levels of cells and tissues. In contrast, melatonin (pineal gland secreted hormone), plays a vital role in the defence system from antioxidants and has an efficient free-radical scavenging activity. This ROS scavenging mechanism has been proven effectual in heat tolerance to the chickens treated with melatonin (Bhimte *et al*., 2018). The melatonin applied exogenously shows further reduction in the cortisol level.

Production losses due to cold stress

During adverse winter months, when the animals kept outside, they utilize more feed yet their production performance reduces because fewer feed energy is accessible for productive procedures (Young, 1981). Among various stress factors, cold stress proves to exist as a vital reason which restricts livestock production (Wang *et al*., 2023). In nursing cows, cold weather and reduced surrounding's temperatures abate milk yield and improved milk fat proportions, with the outcomes most pronounced during the early phases of lactation (Johnson, 1976). An analysis by MacDonald and Bell (1958) describes the consequences of extreme cold on milk yield and reported that the drop in milk production starts in dairy cattle when fed ad libitum at -4°C and marked depression in milk output was found at the temperature of -23°C. Theoretically, every 1°C decrease in normal surrounding temperature results in increasing the maintenance energy requisite of beef cattle roughly around 2.89 kJ/kg (He *et al*., 2022). The long-term exposure to cold stress has shown to increase the feed intake, with additional energy from feed is diverted in favour of thermogenesis to uphold the persistent body temperature (Fig 5). However, the digestive activity gets compromised under cold stress, so it happens to increase the dry matter intake (DMI) making it incapable to encounter the enhanced heat production, which ultimately diminishes growth performance (Roland *et al*., 2016). Diet digestibility in ruminants decreases by 0.2% for each degree decrease below 20°C (Kennedy *et al*., 1986). Lower diet digestibility may occur from an increased gut motility that is secondary to elevated feed intake and T_4 secretion in cold-stressed animals. The reduced exposure time of fibrous nutrients to microbial digestion lowers digestibility (Westra and Christopherson, 1976). Kang *et al.* (2016) conducted an experiment on Korean ruminants and reported that on exposing the cattle to lower temperatures, it brings about curtailed feed utilization and average daily gain (ADG). The adverse effects on beef cattle because of cold stress appear to be predominantly on energy required for maintenance, but during pregnancy the development of the conceptus and, subsequently the birth weight of calf remains unchanged (Wiltbank *et al*., 1962; Jordan *et al*., 1968; Hironoka and Peters, 1969). However, if the level of feeding is exceptionally inadequate and/or protein is scarce, the chances of weak calf syndrome at calving enhances in the spring (Bull *et al*., 1978). Moreover, cows with weak body condition shows compromised lactation potential and also gets prone to repeat breeding (Wiltbank *et al*., 1962). Concurrently, Zhang *et al.* (2022) in their experiment found that cold environment induces depression in live body weight, but increase the expression of hepatic thermogenic genes in Mongolian sheep. It is likely that the enhance in feed consumption in Simmental cattle over a period of cold stress is primarily used for resting thermogenesis to maintain body temperature, which causes hinderance in the growth performance *viz*., body weight gain, ADG, nutrient utilization (Wang *et al*., 2023).

In horses, energy and crude protein digestion did not alter with housing temperature but decreased with age (Cymbaluk *et al*., 1989). Weanling horses kept in cold housing showed a 10% reduction in phosphorus digestion but an 18% to 47% improvement in fibre digestion. Acute cold exposure of adult horses reduced serum phosphorus content but elevated total protein, cholesterol, lactate dehydrogenase and alkaline phosphatase (Dietrich and Holleman, 1973).

When pigs are exhibited to low ambient temperatures, they show improved fibre digestion, which was suggested to improve heat increment and thereby aid in maintenance of body core temperature during cold (Stahly and Cromwell, 1986). Cold stress and contagious disease are presumed to furnish to the 13% to 15% mortality rate recorded for piglets between farrowing and weaning (Bhimte *et al*., 2018).

Under cold environmental conditions, the pair being the prime causes of death is ascites and cardiomyopathy (Mendes *et al*., 1997). Additional results disclosed that not only acute (12±1°C retained for 1, 3, 6, 12, 24 h) but chronic cold stress (12±1°C retained for 5, 10, 20 d) could trigger oxidative stress in the duodenum and change nitric oxide synthase (iNOS), relating with the intestinal damage process in 15 d old broilers (Zhang *et al*., 2011). Another researcher, Chen *et al.* (2015) reported that cold stress set off oxidative stress and yielded reactive oxygen species which commenced the genesis of liver fatty acid-binding protein (L-FABP). This L-FABP in turn appears to disable free radicals and encourage fatty acid intake to govern low temperature via lipid synthesis (Chen *et al*., 2015). There were records which connoted that cold stress has negative affect on meat quality, as there was depletion of glycogen reserves in thigh muscle of broilers, revealing a dark, firm and dry (DFD) quality change when exposed to sub-zero temperature of -8°C (Dadgar *et al*., 2012).

Effect of cold stress on health status

Blood parameters are the most important indicators of animal health. The estimation of various hemato-biochemical parameters assists in comprehending the association of blood characteristics to the habitation and adaptability of animals to the environment. Variations in blood parameters depends on the species, sex, age and nutritional and physical condition of animals (Arfuso *et al*., 2016; Fiore *et al*., 2017; Fiore *et al*., 2018). The investigation of blood parameters in animals represents a crucial tool in the advancement of management conditions, especially concerning the detection of healthy versus infected or stressed animals (Carcangiu *et al*., 2018; Arfuso *et al*., 2023; Perillo *et al*., 2021; Arfuso *et al*., 2022). Blood metabolic profiles including the biochemicals, low-molecular metabolites, cations and anions are the indicators of the metabolic status in ruminants (Zaitsev *et al*., 2020). Puppel and Kuczyńska (2016), reviewed the changes in the blood metabolic profiles of perinatal cows and concluded that the increased concentrations of non-esterified fatty acid and β-hydroxybutyric acid (a ketone body) in the blood are the most commonly used indicators for the negative energy balance of hosts. Yaks showed similar results during starvation with lower concentrations of glucose and triglyceride and greater concentrations of ketone body and non-esterified fatty acid in their serum (Zou *et al*., 2019; Hu *et al*., 2020). For the protein status of hosts, blood protein and urea nitrogen are important indices to indicate the protein intake and protein absorption of digestive tracts (Law *et al*., 2009). Cold stress also affects the carbohydrate metabolism and protein status in ruminants, which could reflect using the biochemical parameters of their blood (Nazifi *et al*., 2003). The above biochemicals are useful for predicting the requirement of major nutrients of ruminants. Metabolomic approaches are powerful tools to investigate the low-molecule metabolites in biological fluids which could reflect the metabolic changes of animals precisely. Recent studies have investigated the energy and protein metabolism of yaks in response to supplementary feeds during the warm season (Xue *et al*., 2021) or the cold season (Zhou *et al*., 2020) using metabolomics technologies. However, the dynamic changes in the blood metabolome of grazing yaks in response to the cold season are still unclear, which causes difficulties for supplementary nutrients precisely for these yaks.

Feeding strategies during cold stress

Ames (1976) proposed and has shown in feeding experiments that protein levels in cattle diets should be decreased during cold weather. More energy is required to maintain body reserves and body temperature when animal is open to cold weather (Vining, 1990). It is predominantly accepted that for every 1^{o}C decline below the cows '*lower critical temperature*' there is a roughly 2% rise in energy requirement (Tarr, 2013). Manzoor *et al.* (2019) have recommended that the increase in feed energy content (77% vs. 70-72% TDN) and protein (17.5% vs. 14.5% CP) proves beneficial during cold climatic conditions. The increase in feed consumption or dry matter intake will help animals outdoor that require about 15 to 20% more feed for the season than animals kept in confinement housing (Graunkle, 2011). Provision of a diet with a higher heat increment help animals to withstand the cold months of the year (MacRae and Lobley, 1982). Rations containing about 20% vs. 17% fiber in the animal feed are helpful to diminish the effects of cold temperatures (Manzoor *et al*., 2019). Some studies revealed that providing NRC nutritional requirement to pregnant beef cattle cows during cold stress tends to offset its negative impact on calf birth weight (Hironaka and Peters, 1969).

After a period of feed deprivation, cold-acclimated horses ate the equivalent of 3.2% of body weight of a pelleted diet when fed ad libitum (Dietrich and Holleman, 1973). Unlike cattle, which ate 10% more feed when external temperatures dipped below -10^{o}C, ad libitum-fed weanling horses reduced feed intake by 6% (Cymbaluk and Christison, 1988). Growing horses fed a high forage diet consumed 0.2% more diet per degree Celsius decrease in ambient temperature below 0^{o}C (Cymbaluk and Christison, 1989). Provide adult horses with about 2.5% more DE per degree Celsius decrease beneath the lower critical temperature. Adult horses will use 0.408 Mcal DE/500 kg of body mass (0.00082 Mcal/kg BW) for each 1^{o}C degree dip beneath the lower critical temperature (McBride *et al*., 1985). Daily supplementation of vitamin A at 30 to 60 IU/kg of body mass accompanying vitamin D at 5 to 10 IU/kg of body weight are recommended (NRC, 1989). The use of good quality hay should be encouraged in extreme cold (<-10^{o}C) for the following reasons: a high HI, a high voluntary intake and good energy content.

Dietary strategies including dietary supplementation with proteins, vitamins, minerals, polyphenols and phytogenics are extensively exerted to mitigate the inimical impacts of environmental stress in poultry (Abd El-Hack *et al*., 2020). These additives have manifested efficacious ensuing their pharmacological and nutritional attributes, minimum or no adverse effects, anti-oxidative and immune contributing functions, acid-base equilibrium and enhanced production potential in poultry (Olgun *et al*., 2021). Antioxidant plays an important role in both nutrition and production performance. Trace minerals such as Selenium, Zinc, Chromium, Copper and Manganese are recommended as external antioxidants (Willcox *et al*., 2004) to combat oxidative stress caused by environmental stressors. Contrary to inorganic minerals, organic trace minerals (such as Zinc and Chromium) are more bioavailable, resulting in better production parameters along with increased profitability (Mateen *et al*., 2023). Chromium, a micromineral, which is required essentially for metabolism of nutrients (Anderson, 1987). The amount of chromium in poultry ration is very low, thus its requirement fosters during stress conditions (Farag *et al*., 2017). Such conditions require supplementation of this essential trace element to augment the production in poultry birds (Shabana *et al*., 2014). The dietary supplementation of vitamin-E at levels higher than the National Research council (NRC, 1994) recommendations for poultry, boosted the immune response (Lin *et al*., 2006) and enhanced the performance of birds (Guo *et al*., 2001). The supplementation of vitamin-E at higher doses had positive effect on the production performance than supplemented in lower doses in quails (Biswas *et al*., 2008). It has been suggested that supplying vitamin-E in high doses helps to alleviate oxidative stress associated with Pulmonary Hypertension Syndrome (Iqbal *et al*., 2002; Niu *et al*., 2018) and can be useful in demoting the mortality related to ascites in broilers (Bottje *et al*., 1995).

Probiotics are the products containing live microorganisms in sufficient number to effectively modify the microflora and exert beneficial effects in the host (Schrenzenmeir and de Vrese, 2001). Wideman *et al.* (2012) demonstrated that administration of a commercial probiotic, PoultryStar, reduced the incidence of lameness in broiler chickens that were stressed by housing on wire flooring, presumably by altering intestinal bacterial populations and decreasing bacterial translocation from the gut. This suggests that probiotics may be efficacious in modulating the effects of other stressors on gut health. Chai *et al.* (2023) reported that the mild cold stress had a negative impact on the growth and health of Rongchang piglets, but can be gradually adapted and adjusted. In this process, *Lactobacillus* spp. played a key role as a part of the external environment providing a new idea for how to alleviate the damage caused by cold stress in the breeding process.

CONCLUSION

The negative impact of cold stress on animals' welfare, health and potential cannot be underestimated. Animals under cold stress shows boost in the secretion of stress hormone which adversely exerts influence on growth resulting in fatality in severe cases. Nonetheless, efficient management strategies are crucial in breeding healthy poultry and financial gain hike in the poultry enterprise. To improve animals' adaptability to cold stress situations, it is important to comprehend the roles of distinct feeding regimes and use of various vitamins and their correct dosage in livestock diets to relieve stress. The harmonious outcomes of various vitamin and minerals could upgrade the growth potential and reduce the impact of cold stress.

Conflict of interest

The author declares that they have no conflicts of interest.

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