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Review Article

Mitigation Strategies for Cold Stress for Enhancing Livestock Productivity in Temperate Areas of Himachal Pradesh

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Abstract

Himachal Pradesh is a North-western hill state of India having four major agro-climatic zones with different climatic conditions. The animals reared in different zones experience cold stress when the temperature is below the thermo neutral zone. Climate change studies highlight the increasing temperature and unpredictable weather conditions around the globe. The cold- stress is likely to become more common in the future, in the present scenario of climate change. Across the globe, incidents of intense cold waves vary from region to region. Over India, the cold wave is observed during winter season spanning from December-February. The aim of this review is to give a general outlook of the different climatic factors, their effect on animals as well as adaptation and mitigation strategies for the domestic animals reared in Himachal Pradesh.

Keywords: Cold Stress; Temperate Areas; Himachal Pradesh; Mitigation Strategies

Introduction

Himachal Pradesh a North-western hill state of India lies between 30º22' to 33º12' N latitude and 75º45' to 79º04 E. The state is divided into four agro climatic zones viz. Shivalik hill zone (Zone-1), Mid hill zone (Zone-2), High hill zone (Zone-3) and Cold dry zone (Zone-4). Area wise zone-4 is the largest with low livestock population density. It is the coldest zone (called as the cold desert) and zone-1 is the hottest in comparison to the other three zones of Himachal Pradesh. Zone 1 and 2 are highly populous zone comprising of low hills, subtropical and mid hills, humid, respectively. These zones are predominant in cattle and buffalo population. Zone 3 predominately comprises the migratory population of livestock [1,2]. Himachal Pradesh is an agricultural state where agriculture, horticulture, animal husbandry and fisheries activities provide direct employment to about 70 - 75% of the total population. However, people living in higher altitudes depend more on livestock because under extreme climate conditions crop production is not possible throughout the year and animal rearing is based on common property resources and forest grazing [1]. The livestock species present in different zones are given in table 1,2.

The body temperature of the livestock species in the agro-ecological zones mentioned above is maintained by the thermoregulatory system within a range of 1°C of its normal temperature under ambient conditions that do not impose climatic stress. The range of environmental temperature at which the sensation of heat or cold is absent and the body temperature of animals is maintained with minimal effort is the zone of thermal comfort [3]. This is the most comfortable ambient temperature range with minimal physiological cost and maximum productivity [4,5]. Whereas the thermoneutral zone (TNZ) is the range of environmental temperature within which the body temperature is maintained constant with the help

Agro-ecological zones	Alititude In meters above sea level	THI index Inside shed Outside shed				Agro-ecological Situation	Area coverage (District wise)	Major livestock species and breed
		Max	Min	Max	Min			
Zone 1	350 - 650	92	66	92	70	Subtropical, low mid hills (Shivalik hill zone) Hot and Humid	Una, Hamirpur, and Bilaspur and parts of Sirmaur, Kangra, Solan and Chamba	Graded, exotic/crossbred & hill cattle, graded and Murrah type buffaloes, Beetal type goat
Zone 2	651 - 1800	84	48	84	51	Mid hills, humid	parts of Kangra, Mandi, Solan, Sirmaur, Kullu, and Shimla	Graded, exotic/crossbred & hill cattle, graded and Murrah type buffaloes, Rampur- bushair and crossbred sheep and Gaddi goat.
Zone 3	1801-2200	82	66	89	69	High hills, wet temperate	Shimla, Parts of Chamba, Kullu, Solan, Mandi and Kangra	Hill cattle, Rampur- bushair and crossbred sheep and gaddi goat.
Zone 4	> 2200	78	56	75	58	High hills and Dry tempelate (Cold dry zone)	Kinnaur, Lahaul Spiti, and parts of Chamba district	Yak, Chamurthi/Spiti horses, Chegu goats, Biangi sheep, Gaddi sheep and goats

Table 1: Agro-ecological divisions of Himachal Pradesh and distribution of livestock species [1,2].

S. No.	Particulars	Changes in animals during Cold	Mitigation strategies
1.	Behavioral	Huddling in animals [3]	Cover the animals especially smaller ruminants during cold days Cover the animal habitat from all sides during the night to avoid direct exposure of animals to cold winds Use some bedding materials such as dry straw under animals during winters.
2.	Physiological	Piloerection in animals (hair coat insulation), shivering and non-shivering (body brown fat) thermogenesis [3], decreased rectal temperature and respiration rate, higher T_3 and T_4 blood concentration, high glucose levels [15].	Construct of climate-smart sheds that allow maximum sunlight during winters and low radiation during summers.
3.	Nutritional	Increase in feed intake [25], decrease in water intake [20]	Use of high-quality forage or pastures Fat supplementation in ration Adlib warm water
4.	Production	Decrease in milk production, increase in body wool, hair and fleece [26].	Selecting animal breeds especially fit for cold weather conditions Improving livestock feeding practice and dietary additives

Table 2: Stress Indicators of cold stress and mitigation strategies.

of behavioral and physiological mechanisms [3]. This range is bounded by the lower critical temperature (LCT) and upper critical temperature (UCT) given in figure 1 for different species. The atmospheric temperature above or below TNZ leads to thermal stress that impairs metabolism, health status, production, reproduction and immune response in mammals [6,7]. This thermal stress is becoming more common in the present situation due to climate change including extreme climatic events [8]. The TNZ range (from LCT to UCT) normally is affected by animal species, breed, age, feed intake, production, housing conditions, the previous state of temperature acclimation or acclimatization (tissue insulation [fat, skin, wool], external insulation (coat) and animal behavior) [6].

Figure 1: A modified diagram from [3,38]; depicting critical environmental temperatures and zones.

Climate change studies normally highlight the increasing temperature around the globe. However, some regions in the world experience high ambient temperatures (above UCT) during the summer and very low temperatures (below LCT) during the winter [9]. Also, the incidents of intense cold waves vary from region to region, across the globe. In India, the trend of the cold wave has been observed during the winter season (December-February). The cold wave is an extreme weather event occurring during the winter season with a rapid fall in temperature within 24 hours, when the minimum temperature of a place is 10°C or less for plains and 0°C or less for hilly regions like Himachal Pradesh. The cold weather however is a well-defined and prolonged period of lower temperatures. The cold wave is distinguished by a marked cooling of the air, or the invasion of very cold air, over a large area [10]. During the cold wave, the ambient temperature moves below the LCT and the animal experiences cold stress. The LCT is the temperature at which the animal begins to "feel cold" and must increase heat production to stay warm. It is also the point at which performance begins to decline with the declining temperature [11]. Recently, occurrences of extremely low temperatures along with the storm of dry cold winds from the north into the sub-continent area have been significant in creating cold wave spells. If heavy and persistent snow occurs along with the cold wave, grazing becomes difficult for animals, hence more fodder needs to be provided indoors. Similarly, wildlife also experiences challenges during winter for both shelter and food [10]. Below the LCT, animal metabolism must increase to generate heat to maintain core temperature, or else animals may move to hypothermia, and eventually, death may occur. In the next section of the review, we will focus on the effects of cold stress in animals and the strategies to mitigate the effect of cold stress for optimal production in animals.

Assessment of cold stress in animals

Cold stress is quantified by means of the wind chill index (WCI) which is an adapted formula (given below) used in the cold stress research in cattle [12].

$$WCI = 13.12 + 0.62 \times T - 13.17 \times [W.S.]^{0.16} + .40 \times T \times [W.S.]^{0.16}$$

WCI values are usually expressed in degrees Celsius or Fahrenheit, T= air temperature in˚C, and WS is the wind speed in km/h. To the best of our knowledge no scientifically validated cold stress risk classes in terms of WCI have been developed for the dairy animals. The data can only be compared to the established LCTs for the dairy animal to get a rough idea of the potential impact on comfort and physiology. More recently WCI has been criticized for not considering all the climatic parameters that influence thermal comfort [13]. Recent climatic indices like the comprehensive climate index (CCI), incorporate the effects of temperature, humidity, wind-speed and solar radiation in order to improve the assessment of cold or heat stress risk [14].

Effects of Cold stress on general physiology and productivity of animals

The cold stress driven alterations in the vital functions affect the growth, reproduction and adaptive performance of the animal [15]. Immediate decrease in the environmental temperature

causes decreased respiration rate, which is due to acclimation to cold temperatures so that the animal may decrease evaporative heat loss through the respiratory tract [16]. Consequently, as the water evaporation declines, there is a reduced need for water consumption. There is also a concomitant decrease in rectal temperature. The levels of hemoglobin concentration (Hb), packet cell volume (PCV), total erythrocyte counts (TEC) and total leucocyte count (TLC) are higher during winter and lower during summer [16-20]. It has also been observed that the levels of Hb, PCV and TEC are higher in breeds adaptated to cold hilly climate due to low level of oxygen concentration and higher Hb and TEC counts help to meet up the oxygen requirement in the body [16,21,22]. Cold environment also stimulates the secretion of thyroid hormone namely T_3 and T_4 to increase BMR (basal metabolic rate) and heat production for maintaining body temperature. The higher T_3 and T_4 are accompanied with high blood glucose level [23]. The cold stress leads to activation of hypothalmo-pituitary adrenal axis and cause release of the glucocorticoids [24] but cold adapted animals have suppression of adrenal functions [16].

Prolonged exposure to the mild cold conditions leads to physiological adaptation in animals i.e., increased thermal insulation, higher appetite and basal metabolic intensity, as well as alterations in digestive functions. When animals are exposed to extreme cold stress, substantial dietary energy gets diverted from production towards the generation of body heat [20,25]. The average milk yield decreases as the temperature's declines. There is also increase in feed intake, blood glucose levels, free fatty acids, aspartate aminotransferase (AST), albumin levels [19,26]. The milk produced during the cold environment has higher fat, protein, and lactose contents [20]. The reduced productivity observed in ruminants during the colder period of the year is due to these adaptive changes [25]. Furthermore, the decreased milk yield is also related to decreased prolactin secretion. Studies report that animals exposed to cold temperatures have reduced concentrations of prolactin and growth hormones in the blood which are important for lactation [27,28].

Molecular response in animals to the cold stress

At molecular level the expression level HSP27 is found to increase in both heat and cold stress conditions. Hence, HSP27 can be considered as useful indicator for assessing *in vitro* stress response which may further be validated *in vivo* studies [29]. However, HSP70 gene is more closely related to the cold tolerance in animals. A study by Banerjee., *et al.* [30] demonstrates the HSP70 gene expression is species and breed specific even though HSP70 genes are highly conserved across evolutionary lines. The species-specific differences in HSP70 isoforms are most likely due to variations in thermal tolerance [31,32]. Hence HSP70 gene expression can be used as a marker for thermal adaptation in different species

Existing housing management

The housing of animals in the state is either part of residence or a separate building having east to west orientation to utilize maximum sunshine hours. Due to easy availability, slates are predominantly used as roofing material followed by galvanized iron sheets. The walls are constructed with bricks and stones. The ventilation in these housing is limited. The floors are generally muddy (non-plasterd) and slippery without provision of drainage. The feed is generally provided in manger and watering is done through bucket using tap water [1].

Management and mitigation strategies for cold stress

Keeping in view environmental conditions and the already existing housing practices followed in Himachal Pradesh following mitigations strategies may be recommended.

Man-made shelter

In conditions with low wind speed and fewer rains, in forest paddocks (vegetation served as a windbreak), cattle can be housed outside year-round having access to rain shelter, windbreaks and lying places with dry bedding, without severe negative effects on productivity, health or welfare [8]. However, in moderate winter conditions where the minimum and the maximum wind chill is -3.9 and -9.9 ^{o}C respectively, shelter augmentation significantly improves animal welfare. The wind reduces the effective temperature and increases cold stress on animals hence, providing shelter in the paddocks under moderate winter conditions improves growth [33]. The walls may be constructed with ordinary building bricks having mud plastering on the outer surface on the outer surface. Double-wall construction with 3 to 4 inches of space in between the two walls to provide insulation is recommended. Slanting roof with GI/ asbestos sheet as roofing material along with ceiling is recommended. The height of the roof may be 8 feet on the front side and 12 feet on the rear side for larger animals [1]. Since zone 3 of Himachal Pradesh has semi-pastoral rearing of animals low-cost shelters are to be constructed.

The roof of an artificial shelter protects against rainfall. The walls can be added and placed perpendicular to the direction of prevailing winds. Shelters are preferably located somewhat higher–never lower–than the surrounding terrain, to prevent water from flowing towards the shelter and accumulating inside. Sufficient individual space and ventilation are important to ensure a dry floor surface [8]. The floor may not be plastered but should be with dry bedding of waste grasses which should be replaced as per need [1]. Cattle are also sensitive to rapid movements [34] so the constructions with cloths or plastic waving in the wind might scare them and hence should be avoided.

Animal feeding

The environmental temperature should be monitored and additional feed should be offered to the animal in cold weather to meet the increased metabolic demands of the animal. If wet feeds are fed, make sure they are not frozen [35]. Increased energy content (77% vs. 70 -72% TDN) and protein (17.5% vs. 14.5% CP) must be provided to animals [36]. The combination of salt and fat can be added to the diet as it has been reported to elevate body temperature and may benefit animals in winters [37]. The rations constituting about 20% as compared to 17% fiber are helpful to increase fat percentage in milk and reduce the effects of cold temperatures in animals. The outdoor animals require about 15 to 20% more feed for the winter season than animals kept in confinement housing. Provision of hay, silage, feed blocks, and urea molasses supplementations may be done during the fodder shortage period [36].

Water supply

Cows should have ample water available at all times preferably warm as frozen troughs and excessively cold water seriously limits water intake in animals. Tank heaters can be used to prevent water sources from freezing [36]. Limited water intake also limits the feed intake and makes it more difficult for dairy animals to meet their energy requirements [34].

Animal rearing

Dry teats after the dairy animal leaves the milking parlor are important to reduce cold stress. It can be done by dipping the teats for about 30 seconds and then blot drying using a paper towel. Wet coats have reduced insulating properties and make cows more susceptible to cold stress hence it's important to keep the cows clean and dry [34]. Calf jackets and blankets made of local gunny bags may be used to keep the calves warm. With planning calving season may be shifted to too late in spring/ early summer, preventing cows to spend late lactation in cold months [36].

Genetic selection of breeds

The lower magnitude of changes occurs in breeds' adapted to cold during winter and hence these animals are resistant to cold-induced hypothermia [16,22]. Recent techniques like infrared thermography are being used to evaluate response of animals to environment and differentiate in between different groups [39]. Modern advances like genome sequencing and transcription profiling can help to display the genetic basis of adaptation to climate change. Hence, thorough studies are needed to understand the ecological context of the environmental changes with genetic regulation in animals [40].

The way forward

Despite the enormous importance of livestock in hilly areas, very little research work has been undertaken to date on the interaction of climate and increasing climate variability on the productivity performance of different livestock species. Hence, more research work needs to be taken up to enhance the sustainability of hill livestock production systems under changing climate scenarios, mitigation strategies for sustaining livestock-based livelihood in cold winter seasons.

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