Effects of Heat Stress on Livestock

Subjects: Veterinary Sciences

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Climate change is receiving more consideration worldwide, and the impact on animal production is particularly relevant due to increasing demand and limitations to production. When predicted temperature/humidity increases as a result of climate change are added, the proportion of time that they are exposed to heat stress becomes more severe. It was concluded that the effects of heat stress are becoming critical for livestock production systems, especially during summer. Livestock responds to these changes by using different mechanisms to survive, but production efficiency is severely compromised by heat stress. Injury and death may even ensue if mitigation measures are not taken quickly.

climate change livestock heat stress behaviour

1. Heat Stress Effects on Livestock Maintenance Behaviours

1.1. Feed and Water Intake

Feed digestion is a heat source for ruminants, thus, under increased heat stress they exhibit reduced appetite, gut motility, and rumination [1][2], which reduces feed conversion efficiency in dairy cows [3]. This assists in decreasing heat production during hot climatic conditions [4]. In temperate climatic conditions, feed intake declines above 25–26 °C in lactating cows, with a rapid decline above 30 °C, and a 40% reduction at 40 °C [5]. This negative energy balance decreases body weight and body condition score [6], which may facilitate heat loss.

Water intake is dramatically increased during summer, for example, a two-fold increase in buffalo calves compared with winter (39.2 vs. 20.1 L/day) and a three-fold increase in relation to metabolic body weight ($W^{0.75}$). This increases the vaporization of water through the skin and respiratory surface [7]. Omran et al. [8] reported higher consumption of water by cattle and buffalo in Lower Egypt than in Upper Egypt due to the higher temperature-humidity index (THI) there.

Goats are less susceptible to heat stress-induced reductions in their feed intake when the temperature rises above the UCT [9]. Chickens have been observed to reduce feed intake by 9.5% up to six weeks of age when temperatures increased from approximately 21 to 32 °C [10]. The reductions in feed intake led to decreased feed conversion efficiency and weight gain [11][12][13][14]. In laying hens, a 1 °C increase in temperature above the ideal temperature reduces feed consumption by 1.6%, and energy consumption by 2.3% [15]. At temperatures above 30 °C, feed consumption is reduced by 5%.

1.2. Defecation and Urination

The urination and defecation frequencies in livestock vary with many factors, including water and feed intake, type of feed, disease condition, immunity, environmental temperature, and stressors [16]. Exposure of goats to high temperatures decreases defecation and urination frequencies, but not the duration of urination [17]. Alam et al. [18] also indicated a significant reduction in the urination and defecation frequencies of black Bengal goats exposed to heat stress. This reduction in the urination and defecation frequencies in goats is associated with increased respiratory and cutaneous evaporation, causing severe dehydration [19]. Non-lactating Holstein cows exposed to heat stress also decreased urine output, but with an elevation in the urinary sodium excretion and a reduction in sodium in serum [20].

1.3. Lying and Standing Behaviours

Cows spend about half of their time lying down, but this is reduced by heat stress [21]. Standing maximizes heat loss through evaporation from the body surfaces and an escape from the hot ground surface [22]. When the heat load increases by 15% (THI = 60–70), standing time increases by 10% to enhance heat loss, by increasing the skin surface area exposed to air [23]. Therefore, the skin is surrounded by air to which most body heat is transferred by convection, reducing the conductive heat loss [24]. In addition, the animals transfer only a small part of their heat load through their feet to the ground because of the small area of contact [25]. Sprinklers from the floor or above the cattle, showers as cattle exit the milking parlour and overhead fans can be used on some farms to mitigate heat stress, which facilitates heat load reduction and increases lying down time [26].

In some situations, livestock has been observed to lie down for longer during heat stress: Shilja et al. [19] recorded that heat-stressed goats had longer lying times when simultaneously exposed to restricted feeding, probably because standing requires more energy than lying down. This indicates a requirement for adequate levels of nutrition to provide sufficient energy levels for animals to perform the behavioural responses that could help them adapt to heat stress [27]. However, if nutrition is adequate reports testify that ruminants spend most of their night lying ruminating, but in heat stress, this reduces to allow more standing [28][29]. The increased standing can lead to increased lameness, particularly when cattle stand for longer than 45% of the day. It has been estimated that the reduction in lying time could reduce milk production by 1.7 kg of milk yield per hour in resting time [30]. There is also increased stamping behaviour, particularly by the left limbs, which suggests the involvement of the right-brain-centered flight or fight reaction [31]. Cattle in heat stress have a particular stance, with a lowered head, backward-facing ears, and a vertical tail [31].

2. Heat Stress Effects on Livestock Sexual Communication and Reproduction

How temperature changes affect sexual communication in animals is not well understood. Sexual communication depends mainly on pheromone detection [32], which might be impaired by variation in environmental conditions [33][34]. High temperatures can enhance pheromone degradation, thus impairing communication between conspecifics (e.g., in ants: [35]). Sex pheromones persistence decreases during the higher evaporation rate at high temperatures [36]. Thus, the impairment of the chemically mediated sexual signals during high temperatures could have an impact on the reproductive success of animals. Not only is the release of the sexual signal affected, but also the olfactory receptors of the recipient are impaired by extreme temperatures [32].

There is also a positive correlation between the temperature dependence of the membrane and odour sensitivity in the chemosensory receptors [37]. Thus, temperature fluctuation not only changes the pheromone profile, so the receiver does not obtain the correct information about the mate, but it also affects the way the pheromone is perceived as the receptors are not able to detect the odour. Livestock species that normally rely on communication between conspecifics for reproduction, in particular cattle and sheep, may therefore experience reduced reproduction rates. In addition, cattle are less likely to display estrous behaviour during the hotter daytime hours, when stock people are around to see them, and time their artificial insemination. They are more likely to display it at night when stock people are not available to detect estrous. Further, during heat stress fewer estrous events where cattle will stand to be mounted are detected, which leads to a reduced conception rate.

In addition, heat stress can inhibit gonadotropin-releasing hormone and luteinizing hormone synthesis which are responsible for estrous signs and ovulation [38]. Any higher body temperature than 39 °C during pregnancy could negatively affect the developing embryo during the period from days 1–6 and lead to abortion. It can also lead to premature calving by 10–14 days, which reduces the viability of calves [39]. In males, heat stress can lead to a reduction in semen quality and quantity and testicular size [40]. In sheep, premature termination of pregnancy reduces the viability of lambs, especially since brown fat laid down in late pregnancy is diminished. In broilers, it has been reported that males are more sensitive than females to heat stress-induced infertility [41], whereas, in layers, heat stress led to delayed ovulation, in addition to a reduction in yolk quality and hatchability [42].

3. Heat Stress Effects on Production

Milk production can dramatically decrease in dairy cows, by up to 35%, during heat stress, through reduced feed intake [43]. High-producing dairy cows are likely to be more sensitive to heat stress as they emit more metabolic heat than low-producing ones [44]. Consequently, due to the increased metabolic heat production under heat stress, milk production declines [4]. Milk protein and fat contents declined in dairy cows when the temperature–humidity index reached 72 or above [45][46]. Similarly, in dairy goats [47] and buffaloes [48], milk composition was adversely affected by heat stress.

Meat-producing ruminants were also affected by heat stress, with reductions in body weight and meat quality [49][50][51]. Goats and sheep as small ruminants are more tolerant of hot and humid weather conditions than large ruminants [52]. Although sheep and goats can cope with different adverse environmental conditions, there is an upper level of tolerance, after which they lose adaptation to heat capabilities, in which mitigation is required. Beef cattle are also more sensitive than other meat-producing livestock as they are more exposed to radiant heat, with their large surface area, and they are fed on high-energy diets [53][54]. Therefore, body weight can decrease in beef cattle under heat stress due to the decrease in feed intake and feed conversion [55].

The exposure of chickens to heat stress leads to the use of energy to attain thermoneutral conditions instead of growth [56]. This reduces the weight gain and feed conversion ratio in broilers [57][58][59]. Laying hens are even more sensitive to heat stress and both egg quality and egg production decline [60], in part due to alterations in calcium metabolism and alkalosis [61]. When the temperature increases above the ideal temperature, egg weight decreases at a rate of 0.07–0.98 g/egg for every 1 °C rise. Above 30 °C, egg production may be reduced by 1.5% [15].

4. Strategies to Overcome the Effects of Heat Stress on Livestock

In 2015, the Paris Climate Change Convention recommended to “hold the increase in the global average temperature to well below 2 °C above pre-industrial levels…. recognizing that this would significantly reduce the risks and impacts of climate change”. Later in 2016, 94 out of 197 nations agreed to apply the Paris Agreement, and developed countries mobilized USD 100 billion for climate projects.

Three strategies have been identified that could help in reducing the impact of climate change on ruminant production: (a) new nutrition methods that could help in increasing feed efficiency, including identification and characterization of new feed resources and utilization of agricultural residues [62], (b) new technologies of animal breeding including gene editing that could help in the use of genetic resources, also selection from the full spectrum of international breeds by new breeding methods, and with better use of local breeds [62], and (c) maintenance and enhancement of animal biodiversity [63].

Nutrition management methods to mitigate heat stress include the addition of novel feed ingredients, such as betaine to improve diet composition, and the alteration in time or frequency of feeding and watering [64]. These can help in increasing energy and electrolyte intake, with better maintenance of water balance. These modifications have been studied in cattle [65][66], and poultry [67][68][69] and showed benefits. In dairy cows, appropriate nutrition through supplying them with high-energy feeds and bypass protein could help animals to maintain their productivity [70]. Providing additional essential micronutrients, including mineral mixtures and antioxidants could also preserve milk production better when the animal is sweating profusely [71]. Yeast supplementation may also reduce the effects of heat stress on dairy cow production [70]. Das et al. [72] deduced that feeding heat-stressed dairy cows with a diet containing 14% acid detergent fiber increases milk yield and fat content. Genetic variation in livestock responses to heat stress has been detected in several studies [73][74]. These can help in selecting breeds that have less sensitivity to heat stress [75], or breeds that have better adaptation either physically or physiologically to heat stress.

Mitigation measures can be classified into interventions related to farm management and structure. Management practices include livestock genotype diversification, using genotypes that are resistant to heat stress and can cope with climate change and improve the livestock farms’ sustainability [76][77]. Livestock integration with forestry also provides shade and reduces solar radiation and ambient temperature, with synergistic positive effects on soil and nutrient cycles, reducing soil degradation and chemical use [78][79]. However, this will take time to establish and is unlikely to be developed in time to cope with rising temperatures unless there is major government support.

Management interventions could also help in improving fertility [71], by hormonal treatment, for example. Preventive vaccination for emerging animal diseases could also help in coping with climate change. In addition to these measures, developing meteorological warning systems could help in determining the most suitable mitigation method to reduce the impact of severe weather events and prevent livestock losses [80].

The main structural interventions for intensive and semi-extensive systems are improving building orientation, insulation, reflectance, shading and ventilation, with or without the use of water cooling [81]. Therefore, providing shelter adjusts the micro-environment to reduce the heat stress effects on milk production [82]. Cooling dairy cows subjected to heat stress allows heat exchange between a cow and its environment, which reduces a cow's core body temperature [83]. Cooling by providing shade can decrease ventilation, whereas cooling by fans alone, or in combination with sprinklers, is better in minimizing heat stress' detrimental effects on milk production, reproduction, and the immune system [70][71].

These adaptation and mitigation strategies are species-, and context-specific. However, there are some options that are expensive or involve intensive resource consumption [84]. Therefore, intensive research is required to identify the appropriate mitigation and adaptation strategies locally, especially in developing countries, in addition to policy implementation [85]. Identifying genes responsible for adaptation phenotypes can also help in better adaptation which can be reached by genetic characterization of livestock species [86].

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