Dairy Cows under Heat Stress

Subjects: Agriculture, Dairy & Animal Science
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Heat stress is a major problem for dairy cattle welfare, and it has several implications for milk production. In this work, automatic sensors were used to monitor cows' activity. Different behaviors were recorded for 40 animals at different heat stress conditions. The main aim of the study was to use automatic sensors to identify behavior changes caused by heat stress on dairy cows. All behaviors studied were affected by environmental conditions. Animals adapted to heat stress by modifying their behavior, and automatic sensors provided valuable information in this regard. These findings might be the early development of an automatic early warning system for heat stress based on the behavioral modifications of dairy cattle.

Keywords: dairy cattle ; behavior ; circadian rhythms ; heat stress ; THI

1. Introduction

The impact of hot weather conditions on livestock is increasingly important, mainly in light of climate change [1]. In addition to temperature, relative humidity plays a key role since it regulates the latent heat exchange from animals, thus conditioning their thermal balance. In this sense, the most widespread environmental indicator in regard to heat stress in animals is the Temperature and Humidity Index (THI) [2]. This index allows for the objective establishment of thresholds for heat stress conditions [3][4][5][6]. In the Mediterranean area, heat stress is a major threat to livestock farming [7]. In this area, the combination of high temperatures and high relative humidity can result in dramatic conditions for dairy cows [8]. In addition, variables related to the animal, such as the breed, productive level or physiological state, can affect the ability of animals to cope with heat, thus modifying the thresholds of THI in practice [9]. Thermal stress leads to production, reproduction and welfare problems [8][10][11], causing changes in the behavior patterns of animals [12].

Fully understanding the behavioral patterns of animals is essential, as variations or alterations of them can be an indicator of environmental or physiological anomalies [13][14]. In the case of dairy cattle, they spend about 3 to 5 h a day eating, between 7 and 10 h ruminating, 30 min drinking, 2 to 3 h being milked and require approximately 10 h of resting time [15]. Some studies have also investigated the daily distribution of these activities [16]. However, no mathematical models describing the daily distribution of these activities have been developed, nor has the effect of heat stress on these behavior patterns been studied. These models might help to identify variations in activity patterns as indicators of welfare or health issues induced by heat stress. Behavioral changes can occur when the environmental temperature exceeds the threshold held by the animal, thus resulting in heat stress, an early indicator of welfare, health and productive issues [10].

With a high THI, animals reduce rumination time, the volume of food eaten and the time they spend lying by altering their resting behavior and changing resting areas [11][17]. In this way, cows modify their feeding behavior, increasing water intake and change feeding times to cooler periods of the day [5][10]. In addition, activity patterns, the periods of minimum activity in the first hours of the day and maximum activity in the afternoon, are also modified [18].

The monitoring of animal behavior may help to identify problems or stressful situations for animals. Nevertheless, this is a tedious and time-consuming task when direct observation is considered, so this is where new technologies can play a significant role. These systems have made the modernization of livestock farms possible. Precision Livestock Farming (PLF) uses these advanced technologies to optimize the operation of farms through the individual monitoring of animals [19]. These types of systems have great potential to help farmers to raise animals in the best possible conditions [20] by supporting decision-making through the optimization of the information received [21][22]. In recent years, there has been an important progress in the development of sensors that allow us to monitor the activity, behavior, welfare, health and production of farm animals, as well as the surrounding environment. The more control the farmer has over the animals, the easier it is to detect unexpected behaviors and make decisions [23][24]. One of the species with the longest tradition of using this type of system is dairy cattle [25]. One of the key topics tackled by the PLF of dairy cattle is health improvement. Improving health conditions allows for the reduction of drug costs, the improvement of animal welfare, avoiding production losses, the increase in efficiency and, consequently, the improvement of the environmental, economic and social sustainability of dairy products [26]. In the market, we find some alternatives aimed at this purpose such as ear tags, necklaces or pedometers, among others [27]. These types of systems are based on the micro-movement patterns of the animals, which include behaviors such as eating, degree of activity, motor behaviors or even rumination. They establish a baseline of behavior at the individual level, and any deviation from normal behavior triggers an alert in the program [28].

The main aim of this work was to evaluate the effects of heat stress on the behavior of dairy cows using PLF technology. To this aim, two approaches were employed: on the one hand, the average time devoted to different activities under varying heat stress conditions was determined; on the other hand, mathematical models describing the daily patterns of different behaviors were developed for both sets of data (heat stress and no heat stress) and compared.

2. Dairy Cows Activity under Heat Stress

Little data is available on the daily activity patterns for farm animals and the effects of heat stress. Changes in dairy cows' behavior under heat stress conditions have already been reported in the literature [10]. Despite the THI equation used possibly presenting some constraints for the actual genetic strains of dairy cattle [29], the classification used in this work resulted in consistent differences between heat stress conditions. Heavy breathing might be considered a key indicator for heat stress, and the sensors used in this work have been satisfactorily validated as heat stress indicators through heavy breathing [30]. In this work, for the data categorized as HS, heavy breathing increased during the afternoon, coinciding with the warmer hours of the day. Lees et al. [31] observed similar results for dairy cows under heat stress conditions. Panting is an evaporative cooling process that is directly related to heat stress [5][32]. This cooling process is characterized by an increased respiratory rate with characteristic changes in breathing dynamics [12][33][34], by which body heat is released as the latent heat of the vaporization of moisture from the skin surface and the mucosa of the respiratory tract. This behavior is a fast and acute response to heat stress and thus occurs under high THI conditions, as depicted in this work.

In this study, it was observed that with a high THI, the animals reduced the time devoted to eating as well as the rumination time. This might be considered as a behavioral adaptation to heat stress since forage digestion leads to a large amount of metabolic heat production, which causes an increase in body temperature [35][36]. Thus, when environmental temperatures rise and reduce the ability of heat to dissipate, in order to keep the thermal balance, cows decrease their feed intake as a strategy to alleviate heat stress [17]. This is consistent with the results observed when attending to the daily eating patterns, where it can be observed that, under heat stress, animals tend to reduce their eating time during the afternoon, coinciding with higher THI values. This reduction is partially compensated during the night, when animals under heat stress conditions increase the time devoted to eating during the cooler hours of the day. The distribution of eating time for animals without heat stress followed a much more constant pattern. Three similar peaks corresponding with feeding time after milking were found, when a considerable amount of fresh feed is available. This is also consistent with the results obtained by Polsky et al. [5] and Fournel et al. [10] who found that, when the animals were exposed to heat stress, in addition to reducing the total feeding time, there was a shift in the feeding schedule towards cooler times of the day.

The negative correlation between rumination time and THI observed in this work has also been reported in the literature [7][37]. As observed in this work, this reduction in rumination time under heat stress conditions occurs during the night. During these cooler hours, when there is no heat stress conditions, animals tend to spend more time ruminating. During these hours, the highest peak in ruminating time was observed [38]. A secondary, much less intense peak is found during the afternoon. Under heat stress, animals maintain both rumination peaks, but the intensity of the one at night is much lower when compared to that under no heat stress conditions. This might be related to the heat production caused by rumination. Animals under heat stress conditions may reduce rumination during the cooler hours of the day in order to effectively reduce their metabolic temperature and compensate for daily heat stress.

Resting behavior is also affected by heat stress [39]. According to the literature, cows spend, on average, between 9 and 12 h per day resting [8]. That is an average between 22 and 30 min per hour. This behavior is an indicator of animal welfare in cattle, since when the animals suffer some type of stress or are not comfortable, it is strongly altered [40]. In this study, the resting time per daily hour was lower when heat stress occurred. This difference occurs mainly during the afternoon when animals under heat stress tend to rest much less than when no heat stress is a factor. As mentioned by Provolo and Riva [39] and De Palo et al. [41], cows under heat stress spend more time standing to achieve a greater heat dissipation through the skin, which is consistent with our study, the results of which indicate that resting time during the warmest hours is reduced under heat stress conditions. These results are consistent with the significant differences found for the activity level results. As previously described by Cook et al. [42] and Brzozowska et al. [43], animals increase their activity when THI increases. This lack of resting time is negative for cows, as it hinders the blood circulation in their udders [44], decreasing milk production [45] and increasing the risk of lameness [46].

In summary, the observed results show that the behaviors are related to each other such that feeding and activity increase, rumination and rest decrease and vice-versa. On the other hand, behaviors are influenced by environmental conditions. Increasing THI produces an increase in activity and changes in feeding patterns and a decrease in rumination and resting, impairing animal welfare.

3. Conclusions From the Case Study in Spain

Heat stress affected all behaviors recorded: heavy breathing, eating, ruminating, resting and activity. The higher the THI, the lower the time for feeding, rumination and resting. Panting and activity increase, as the animals remain standing for a longer time to dissipate heat. In addition, behavior patterns changed throughout the day depending on the heat stress suffered by the animals, occurring at cooler times of the day in the case of feeding, rumination and rest. PLF sensors and modelling daily patterns were useful tools for monitoring animal behavior and detecting changes due to heat stress.

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