v. 2, n. 3, 2022

Journal of
Agricultural
Sciences
Research

ASSESSMENT OF THERMAL COMFORT IN CALF BARN: USE OF INFRARED THERMOGRAPHY

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Abstract: The objective was to evaluate the thermal comfort of Holstein calves, in masonry calf barn, individually, by obtaining the body surface temperature obtained by the infrared thermography technique. Data collection took place during the month of October 2021, at 1 pm. Thermographic images were obtained at a distance of 1.5 m from the animal (head and side). Local climatic conditions were recorded and the indices of temperature and humidity (THI) and black globe temperature and humidity (BGHI) were estimated in the external environment and inside the pens (calf barn) (THIsun 79.76±0.33 and THIpen 80.93±0.18; BGHIsun 84.73±0.49 and BGHIpen 84.28±0.21). The calves were kept confined in an individual masonry stall (two animal per each), with a fiber cement tile roof covering. On the sides of the pen, the walls are 1.5 m high, reaching up to the right foot (2.2 m). According to the thermographic images, the thermal exchange between the animal and the environment of the stall proved to be inefficient, as it was found that the average temperature of the body surface (side) of the calves was 37.26°C and that of the head was 33°C. Inside each pen, on the underside of the tile, thermographic images indicated an average temperature of 55.38°C. According to the estimated THI, the environment is alert for the animal category. The body surface temperature of the calves is influenced by the radiation from the tiles that cover the stalls. The values of THI and BGHI demonstrate that the microclimate of the pen is superior to the condition of the external environment. It was concluded that the installation where the calves are kept, promotes heating on the body surface, in addition to resistance to the loss of this heat. Thermographic image proved to be effective in the assessment of the thermal comfort of Holstein calves, pointing out the flaws in the physical environment.
Keywords: Heat stress, thermographic imaging, heat exchange.

INTRODUCTION

Infrared thermography is a technique that relates to the acquisition and processing of values of infrared electromagnetic radiation (wavelengths longer than those of visible light) emitted by the body, through thermal measuring devices (thermographic cameras or camcorders), contactless (non-invasive).

The working principle of this technique and its use in animals is based on the detection of radiated heat from certain areas of the animal's body, which have a density of blood vessels on the surface, which regulate the gain or loss of temperature in relation to the environment, modifying blood flow.

For the technique to be effective in fulfilling its purpose, it is necessary to respect some requirements or technical parameters of image taking (technical factors such as emissivity, observation angle and distance), as well as environmental parameters, as in cases of insolation (time of day and location) and, of the animal itself, such as taking the image in an area of interest with no hair (pinna, lacrimal caruncle of the eye, orbital, anal and nasal region), in addition to the differences interspecific, sex, age and race. Topographic areas of interest in cattle have been investigated and differ between animal categories and the purpose of analysis (IDRIS et al., 2021; GIRO et al., 2019; LOWE et al., 2019; THOMPSON et al., 2018; MONTANHOLI et al., 2008).

In this sense, it must be noted that Kleiber and Krieger (1975) considered that up to 60% of an animal's heat loss can occur in the infrared range and, therefore, when using a thermographic device or camera, information is obtained. of radiated heat loss as an early indicator of animal fever conditions, for example.

According to Mota-Rojas et al. (2021a) it is necessary to differentiate a hyperthermic state from a febrile state. Different metabolic mechanisms of thermoregulation can be effected in the febrile response, centrally and peripherally, and in cellular events. The brain, upon high or low temperature stimuli, triggers (hypothalamus) thermoregulatory responses, including autonomic effectors (thermogenesis, vasodilation, sweating) and behavioral mechanisms, which trigger actions in an attempt to control the effects of temperature changes (heat or cold). On the other hand, hyperthermia is described as an increase in temperature due to changes in the thermoregulation mechanism (Broom, 1991).

In general, thermoregulation involves a mechanism that includes the integration of peripheral signals that are sent to the lateral parabrachial nucleus of the brainstem and then to the preoptic nucleus of the hypothalamus to generate physiological variations such as vasodilation to dissipate heat under heat stress conditions, or vasoconstriction to conserve heat in the perception of cold stimuli (MOTA-ROJAS et al., 2021b).

Given the facts and research reports, infrared thermography can be considered one of the advanced technologies for monitoring animal health and welfare, presenting opportunities and challenges for its use in animal production systems. In dairy farming, infrared thermography has been validated through scientific studies.

The health and well-being of calves in the infant stage, which is considered a vulnerable stage of life, was evaluated by Lowe et al., (2019). The authors investigated the possibility of using infrared thermographic images, obtained by a thermographic camera, in the evaluation of temperature fluctuations of the air that passes through the nostrils and to relate it to the animal's respiratory rate. The results suggest that infrared (video) thermography is a suitable technique for recording the respiratory rate of young calves based on the thermal fluctuations that occur as air passes through the nostrils during inspiration and expiration.

Schaefer et al., (2004) indicate that the infrared image of the bovine eye presents the earliest response to the challenge of the disease and, in addition, it was considered as the part of the body that provides the most consistent infrared image temperature measurement, when calves at 12 weeks of age and kept in individual calves were evaluated.

Schaefer et al., (2007; 2012) observed a significant increase in eye temperature as a result of the onset of bovine respiratory disease up to a week before clinical signs of the disease were apparent. According to the authors, it would be possible that the thermal fluctuations of the eye could be recorded along with the respiratory rate by an automated system that uses infrared thermography. They emphasized that recording respiratory rate associated with other behavioral and physiological assessments has the potential for the development of highly accurate composite measures of calf health and well-being.

As for the assessment of heat stress, heat stress can be defined as physiological stress experienced as a result of excessive heat. It must be noted that, according to Allen et al. (2015), stress includes reactions to all challenges to homeostasis.

The physiological processes used by animals to react to discomfort or heat stress include respiratory rate, which increases in an adaptive response to dissipate excess heat by evaporation and maintain homeothermy; surface temperature of parts of the body that, made up of a vasomotor mechanism, have the ability to control blood circulation from the core of the body to blood vessels and capillaries, which can be dilated and contracted by means of a vasomotor tool that favors heat dissipation.

Regarding the environment, estimates of the values of meteorological variables associated with specific rectal temperatures can be used in the assessment of the environmental condition and hyperthermia experienced by cows under heat stress.

Dikmen and Hansen (2009) indicate that both the dry bulb temperature (Tdb) and the temperature-humidity index (THI) are good predictors, as well as the rectal temperatures of lactating Holstein cows monitored in a subtropical environment. for the assessment of heat stress.

Berman et al., (1985) suggest that the upper limit of ambient temperature at which Holstein cattle can maintain a stable body temperature is 25 to 26°C, and that above 25°C practices must be instituted to minimize the increase in temperature. of body temperature. According to Baccari Jr. (2001), the thermoneutral zone for dairy cattle is between 0 and 5°C (lower critical temperatures) and 24 to 26°C (higher critical temperatures).

The heat load accumulated by the cow subjected to heat stress, for example, is the sum of the heat accumulated from the environment and the failure to dissipate the heat associated with metabolic processes (PURWANTO et al., 1990).

According to Collier et al., (2006), when ambient temperature conditions approach body temperature, the only viable route of heat loss is evaporation; if ambient conditions exceed body temperature, heat flow will be reversed. Therefore, estimating the thermal environment around animals is critical to understanding their cooling needs.

According to the same authors, in a study carried out with dairy cows, evaluating different environments and air conditioning of sheds on production, physiological and productive parameters, it was observed that the skin temperature obtained by infrared thermographic camera is highly correlated with the respiration rates and is a good measure of the microenvironment around the animal. In addition, the measurement can be done remotely, which does not require restrictions on the animals' movement.

In this sense, the objective of the present study was to relate the thermal comfort indices obtained in masonry calves, with fiber-cement material coverage, and the use of thermographic images of suckling Holstein calves as an assessment tool of the thermal comfort promoted in this type of installation.

MATERIAL AND METHODS

The study was carried out on a farm (21 °54 '05.1 "S 47 ° 33 '20.8 "W) located in the municipality of Descalvado-SP. Data collection took place during the month of October 2021, when twelve Holstein calves, 1.5 months old and average weight of 72 kg, were evaluated. The animals were selected by age, health status (absence of diarrhea or respiratory diseases) and similarities in the percentage of area of the net of white and black fur.

The calves were kept confined in a masonry stall (concrete blocks), with a fiber cement roof covering. On the sides of the pen, the walls were 1.5 m high, with a gap up to the right foot (2.2 m).

A FLIR T297 thermal camera (FLIR Systems Inc.) was used. Infrared images were taken in the afternoon, at 2:00 pm and obtained at a distance of 1.5 m from the area of interest (head/front and side) and on the lower surface of the pen roof tile. The imaging procedure was repeated 5 times in the areas of interest and the animal.

The surface of interest for imaging was inspected for any external artifacts that could affect the surface temperature, adding cold spots to the thermogram, such as dirt, food particles, or manure.

During the image taking process, the relative humidity (%), atmospheric temperature (°C) and wind speed (m/s) were measured, using a thermo-hygrometeranemometer (Extech Instruments), in addition to recording the black globe (TG) and dew point (DEW) temperatures. The temperature and humidity index (THI) was calculated using the equation described by Mader et al., (2006), and the black globe temperature and humidity (BGHI), according to Buffington et al. (1981). The THI and BGHI parameters were estimated in the external environment and inside the calf barn (entrance, hallway and inside of the pen) by recording 10 readings.

RESULTS AND DISCUSSION

According to the thermographic images (Figure 1), the thermal exchange between the animal and the environment in the calf barn is inefficient, as it was found average air temperatures at the entrance and hallway of the calf barn and inside the pen of 34.7±2, 3 °C) higher than those suggested as suitable for dairy cattle (18-21 °C). It must be noted that the temperature measured on the inner surface of the tile of the pen was 55.4 °C, which gives the environment a heat load in the stall.

Barreto et al., (2020) established positive linear correlations between thermography and temperature measurements, thermal comfort and radiation indices, suggesting that infrared thermography can be used as a tool to estimate and monitor microclimate and thermal comfort, presenting a potential use of measurement in production systems.

Moderate to strong associations were identified between the microclimatic parameters and those monitored through thermographic measurements, suggesting positive relationships and equally well explained by air temperature, black globe temperature and relative humidity (JUNIOR et al., 2020).

According to Souza and Batista (2012), maintaining a homeotherm's constant body temperature can be compromised when environmental conditions limit metabolic heat loss or contribute to the animal's heat load.

Kovács et al., (2018) evaluated heat stress in Holstein calves (7 weeks old) during a hot summer episode. According to their results, heat stress indicators show a strong positive correlation with ambient temperature and THI. Furthermore, they indicate that the use of air temperature may be suggested for estimating the acute heat stress experienced by dairy calves.

The same authors also suggest that, for

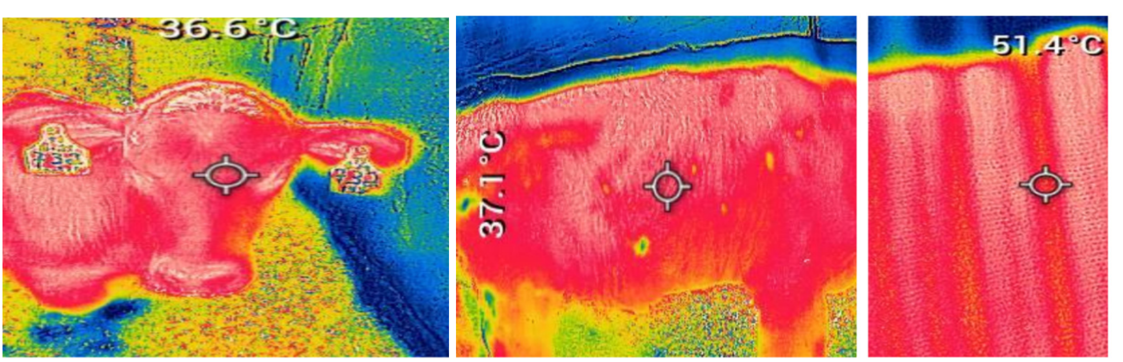

Figure 1. Thermographic images of the head/front and side (left side) in infrared wavelength. The red and blue colors at the ends of the scale represent the hottest and coldest regions, respectively.

the evaluation of physiological reactions to heat stress, measures of respiratory rate, heart rate or ear skin temperature may be more appropriate to estimate acute heat stress, to the detriment of rectal temperature in dairy calves.

Local climatic conditions were recorded and the comfort indices (temperature and humidity (THI) and black globe temperature and humidity (BGHI)) were estimated in the environment outside the housing (sun), and inside (pen), at the entrance (entr), and in the hallway (hall) of the calf barn: THIsun 79.76±0.33; THIentr 79.7±0.33; THIhall 80.49±0.20; and THIpen 80.93±0.18; BGHIsun 84.73±0.49; BGHIentr 84.73±0.49; BGHIhall 84.28±0.05 and BGHIpen 84.28±0.21 (Figure 2).

To position THI values against a heat stress scale or score, Armstrong (1994) classified heat stress according to the THI range as mild or mild (72 to 78), moderate (79 to 88) and severe (89 to 98). Environment without heat stress comprised THI values below 72.

Different scale values to characterize heat stress were suggested by Pires and Campos (2004), with the following classification, according to values lower than or equal to 70 (normal, in which the animals are in a range of temperature and humidity ideal for its productive performance); 70 to 72 (alert, in which weather conditions are at the limit for good productive performance); 73 to 78 (alert, and above the critical index for milk production, in which production performance is compromised); 79 to 82 (danger, because all the organic functions of the animals are compromised); above 82 (emergency, in which urgent measures must be taken). According to the comfort index results obtained in the present study, taking into account data described by Armstrong (1994) and Pires and Campos (2004) based on the THI, the calves were in moderate to severe heat stress, respectively (Figure 3).

A similar behavior, in all pens, was observed in the present study. Calves were often found in a standing posture, close to the drinker or, lying with their heads close to or leaning against the water source (drinker) in the pen.

According to Kim et al., (2018), increased heat stress relatively increases the standing time of native Korean beef calves. On the other hand, the decubitus time decreased. In light of these researchers' findings, the lying position was significantly decreased in the THI from 74.22 to 87.72 compared to the THI of 70.01. On the other hand, standing was significantly higher in the THI of 74.22 to 87.72 than in the THI of 70.01.

The Black Globe Temperature and Humidity Environmental Comfort Index (BGHI), developed by Buffington et al. (1981), can be used as a precise parameter when related to the thermal comfort of ruminants.

The BGHI values observed in the present study indicated that the animals were in a dangerous condition. When the moisture content of the black globe exceeds 80, animals seek areas of lower heat to avoid direct absorption.

Campos et al. (2022) observed THI and BGHI values for crossbred calves (Girolando, Jersey and Holstein) in a situation of danger of heat stress and impaired function between 12 and 14 hours of the day (THI 77.11 and BGHI 80.97), even being shade was offered, which proved to be insufficient to guarantee the thermal comfort of the animals during this period.

In this sense, Kawabata et al., (2005) indicated that shelters exposed to the sun and with asbestos-cement tile presented the least satisfactory indices in terms of animal thermal comfort, in relation to other shelters in the sun (BGHI 85.3, at 2 pm hours).

In view of the above, it can be inferred that

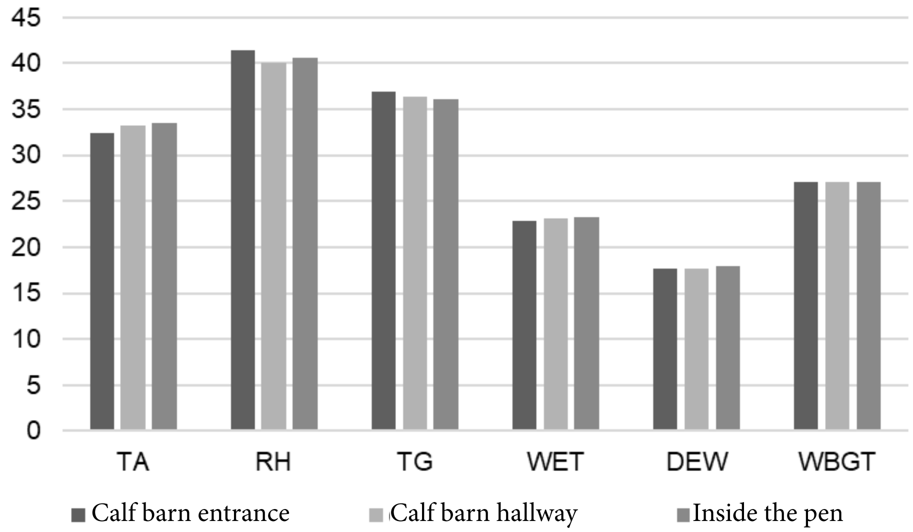

Figure 2. Means of climatic parameters in the evaluated sections of the calf barn at entrance, in the hallway and inside the pen. Parameters were recorded at 2 pm: TA (room temperature, °C), RH (relative humidity, %), TG (black globe temperature, °C), WET (wet bulb temperature, °C), DEW (dew point temperature, °C) and WBGT (wet bulb globe temperature, °C).

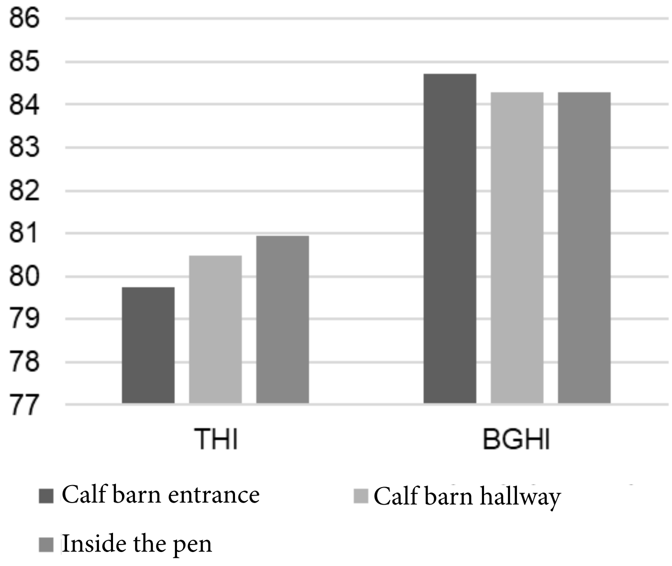

Figure 3. Averages of thermal comfort parameters, estimated for the temperature and humidity indexes - THI and black globe temperature and humidity - BGHI, in the evaluated sections of the calf barn at entrance, in the hallway and inside the pen.

the values of climatic parameters, thermal comfort index and temperature of the body surface and internal surface of the fiber cement tile observed are associated with the increase in body temperature due to the failures of the environment used as shelter for the calves. In this environment, the thermal exchanges may have been impaired and, as a consequence, it promoted a situation of danger to the vital functions of animals due to thermal stress.

CONCLUSIONS

It was concluded that the facility where the calves are housed does not favor thermal comfort, which may cause damage to the proper development and growth, taking into account that this category represents the future replacement animals in the production system. Thermographic images and the estimation of comfort indices support this characterization.

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