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Heat stress mitigation strategies for beef cattle under intensive finishing in the Mexican dry tropics

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ABSTRACT

Objective: Review the heat stress mitigation strategies in intensive cattle feedlots in the tropical region of México.

Approach: Beef cattle production is one of the principal activities of the agricultural sector; therefore, to maintain the inventory in intensive finishing pens, a considerable number of cattle are moved to geographic areas where climatic conditions are not always favorable for most of the year. High environmental temperature combined with relative humidity create heat stress conditions and consequently affecting the productive indicators by compromising the physiological stability of the cattle.

Implications: The improvement of housing conditions to mitigate the effects of heat stress in beef cattle in intensive finishing involves considering living space, available shade area, feeding and watering space that assure the cattle welfare during their stay in livestock production units.

Conclusions: Heat stress mitigation strategies in beef cattle during intensive finishing in practical conditions should contribute to animal welfare and the improvement of the productive indicators at the Mexican dry tropics.

Keywords: cattle, meat production, heat stress.

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INTRODUCTION

In Mexico, beef cattle production represents one of the principal activities of the agricultural sector, due to its contribution to the supply of meat products, as well as its participation in the country's trade balance (Rubio *et al.*, 2013; FIRA, 2019). The evolution of the world beef market and the competitiveness of the countries participating in it influence the dynamics of this activity (Magaña *et al.*, 2020). In this sense, beef production in 2019 reached a historical maximum of two million tons, which is 2.4% higher compared to 2018; 86% of the Mexican beef exports went to the United States. In this activity, the states of Veracruz, Jalisco, San Luis Potosí, Sinaloa and Chiapas stand out, producing 838,930 tons, this implies a contribution of 41.3% of the national total (SADER-SIAP, 2019).

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In northwestern Mexico, the Culiacán Valley, Sinaloa is located at 24° 48"00"'N and 107° 23' 00" W and 70 m asl; the average maximum temperature is 36 °C, persistent during the spring-summer-autumn period, and an average minimum of 11 °C during winter; the average annual relative humidity is 68%, its maximum 98% and minimum 14% (CIAD, 2018). It has dry tropical climatic conditions (BS1(h')w(w)(e)) (Garcia, 2004) and an estimated 493,164 head of cattle are annually housed in feedlots, where 106,289 t are produced, it is equivalent to 5.4% of the national beef production. Renaudeau *et al.* (2012) state that the decrease in cattle production indicators in hot regions is affected by several factors. The main one is heat stress, which is generated by high environmental temperatures; this thermal condition occurs once the environmental temperature exceeds the cattle's thermo-neutral zone, which prevents them from dissipating the extra heat (Bernabucci *et al.*, 2010). Therefore, the objective of this research was to review heat stress mitigation strategies in intensive cattle feedlots in the dry tropical region of Mexico.

What is stress?

The biological expression of stress has been used as an indicator of the loss of animal welfare (Broom, 2003) and is defined as the action of sensory and emotional stimuli provoked by the environment on the nervous, endocrine, circulatory and digestive systems of an animal (Broom, 2005). It is referred to as distress when the animal's response to the stressor causes risks to its well-being and life (Mormède *et al.*, 2007).

Physiological response to heat stress

The body temperature of cattle can vary from 37.8 to 40 °C; within this range, their organism efficiently fulfills its cellular and biochemical functions, due to this, they need to generate or dissipate heat towards the environment; when they face diverse environmental conditions to which they are not adapted, they tend to alter their physiological, behavioral and productivity mechanisms, to maintain their body temperature (Arias *et al.*, 2008). For this reason, thermoregulation mechanisms are activated (Sanmiguel and Avila, 2011). Several studies have established that cattle perform better in the thermoneutral zone of 20 °C, which varies between 10 to 26 °C; but when the temperature exceeds 27 °C, especially if relative humidity exceeds 40%. Then, they begin to have difficulties to self-regulate and heat stress is triggered, which manifests as reduced feed intake and consequently lower weight gain (Mader *et al.*, 2007; Lagos *et al.*, 2014). Due to the environmental temperature being above the comfort zone, the heat load causes cattle not to dissipate heat without additional energy expenditure to maintain corporal temperature; this generates physiological and behavioral responses to ease the effect of heat stress (Bernabucci *et al.*, 2010). Both respiratory rate and panting are appropriate indicators to assess the intensity of heat stress experienced by cattle (Brown-Brandl *et al.*, 2005; Gaughan and Mader, 2014).

Heat stress, an approach to beef production

To reduce heat load in high-temperature conditions, cattle tend to reduce heat production through voluntary anorexia, since fermentation of the rumen and digestion generates heat (Cedeño, 2011); which consequently decrease energy consumption, a negative energy balance is generated, which partially explains their weight loss and end up with a poor body condition when subjected to heat stress (Muñoz *et al.*, 2013). Valente *et al.* (2015) mention that cattle of breeds specialized for meat production tend to decrease in 24% their dry matter consumption during the day under heat stress conditions, reducing metabolic heat production; consequently, water consumption increases their physiological response to decrease body temperature. Pereyra *et al.* (2010) observed that the frequency to access water also increases; though, cattle appear to drink, but do not do so, due to a decrease in their body activities, including feed intake and walking. With rumination decreased, increased respiratory rate and panting, the concentration of HCO_3 decreases, generating the risk of ruminal acidosis, affecting weight gain and consequently feed conversion (Malafaia *et al.*, 2011).

To increase the heat loss through evaporation, the respiratory rate increases under heat stress conditions (Morais *et al.*, 2008; Bernabucci *et al.*, 2010). Research has shown that Angus cattle have elevated respiratory rate, even in comfort temperatures, due to the demanding rate of weight gain, which implies an extraordinary metabolic activity and consequently metabolic heat production gets elevated (Valente *et al.*, 2015). Cattle under heat stress tend to lose more saliva and minerals such as sodium and potassium, besides the potential ruminal acidosis due to the excessive saliva loss effect (Hall, 2000). These conditions negatively impact the productive indicators and consequently generates economic losses for the beef industry (O'Brien *et al.*, 2010; Renaudeau *et al.*, 2012).

Temperature and relative humidity index: effect on caloric load

Thom published in 1959 a famous formula to calculate a thermal discomfort index based on the ambient temperature and relative humidity, focused on the human population. Similarly, the effect of climate on animal production has been highly studied, achieving important advances to understand physiological and behavioral aspects of animal behavior under climatic stress conditions, by jointly evaluating factors such as solar radiation, relative humidity, ambient temperature, wind speed and rainfall; together, these variables have a direct effect on animal welfare (Mitloehner *et al.*, 2001; Brown-Brandl *et al.*, 2006). Mader *et al.* (2006) applied the following equation to assess heat stress in feedlot beef cattle:

$$ITH = 0.8 * \textit{ambient temperature} + (\%\ \textit{relative humidity}/100) * (\textit{air temperature} - 14.4) + 46.4$$

and used the Livestock Weather Safety Index (LWSI), published by LCI in 1970, as a reference to assign heat stress levels to the following categories: Comfort, ≤ 74; Alert, $74 < ITH < 79$; Danger, $79 \leq ITH < 84$; and Emergency, $ITH \geq 84$. In this way, the temperature and humidity index are indicators used to measure the heat stress degree to which cattle are subjected (Gaughan *et al.*, 2008; Olivares *et al.*, 2013).

Climatic conditions at Culiacán valley

Table 1 shows a summary of the climatic variables frequently recorded throughout the months in the valley of Culiacán, Sinaloa, México.

Table 1. Annual summary of climatic variables in the Culiacán valley, Sinaloa.

Month	T Min (°C)	T Max (°C)	RH, (%)	THI Min	THI Max	UV	Light (h)	Sun (h)
January	10.9	27.8	72	52.6	78.3	5	10.8	6.1
February	11.3	28.9	70	53.3	79.7	7	11.4	6.7
March	12.1	30.5	67	54.5	81.6	10	12.0	7.4
April	14.5	32.8	65	58.1	84.6	11	12.8	7.1
May	18.0	34.9	64	63.1	87.4	12	13.4	8.0
June	23.2	35.9	67	70.9	89.5	12	13.7	7.4
July	24.1	35.5	72	72.7	90.0	12	13.5	6.2
August	23.8	34.8	75	72.5	89.5	12	13.0	6.4
September	23.6	34.4	75	72.2	88.9	11	12.3	6.5
October	20.7	34.2	72	67.5	88.0	9	11.6	7.4
November	15.6	31.5	71	59.7	83.7	6	10.9	7.1
December	12.2	28.2	72	54.6	78.9	5	10.6	5.9

T: ambient temperature in degrees Celsius; RH: relative humidity in percent; THI: temperature and humidity index; UV: ultraviolet radiation.

The maximum average value of THI indicates that, during winter, cattle are in distress, and from spring to fall in emergency conditions (Table 2). Heat stress is associated with reduced productivity and animal welfare, especially during the summer months (Lees *et al.*, 2019).

Table 2. Heat stress categories for animals in production established by the World Meteorological Organization (1989).

THI	Categories	Interpretation
< 70	Confort	Suitable conditions, the animal is not under any heat stress.
71 - 79	Alert	Approaching the critical limit of production; prepare to take precautions, do not leave animals exposed to the sun.
80 - 83	Danger	Above the critical limit of production; do not subject the animals to too many movements.
> 84	Emergency	Extreme heat stress conditions in production; minimize any activity, activities should be done during the morning.

Therefore, it is considered necessary to establish mitigation measures to ease the heat stress consequences.

Heat stress mitigation measures

To maintain body temperature, cattle need to gain or lose heat from their surrounding environment; this process, called heat balance, is achieved through a constant thermoregulation process that involves the flow of heat through four basic pathways: conduction, convection, radiation and evaporation. When the physiological mechanisms to maintain thermoneutrality are not sufficient, the animal enters what is known as the heat stress zone (Beatty *et al.*, 2006). Cattle can subsist in adverse climatic conditions, for which, various individual characteristics are involved; however, there are geographical areas, such as tropical regions, where mitigation measures need to be implemented. One of the main mitigation measures is shading feedlots, which reduce the impact of solar radiation and heat load by up to 30% (Brown-Brandl *et al.*, 2013). To avoid the excess heat effects, cattle also modify their usual behavior; under heat stress conditions they decrease the time spent consuming feed and lying down, increase the time spent drinking water and standing near water troughs; or places with better ventilation (Arias *et al.*, 2008). If their body temperature reaches a critical level, the animals may die due to the lack of control over the regulation of this physiological indicator (Renaudeau *et al.*, 2012). In this matter, Gaughan and Mader (2014) observed that panting is a heat stress indicator in cattle. In this regard, several authors indicate that shading helps to mitigate heat stress; Mitlöhner *et al.* (2001), Mitlöhner *et al.* (2002), Gaughan *et al.* (2010), Blaine and Nsahlai (2011) and Sullivan *et al.* (2011) agree that shade availability helps cattle to mitigate heat load.

Availability of shade in feedlots

Providing shade in intensive beef cattle finishing pens influences the reduction of direct or indirect losses in livestock (Brown-Brandl *et al.*, 2005). Renaudeau *et al.* (2012) indicated that shade usage helps to mitigate heat stress; similarly, Mitlöhner *et al.* (2001) noted that cattle housed under the shade provided by 80% solar filtering (FS) polypropylene fabric at a 3 m height, had lower respiration rate, as well as higher feed intake and higher weight gain, reaching finishing weight 20 days earlier than cattle without access to shade. Blaine and Nsahlai (2011), in South Africa during the winter season, provided 2.87 m^2 of shade per head, from corrugated iron sheeting, placed at a 5 m height. They observed that cattle housed in shade obtained higher final weight than those housed without shade, as well as higher weight gain and improved feed conversion; also, the carcass weight difference was higher; they also indicated a panting decrease and increased resting time. In Australia, Angus steers were provided with a 3.3 m^2 shade per bovine, with a black polypropylene fabric at 80% FS at 4 m height. Gaughan *et al.* (2010) observed lower body temperature and panting in animals housed with shade, as well as higher CMS, GDP, finishing weight and hot carcass weight. Sullivan *et al.* (2011) assessed the shade availability (0, 2.0. 3.3 and 4.7 m^2/animal) provided by 70% black FS solar fabric at 4 m height; it shows that shade-providing improved animal welfare and performance, while different areas of shade/bovine did not affect productive variables, but shades greater than 2.0 m^2 improved bovine welfare. In a tropical climate, Castro *et al.* (2020) determined that increasing shade space in feedlots tends to linearly increase the average of daily gain and dry matter intake; this effect was more evident between 1.2 and 2.4 m^2 of shade/head.

The recommended shade space is 3.7 m^2 in adult animals (Gasque, 2008); the shade height should be at least 4 m so that it does not interfere with air movement and thus achieve greater projection inside the pen; a strategy to keep the floor of the pen dry is to leave unshaded spaces of 15 cm in the structure (Lagos *et al.*, 2014).

Feeding space

While feeding cattle tend to show hierarchical behavior, because those of higher rank fed first (Méndez *et al.*, 2013); the required space may vary between young animals and large animals; for young animals, a linear space of 0.45 m per head is required, and larger than 300 kg animals require 0.70 to 0.90 linear m per animal (Gasque, 2008; Lagos et al., 2014).

Drinking trough space requirements

Water troughs are an important part of feedlots, since they provide fresh, clean water in necessary quantities, so the required size of water troughs is 30 cm^2 per 10 bovines; these should not be deep, to avoid water stagnation and consequently its contamination, offering less freshwater for cattle (Lagos *et al.*, 2014).

Feedlot density

It is important to take into account for the construction of the pens for intensive feedlots, cattle in production require a living space where they can express their natural behavior while remaining within the finishing cycle (Gasque, 2008); the required living space for fattening animals is of 18. 5 m^2 per animal, but this can be modified according to the animal's weight, requiring up to 15 m^2 per animal when they weigh 300 kg or less, and 20 m^2 per animal over 400 kg; this is why, the number of cattle per pen should be established according to the m^2 of available surface area in the feedlot (Lagos *et al.*, 2014). The scientific information regards the effect of feedlot density and its relationship with the productive performance of cattle is limited; in this sense, Ha *et al.* (2018) researched the density and the productive response of cattle; in that research, the authors state that increasing the space per animal in feedlots can improve the cattle's welfare, since they can express their natural behavior, tend to increase their social behavior and decrease agonistic behaviors, which usually occur in pens with less living space per animal. In the aforementioned study, an improvement in carcass characteristics, such as rib-eye area (REA) and marbling percentage, was also observed; in another study, conducted by Lee *et al.* (2012), they reported that a low density per pen helps cattle grow faster, obtain larger REA, improve feed efficiency, GDP and improve carcass weight.

CONCLUSIONS

Heat stress mitigation strategies in beef cattle in intensive finishing under practical conditions should contribute to animal welfare and improve productivity indicators in the Mexican dry tropics. Heat stress mitigation strategies in beef cattle under intensive finishing directly contribute to productive indicators and animal welfare in the Mexican dry tropics.

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