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Importance of living space in the productive response and welfare of beef cattle in feedlot

Importancia del espacio vital en la respuesta productiva y bienestar del ganado bovino productor de carne en confinamiento

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ABSTRACT

In the intensive beef production system, the living space allocated in the feedlot is fundamental for cattle to show their natural behavior, establish a hierarchical order and express their productive potential. If living space in the feedlot is reduced, the available area for shade and feeders is also reduced, compromising productive indicators and modifying cattle behavior by increasing agonistic behavior to define hierarchies within the pen. For the allocation of living space, it is necessary to consider climatic conditions of each region, especially in areas with high rainfall, or high environmental temperature and relative humidity; on the one hand, the excess of mud generates problems in the extremities, hinders the displacement of cattle inside the corral and decreases the feed conversion, as it requires more energy expenditure to facilitate the displacement. Increasing the living space in the pen improves cattle welfare, decreases morbidity and increases weight gain. It is therefore important to consider the environmental setting and the physical characteristics of the pens to provide optimal housing conditions.
Keywords: living space, bovines, intensive production.

RESUMEN

En el sistema de producción intensiva de carne bovina, el espacio vital asignado en el corral de engorda es fundamental para que los bovinos manifiesten su comportamiento natural, establezcan un orden jerárquico y expresen su potencial productivo. Si en el corral de engorda disminuye el espacio vital también se reduce el área disponible de sombra y comedero, se comprometen los indicadores productivos y se modifica el comportamiento del ganado, al incrementar la conducta agonista para definir las jerarquías dentro del corral. Para la asignación de espacio vital se necesitan considerar las condiciones climáticas de cada región, especialmente en áreas con mayor precipitación pluvial o de elevada temperatura ambiental y humedad relativa; por una parte, el exceso de lodo genera problemas en las extremidades, dificulta el desplazamiento de los bovinos dentro del corral y disminuye la conversión alimenticia, al disponer de mayor gasto energético para facilitar el desplazamiento. Al aumentar el espacio vital en el corral mejora el bienestar de los bovinos, disminuye la morbilidad y aumenta la ganancia de peso. Es por ello importante considerar el entorno medioambiental y las características físicas de los corrales para proveer condiciones óptimas de alojamiento.
Palabras claves: espacio vital, bovinos, producción intensiva.

INTRODUCTION

In response to the growing demand for animal protein, production systems have intensified and, consequently, intensive beef cattle production has increased (Miranda de la Lama, 2013), thus displacing more traditional systems (Mota-Rojas *et al*., 2016). According to the United States Department of Agriculture (USDA, 2020), world beef production grew 1% in 2019, to stand at 62.6 million tons; mainly due to increased production in China. With respect to consumption, it is estimated that during 2019, world beef consumption increased 0.8%, to 60.7 million tons. In Mexico, the national herd of beef cattle producers, during the period 2012 to 2017 the annual rate grew 1%; but showed higher growth in the biennium 2016 to 2017, by increasing by 2%. The production record during 2020 in Mexico shows that it was 2 079 362 tons (SIAP, 2021).

When faced with the growth in beef demand, confinement of cattle in intensive finishing pens can negatively impact welfare indicators (Mota-Rojas *et al*., 2016), as cattle's natural behavior is modified, common space is reduced in both waterers, shade and feeders, and productive performance can be compromised (Li *et al*., 2010; Lee *et al*., 2012).

One of the most important aspects to consider in the intensification of the confinement beef production system is living space, which is defined as the amount of square meters available per individual; in other words, living space is the need of all organisms to have a habitat; animals, preferably in pairs or groups, occupy a territory and defend it against other animals or groups, especially against those of the same species. The extension of the living space is a characteristic feature of each species and depends on the quantity and quality of food needed, size and sex of the animal, population density and climatic conditions of the area (Landaeta-Hernández, 2011).

By respecting the living space of farm animals, a better productive result is guaranteed, since the animals develop and reproduce in adequate conditions by reducing competition among their members; in this sense, overcrowding, which increases aggression, should be avoided; in this regard, if physical protection measures are taken, such as dehorning cattle and keeping the herd or flock homogeneous with respect to body development, special attention is guaranteed to the weakest animals, since competition is reduced, mainly at the feeding trough when serving feed. It is important to consider that the area physically occupied by an animal is not necessarily the actual space it needs in practice (Landaeta-Hernández & Drescher, 2012). Currently most of the studies about cattle welfare have been conducted on dairy cattle; however, beef cattle do not have the same behavior as dairy cattle; as well as they receive a completely different management (Schwartzkopf-Genswein *et al.*, 2012).

Therefore, the objective of this research is to document the importance of living space availability on productive and welfare indicators of beef cattle in intensive confinement.

Cattle grazing performance

In a production system, whether grazing or confinement, cattle behavior is determined by instinct, sensory perceptions and experience. Instinctive behavior refers to naturally motivated behavior; sensory perception is that which results from interaction with the environment and from which situations developed with acquired experience, either negative or positive, derive (Sowell *et al.,* 1999).

Some of these behavioral expressions include the capacity of animals to consume food, rest, interact socially and flee in the face of danger, among others. In this sense, grazing cattle tend to use 95% of their diurnal time to perform major behaviors such as grazing, resting, ruminating and walking (Kilgour *et al.,* 2012). In this regard Manning *et al.* (2017), established that the proportion of time allocated to grazing can vary from 30 to 69% per day and this depends on the availability of feed in the pasture and the nutritional demand that at a given time the herd has. Da Silva *et al.* (2013) observed that in tropical regions, grazing time can increase or decrease depending on the year time, so it is understood that in months of greater light intensity, grazing frequency decreases. It has been observed that in tropical regions, grazing cattle spend part of the time grazing to mitigate the effect of intense solar radiation under the shade of trees or nearby buildings, this situation occurs naturally between 9:00 and 14:00 hours (Da Silva *et al.,* 2010). Kilgour *et al.* (2012), refer that most of the studies aimed at elucidating the behavior of cattle in grazing, point out that given the nature of this production system, factors such as herd size, breed type of cattle, availability and type of pasture intervene and interfere, as well as complications to observe the entire herd, without altering or modifying its behavioral pattern. To make these measurements more objective and interpret them according to behavioral determinants, technologies such as the use of GPS (Global Positioning System) or Geographic Information System (GIS) (Turner *et al.* 2000), or by means of UAVs (Unmanned Aerial Vehicles) and the analysis of photogrammetric images (Mufford *et al.,* 2019); as well as the use of drones (Rivas *et al.,* 2018) to monitor the behavior of grazing cattle have been proposed. The observation and recording of behavioral patterns of cattle under grazing conditions, through the use of alternative technological tools will provide new elements to understand and address aspects related to the identification of hierarchies, social, agonistic and reproductive behavior patterns, feeding patterns, predator threats, health schemes and production indicators.

Behavior of beef cattle in confinement

One type of instinctive behavior commonly observed in cattle is social dominance, which exists when the behavior of one animal is inhibited or altered by the presence or threat of another animal, it is recognized that other animals maintain a hierarchical dominance over other individuals in the same herd (Hubbard *et al.,* 2021). Thus, the establishment of hierarchies is a substantial aspect of bovine behavior and has consequences, both in productive indicators and welfare indicators, since one of hierarchy particularities is to avoid the creation of conflicts every time a resource such as feed, access to water or resting place has to be accessed. One of the hierarchical expressions in cattle herds in intensive feedlots is established through fights and mating, but the continuity and persistence of these behavioral and agonistic expressions can negatively affect productive indicators and meat quality (Mota-Rojas *et al*., 2016).

In the feedlot, dominance behavior is important, since groups of cattle will establish social hierarchies; for example, if an animal has a high hierarchy in the group, it is not going to let those of lower rank feed in anticipation of those of higher dominance (Bruno *et al*., 2018). In this regard, Jezierski *et al.* (1989), refer to genotype as a factor that modifies both agonistic and social behavior of cattle and that maintains a close relationship with their individuality; thus, for example, cattle breeds specialized for dairy production tend to manifest a homosexual and social behavior more expressed than in breeds whose zootechnical purpose is meat production; although it is worth mentioning that genetic selection influenced docility, which is an important trait in cattle, since it influences human safety and animal welfare, and also has an important influence on the productivity of livestock enterprises (Norris *et al*., 2014).

In contrast, dominance behavior is an important component in social behavior, as animals establish hierarchies, which can reduce or increase the level of aggression to individuals that integrate the herd (Bruno *et al*., 2018).
Among the social behaviors that cattle develop, grooming is performed to fulfill three specific functions: cleaning effect, group tension reduction effect and bonding effect among their peers (Sato *et al.,* 1991). Another type of behavior is agonistic, including sexual behavior, which is manifested by physical harassment and mating between bovines of the same sex. This behavior may involve two or more animals, so that one bovine may be mounted by one or more on several occasions, or several bovines may be mounted; although this behavior is agonistic, it is frequently used to determine the order of hierarchy within the herd (Blackshaw *et al.,* 1997).

The confinement of cattle in intensive feedlots can alter or modify the innate behavioral behavior that cattle exhibit under natural conditions or in the open range (Ratnakaran *et al.,* 2017). When in confinement, cattle may show stereotypies, such as repeatedly rolling and unrolling their tongues, or even manipulating objects in the pen with their tongues (Schneider *et al.,* 2020). In this regard, Romo-Valdez *et al.* (2019), indicate that beef cattle in confinement show behavioral expression with diurnal variation that obeys their biological rhythms. However, another aspect to highlight is that social organization in same-sex groups, artificially formed in intensive production systems increases the level of aggression, compared to ruminants that develop in semi-intensive and extensive systems (Park *et al.,* 2020). Šárová *et al.* (2013), state that hierarchical dominance in social groups of beef-producing female cattle can be based on asymmetries, which are important in agonistic interactions, such as body mass and age; which are respected despite having little relation to fighting abilities among animals.

Within the herd, members can define their position and space without the need for confrontation; in this sense, order is established by subtle threats through body signals, in a sort of symbolic struggle, after which the dominated animals yield to the dominant one (Sowell *et al.,* 1999).

Another behavioral pattern that is affected by the cattle confinement is social facilitation; this is understood as the rupture in social behavioral synchronization caused by the lack of space and consequently by the increase in aggression, increasing the range of individual variation in patterns of maintenance behaviors: eating, moving, resting and grooming (Hubbard *et al.,* 2021).

Importance of living space in beef production

Living space is the space necessary for the animal to be in comfort and free of social stress, which is important to take into account in the design of facilities (Landaeta-Hernández & Drescher, 2012). Unfortunately, there is a worldwide tendency to reduce the living space of intensive production animals in order to increase the profitability of the production unit; however, the reduction of living space affects both the environment of the pen and the behavior of the cattle and their health, generating stress and seriously reducing their welfare (Macitelli *et al*., 2020). Individual space for each member of the same species is of utmost importance, as this favors them to delimit social contact with another member. This space can vary in certain circumstances, with fights between dominant males for the defense of their territory (García, 2000).

Cattle confined for meat production require a predetermined living space according to intrinsic and extrinsic factors, where they can express their innate behavior, while they are kept inside the feedlot (Gasque, 2008); this is important since their availability may vary, depending on the breed type, or even the social rank within the herd (Landaeta-Hernández & Drescher, 2012); therefore, the number of animals housed per pen will depend on the available space.

In a feedlot, it is important to consider the density and size of the pen to define the sufficiency of living space for cattle during the feeding period, as this can have an effect on the microclimatic conditions of the feedlot; in addition, an adequate density allows maintaining the moisture balance on the feedlot surface, which should be neither too dry, but not too wet either (Watts et al., 2016). In order to provide better habitat conditions during the cattle's stay in the feedlot, the amount of square meters to be provided for each cattle, from the beginning to the end of the production cycle, should be considered (Macitelli *et al.,* 2020).

According to the space required by beef cattle during their stay in the feedlot there are several sources, Lagos et al. (2014), state that 18. 5 m^2/head, to provide ideal living space conditions, which can be adjusted to the weight of the cattle, since cattle of 300 kg or less require 15 m^2 and cattle of 400 kg or more need 20 m^2; while in Mexico, the Manual of Good Production Practices published by SAGARPA (2014), indicates that 12 to 12.5 m^2 per cattle, they are sufficient for them to develop their natural behavior. However, when designing and building pens for the confinement of beef cattle, other aspects must be considered, since the proposal of SAGARPA, today SADER, does not take into account that animals will gain weight during their stay in the feedlot and as time goes by the body mass of the cattle increases, and that eventually they will need more space availability; Therefore, for its correct determination, important aspects must be taken into account, such as the weight at which the cattle will finish, racial type and the climatic conditions of the macro-environmental environment, as well as the area and type of shade, since they provide aspects that benefit in sum the productive and welfare indicators of the cattle.

In this regard, in a survey conducted by Simroth *et al.* (2017), to 43 feedlots in Texas, Kansas, Nebraska, Oklahoma, New Mexico and Colorado states in the United States of America, it is described that 10 % of feedlots provide from 4.7 to 9.3 m^2/animal of living space; 66 % of pens provide from 9.4 to 23.2 m^2 of living space and the remaining 24 % provide more than 23.2 m^2/animal. Related to this issue, Lee *et al.* (2012), designed an experiment to house 1, 2, 3 and 4 steers per pen and provide 32, 16, 10.6, 10.6 and 8 m^2/head, respectively. The authors report that cattle housed in pens with lower density, i.e. greater living space, grew faster ($P<0.05$) and presented greater rib eye area ($P<0.01$), but without differences in meat quality ($P>0.01$). In this regard, Ha *et al*. (2018), developed a study with the objective of assessing the density in the bovine feedlot; for this, they used 3, 4 and 5 steers per pen to provide 16.7, 12.6 and 10 m^2/head, respectively. The authors recorded that decreasing the density in the pen improved carcass quality and welfare indicators, as well as the behavioral behavior of the cattle. However, these studies were not conducted at densities similar to commercial feedlot conditions, so the results may not be due to pen density or group size.

On the other hand, in a comparison of living space, it was observed that providing reduced living space (<2.5m2 / head) has a negative impact on animal welfare, but conversely, providing more space has a positive impact (Park *et al.,* 2020).

Relationship between living space and physical conditions of the pen

The allocation of living space per head of cattle during the fattening period will depend on the geographical area where the finishing pens are located, because the higher or lower rainfall can influence the moisture saturation on pens´ floor. Under this reasoning, Macitelli *et al.* (2020), assigned 6, 12 and 24 m^2 /head, both in rainy and dry seasons of the year. It was determined that in the rainy season the cattle assigned to 6 and 12 m^2/head, visited the feeder less frequently compared to the dry season; but when 24 m^2 were provided, no difference was observed.

Watts et al. (2016), initially provided 10 m^2/head with the objective of determining that this space per cattle was the most advisable for areas where rainfall is low (<500 mm/year); however, in cattle with body weight greater than 752 kg and housed in pens where the proportion of living space is 10 m^2/head, 3.3 mm of moisture can be generated daily; this implies greater concentration of moisture on pens´ floor. In the same vein, Mader (2011), evaluated the depth of mud in different living space in feedlots and observed that increasing the living space from 14 m^2 to 23 and 32.5 m_2 in low temperature conditions in latitudes where snowfall occurs, decreases the proportion of mud in the pen. In this regard, Munilla *et al.* (2019), mention that in pens where there is abundant presence of mud, cattle register lower weight gains than those housed in pens with dry floor. The main productive disadvantage under these conditions is reflected in lower feed conversion, since cattle use part of the energy supplied in the diet to move through the mud; thus increasing energy expenditure more than in dry floor; in addition, the excess of mud in feedlots implies a loss of cattle welfare (Grandin, 2016).

Regarding dust concentration in feedlots Henry *et al.* (2007), observed that it decreases during the dry season of the year by allocating 27.8 m^2/head; however, they recommend that in dry climates the space allocated per head can vary within 18.6 to 23.2 m^2. The authors suggest the latter figure with the function of reducing dust inside the pens. In a study conducted by Macitelli *et al.* (2020), they observed that increasing the living space from 6 to 24 m^2 reduces dust concentration during the dry season. Similarly West (2011), mentions that one of the ways to reduce dust emissions in open feedlots is the use of water sprinklers to inhibit the trajectory of fine dust particles in the air. On the other hand, Grandin (2016), mentions that an adequate stocking density inside the feedlot helps to keep cattle clean, since they contribute moisture to the soil through urine and excreted feces.

In the definition of living space to be provided in the feedlot, some climatic variables must also be considered, such as the abundance and seasonality of rainfall, ambient temperature, relative humidity, speed and direction of prevailing winds, as well as the amount of dust generated by the movement of cattle inside pens (Landaeta-Hernández & Drescher, 2012). On the other hand, in rainy regions, it is necessary to point out that mud inside the pen is a factor that impacts the health and welfare of cattle, since lameness and limb injuries are associated with slippery conditions due to excessive mud (Schwartzkopf-Genswein *et al.,* 2012). However, to date, there is no study that sufficiently explains why cattle engage in intense evening activities that cause enormous amounts of dust in feedlots.

Under heat stress conditions, the most important effect is the decrease in feed intake and consequently feed efficiency (Sullivan *et al*., 2011), so it is necessary to reduce animal density per pen to avoid crowding of animals in the feedlot when space is limited, but it is further intensified under an intensive confinement production system (Vásquez-Requena *et al*., 2017). Several factors affect the level of productive response of cattle in confinement given that they will have to adapt to a particular environment; these susceptibility factors include coat color, sex, species (*Bos indicus*, *Bos taurus*), temperament, health status, and previous exposure; as well as body condition and age (Brown-Brandl, 2018). In intensive beef cattle finishing pens, limited space and floor characteristics can negatively affect animal performance, health, and welfare (Cortese *et al*., 2020).

Among the different types of cattle fattening facilities, in Mexico mainly one single pen design is used within the existing variety, these designs can be open pens with windbreaks, open pens with sheds, pens with beds and pens with deep pit; depending on the pen design the living space for the cattle is provided. In the open pen design with windbreak a space of 14 m^2 per head is allocated, in the case of the open pen with shed 2.3 m^2/head are provided inside the shed and 11.6 m^2/head on the outside of the pen, in the case of pens with bedding they will be allocated 3.7 m^2/head; finally in the case of the pens with deep well only 2 to 2.3 m^2/head are provided (Euken *et al.,* 2015).

When evaluating different densities during the fattening of steers Ha *et al.* (2018), observed that when the fattening period was extended, consequently, the living space was reduced which decreased the activities of cattle. On the other hand, Montelli *et al*. (2019), economically evaluated the allocation of 6, 12 and 24 m^2 per bovine, in outdoor feedlots for fattening cattle; through study results, it was determined that by increasing the availability of living space, fixed costs per animal rise; however, the profitability of production unit is improved and the financial loss is decreased since in pens with more living space in sick cattle decreased and the carcasses obtained at the end of the fattening period resulted heavier. In the same sense, in cattle housed in 12 and 24 m^2 spaces, the frequency of sneezing in dry season decreased, compared to cattle housed in 6 m^2/head (Macitelli *et al.,* 2020).

The consequences of confining cattle in pens with high density, are manifested in the increase of feed consumption, due to the competition that occurs between them (Watts et al., 2016); and if to this are added the conditions of heat stress due to environmental effect, changes in nutritional requirements are manifested, which considerably reduces the consumption of dry matter and increases the consumption of water as a thermoregulatory mechanism (Mader *et al*., 2006). Mitlöhner *et al*. (2002), affirms that the reduction in feed intake affects the performance of cattle in the feedlot. All of the above justifies the importance of providing sufficient living space to ensure the welfare and improve the productivity of cattle in confinement (Rind & Phillips 1999).

CONCLUSIONS

In intensive beef cattle production, it is necessary to consider the living space to be provided, to ensure that the expression of cattle behavior during their stay has a positive impact on productive and welfare indicators; it is important to consider the environmental setting and the physical characteristics of the pens to provide optimal housing conditions.

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