ISSN 2318-1265

REVIEW

Environment, behavior and welfare aspects of dairy cows reared in compost bedded pack barns system

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Received: March 07, 2017 ▪ Revised: May 24, 2017 ▪ Accepted: June 07, 2017

Abstract The compost bedded pack barns is a loose housing confinement system for dairy cows, which aims to provide greater comfort in the resting area. Therefore, objective of this review was to investigate the environment, behavior and welfare aspects of dairy cows in the compost bedded pack barns system. The system is characterized by the large collective bed area, in which the objective is the composting of that area. In this way, the ideal bed management is the key point to the success of this system. In addition to daily revolving, an efficient ventilation system is required to perform the air exchange in the shed, and maintain adequate bed humidity levels, while maintaining a comfortable dry environment for the cows to lie down. The ventilation system also has great importance in the cows' thermal comfort. In seasons of high average temperatures, ventilation reduces possible stress situations, raising the animals' welfare level. Another characteristic of compost bedded pack barns is the greater spacing per animal in the bed area, allowing animals to express naturally the behavior of lying down and decrease the competition among animals. The compost bedded pack barns system presents the potential to provide comfort and welfare for dairy cows. However, good bed management and microclimatic environmental conditions are necessary. However, further studies are needed at the national level to provide more information on the ideal management of the system under climatic conditions in Brazil and the cows' behavior in the system.

Keywords: composting, ethology, loose housing, stabling, thermal comfort

Introduction

In Brazil, the predominant system in milk production is pasture system; however, many producers have opted for confinement systems. In addition to the intensification of production, the increase in agricultural production area and greater control of environmental conditions are the main reasons for this choice.

However, conventional housingt systems may present critical points regarding the animal welfare aspects. The main problems encountered can be classified as the restriction of the cows'smovement, the littlebed area available, high animal density and problems in the joints and hooves of animals due to the floor type used.

In this sense, many producers have opted for an alternative system that prioritizes more comfort for cows in the bedding area. The compost bedded pack barns is a relatively new loose housing system in Brazil. Nevertheless, this one appeared in the 80's in the United States, but it was successful only in 2001. This system provides a dry and comfortable place for cows, because it consists of a housing system with a large deep bedding area for all animals. The bedding usually consists of wood shavings with an initial depth of 30 to 50 cm, which is separated from the feeding area (Janni et al 2007). The compost bedded pack barns require a good ventilation system, and an intensive handling of the bedding, to control humidity and the animal comfort. This bedding can be used during a year in the system and soon after it can be reused as a fertilizer in agriculture.

The compost bedded pack barn system, besides having thermal control features, which characterizes itself in the majority of dairy cattle housing systems, also allows greater comfort for the cows in the resting area. This is due to the soft surface and to the greater bedding area per animal, mainly reducing foot injuries and improving welfare levels in the productive environment (Endres 2009).

However, there is still a scarce literature that brings behavioral informations and animal welfare into this system. Based on the implementation of the system in Brazil and the producers' interest in the South of the country, the present review is justified to study the ambience, behavior and welfare aspects of dairy cows in compost bedded pack barns confinement system.

doi.org/10.31893/2318-1265jabb.v5n3p97-105

Ambience and thermoregulation of dairy cows

The term ambience is used to characterize environmental aspects in animal raising. Ambience can be defined as the physical and psychological means that animals perform their activities (Paranhos Da Costa 2000). Raising environments seen as everything that is inserted in the space that surrounds the animal, including the physical and social environment and human beings (Paranhos Da Costa 2002). Physical environment characterizes itself by equipments, installations, light and sound, and the social aspect includes population density, behavior and dominance factors (Baêta and Souza 2010).

The physical aspects of the facilities directly influence the comfort and life quality of confined dairy cows. In systems such as free stall, for example, the flooring type used may lead to joint and hoove problems, and may increase the lameness rate of of the herd (Burgstaller et al 2016). Population density is a social aspect that can determine changes in dairy cows' behavior, and elevate the stress level of confined animals (Krawczel et al 2012).

In Brazil, climatic conditions present another problem for the ambience of confined animals. Facilities without proper control of the microclimatic variables become a challenge for thermal comfort. In this condition, animals use mechanisms to regulate body temperature, which can result in a high level of stress, and as result, a lower degree of welfare.

The bovine species are characterized as homeotherm because they keep the constant body temperature within a variable ambient temperature range (Baêta and Souza 2010). To maintain body temperature within the homeothermia limits, the animals have some mechanisms of temperature control. Thermoregulation is a set of strategies used to regulate body temperature, being an essential mechanism in the adaptation and maintenance of animal species (Souza and Batista 2012).

Neuroendocrine interaction regulated by the hypothalamus maintains body temperature. In situations of thermal discomfort, temperature receptors distributed in the body (cold and heat) capture sensations and send information to the hypothalamus, which coordinates thermolysis responses and thermogenesis (Robertshaw 2006) (Figure 1).

The first response of an animal to heat stress is peripheral vasodilation (Robinson 2004). If this is not enough to maintain body temperature, according to the same author, there is an increase in the evaporative cooling mechanism through sweating and breathing (or increased respiratory rate). Animals also change their behavior to decrease the body thermal load. As an initial response, cows cease their activities, seek shade and windy places, then they reduce feed intake to reduce the endogenous heat production and increase water consumption (Spencer 2011).

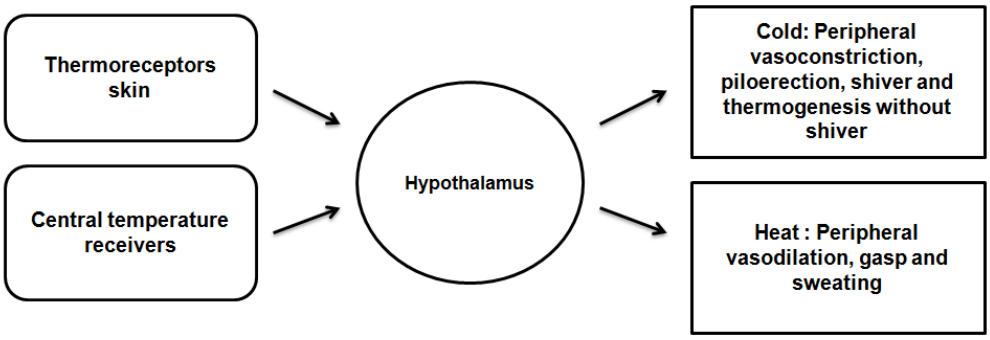

Figure 1 Diagram of the interaction of body temperature control by the hypothalamus.
Source: Adapted from Robertshaw (2006)

When the hypothalamus receives informations from the cold receptors, the body temperature is regulated through physiological reactions of cutaneous vasoconstriction, piloerection (Reece 2015) and behavioral changes such as shelter seeking from the cold and wind.

For each animal species, there is a thermoneutral zone, or also called thermal comfort zone (Figure 2). In thermoneutral zone, the metabolic rate to maintain body temperature is minimal (Dash et al 2016).

The thermoneutral zone is between an upper critical temperature (UCT) and lower critical temperature (LCT). The animal is able to maintain body temperature to the limit zones h_i and h_u, with available thermoregulatory resources. When the temperature is above or below the limit zones,

doi.org/10.31893/2318-1265jabb.v5n3p97-105

these mechanisms cannot maintain body temperature and the animal enters hyperthermia state (elevated body temperature) or hypothermia (decreased body temperature). Zone a_i and a_u represent the lower and upper limits of animal survival, respectively (Silva 2000).

The homeothermic animals perform their thermal energy exchanges with the environment through sensitive and latent forms of heat transfer (Baêta and Souza 2010). In thermal gradient situations, i.e., when there are differences between body and ambient temperature, the sensitive mechanisms of thermal exchanges (conduction, radiation, and convection) are more efficient (Nunes Batista et al 2015). Evaporation, a latent form of energy transfer, is the most important way of heat exchange at high temperatures, because it allows thermal exchange under reduced thermal gradient conditions (Collier et al 2006). The evaporative cooling is the only form of heat loss that occurs in situations, which air temperature exceeds body temperature (Robinson 2004). At temperatures around and above 32 °C, Holstein cows begin to gain sensible heat from the environment, in this condition latent heat exchange become more efficient (Maia et al 2005). The authors mention that under these conditions approximately 85% of the heat loss occurs through the dermal route and the remainder through respiratory evaporation. However, according to the same authors, the cutaneous heat loss is extremely compromised in situations of relative humidity above 80%.

Thermal stress occurs when an animal cannot dissipate a sufficient amount of heat, which the body produces or absorbs (Bernabucci 2014). Thermal comfort temperatures for European cattle vary from 1 to 16 °C and for Zebu breeds vary from 10 to 27 °C (Azevedo and Alves 2009). Perissinotto and Moura (2007) defined that the highest critical temperature for Holstein cows is around 26 °C. The authors also stated that temperature below 22 °C provides thermal comfort for cows, regardless of relative air humidity indexes. For lactating cows, comfort temperature range from 4 to 24 °C and 75% relative humidity (Nääs 1989).

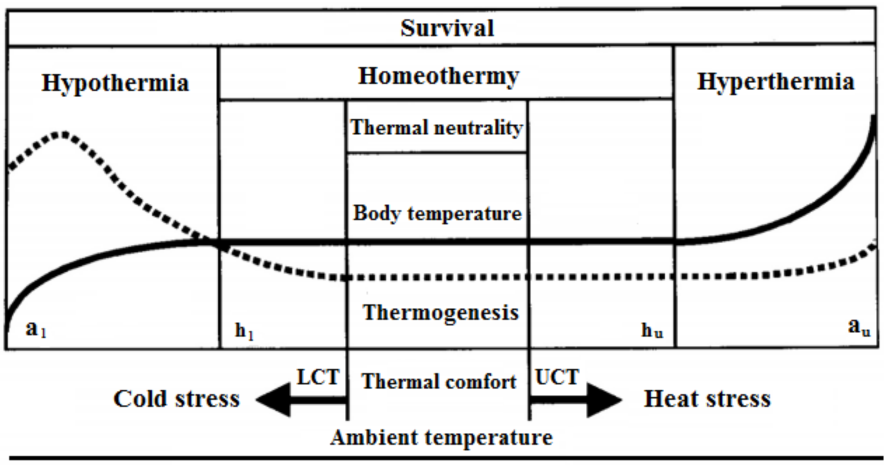

Figure 2: Simplified schematic representation of homeothermic thermoregulation.
Source: Adapted from Silva (2000)

The respiratory rate is used as a physiological variable to evaluate animal thermoregulation; this refers to the number of breaths or cycles per minute. It is an excellent indicator of health and can be affected by age, exercise, excitement, pregnancy, room temperature, filling degree of the digestive tract and diseases (Reece 2006). The mean respiratory rate of dairy cows at rest is 26 movements per minute. Silanikove (2000) characterized stress situations in cattle by respiratory rate, with values between 40-60 mov./min. because they represent low stress level, of 60-80 average, of 80-120 high and above 150 mov./min. as severe stress. Another physiological variable that can be used as a diagnostic tool in stress situations is rectal temperature. For dairy cows, mean rectal temperature is 38,6 °C, varying between 38 and 39,3 °C, considered normal according to their physiological state (Robinson 2004).

In addition to the physiological variables, the animal behavior observation helps to diagnose stress situations, since cattle change their behavioral pattern to improve the thermal changes with the environment. In this way, the behavioral study is of great value to evaluate the influence of the environment on the dairy cows' welfare.

Dairy cows' behavior

doi.org/10.31893/2318-1265jabb.v5n3p97-105

Ethology is the science that studies animal behavior, its cause and biological function (Jensen 2002). For this author, the behavior can be the result of the specific stimulus as well as a reflex, or also the result of a physiological reaction and even a reaction because of the joint action of these factors. Broom and Molento (2004) described that animal behavior is determined by the particularities of their body, which correspond to their physical, physiological, and emotional characteristics, and which can be influenced by the environment to which they are exposed. Therefore, knowing the natural behavior of each species is of great value, especially for the diagnosis of stress situations that may endanger animal welfare, as well as to define adequate management strategies (Bond et al 2012).

Cows are gregarious animals that need to live with their family members and maintain relationships mainly between mothers, sisters and daughters (Grandin and Johnson 2010). In most dairy herds, animals are grouped according to their age and physiological state. This management practice interferes in the social organization of the animals, creating tension situations mainly in the regrouping moments.

The dairy cows' social structure can be defined as hierarchical relations of dominance and links, characterized by positive and/or aggressive social interactions (Gibbons et al 2010). Dominance is established in the face of competition interactions among animals, disputing for resources such as water, food and space (Paranhos Da Costa and Costa e Silva 2007). These authors affirm that cattle age, weight, and breed define the hierarchical position. Dominant animals are at the top of the hierarchy organization, next, the intermediates and subordinate animals (Machado Filho et al 2015).

Dominant cows will always have priority access on resources to submissive or dominated animals. Animals keep the dominance relationship through agonistic relations that can be characterized as head butting and pushing. Cattle kept in intensive raising systems can feature a higher index of aggressive social interactions, because the individual space violation (Broom and Fraser 2010). Still according to the same authors, the individual space is the minimum distance that the animal preserves from others, being characterized by the minimum physical space so that they can perform basic movements (lying down, getting up, turn around, scratching, and standing). High-density systems has also influence on the cattle escape distance. According to Paranhos da Costa (2002), escape distance is the maximum space of approximation that an animal tolerates before of threats before their escape. Thus, to minimize these aspects it is necessary to adapt the capacity to preserve the individual space of each animal in order to ensure that all they have free access to the resources, mainly, water and food.

Beyond hierarchy relations, social behavior also includes positive aspects of interactions among animals that have good reflexes on the animal welfare. These interactions usually happen among cows with kinship or among animals that are always close. The main positive social behavior among dairy cows is the social licking. We believe that this practice has effects on psychological stability or simply on the cleanliness of other animal (Broom and Fraser 2010). In herds, where the cow and calf live, this practice is very common and called allogrooming. Heifers raised in a free stall system presents more social licking behavior compared to heifers in pasture systems (Tresoldi et al 2015). The total number of social interactions is also higher in free stall system, however, no difference is observed in social licking when expressed as a total number proportion of social interactions among treatments. The study revealed that this behavior occurred more frequently among heifers close one another.

Management aspects, feeding and milking time determine the behavioral pattern of cows within a dairy farm. The dairy cows'behavior can also be directly influenced by the technology level of the production system. As an example, cows in an automated milking system have the potential to define their milking time (Jacobs and Siegford 2012). The same authors pointed out that the traffic design system of the free stall shed influences the feeding behavior, the frequency and the milking number, as well as the maintenance time of standing animals. Another factor that can influence this time in free stall systems is the bedding quality and the floor type in the shed, which can develope diseases in the hooves and joints (Kara et al 2015). This situation can compromise the animal movement, causing pain and decreasing the welfare level.

This situation serves as an example that the behavior study as a diagnosing animal welfare is very important. This helps to detect situations to which animals are subjected, considering those that do not meet their basic needs, or causing pain and discomfort.

Animal welfare

The definition of animal welfare and the factors that influence it are large and have been discussed for some decades. The book Animal Machines, published by Ruth Harrison in 1964, opened an ethical discussion about the ill-treatment of confined animal in England (Weerd 2008). In 1965, due to the repercussion of the book denunciations, the British government created the Brambell Committee to discuss the matter. In the Brambell Report context, minimum conditions were proposed to ensure animal welfare (Brambell 1965). In 1979, the FAWC (Farm Animal Welfare Council) revised the codes proposed by the Brambell Report, giving rise to Five Freedoms that in 2009 were classified as: (1) freedom hunger and thirst, (2) freedom discomfort, (3) free ofpain, injury or illness, (4) freedom to express their

doi.org/10.31893/2318-1265jabb.v5n3p97-105

natural behavior, and (5) freeof fear and distress (FAWC 2009).

Donald Broom, in 1986, defined animal welfare as an individual condition on the attempts to deal with the environment. The individual state in relation to environment will depend on biological functioning (Broom 2011), which can be affected by unmet needs or frustrations. Situations of prolonged failure, to face a particular condition involving suffering, may result in frustration, and may lead to failures in growth, reproduction and even the animal death (Broom and Molento 2004). Biological functioning can be assessed by performance measures; however, it should not be used as the sole welfare indicator, because it does not fully meet its needs (Honorato et al 2012).

Duncan and Petherick (1991) defined animal welfare as being dependent only on their feelings. The authors' thesis was that animal welfare would be restricted only to their psychological, their mind and cognitive needs. In short, if mental needs are met, they would cover physical needs. The feelings study is a subjective way of evaluating animal welfare, and usually involves preference tests (Duncan 2005), which, in turn, depart from the logic that the animal choice will be made according to their feelings regarding to the environment, prioritizing their welfare.

However, in order to evaluate or measure animal welfare, one should consider as many factors as possible, since both the biological functioning and the animal feelings can cause reactions in situations or conditions to which the animal is being exposed. These concepts were and are very important not only from the point of view of animal welfare itself. They are also important for society's reflection on what animal welfare is, how animals should be treated, how to handle them, and the attitudes to be taken. These reflections were the starting point for the animals' rights to be considered by governmental organizations.

Currently, animal welfare is well disseminated and accepted by international organizations. The European Union has the most stringent standards of animal welfare. This organization has established laws and guidelines for the protection of all raising animals (EFESA 2016). The World Organization for Animal Health (OIE), in chapter seven of the Terrestrial Animal Health Code, describes guidelines for animal welfare. These recommendations include transportation timing, slaughter, animal use for research and education and specific recommendations for some animal species such as beef cattle and milk (OIE 2016).

Raising dairy cows presents several critical points regarding animal welfare. This can be positively or negatively affected by various factors, from social interactions with other animals, interactions with humans, management systems, nutrient supply and management, climate, environmental conditions and diseases (Honorato et al 2012).

In Brazil, most dairy herds have access to pasture, which potentially increases the welfare degree (Charlton et al 2011). In this situation, management practices should be adequate, prioritizing shade access for cows (Bond et al 2012). Deficiencies in shade features in pasture, and drinking water supply were common in three evaluated raising systems (extensive, semi-intensive and pasture) in the State of Santa Catarina, Brazil (Coast et al 2013). The study evaluated the management practices that influence the production and welfare in the milk activity. Mastitis, tick infestations, and lameness were diagnosed as the major health problems affecting animals.

In more intensive production systems, facilities and sanitary problems are common and closely related to the animal welfare level. High producing cows are more prone to metabolic problems, claudication, hoove diseases, reproductive failure, and mastitis incidence (Broom and Fraser 2010). These health problems may reduce the productive life of animals, especially in environmental conditions that do not offer safety and comfort.

The main problems encountered in raising dairy cows are related to the type of commercial exploitation. Sanitation problems are common to all systems, but the environmental impact is very important in this regard. Providing comfort to animals is the key point related to the environment, to improve the quality of life of production animals. Some alternative systems have great potential and should be considered in order to improve conditions for better animal welfare.

Compost bedded pack barns system

The confinement systems can compromise the welfare and dairy cows comfort due to limited space, hard surface, often covered with urine and feces. These factors predispose feet injuries, lameness, digital dermatitis and other hoove injuries. Housing systems with deeper beddings in the rest areas offer more comfort for the animals, mainly reducing the hoove injuries incidence (Klaas et al 2010). To reduce these problems, new systems have been developed to meet the demand for better conditions for high levels of welfare for cows.

The compost bedded pack barns (CBP) is an alternative loose housing confinement system for dairy cows (Eckelkamp et al 2016a), which allows animals more movement freedom and more comfort to lie down in a more natural way (Endres and Barberg 2007). This system provides greater longevity, a comfortable, dry and safe environment all year for cows (Damascene 2012). The installation consists of a shade, whose rest area is covered by a collective bedding, the feeding lane and drinking troughs being separated from the rest area by a wall or a lifting step (Ofner-Schröck et al 2015).

doi.org/10.31893/2318-1265jabb.v5n3p97-105

The success of CBP depends exclusively on proper bedding maintenance. For this to be ideal, the bedding should be revolved at least twice a day by means of a cultivator or scarifier at a depth ranging from 15 to 25 cm (Barberg et al 2007). This management is essential to avoid moisture accumulation, compaction and to incorporate oxygen into the bed, increasing the aerobic decomposition of the wastes and keeping the surface soft for the animals to lie down (Janni et al 2007). This author considers that the ideal temperature inside the bedding should be between 54 and 65 °C, thus enabling the composting of the material. As for bedding humidity, values between 40 and 65% are recommended for adequate composting (NRAES-54 1992).

The material commonly used for bedding in the compost bedded pack barns system is the dry wood shaving. However, in times of poor supply of this product, or even to reduce costs, other alternative materials can be used successfully. Shanne et al (2010a) conducted a study during the cold months in the United States to test four different types of bedding materials, including sawdust and pine shavings, corncobs, soybean straw and combinations of materials. The overall temperature of the bedding interior for all materials was 25,4 °C, which was higher in relation to the air temperature. This elevation in bedding temperature in relation to surface temperature represents the action of microorganisms decomposing organic matter. The authors have described that all well-managed materials have potential for use in the system. In conclusion, they emphasized that the ideal material for bedding in compost bedded pack barns system should be dry, processed with particle smaller than 2,5 cm in length and good water retention and absorption capacity.

Another issue that influences the management and bedding quality in the system is the animal density. The compost bedded pack barns should provide a dry and comfortable environment for the cows, space for all animals to lie down naturally, as well as allowing space for their locomotion. The ideal spacing of bedding area per animal is around 9,4 m^2, and for Holstein cows the minimum spacing should be 7,2 m^2 and for Jersey 6,2 m^2 (Endres 2009). Also according to the author, the greater spacing per animal will influence less bedding replacement.

In Israel, the recommendation for animal density is due to lower water retention capacity in moist climates (Klaas et al 2010). These authors recommended an area per animal of 15 m^2 if the feeding area is separated from the bedding and of 20 to 30 m^2 if the feeding area is also composed of bedding area. In this sense, it is worth mentioning that climatic conditions should be considered at the implementation time of a compost bedded pack barns system. In regions with a humid climate, a greater bedding space per animal should be considered in order to avoid the accumulation of moisture in it.

The microclimatic conditions of the compost bedded pack barns, in addition to influencing animal thermal comfort, are directly related to the quality of the bedding. In conditions of high relative humidity, an efficient ventilation system is required to help maintain the bedding at the appropriate humidity levels. Lobeck et al (2012) evaluated microclimatic and air quality aspects in a naturally ventilated CBP system in the state of Minnesota, USA. In relation to wind speed, the authors found average values of 0,5 and 0,93 m/s and average air temperatures of -3,8 and 20,7 °C in winter and summer, respectively. As for air humidity, mean values of relative humidity were 83% in winter and 72,2% in summer. The ammonia concentrations and hydrogen sulfide in the CBP shed were within the appropriate limits for the performance and health of both animals and humans.

A well-managed compost bedded pack barns system with adequate bedding management, good natural ventilation and an additional ventilation system have a high potential to provide welfare to confined cows. Improvements in mastitis, lameness and hygiene rates are the main benefits of the compost bedded pack barns in relation to animal welfare, according to the first studies in the system. In well-managed CBP systems, the mastitis index was 12% lower than the same herd initially housed in a free stall (Barberg et al 2007). In the same study, the detection rates of estrus and pregnancy presented values higher than 25,9 and 34,5%, respectively, in relation to the free stall. These higher values of estrus detection are linked to the lower rates of locomotion problems in cows, thus the animals can express the mounts behavior, being this one of the estrus identification forms in cattle.

Lobeck et al (2011), comparing three dairy cow housing systems, found that these housed in the CBP had a lower prevalence of lameness and hock injury, compared to free stall systems with ventilation and free stall naturally ventilated. However, in a more recent study, Eckelkamp et al (2016b) evaluated milk somatic cell count (SCC), hygiene score and lameness index of the animals between compost bedded pack barns system and free stall with sand bed. The authors concluded that the confinement systems evaluated did not present differences in SCC, welfare criteria, hygiene score and lameness.

Another aspect related to the animal welfare that the compost bedded pack barns system allows in a more natural way is the rest position. Cows in the CBP system spend more time in the lying position, and even when the animals remain standing, they spend more time on a less hard surface than the concrete floors of free stall sheds (Fregonesi et al 2007; Ofner-Schröck et al 2015). Endres and Barberg (2007) evaluated the dairy cows' behavior regarding the animals' positioning, the compost bedded pack barns system allowed the cows to lie down in all ways considered natural, with the head up, with the head on the ground, with the head back and

doi.org/10.31893/2318-1265jabb.v5n3p97-105

lying on their side. These authors also evaluated the social behavior of cows in CBP, but did not find differences in relation to other systems reports. In this way, it is possible to suppose that the CBP does not interfere negatively in relation to the cows housed behavior in this system.

In addition to the comfort and animal welfare aspects, a final aspect should be evaluated in CBP as a confinement system for dairy cows. The cost of system deploying, as well as the cost and availability of the bedding material, are of the utmost importance for the producers' decision on the choice of installation type. As for the initial investment, CBP has a lower implementation cost than the free stall system (Barberg et al 2007, Janni et al 2007). Although the CBP requires a larger area per animal, this system has fewer areas built with concrete flooring and the bed area is not divided into metal separation bays, thus reducing the initial investment. In a descriptive study, Shane et al (2010b) raised the approximate costs of building CBP sheds in the United States. One CBP to house 100 animals with a size of 23 x 46 m and a bedding area of 690 m^2, including 4 drinking fountains, cost approximately US $ 1400 per housed animal.

In Brazil, there are still no published studies about CBP costs. However, producers report that the deployment cost is lower than other systems. Moreover, CBP provides gains related to the bedding use in agriculture or its sale when it is partially removed to maintain the height between 30 and 120 cm.

Therefore, compost bedded pack barns can be considered as a viable alternative system for confining dairy cows without damage to health, behavioral aspects, providing more comfort and a welfare high level for dairy cows.

Final considerations

The compost bedded pack barns system has great potential to provide comfort and welfare for dairy cows. Good system management is required with regard to bed management aspects. The microclimatic conditions of the environment should be adequate to provide thermal comfort to animals and to maintain the bed at adequate moisture levels. However, more studies are needed mainly at the national level, to fill a lack of information, especially regarding the ideal management of the system in Brazil climatic conditions and in relation to cows' behavior in the system.

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