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ANIMAL PRODUCTION

Assessing different holding pen cooling systems through environmental variables and productivity of lactating cows

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ABSTRACT. This studyaimed to assess different holding pen climatization systems for dairy cattle through environmental variables, milk production and economic indexes. Sixteen lactating cows were used, distributed in a 4 x 4 Latin square design consisting of four groups of four animals, assessed in four periods, seven days each, and in four holding pen environments: SUN– external environment (in the sun), SHA– 80%-protection polypropylenemesh shading, SHA + SPR– 80% polypropylene mesh shading + water sprinkling, SHA + SPR + VEN – 80% polypropylene mesh shading + water sprinkling + ventilation. The animals remained for 30 minutes in their respective environments. In this period, environmental variables were collected using data loggers, and the milk produced, in kg, by each animal was subjected to the treatments. Fixed and variable costs were calculated for economic analysis. The SHA + SPR + VEN treatment presented itself as the best environment ($p < 0.05$), promoting an increase in the milk produced by the cows and in themonthly income, with 44 days for return on investment.

Keywords: ambience, economic viability, dairy cows.

Diferentes sistemas de resfriamento em sala de espera sobre variáveis ambientais e produtividade de vacas em lactação

RESUMO. Este trabalho foi conduzido com o objetivo de avaliar diferentes sistemas de climatização em sala de espera para bovinos leiteiros, através das variáveis ambientais, produção de leite e índices econômicos. Foram utilizadas 16 vacas em lactação, distribuídas em um delineamento quadrado latino 4 x 4, constituído de quatro grupos de quatro animais, avaliados em quatro períodos, de sete dias cada e em quatro ambientes de sala de espera: SOL – ambiente externo (ao sol), SOM –sombreamento de malha de polipropileno 80% de proteção, SOM + ASP – sombreamento de malha de polipropileno 80% + aspersão de água, SOM + ASP + VEN – sombreamento de malha de polipropileno 80% + aspersão de água+ ventilação. Os animais permaneciam por 30 minutos em seus respectivos ambientes. Neste período, foram coletadas as variáveis ambientais, com o uso de *data loggers*, e a produção de leite, em kg, de cada animal submetido aos tratamentos. Foram calculados os custos fixos e variáveis para análise econômica. O tratamento SOM + ASP + VEN apresentou-se como o melhor ambiente ($p < 0,05$) promovendo aumento na produção de leite das vacas e na renda mensal, verificando-se um prazo de 44 dias para o retorno do investimento.

Palavras-chave: ambiência, viabilidade econômica, vacas leiteiras.

Introduction

In recent years, with the improvement of animals of Dutch genetic composition, the latter have become more susceptible to caloric stress, derived mainly from a higher food intake and, consequently, a higher production of metabolic heat (Pergorer, Vasconcelos, Trinca, Hansen & Barros, 2007). Among the causes that influence the wellbeing of cows, microclimatic conditions are a relevant factor (Porto, D'Emilio & Cascone, 2017). In adverse environments, cows activate their thermoregulatory mechanisms seeking to dissipate heat, having as one of the effects the release of adrenaline, which decreases blood flow to the mammary gland and reduces milk ejection (Machado et al., 2011).

In this way, facilities have become a critical point for the success or failure of the dairy activity. When properly planned, they can provide a favorable environment for the animals to express their genetic potential; however, inadequate facilities, with high temperatures, cause thermal stress, especially in animals of European origins, resulting in lower milk production (Tosseto et al., 2014).

One of the critical points as to ambience within the dairy cattle production system is the holding pen, due to the agglomeration of animals and the production of heat, exposing them to an unfavorable environment (Collier , Dahl & Vanbaale, 2006).

Holding penclimatization presents favorable results. Silva, Pandorfi, Almeida, Guiselini and

Henrique (2011) verified a 3.66% increase in milk production as of the implementation of a climatization system with shading, ventilation and water sprinkling. Almeida, Pandorfi, Guiselini, Almeida and Morril (2010), in their turn, found an increase of 4.35% in the milk production of cows subjected to climatization with a similar system.

Nevertheless, to analyze the viability of a climatization system, the productive response alone is insufficient, because the adoption of costly measures to mitigate the effects of thermal stress can make its use unfeasible, especially when the number of animals in production is not enough to dilute, in the short term, the fixed costs of the technology adopted, and productivity gains are not sufficiently high to offset the investment (Cerutti, Bermudes, Viegas, & Martins, 2013).

Thus, this study aimed to analyze different holding pen climatization systems through environmental variables, their influence on productive responses and the economic viability of implantation.

Material and methods

The experiment (CEUA/PrP/UEG 008/2013) was carried out in a commercial property located in the municipality of Trindade-GO –16°S38'58", 49°W29'20"and 756 meters high. According to Cardoso, Marcuzzo and Barros (2014), the region has a Köppen climate classification of AW type (tropical wet), characterized by two well-defined seasons – rainy season (summer) and dry season (winter) –, average annual temperature of 23.2°C, average wind speed of 3.7 km h^{-1} and relative air humidity of 66%. The experiment was performed between October 13th and December 7th, 2014 (during spring), totaling 56 days.

The 4 x 4 Latin square design was adopted, with 4 groups of animals (G1, G2, G3, G4) randomly chosen, distributed in 4 experimental periods, 7 days each (P1, P2, P3, P4) and 4 treatments; thus, the four groups of animals were subjected to the four environments in different periods. Before each collection period, a 7-day adaptation period was defined.

The treatments consisted of four holding pen environments:

SUN - external environment, in full sun (witness);

SHA - polypropylene meshshading, with 80% protection;

SHA + SPR - polypropylene meshshading (80%) + water sprinkling;

SHA + SPR + VEN - polypropylene mesh shading (80%) + water sprinkling + ventilation.

Sixteen lactating cows were selected, of ⅞ Dutch + ⅛ Gir Leiteiro genetic composition, being homogeneous as to milk production (20 ± 5 kg), live weight (550 ± 50 kg), lactation stage (120 ± 40 days) and number of lactations (2 to 4).

The holding pen was built with dimensions of 12.00 x 4.90 m, and 3.5 m of ceiling height; polypropylene mesh was used as cover material, with 80% of solar radiation protection. The mesh was placed in two layers and fixed with plastic (nylon-like) clamps.

For the ventilation system, two fans were installed – one meter in diameter, air speed of 3 m s^{-1} in the south face of the holding pen, 2.5 meters high (measured from the center of the equipment), with a slope of 30° in relation to the vertical plane towards the floor.

The sprinkling system consisted of a PVC line measuring 25 mm, with 6 micro sprinklers, with a 1.2 mm nozzle andaverage flow of 66 l h^{-1}, with a distance of 2.40 m between the nozzles. The system was activated by a peripheral centrifugal pump connected to a 500-liter water tank.

The climatization system was activated when the temperature of the air or of the dry bulb was higher than 26°C; thus, during the experiment, the climatization system was only activated in the afternoon milking.

The groups that were in the SUN and SHA treatments were first taken to their respective environments. The SHA treatment animals were taken to the holding pen, and the SUN treatment animals were kept in an environment in the sun attached to the milking parlor, and after 30 minutes the two groups entered together into the milking parlor.

Subsequently, the animals in the SHA + SPR and SHA + SPR + VEN treatments were taken to the environment attached to the holding pen. The SHA + SPR group entered the holding pen where, then, the sprinkler system was activated. The second group waited until the 30-minute climatization time of this treatment was completed. Afterwards, the SHA + SPR + VEN group was placed in the holding pen, where the ventilation system associated with the sprinkling was activated, for 30 minutes, after which they were sent to the milking parlor.

For collection of meteorological data, two HOBO ONSET® H21-002 data loggers were installed, one in the external environment and the other in the holding pen, recording the variables every minute. Each equipment was composed of four sensors: humidity and dry bulb temperature, wet bulb temperature, black globe temperature and wind speed sensor.

Production was measured daily during the experimental period in the afternoon and morning milking. To measure this variable, eight vacuum pressure gauges were used, with weighing capacity of up to 31 kg, connected to the milking system.

In the economic analysis, the costs and gains of the climatization process were extrapolated to 60 animals, which represented the total number of lactating animals at the property, and the direct cost methodology was established.

The fixed cost was calculated by the sum of the monthly depreciation, which in turn was determined by dividing the cost of the investment by the number of years of use of the structure and the equipment, and this value was then divided by twelve to obtain the monthly depreciation.

For variable costs, water costs were added, obtained by the mean flow rate of the six sprinklers, multiplied by the flow time to climatize the entire herd during the afternoon milking. Besides electric energy costs, calculated by estimating the average consumption of the pump that activated the sprinkler system, added to the consumption of the two fans.

For the revenue values of each climatization system, increase in milk production was quantified for each analyzed environment. These values were extrapolated to the total herd of the property, quantifying the gain in daily and monthly productivity, and multiplying by the average milk price during 2014, according to data from the *Centro de Estudos Avançados em Economia Aplicada* [Cepea] (2014).

Through the difference between the monthly cost and the revenue, the monthly net margin for the different climatization systems was obtained, and with these values the time of return on investment was calculated in days.

Data on environmental variables were subjected to analysis of variance by the F test and, when significant, the means were compared by the Scott-knott test, at a 1% significance. For milk production data, the means were compared by the Tukey test, at a 5% probability. The Sisvar 5.3 software was used for the analyses (Ferreira, 2011).

Results and discussion

Statistical differences were found between treatments ($p < 0.01$) for environmental variables during the afternoon milking (Table 1). The SUN and SHA environments did not differ statistically from each other; however, there was a decrease in the DBt (°C) of numerical order as to the SHA treatment in relation to the SUN environment.

The SHA + SPR and SHA + SPR + VEN systems reduced the DBt (°C) values to below the upper limit of the thermoneutrality zone, which, according to Perissinoto and Moura (2007), is close to 26°C, with its lower limit being 22°C. Similar reductions were found by Almeida et al. (2010), who reported average DBt values of 24.3°C for 30 minutes of climatization with misting plus ventilation.

Table 1. Means of environmental variables: dry bulb temperature (DBt), relative air humidity (%) and black globe temperature (BGt) in the afternoon milking period, with the respective coefficients of variation and statistical probabilities.

Climate Variables	Treatments					
	SUN	SHA	SHA + SPR	SHA + SPR + VEN	C.V. (%)	Prob. F
DBt (°C)	27.55 a	26.60 a	22.83 b	22.32 b	13.18	0.0001
RU (%)	67.17 a	68.29 a	87.95 b	89.53 b	19.20	0.0001
BGt (°C)	31.15 a	28.73 b	23.71 c	22.54 c	15.54	0.0001

SUN – External environment; SHA – Shading; SHA + SPR – Shading + sprinkling; SHA + ASP + VEN – Shading, sprinkling and ventilation. Means followed by different letters in the lines differ from each other by the Scott-knott test ($p < 0.01$).

Relative air humidity showed the opposite behavior compared to DBt. In the treatments that used climatization with water, RU was high, withgreater values than those considered ideal for dairy cattle – 70% (Nääs & Arcaro Junior, 2001). However, considering the total time of climatization of 30 minutes, this factor alone was not able to compromise the performance of the animals.

BGt values (°C) confirm the efficiency of shading in reducing the radiation received by the animals, being the only variable with a significant difference between the SUN and SHA environments, corroborating Souza et al. (2010), who also verified this reduction in BGt with the use of shading in the afternoon, reporting a reduction from 35 to 29°C.

The SHA + SPR and SHA + SPR + VEN environments did not show any differences between each other, but differed from the others, SUN and SHA, causing reductions of 7.44 and 8.61°C in the BGt in relation to the SUN environment; and 5.02 and 6.19° C in relation to SHA, respectively. This reduction placed the BGt values within the limit values of the thermal comfort zone proposed by Rodrigues, Souza and Pereira Filho (2010), which are between 7 and 26°C. Arcaro Junior et al. (2003), assessing the effect of sprinkling plus ventilation in the holding pen, compared to the non-climatized holding pen, verified a reduction in DBt from 27.49°C in the control environment to 22.94°C in the environment with sprinkling and ventilation, while the BGt values were 27.55 and 22.49°C, respectively.

Table 2 shows the effect of each holding pen environment on milk production in the morning and afternoon, as well as total production. There was no significant difference between treatments for milk production in the morning; however, a numerical difference was observed, which may be related to the effects of climatization in the afternoon. The animals that underwent SHA + SPR + VEN treatment had an increase in daily milk production of 0.04, 0.51 and 0.84 kg animal^{-1}, compared to the animals in the SHA + SPR, SHA and SUN treatments, respectively, in the morning.

Table 2. Means of daily milk production, in animal kg^{-1}, in the different treatments, with the respective coefficients of variation and statistical probabilities.

Milk production	Treatments					
	SUN	SHA	SHA + SPR	SHA + SPR + VEN	C.V. (%)	Prob. F
Morning (Kg)	11.88	12.21	12.68	12.72	23.38	0.089
Afternoon (Kg)	8.41 b	8.58 b	8.93 ab	9.45 a	25.25	0.002
Total (Kg)	20.29 b	20.80 ab	21.61 ab	22.18 a	22.07	0.013

SUN - Environment in the sun; SHA - Shading; SHA + SPR - Shading plus sprinkling; SHA + SPR + VEN - Shading, sprinkling and ventilation. Means followed by different letters in the lines differ from each other by the Tukey test ($p < 0.05$).

However, in the afternoon, there was significant difference ($p < 0.05$) favorable to the SHA + SPR + VEN system in relation to the SUN and SHA treatment, which reflected in the total milk production. The SHA + SPR + VEN treatment showed an increase in production, during the afternoon milking, of 0.52, 0.87 and 1.04 kg animal^{-1}, compared to the SHA + SPR, SHA and SUN environments, respectively.

As for total milk production, the SHA + SPR + VEN system provided an increase in average production of 1.89 kg animal^{-1} day^{-1} (9.3%) compared to the non-climatized environment. Almeida et al. (2013), using a misting system for 30 minutes, reported an increase of 0.77 kg animal^{-1} day^{-1} (4.3%) compared to the animals subjected to an environment without climatization.

Comparing the SHA + SPR + VEN system with the SHA environment, there was an increase in total milk production of 6.6% (1.38 kg animal^{-1} day^{-1}). Arcaro Junior et al. (2003) found an increase of 3.4% (0.73 kg animal^{-1} day^{-1}) comparing the same systems. Silva et al. (2002), assessing the misting system plus ventilation in holding pen, observed an increase of 7.28% in total production, compared to the non-climatized environment.

In the present study, the SHA + SPR system promoted an improvement in total milk production of 6.5% in relation to the SUN environment, which accounts for 1.32 kg animal^{-1} day^{-1} more in production. Cerutti et al. (2013), assessing the productive response of Dutch-breed animals to the sprinkling system in holding pen found a growth of 12.4% for the animals subjected to this system.

Tresoldi, Schütz and Tucker (2016),working with Dutch cows and different cooling times, using high-flow sprinklers (0, 0.5, 1.5, 3 and 13 min., flow of 4.9 L min^{-1}), verified cooling benefits, as well as changes in air temperature, more pronounced when water was sprinkled for longer (over 13 min.); thus, the determination of adequate sprinkling strategies, such as climatization time, can improve the efficiency of heat loss and water use.

Avendaño-Reyes et al. (2012) as well, working with Dutch cows and different cooling times, with misting and ventilation, in pre-milking (1, 2 and 4 hours), found greater milk production in cows cooled in the morning and afternoon, totaling 4 hours of misting, compared to the 1h-cooling group, in the morning (18.7 vs 17.4 kg, respectively).

Contrasting these results, Pinheiro et al. (2005) did not find significant differences comparing the holding pen environment that had sprinkling and ventilation with the non-climatized environment; however, there was a numerical difference favorable to the air-conditioned environment of 0.56 kg animal^{-1} day^{-1}. This fact was justified by the low productive potential of the cows used in the study, as well as a likely higher heat tolerance and a milder environment compared to the present study.

Table 3 displays the calculation of the costs for assembling the climatizedholding pen.

Table 3. Calculation of expenses for building a climatized holding pen.

Holding pen				
Surveyed Materials	Price (unit)	Unit	Quant.	Total
Steel tube	45.00 BRL	bar	10	450.00 BRL
Hardened structural U-shaped profile	75.00 BRL	bar	13	975.00 BRL
Shade cloth 80% (4 mts)	4.52 BRL	meters	34	153.68 BRL
Manpower	-	-	-	1,000.00 BRL
Other				142.25 BRL
Subtotal 1				2,721.18 BRL
Sprinkling system				
Surveyed materials	Price (unit)	Quantity	Unit	Total
Peripheral engine	192.00 BRL	1	unit	192.00 BRL
Electric material	-	-	-	21.55 BRL
Manpower	-	-	-	250.00 BRL
Water tank	179.00 BRL	1	unit	179.00 BRL
Hydraulic material	-	-	-	182.50 BRL
Subtotal 2				825,05 BRL
Ventilation system				
Surveyed materials	Price (unit)	Quantity	Unit	Total
Fan	504.02 BRL	2	unit	1,008.04 BRL
Electric material	-	-	-	21.55 BRL
Manpower				250.00 BRL
Subtotal 3				1,279.59 BRL
Total				*4,825.82 BRL*

For the SHA treatment, it was necessary to consider only expenses related to the construction of the holding pen, which amounted to 2,721.18 BRL. For the SHA + SPR treatment, the expenses with the construction of the holding pen were considered, added to the sprinkler system, generating a total cost of 3,546.23 BRL. The SHA + SPR + VEN environment considered the expenses with the assembly of the holding pen, sprinkler system and ventilation system, generating a total cost of 4,825.82 BRL.

For revenue analysis, the monthly cost of each climatization system was calculated first (Table 4), which is the sum of the fixed cost (equipment depreciation rate) and the variable cost (sum of necessary water and energy costs for the climatization of the whole herd).

Table 4. Increment in variable costs due to the insertion of different climatization systems.

Treatments	Monthly cost		
	Fixed (BRL)	Variable (BRL)	Total
SHA	45.34 BRL	BRL	45.34
SHA + SPR	57.30 BRL	7.12 BRL	64.42
SHA + SPR + VEN	78.44 BRL	21.36 BRL	99.80

Table 5 shows the revenues generated with the implementation of each climatization system. The difference in the average daily production, in liters, of the SUN treatment in relation to the other systems was used to estimate the increase in production generated by each treatment. First, production was converted from kg to liters, considering the average milk density of 1.04 g mL^{-1}. The average individual increase was multiplied by 60 (number of lactating animals), which resulted in the average daily production increase of the herd and, subsequently, the monthly production increase. This amount was multiplied by the average milk price in 2014.

Table 5. Analysis of the revenue increase provided by the different holding pen climatization systems, for a herd of 60 animals.

	Climatization effect on revenue		
	SHA	SHA + SPR	SHA + SPR + VEN
Increase in production (l)	0.49	1.27	1.82
Total herddaily gain (l)	29.40	76.20	109.2
Total herd monthly gain (l)	896.70	2,324.10	3,330.60
Average R$ 2014	1.04 BRL	1.04 BRL	1.04 BRL
Month monetary value	932.56 BRL	2,417.06 BRL	3,463.82 BRL
	SHA	SHA + SPR	SHA + SPR + VEN
Month revenue	932.56 BRL	2,417.06 BRL	3,463.82 BRL
Month cost (fixed + variable)	45.34 BRL	64.42 BRL	99.80 BRL
Monthly net margin	887.22 BRL	2,352.64 BRL	3,364.02 BRL
Daily profit	29.08 BRL	77.13 BRL	110.29 BRL
Initial investment	2,721.18 BRL	3,546.23 BRL	4,825.82 BRL
Total days for return	93 days	46 days	44 days

By decreasing fixed and variable cost values, by the monthly revenue, the monthly net margin was obtained, which was divided by 30.5 to obtain the daily profit. By dividing the value of the initial investment by the daily profit, the number of days for return on investment was obtained.

The treatment that obtained the shortest time for return on investment was SHA + SPR + VEN, with a period of 44 days. Almeida et al. (2010), assessing a holding penclimatization system by misting, obtained a time of 58 days for return on investment. Silva et al. (2011), in turn,observed a better result with 40 minutes of misting climatization, reporting 43 days for return on investment.

Conclusion

Compared to the environment without climatization, all the others had some gain over environmental variables. Polypropylene mesh shading (80%) improves the environment; however, its isolated use is not enough to reach comfort situations for lactating cows.

Cooling systems that use water sprinkling are more efficient in reducing values of environmental variables, also promoting increases in total milk production.

The system that provided greater economic profitability was the one that combined shading with sprinkling and ventilation, resulting in greater increase in monthly revenue and less time of return on investment.

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