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Behavior and wear of the hooves of confined sheep in different types of floors

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ABSTRACT: The objective of this work was to evaluate the thermal environment, the surface temperature of the floor, wear of the hooves, ingestive behavior, and the productive performance of Santa Inês sheep, confined in facilities with individual pen, with three types of floor (masonry, rubber, and sand). The research was developed in the dry period in the Brazilian Semiarid region, using 18 females with 120 days of age and weighing 21.33 ± 2.62 kg. It was used a completely randomized design with three treatments and six replications. A 3 × 4 factorial was used for the surface temperature, with three types of floor and four collection times, applying the Tukey test at 5% probability and regression analysis by the SAS software. For the morphometric measures, ingestive behavior, and performance of the animals, the Tukey test at 5% was applied through the PROC GLM, and the continuous behavioral measures had their frequencies compared by the Chi-square test at the level of 5% through the PROC FREQ. The sand floor had the highest surface temperature concerning the other floors, regardless of the time. The animals kept on the masonry floor had a reduction of 6.17 and 5.56 cm in the upper length of the front hull and a reduction of 3.37 and 3.36 cm in the rear hull, respectively. The ingestive behavior and performance of the animals (90 g animal^{-1} day^{-1}) were not affected by the type of floor used.

Key words: animal welfare; rural buildings; Santa Inês; thermal comfort

Comportamento do desgaste dos cascos de ovelhas confinadas em diferentes tipos de pisos

RESUMO: Objetivou-se com este trabalho avaliar o ambiente térmico, a temperatura superficial do piso, o desgaste dos cascos, o comportamento ingestivo e o desempenho produtivo de ovinos Santa Inês, confinados em instalações com curral individual, com três tipos de piso (alvenaria, borracha e areia). A pesquisa foi desenvolvida no período de seca no Semiárido brasileiro, utilizando 18 fêmeas com 120 dias de idade e peso de 21,33 ± 2,62 kg. O delineamento experimental foi inteiramente casualizado com três tratamentos e seis repetições. Foi utilizado um fatorial 3 × 4 para a temperatura superficial, com três tipos de piso e quatro tempos de coleta, aplicando-se o teste de Tukey a 5% de probabilidade e análise de regressão pelo software SAS. Para as medidas morfométricas, comportamento ingestivo e desempenho dos animais, foi aplicado o teste de Tukey a 5% por meio do PROC GLM, e as medidas comportamentais contínuas foram comparadas pelo teste Qui-quadrado ao nível de 5% por meio do PROC FREQ. O piso de areia apresentou a maior temperatura superficial em relação aos demais pisos, independente do tempo. Os animais mantidos no piso de alvenaria tiveram redução de 6,17 e 5,56 cm no comprimento superior do casco dianteiro e de 3,37 e 3,36 cm no posterior, respectivamente. O comportamento ingestivo e o desempenho dos animais (90 g animal^{-1} dia^{-1}) não foram afetados pelo tipo de piso utilizado.

Palavras-chave: bem-estar animal; edificações rurais; Santa Inês; conforto térmico

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Introduction

The environmental conditions in which sheep are kept can interfere with their behavior, productive performance, and the morphometry of some parts of their body (Lima et al., 2013). Creole sheep, such as the Santa Inês breed, are animals adapted to the Brazilian semiarid climate and tolerant to high temperatures (Silva Filho et al., 2013; Furtado et al., 2017; Silva et al., 2018). The air temperature of 26 °C and relative humidity of 65% can be considered the comfort zone for sheep (Eustáquio Filho et al., 2011; Furtado et al., 2020). When kept within this range, animals can maximize their production (Souza et al., 2012; Lima et al., 2017).

Thus, it is noticeable that the thermal environment exerts a strong influence on animal performance, o it affects the heat transfer mechanisms and, thus, the regulation of the thermal balance between the animal and the environment. Therefore, the thermal environment represents a restriction factor for maximum production efficiency, especially in intensive systems, where sometimes the animal is prevented from using specific adaptive behavioral responses (Perissinotto et al., 2007). The intensive production system is widely used in order to improve production (Muñoz-Osorio et al., 2017), being necessary to have facilities with appropriate space; adequate ventilation; trough and individual drinking fountains avoiding competition, in addition to comfortable floors, ensuring adequate rest, comfort and well-being for the animals (Lopes Neto, 2017; Azevedo et al., 2020).

The floor and its surface temperature interfere in the exchange of sensitive heat between the animal and the floor. Thus, floors with high temperatures can interfere with the ingestive behavior and performance of the animals, causing them to have more significant movement and increase water consumption. Therefore, the use of alternative materials on the floor of the pens is viable as long as they do not interfere with the comfort, production, and productivity of the animals (Blowey & Edmondson, 2010; Teixeira et al., 2013).

Construction materials can be simple or composite, obtained directly from nature (e.g., stone, sand) or industrial origin (e.g., cement, tile). The knowledge allows one to choose the most suitable for each situation. The solidity, durability, cost, and beauty (finish) of the works depends mainly on its correct use (Novais, 2014). For example, hard and rough floors can cause changes in the conformation of the hooves and the dynamics of animal locomotion, favoring the occurrence of diseases (Van Der Tol et al., 2004). The sand floor is considered a non-slip material, avoiding risk to the animal (Cook et al., 2004). However, they can store more moisture due to the accumulation of urine and feces and, because they are abrasive materials, they can cause injuries to the animals hooves (Carvalho et al., 2021). Rubber flooring, on the other hand, can be used on floors, as long as periodic cleaning is performed (Cook, 2009; Blowey & Edmondson, 2010), its coefficient of friction and compressibility being high, allowing the animals to walk with fewer steps (Telezhenko & Bergsten, 2008).

The central hypothesis of the work is that the material used on the floor of the stalls influences the floor temperature, performance, behavior, and the animals' hooves. Thus, the objective of this study was to evaluate the thermal environment of the facilities, the surface temperature of the floor, wear of the hooves, ingestive behavior, and the productive performance of Santa Inês sheep confined in facilities with three types of floor.

Materials and Methods

Experimental site

The experiment was carried out at the Estação Experimental farm of the Instituto Nacional do Semiárido, municipality of Campina Grande, PB, Brazilian semiarid region, geographic coordinates of 07° 13' 51'' S and 35° 52' 54'' W. According to Koppen, the region's climate is As, characterized by a tropical climate with dry summer, with short periods of rain, irregularly distributed, and prolonged droughts. The average annual temperatures in the region are around 22.9 °C and average 765 mm year^{-1} rainfall.

Animals and management

The Research Ethics Committee approved the procedures performed in this study of the Universidade Federal de Campina Grande (Protocol n. 105/13).

Eighteen black-haired female Santa Inês sheep were used, with an average age of 120 days, an average weight of 21.33 ± 2.62 kg, kept in individual pens, vaccinated, and dewormed. The animals were weighed at the beginning, and the end of the experiment, and the values were divided by the 75 days of the experimental period to perform the daily weight gain.

Of these 75 experimental days, 15 were used for the adaptation phase of the animals and 60 days for data collection, carried out from November to January, which comprise the dry period of the year in the Brazilian semiarid region.

The animals were kept under intensive care during the experimental period, and the diet was supplied with a roughage: concentrate ratio of 50:50 to provide a gain of 250 g day^{-1}, as recommended by the NRC (2007).

The experimental diet consisted of chopped elephant grass and concentrate composed of corn meal, soybean meal, urea, mineral mixture, and calcium in the proportions of 580, 380, 10, 20, and 10 g kg^{-1} of dry matter. The mineral mixture (per kg) is composed of P = 70 g; Ca = 140 g; Na = 148 g; S = 12 g; Mg = 1320 mg; F = 700mg; Zn = 4,700 mg; Mn = 3.690 mg; Fe = 2,200 mg; Co = 140 mg; I = 61 mg; If = 15 mg; monensin sodium = 100 mg.

The animals were fed a complete mixture twice a day (7:30 a.m. and 4:30 p.m.), with feed provided and the leftovers weighed daily to calculate the voluntary intake and readjustment of the amount offered, establishing 10% of the leftovers based on dry matter. Water was offered daily to each animal using 5 L buckets placed beside the feeding stalls.

Installation characterization

The installation is 24 m long, 12 m wide, and has a ceiling height of 3.00 m, arranged in an East-West direction, and a roof composed of fiber cement tiles with a 27% slope. Each bay was 1.77 × 1.13 m in length and width, respectively, totaling 2.00 m^2 of covered area with a masonry floor.

In the experimental area, three types of floors were used, masonry, rubber, and sand, randomly distributed in the installation. The rubber floor was made of pre-existing masonry material, using 0.5 cm thick rubber, added with a thickness of 10 cm over the pre-existing floor for bays with a sand floor. In addition, each pen was provided with a wooden and plastic drinking trough to provide water and food ad libitum.

Collection of climate variables

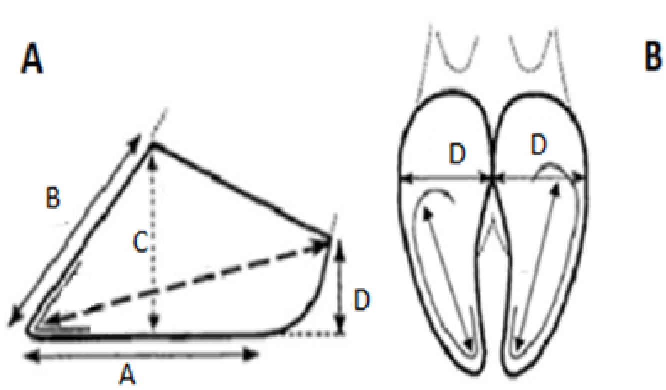
The climatic variables air temperature (AT) and relative humidity (RH) were collected and stored by a meteorological station of the Instituto Nacional do Sermiárido - INSA. The system was programmed to perform a daily collection of climate data at 1-hour intervals.

Floor surface temperature

The floor's surface temperature was obtained with the aid of a laser thermometer (Minibar MT-350, São Paulo, Brazil), at a distance of 10-50 cm, positioned at the ends of the floor and the geometric center of the bay, and subsequently obtained. The average surface temperature of the bay, with the collection being carried out twice a week, at 8:00 a.m., 11:00 a.m., 2:00 p.m., and 5:00 p.m.

Hull evaluation

For hoof evaluations, each animal's thoracic and pelvic locomotor limbs were used, and the animals were examined by treatment and submitted to an analysis of the locomotor limbs of both antimeres (Figure 1). The morphometric measurements were obtained with the aid of a digital caliper (Starrett, 799 series), with 150 × 0.01 mm, being analyzed (cm) the variables, front and rear lower and upper length, front and rear width, and front and rear thickness.



Source: Adapted from Lima et al. (2013).

Figure 1. Schematic representation of digital morphometry in sheep. (A) lower hull length (COMINF); (B) upper hull length (COMSUP); (C) width (WID); and, (D) bead thickness (ESPES).

Behavioral assessment

For the ingestive behavior of the animals, all animals were evaluated by type of floor, with four direct visual assessments being carried out within 24 hours (8:00 a.m. to 08:00 a.m), with an interval of 10 minutes, following Carvalho methodology (Carvalho et al., 2008). Variables were evaluated: ruminating (chewing, the index finger in the mouth), idleness (standing without any behavior, movement), eating (taking the food from the trough), and drinking (water being swallowed).

Statistical analysis

The treatments were distributed in a completely randomized design (DIC), consisting of three treatments (masonry, rubber, and sand) and six replications, and the data obtained were evaluated by analysis of variance (ANOVA).

The surface temperature was collected as a function of treatments and times of day in a 3 × 4 factorial, with three types of floor: masonry, rubber, sand, and four collection times: 8:00 a.m., 11:00 a.m., 2:00 p.m., and 5:00 p.m. The averages were compared by Tukey test at 5% probability through PROC GLM (General Linear Model) and regression analysis through PROC REG of SAS® (SAS, 2002).

Morphometric measures, ingestive behavior, and animal performance had their averages compared by t-test at 5% probability through PROC GLM (General Linear Model) (SAS, 2002).

Results and Discussion

The daily averages of air temperature showed fluctuations, reaching their maximum value (31.4 °C) between 1:00 p.m., 02:00 p.m. and minimum (22.1 °C) at 02:00 a.m. and 05:00 a.m. The relative humidity of the air, in turn, had a maximum value (91.9%) at 5:00 a.m. and a minimum value (46.5%) at 2:00 p.m. Furthermore, it is observed that there is a decrease in RH (Figure 2). This thermal amplitude, typical in semiarid regions, requires the animals to adapt to this oscillation, interfering with their behavior and production.

During the hottest times of the day, the AT was above the thermal comfort zone for sheep, which should be below 26 °C, while the RH, in turn, was below the recommended 65% for

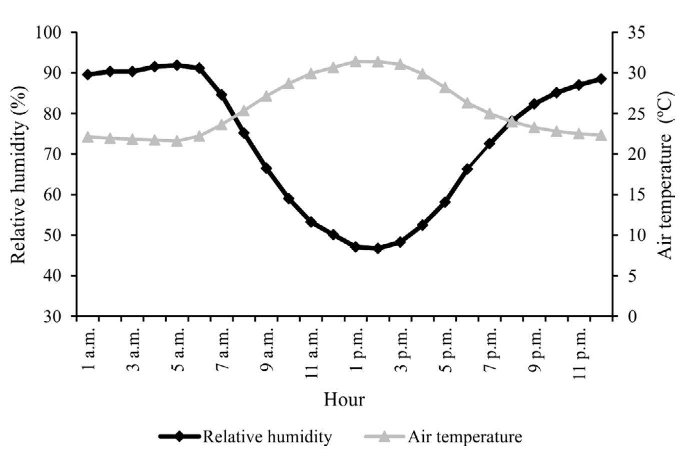


Figure 2. Average values of air temperature and relative humidity during the evaluated times.

Santa sheep. Inês (Eustáquio Filho et al., 2011; Furtado et al., 2020). High AT values associated with a low RH were observed by Nobre et al. (2016), Furtado et al. (2017), Dantas et al. (2019), and Furtado et al. (2020) in research in the semiarid region.

High temperatures, low RH, and direct solar radiation are factors that can cause thermal discomfort in sheep, forcing them to adopt physiological and behavioral measures to maintain themselves in homeotherm, which can cause a reduction in productive performance (Furtado et al., 2017; Torres et al., 2017; Furtado et al. 2020).

The floor's surface temperature was significantly influenced ($p < 0.05$) by the type of floor, schedules, and an interaction between the schedules and floors was observed, where the TS showed a quadratic regressive effect. The masonry floor had a minimum surface temperature at 8:00 a.m. (25.24 °C) and a maximum value at 2:00 p.m. (28.85 °C) with no statistically significant difference between 8:00 a.m. and 11:00 a.m., as well as between 2:00 p.m. and 5:00 p.m. (Table 1).

Masonry floors had a lower average TS at all times of the day, except at 5:00 p.m., demonstrating that it stores the heat acquired during the day for a longer time compared to other materials used.

The rubber flooring, on the other hand, had a minimum surface temperature value at 8:00 a.m. (25.66 °C) and a maximum value at 2:00 p.m. (29.38 °C) with no statistically significant difference between the hours of 8:00 a.m. and 5:00 p.m., as well as between 11:00 a.m. and 2:00 p.m.

The rubber floors had an average TS higher than the masonry floor at all times, except at 5:00 p.m., when temperatures are milder, demonstrating the material's cooling capacity with the AT decline, providing greater exchange conditions thermal during the cooler hours of the day.

While the sand floor had a minimum surface temperature at 8:00 a.m. (25.95 °C) and a maximum value at 2:00 p.m. (29.99 °C), but it did not present a statistically significant difference between the times evaluated. This floor had higher temperatures than the others at all times evaluated, given that it is a poor thermal conductor and can be influenced by the thickness of its layer and the existing moisture content (Alder et al., 2020).

The humidity from animal excreta increases moisture content and reduces thermal conductivity (Pedreira et al., 2014). When used for long periods, this type of floor can compromise the animals health (Alder et al., 2020), requiring constant changes and overloading the management.

The surface temperature of the sand floor showed the worst thermal performance compared to the others, possibly due to the presence of masonry underneath this material.

Contrary to what was obtained in this research, Cecchin et al. (2014) cite higher TS values for the rubber floor about the sand floor, which may be associated with the thermal properties of the material used NBR15220 (ABNT, 2005).

It is observed that the floor materials increased ±2 °C in the transition of temperatures from 8:00 a.m. to 11:00 a.m. and from 11:00 a.m. to 2:00 p.m., but at the mildest temperature of the day (5:00 p.m.), the rubber showed the fastest temperature decline (2.31 °C), followed by sand (1.98 °C) and masonry, the latter being the slowest material to lose heat, with a reduction of 0.93 °C.

Regarding the morphometric measurements of the sheeps hooves, the type of floor showed a significant difference ($p < 0.05$) only for the variables lower front hoof length and upper rear hoof length (Table 2).

The upper length of the front hull of the animals submitted to the masonry floor showed a reduction of 6.17 and 5.56 cm concerning the rubber and sand floor, respectively. While in the upper length of the rear hoof of the animals on the masonry floor, reductions of 3.37 and 3.36 cm were observed for the rubber and sand floor, respectively. The most extended top length observed in both variables was the rubber floor, considering that this is a softer material compared to masonry and less rough compared to sand, given that hard and rough floors can reduce the size and the thickness of the animals hooves, affecting their locomotion dynamics (Van Der Tol et al., 2004).

Among the variables of ingestive behavior of the evaluated animals, only water consumption was influenced by the type of floor in the stall (Table 3), being higher on the masonry floor and lower on the sand floor, with the rubber floor being similar to other floors, being justified by the slow

Table 2. Average and standard deviation of morphometric parameters of sheep hooves subjected to different types of floor.

Morphometric parameters (cm)	Types floor		
	Masonry	Rubber	Sand
Front hull			
Lower length	37.44±7.86	40.26±6.77	38.27±7.77
Width	28.06±11.46	30.42±11.78	29.19±12.05
Thickness	21.18±3.88	23.16±6.19	23.39±6.92
Top length	33.06±3.30b	39.23±5.89a	38.62±3.90a
Rear hull			
Lower length	35.15±7.43	34.78±7.63	35.93±6.24
Width	26.60±11.06	29.04±10.96	26.38±12.17
Thickness	21.25±5.24	20.91±5.22	20.85±4.74
Top length	33.28±3.10b	36.65±3.78a	34.64±2.42ab

Different letters on the line differ from each other by the t-test at the 5% probability level.

Table 1. Average and standard deviation of the surface temperature of the bones of the bays measured at four times of day.

Floors	Schedule			
	8:00 a.m.	11:00 a.m.	2:00 p.m.	5:00 p.m.
Masonry	25.24±0.81 Bb	27.16±0.80Bb	28.85±1.20Ba	27.92±0.89Ba
Rubber	25.66±0.88ABb	27.98±1.28Ba	29.38±1.32Ca	27.07±1.12Bb
Sand	25.95±1.09Aa	28.37±0.97Aa	29.99±1.74Aa	28.01±0.92Aa

Averages followed by the same uppercase letter in the column (between treatments) and lowercase in the row (between times) do not differ by Tukey test at the 5% probability level.

Table 3. Average performance and ingestive behavioral activities of Santa Inês sheep raised in pens with different floor types.

Variable (min day^{-1})	Floor types			SEM	p-value
	Masonry	Rubber	Sand		
Ruminating	440	400	358	77.66	0.3652
Idleness	683	780	740	75.92	0.2422
Feeding	273	273	280	44.66	0.9632
Drinking	45a	30ab	20b	10.00	0.0192

Different letters on the line differ from each other by the t-test at the 5% probability level; SEM = standard error of the average.

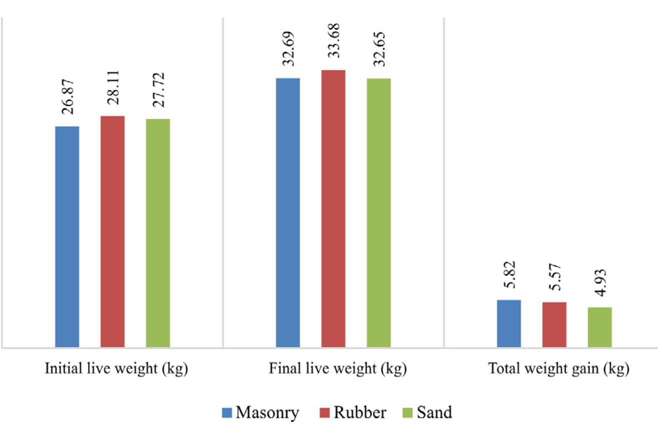
heat dissipation observed in the masonry floor throughout the day.

Even with the installations with sand floor showing higher TS, the demand for water of the animals in this type of floor was lower compared to the others, which the lower reflection can explain that this material provides, avoiding reflection and surface heating of the animals body, which had dark fur, reducing their surface temperature and peripheral vasodilation. Silva Filho et al. (2013) mention that animals from Santa Inês with white coats showed greater tolerance to heat compared to animals with brown and black coats.

Although there were changes in the surface temperature of the floors, this variation was not enough to modify the ingestive/interactive behavior of the sheep. Daily behavioral activities are influenced by food availability, adopted management, breed, and daytime (Aleena et al., 2016; Torres et al., 2017), and their changes can be characteristic of animals in stressful situations (Alder et al., 2020).

Rumination in sheep can vary from four to nine hours, depending on factors such as the nature of the diet, climatic conditions, and typology of facilities (Oliveira et al., 2015). For example, leisure activities can be associated with climatic factors, where at high temperatures, animals tend to stand still to avoid the formation of endogenous heat, to confinement, which reduces the movement of animals in search of food and water and diet, there is since in the present experiment they had low fiber contents.

The initial and final weight, and total weight gain were not influenced ($p < 0.05$) by the floor of the stalls (Figure 3).



Different letters differ from each other by Tukey test a 5% probability level.

Figure 3. Initial and final weight and total weight gain of Santa Inês sheep confined in pens with different floor types.

Even kept in environments considered stressful, with high temperature and low relative humidity, the sheep managed a daily weight gain of 90 g animal^{-1} day^{-1} and growing native sheep achieve good performance when kept in higher temperature ranges.

Conclusions

In the internal environment of the facilities, the air temperature during the hottest times of the day was above the thermal comfort zone for sheep and the relative humidity below that recommended.

The sand floor had the highest surface temperature compared to the rubber and masonry floor for most of the day

The animals showed minor hull wear on the rubber floor, considering that this is a softer material than masonry and less rough than sand.

The ingestive behavior and performance of the animals (90 g animal^{-1} day^{-1}) were not affected by the type of floor used.

A temperature increases of ±2 °C is observed between the floor materials in the transition of temperatures from 8:00 a.m. to 11:00 a.m. and from 11:00 a.m. to 2:00 p.m., but at the mildest temperature of the day (5:00 p.m.), rubber showed the fastest temperature decline (2.31 °C), followed by sand (1.98 °C) and masonry was the slowest material to lose heat, with a reduction of 0.93 °C

Compliance with Ethical Standards

Author contributions: Conceptualization: JHSC, JPLN, DAF; Data curation: JHSC, LFDS, RSN, JRM; Formal analysis: NLR; Funding acquisition: JHSC, DAF, GRM; Investigation: JHSC, LFDS, RSN, JRM; Methodology: JHSC, JPLN, DAF, NLR; Project administration: JPLN, DAF, GRM; Resources: JHSC, DAF, GRM; Software: NLR; Supervision: JPLN, DAF, GRM; Validation: JHSC; Visualization: JHSC, DAF, NLR; Writing – original draft: JHSC, DAF, NLR; Writing – review & editing: JHSC, DAF, NLR.

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Literature Cited

Alder, C.; Tiemann, I.; Hillemacher, S.; Schmithausen, A.J.; Muller, U.; Heitmann, S.; Spindler, B.; Kemper, N.; Buscher, W. Effects of a partially perforated flooring system on animal-based welfare indicators in broiler housing. Poultry Science, v.99, n.7, p.3343-3354, 2020. https://doi.org/10.1016/j.psj.2020.04.008.

Aleena, J.; Pragna, P.; Archana, P.R.; Sejian, V.; Bagath, M.; Krishnan, G.; Manimaran, A.; Beena, V.; Kurien, E.K.; Varma, G.; Bhatta, R. Significance of metabolic response in livestock for adapting to heat stress challenges. Asian Journal of Animal Science, v. 10, n.4, p.224-234, 2016. https://doi.org/10.3923/ajas.2016.224.234.

Associação Brasileira de Normas Técnicas - ABNT. NBR 15220: Desempenho térmico de edificações. Rio de Janeiro: ABNT, 2005.

Azevedo, H.H.F.; Pacheco, A.; Pires, A.P.; Mendonça Neto, J.S.N.; Pena, D.A.G.; Galvão, A.T.; Ferrari, E.D.M.; Almeida, B.V.F.; Batista, T.V.L.O.; Araújo, C.F.; Batista, W.L. Bem-estar e suas perspectivas na produção animal. PubVet, v.14, n.1, 2020. https://doi.org/10.31533/pubvet.v14n1a481.1-5.

Blowey, R.; Edmondson, P. Mastitis control in dairy herds. 2.ed. Cambridge: CAB International, 2010. 266p. https://doi.org/10.1079/9781845935504.0000.

Carvalho, G.G.P.; Pires, A.J.V.; Silva, R.R.; Veloso, C.M.; Silva, H.G.O. Ingestive behaviour of sheep fed with ammoniated or non-ammoniated elephant grass silage and agro-industrial by-products. Revista Brasileira de Zootecnia, v. 35, n. 4, suppl., p. 1805-1812, 2008. https://doi.org/10.1590/S1516-35982006000600031.

Carvalho, C.L.; Cavalcante, M.M.; Camargo, N.O.T.; Andretta, I. Bem-estar animal em suíno. In: Oelke, C. A. (Org.). Suinocultura e avicultura: do básico a zootecnia de precisão. São Paulo: Editora Científica Digital, 2021. Cap. 6, p. 90-115. https://doi.org/10.37885/210203348.

Cecchin, D.; Campos, A.T.; Pires, M.F.A.; Lima, R.R.; Yanagi Junior, T.; Souza, M.C.M. Avaliação de diferentes materiais para recobrimento de camas em baias de galpão modelo free-stall. Revista Brasileira de Engenharia Agrícola e Ambiental. v. 18, n. 1, p.109-115, 2014. https://doi.org/10.1590/S1415-43662014000100014.

Cook, N.B. Free-stall design for maximum cow comfort. WCDS Advances in Dairy Technology, v.21, p. 255-268, 2009. https://wcds.ualberta.ca/wcds/wp-content/uploads/sites/57/wcds_archive/Archive/2009/Manuscripts/FreeStallDesign.pdf. 25 Aug. 2021.

Cook, N.B.; Bennett, T.B.; Nordlund, K.V. Effect of free stall surface on daily activity patterns in dairy cows with relevance to lameness prevalence. Journal of Dairy Science, v.87, n.9, p.2912–2922, 2004. https://doi.org/10.3168/jds.S0022-0302(04)73422-0.

Dantas, N.L.B.; Souza, B.B.; Silva, M.R.; Silva, G.A.; Pires, J.P.S.; Batista, L.F.; Souza, M.F.; Furtado, D.A. Effect of the environment and diet on the physiological variables of sheep in the Brazilian semiarid region. Semina: Ciências Agrárias, v.40, n.2, p.971-980, 2019. https://doi.org/10.5433/1679-0359.2019v40n2p971.

Eustáquio Filho, A.; Teodoro, S.M.; Chaves, M.A.; Santos, P.E.F.; Silva, M.W.R.; Murta, R.M.; Carvalho, G.P.; Souza, L.E.B. Thermal comfort zone of Santa Inês sheep based on physiological responses. Revista Brasileira de Zootecnia, v.40, n.8, p.1807-1814, 2011. https://doi.org/10.1590/S1516-35982011000800026.

Furtado, D.A.; Carvalho Júnior, S.B.; Lopes Neto, J.P.; Souza, B.B.; Dantas, N.L.B. Adaptability of sheep to three salinity levels in different environments. Semina: Ciências Agrárias, v.41, n.1, p.285-294, 2020. https://doi.org/10.5433/1679-0359.2020v41n1p285.

Furtado, D.A.; Oliveira, F.M.M.; Sousa, W.H.; Medeiros, G.R.; Oliveira, M.E.C.; Veigas, R.R. Thermal comfort indexes and physiological parameters of Santa Inês and crossbreed ewes in the semi-arid. Journal of Animal Behaviour and Biometeorology, v.5, n.2, p.72-77, 2017. https://doi.org/10.31893/2318-1265jabb.v5n2p72-77.

Lima, E.M.M.; Borges, J.R.J.; Lima, F.B.; Silva, F.O.C.; Leonardo, A.S.; Barreto-Viana, A.R.C. Morfometria do casco de bovinos nelorados em diferentes sistemas de criação. Bioscience Journal, v. 29, n.2, p.412-418, 2013. http://www.seer.ufu.br/index.php/biosciencejournal/article/download/13568/12284/0. 25 Aug. 2021.

Lima, L.O.; Lima, R.M.A.; Castro, A.L.A.; Dias, F.J.S.; Dias, M. Influência da cor do pelame nos parâmetros fisiológicos e comportamentais de ovelhas da raça Santa Inês ao sol e à sombra. PubVet. v.11, n.8, p.744-753, 2017. https://doi.org/10.22256/pubvet.v11n8.744-753.

Lopes Neto, J.P. Construções e Instalações rurais. 1.ed. Brasília: NT Editora, 2017. 138p.

Muñoz-Osorio, G.A.; Aguilar-Caballero, A.J.; Sarmiento-Franco, L.A.; Wurzinger, M.; Gutiérrez-Reynoso, G.A. The effect of two housing systems on productive performance of hair-type crossbreed lambs in subhumid tropics of Mexico. Journal of Applied Animal Research, v. 4, n.1, p.384-388, 2017. https://doi.org/10.1080/09712119.2016.1200979.

Nobre, I.S.; Souza, B.B.; Marques, B.A.A.; Azevedo, A.M.; Araujo, R.P.; Gomes, T.L.S.; Batista, L.F.; Silva, G.A. Avaliação dos níveis de concentrado e gordura protegida sobre o desempenho produtivo e termorregulação de ovinos. Revista Brasileira de Saúde e Produção Animal, v.17, n.1, p.116-126, 2016. https://doi.org/10.1590/S1519-99402016000100011.

Novais, D. Instalações rurais. Barra da Estiva: Instituto Formação, 2014. 24p. http://www.ifcursos.com.br/sistema/admin/arquivos/13-35-34-apostilainstalacoesrurais.pdf. 10 Aug. 2021

National Research Council - NRC. Nutrient requeriments of small ruminants: sheep, goats, cervids, and new world camelids. Washington, DC: National Academic Press, 2007.

Oliveira, M.V.M.; Rufino Junior, J.; Romero, J.V.; Silva, D.C.G.; Luz, D.F.; Vargas Junior, F.M.; Fernandes, H.J.; Salla, L.E. Comportamento ingestivo de novilhas Pantaneiras mantidas em regime de confinamento. Revista Brasileira de Saúde e Produção Animal, v.16, n.3, p.688-698, 2015. https://doi.org/10.1590/S1519-99402015000300019.

Pedreira, B.C.; Pereira, D.H.; Pina, D. S.; Carnevalli, R.A.; Lopes, L.B. (Eds.). Anais do I Simpósio de Pecuária Integrada. Intensificação da produção animal em pastagens. Brasília: Embrapa, 2014. 294p. https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/1003374/1/cpamt2014pedreirariscoedafico.pdf. 18 Aug. 2021.

Perissinotto, M.; Moura, D. J.; Cruz, V. F. Avaliação da produção de leite em bovinos utilizando diferentes sistemas de climatização. Revista de Ciências Agrárias, v.30, n.1, p.135-142, 2007. https://doi.org/10.19084/rca.15388.

SAS Institute. SAS statistical software. Cary: SAS Institute, 2002.

Silva Filho, F.P.; Azevedo, M., Costa, L.A.B., Lana, A.M.Q., Ferreira, M.A., Batista, A.M.V. Heat tolerance index, food intake and weight gain of Santa Ines sheep in the agreste region of Pernambuco State, Brazil. Acta Scientiarum. Animal Science, v.35, n.3, p.307-310, 2013. https://doi.org/10.4025/actascianimsci.v35i3.18466.

Silva, V.C.; Lopes Neto, J.P.; Costa, J.H.S.; Furtado, D.A.; Miranda, J.R. Ethological behavior of created sheep in the sun and shade in the semiarid region of Paraiba state. Energia na Agricultura, v.33, n.4, p.338-344, 2018. https://doi.org/10.17224/EnergAgric.2018v33n4p338-344.

Souza, P.T.; Salles, M.G.F.; Araújo, A.A. Impacto do estresse térmico sobre a fisiologia, reprodução e produção de caprinos. Ciência Rural, v.42, n.10, p.1888-1895, 2012. https://doi.org/10.1590/S0103-84782012005000072

Teixeira, D.L.; Lama, G.C.M.; Pascual-Alonso, M.; Aguayo-Ulloa, L.; Villaroel, M.; María, G.A. A note on lamb´s choice for different types of beeding materials. Journal of Veterinary Behavior, v.8, n.3, p.175-179, 2013. https://doi.org/10.1016/j.jveb.2012.06.007.

Telezhenko, E.; Bergsten, C.; Magnusson, M.; Ventorp, M.; Nilsson, C. Effect of different flooring systems on weight and pressure distribution on claws of dairy cows. Journal of Dairy Science, v. 91, n. 5, p. 1874-1884, 2008. https://doi.org/10.3168/jds.2007-0742.

Torres, T.S.; Silva, L.O.; Borges, L.S.; Sena, L.S.; Moreira, A.L.; Machado, L.P.M.; Cardoso, J.P.B.; Sousa Júnior, A. Behavioral and thermoregulatory characteristics of Dorper Sheep. Journal of Animal Behaviour and Biometeorology, v.5, n.3, p.85-90, 2017. https://doi.org/10.31893/2318-1265jabb.v5n3p85-90.

Van der Tol, P.P.J.; Van der Beek, S.S.; Metz, J.H.; Noordhuizen-Stassen, E.N.; Bach, W.; Braam, C.R.; Weus, W.A. The effect of preventive trimming on weight bearing and force balance on the claws of dairy cattle. Journal of Dairy Science, v. 87, n. 6, p. 1732-1738, 2004. https://doi.org/10.3168/jds.S0022-0302(04)73327-5.