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Performance and carcass and meat quality of crossbred sheep confined with and without access to artificial shade

Desempenho e qualidade de carcaça e carne de ovinos mestiços confinados com e sem acesso ao sombreamento artificial

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ABSTRACT

The aim of this study was to evaluate the performance and carcass and meat quality of sheep in an intensive production system with and without artificial shade available. Twenty Santa Inês × Dorper crossbred lambs were allotted to two collective stalls, one of which was covered with a black polypropylene shade net with 80% light interception, providing 2.5 m² shade animal^{-1}. Performance was evaluated by measuring initial weight, final weight, carcass yield, average daily weight gain, and total weight gain. Carcass and meat traits were evaluated based on the variables of fatness, conformation, loin-eye area, subcutaneous fat thickness, marbling, texture, pH, temperature, and color. Performance and carcass and meat traits were similar between the animals reared in stalls with and without shade available. The groups with and without access to shade showed initial weights of 26.52 and 25.37 kg, final weights of 35.59 and 34.76 kg, carcass yields of 45.73 and 45.50%, loin-eye areas of 14 .11 and 13.61 cm², and marbling scores of 4.78 and 4.44, respectively. Subcutaneous fat thickness (2.02 cm), texture (3.67), and fatness (2) values were equal for both groups. Based on the results, artificial shading did not affect the performance or carcass and meat quality of the sheep.

Keywords: intensive system, *Longissimus*, thermal comfort

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RESUMO

Objetivou-se avaliar o desempenho, qualidade de carcaça e carne de ovinos em sistema intensivo de produção, com e sem disponibilidade de sombra artificial. Foram utilizados 20 cordeiros mestiços Santa Inês x Dorper, distribuídos em duas baias coletivas, onde em uma das baias foi implantado o sombrite de malha de polipropileno, na coloração preta, com 80% de interceptação luminosa, respeitando 2,5m² de sombra. animal^{-1}. No desempenho foi avaliado o peso inicial, peso final, rendimento de carcaça, ganho de peso médio diário e ganho de peso total. Para as características de carcaça e carne, foram observados o acabamento, conformação, área de olho de lombo, espessura de gordura subcutânea, marmoreio, textura, pH, temperatura e coloração. Foram observados valores semelhantes de desempenho e características de carcaça e carne entre os animais criados em baias com e sem acesso ao sombreamento. O peso inicial foi de 26,52 kg e 25,37 kg, peso final de 35,59 kg e 34,76 kg, com rendimento de carcaça de 45,73% e 45,50%, área de olho de lombo de 14,11 cm² e 13,61 cm², marmoreio de 4,78 e 4,44 para os animais com e sem sombreamento, respectivamente. Os valores de espessura de gordura subcutânea (2,02 cm), textura (3,67) e acabamento (2) foram iguais para ambos os grupos de animais. Pelos resultados obtidos, considera-se que o sombreamento artificial não interferiu no desempenho e qualidade de carcaça e carne ovina.
Palavras-chave: conforto térmico, *Longissimus*, sistema intensivo

INTRODUCTION

In addition to increasing profitability, the practice of feedlotting is aimed at allowing an earlier slaughter of animals and increasing their carcass fatness and improving meat quality. Small ruminants are animals that respond well to the intensive production system, but need care in terms of facilities, handling, food, and sanitation for this system to succeed.

The intensive rearing of lambs requires the use of animal breeds with good production ability to meet the market demands. In this respect, Oliveira et al. (2013) stated that selective breeding is essential as a strategy to improve carcass yield and quality and, therefore, crossbreeding should preferably involve breeds that encompass characteristics of productive efficiency and the ability to adapt to the region of production. Dorper sheep are largely used in crosses with the Santa Inês breed to generate progeny with productive efficiency and carcass quality.

To ensure the qualitative characteristics that consumers desire, there is a growing concern with developing sustainable production that does not harm the environment and advocates animal welfare (Leva et al., 2014). Aviez et al. (2018) argued that characterizing, knowing, and classifying the environment and the production system makes it possible to understand the capabilities, limitations, and threats in the development of the activity in the place.

Adaptability to the environment is an important factor when seeking greater thermal comfort for the animals, welfare in production, and productivity. Accordingly, shading reduces the thermal load, thereby decreasing the thermal discomfort caused by direct

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solar radiation to which animals are susceptible at certain times of the day.

The quality of carcasses and meat is determined through parameters such as morphometric measurements, conformation, fatness, color, pH, tenderness, juiciness, marbling, and texture (Marin, 2014).

In view of the foregoing, this study was developed to examine the influence of synthetic-polypropylene shading in the feedlotting of crossbred sheep on production performance and carcass and meat quality.

MATERIAL AND METHODS

Twenty Santa Inês × Dorper crossbred male sheep with an average live weight (LW) of 25 ± 5.48 kg (mean ± standard deviation) were divided into two collective stalls, with 10 animals in each. The experiment was developed in the feedlot of Fazenda Escola farm, State University of Goiás, located in São Luís de Montes Belos - GO, Brazil. All experimental procedures were approved by the Ethics Committee on Animal Use (CEUA) (case no. 001/2019).

The sheep were identified by numbered collars, weighed, dewormed, and finally sent to the feedlot. The experiment lasted 70 days, which included a 14-day period of adaptation to the diet and facilities.

The pens provided an area of 17.20 m²/animal. A black synthetic-polypropylene shade net with 80% light interception was implemented in one of the stalls in the north-south direction. The total shaded area was 25.5 m², corresponding to 2.5 m² of shade/animal.

Both treatment groups (with and without access to shade) received the same feeding management, which comprised a 20% crude protein concentrate based on ground maize, soybean meal, urea, and mineral mixture, supplied at the rate of 1.4% of LW, on a dry matter (DM) basis. On the first seven days, the animals received concentrate without urea, here called “Concentrate 1”. In the second week, urea was included in the diet, characterizing “Concentrate 2” (Table 1). The inclusion (% of LW, DM basis) was adjusted according to the animals’ intake, forcing consumption with caution regarding feed leftovers, which were weighed in the morning, before the first treatment of the day, to allow up to 5% orts.

Table 1. Percentage of inclusion of each ingredient in the sheep concentrate, divided into concentrate 1 and 2, according to the adaptation of the animals to the feeding management.

Ingredient	Concentrate 1	Concentrate 2
	%	%
Ground maize	55.5	72.5
Roasted soybean meal	38.0	22.5
Mineral mixture	6.5	4.0
Agricultural urea	0	1
TOTAL	100	100

The roughage was based on sorghum silage and constituted 40% of the diet, in the initial proportion of 2.0% LW (DM basis). It was supplied in troughs inside the pens, together with the concentrate, four times a day (at 07h00, 10h00, 13h00, and 16h00). Water was available *ad*

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libitum in a concrete drinker. The sorghum silage showed the following nutritional values: 32.0% DM, 8.3% CP, 68.4% TDN, 65.3% NDF, 48.0% ADF, and 1.7% EE.

For the production-related variables, the animals were weighed every 15 days and average daily gain (ADG) was calculated as the difference between their initial (IW) and final (FW) weights divided by the time in the feedlot in days.

After 70 days, the lambs were taken to the slaughterhouse, where they underwent a solid-feed deprivation period of 16 h prior to slaughter. Then, the animals were weighed (slaughter weight - SW) and the slaughtering process began, complying with the current rules of the Regulation for the Industrial and Sanitary Inspection of Animal Products - RIISPOA, and following the standard humane slaughtering and operational procedures of stunning by electronarcosis, bleeding, skinning, evisceration, and division of the carcass into half-carcasses.

Hot carcass weight (HCW) was determined after skinning and evisceration, where the head, feet, skin, tail, and testicles were removed (Osório et al., 2014). This variable was then used to calculate hot carcass yield (HCY = HCW/SW ×100).

Evaluations of carcass variables such as conformation, fatness, morphometric measurements, color, and pH; and meat variables such as loin-eye area (LEA), subcutaneous fat thickness (SFT), texture, marbling, and color, were carried out 24 h *postmortem*, inside the cold room, after the establishment of *rigor mortis*.

Conformation was assessed by the visual method, through a comparison of standards, by analyzing the shape as a whole and taking into account the different anatomical regions and thickness of the adipose and muscular planes relative to the size of the skeleton that supports them (Osório et al., 2014). This assessment involved the use of photographic standards adapted from Ministerial Ordinance No. 307 of December 26, 1990, of the Ministry of Agriculture, Livestock, and Supply (MAPA), which recommends the following scale of scores for sheep: 1 = bad or concave; 2 = regular or sub-concave; 3 = good or straight; 4 = optimal or sub-convex; and 5 = excellent or convex.

Fatness was evaluated by classifying the carcass as follows: 1 = fat absent; 2 = little fat (1 to 3 mm thick); 3 = medium fat (3 to 6 mm); 4 = uniform fat (6 to 10 mm); and 5 = excessive fat (above 10 mm) (Vaz et al., 2012).

In the left half carcass, the pH was measured between the 12th and 13th ribs with a digital pH meter. Then, a cross-section was made in the same region, thus exposing the *Longissimus dorsi* muscle, where LEA, SFT, texture, marbling, and muscle color were determined.

Loin-eye area (cm²) was measured by outlining the muscle on tracing paper, which was positioned over the muscle. The area was determined using graph paper, which was superimposed onto the tracing paper, by counting the number of squares within the muscle's drawn outline, considering each square of the paper one square centimeter (Osório et al., 2014).

Subcutaneous fat thickness was determined on the section of the *Longissimus dorsi* muscle, using a caliper at ¾ of the distal portion (Muller, 1987). The texture of the

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Longissimus dorsi muscle was analyzed visually and classified according to a scale of 1 to 5 with 0.5-point intervals, where 1 = very coarse; 2 = coarse; 3 = slightly coarse; 4 = thin; and 5 = very thin. This variable represented the thickness of fiber bundles in transverse form (Osório et al., 2014).

The degree of marbling was determined in a subjective assessment, following the method proposed by Muller (1987), which involved the use of a scale of 1 to 18 that represented the amount of intramuscular fat, through the muscle. Scoring was as follows: 1 to 3 = traces; 4 to 6 = light; 7 to 9 = little; 10 to 12 = medium; 13 to 15 = moderate; and 16 to 18 = abundant.

Color was measured objectively using a digital colorimeter operating in the CIELab system (International Commission on Illumination), in the hindquarter region and on the striploin, after exposing the muscle for 30 min in an oxygenated environment. Three color values were determined, namely, L* = lightness, which represents the water-holding capacity (the more water, the greater the L* value), expressed in percentage terms (0 for black to 100 for white); and a* and b* = ranges of color from red to green and yellow to blue, respectively. Because a* represents the intensity of red, the higher the value, the redder the meat. Likewise, b* represents the intensity of yellow, so the higher the value, the yellower the meat (Andrade et al., 2010).

The experiment was laid out in a completely randomized design with two treatments (with and without access to artificial shade) and ten replications. In the evaluations of production, the Shapiro-Wilk test was performed to evaluate normality; analysis of variance and the F test (5% significance level) and the Mann-Whitney test were applied for non-parametric variables, using R statistical software version 2.15.2.

RESULTS AND DISCUSSION

The average air temperature during the experimental period was 29.34 °C and 30.30 °C in the shaded and unshaded environments, respectively (Table 2).

Table 2. Temperature (T), relative air humidity (RH), and temperature-humidity index (THU) in the sheep feedlot with and without available shade

Environmental variable	Shade		p[1]	CV (%)[2]	SD[3]
	Available	Unavailable			
T (ºC)	29.34	30.30	0.2487	20.91	6.30
RH (%)	43.32	42.11	0.7658	44.95	19.20
THI	77.94	79.67	0.2587	9.06	7.14

[1] Probability value of F test in analysis of variance. [2] Coefficient of variation. [3] Standard deviation.

The temperature-humidity index (THI) values found in the shade and in the sun were 77.94 and 79.67, respectively. Leitão et al. (2013) observed a higher THI value, of 81.6, between 14h00 and 15h00, which characterizes that the sheep were in a situation of thermal stress alert. Costa et al. (2010) examined the adaptability of Santa Inês sheep and found a THI of 84.8, indicating that the small ruminants were under severe stress.

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Relative humidity (RH) averaged 43.3% in the shade and 42.1% in the sun, which are values below the 63.3 and 60.9%, respectively, found by Ferreira et al. (2011) in a study on the thermal comfort of Santa Inês sheep. Bezerra et al. (2011) investigated the environment for sheep in the semi-arid region of the state of Paraíba, Brazil, and observed that RH did not differ significantly between the morning and afternoon periods in the evaluated environment, averaging 60.5% in the morning and 51.83% in the afternoon. These values are within the ideal range for small ruminants, which is between 40 and 70%.

By comparing the climatic data found in the shade and in the sun, we observe that the average ambient temperature was 1 °C lower in the shade in contrast to full sun. The average THI was also reduced in the shaded environment and RH was 1% higher, which shows that, by mitigating direct sunlight, shading can reduce the thermal load that is transmitted to animals, thereby reducing the need for physiological efforts in the search for homeothermy.

Initial (IW) and final (FW) body weights, average daily gain (ADG), total weight gain (TWG), and carcass yield (CY) did not differ between the treatments (with and without shade) (Table 3). This result is explained by the fact that the animal breed used in this experiment is adequate or favorable to the environment in which it was introduced. The sheep were in thermal comfort conditions, since the environmental variables—with or without access to shade—were found within the normal range for the animals.

Table 3. Initial weight, final weight, total weight gain (TWG), average daily gain (ADG), and carcass yield of lambs confined with and without shade.

Production variable	Shade		p^1	CV (%)[2]	SD[3]
	Available	Unavailable			
Initial weight (kg)	26.52	25.37	0.6656	21.13	5.48
Final weight (kg)	35.59	34.76	0.8015	20.19	7.10
TWG (kg)	9.07	9.39	0.7920	27.76	2.56
ADG (kg)	0.15	0.156	0.7923	29.05	0.04
Carcass yield (%)	45.73	45.50	0.8687	6.76	3.08

[1]Probability value of F test in analysis of variance. [2]Coefficient of variation. [3]Standard deviation.

The uniformity between IW and FW caused TWG not to vary significantly. This, in addition to the homogeneity of age and genetics, contributed to the non-difference in the performance of the animals.

For Simioni et al. (2014), in intensive small ruminant production, animals must have an IW of at least 15 kg, and after the feedlot period, at an average age of 60 to 70 days, they are expected to exhibit an average FW between 25 and 30 kg. By comparing these questions regarding weight, we observe that the sheep in the present experiment are within the desirable range to serve the market.

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In comparison to this study, Silva et al. (2013) evaluated the weight gain of feedlot Santa Inês sheep and observed an average FW of 29.80 kg, with an ADG of 107.20 g/animal/day, which are lower values than those obtained in the present study. In our experiment, the animals showed ADG of 151.12 g/animal/day (shade) and 156.5 g/animal/day (no shade). Even in the absence of shading as a form of protection from solar radiation, the lambs showed a reasonable ADG.

Santos et al. (2012) conducted a bioclimatological evaluation in Santa Inês sheep and reported an ADG of 174 g/animal/day in animals with access to shade and 122 g/animal/day in those that were exposed to the sun all the time. The animals that benefited from the artificial shade showed, on average, a 30% higher TWG compared with those kept under solar radiation. This shows that shading is essential to improve lamb production under thermal stress conditions, which was not observed in this experiment as the ambient temperature was within the thermal comfort zone.

The carcass yields obtained in this study (45.73% in the shade and 45.50% in the sun) were superior to those found by Motta et al. (2016), who evaluated the productive performance of Corriedale lambs in the finishing phase and reported mean CY values of 32.7% and 37.1% under the analyzed treatments. Almeida et al. (2015) investigated the performance, body measurements, and CY of Santa Inês × mixed-breed crossbred lambs and found an average CY of 46.0%, a value very close to those observed in this study, and similar weights. Our findings are in line with the desirable CY for sheep, which should be a minimum of 42%. Gastaldello Junior et al. (2010) found an average CY of 50% in Santa Inês lambs.

The treatments had no significant effect on the evaluated quantitative or qualitative traits of carcass and meat (Table 4).

Table 4. Marbling, texture, fatness, conformation, pH and temperature (T) *postmortem* and 24 h *postmortem*, subcutaneous fat thickness (SFT), and loin-eye area (LEA), measured on the carcass and meat of sheep confined with and without access to shade.

Variable	Shade		p[1]	CV (%)[2]	SD[3]
	Available	Unavailable			
Marbling	4.78	4.44	0.6838	36.68	1.69
Texture	3.67 (4)	3.67 (4)	0.9955*	13.64	0.50
Fatness	2.22 (2)	1.78 (2)	0.2742*	41.66	0.83
Conformation	2.56 (3)	2.33 (2)	0.6245*	21.02	0.51
pH – *postmortem*	6.42	6.36	0.7029	4.92	0.31
pH – 24 h *postmortem*	5.55	5.71	0.2729	5.27	0.30
T (ºC) – *postmortem*	30.77	32.13	0.2703	8.05	2.53
T (ºC) – 24 h *postmortem*	8.50	8.7556	0.5840	11.06	0.95
SFT (mm)	1.77	2.31	0.1359	36.52	0.74
LEA (cm²)	14.11	13.61	0.6756	17.79	2.47

[1] Probability value of the F test in analysis of variance. [2] Coefficient of variation. [3] Standard deviation.

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* Nonparametric Mann-Whitney test with mean and median values.

Marbling values were 4.78 and 4.44—considered traces of light marbling—for the treatments with and without shade, respectively. As for texture, the result found in both treatments was 3.67, classified as fine.

Fatness was 2.22 and 1.78 in the environments with and without shade, respectively, both values of which fit scale 2 of fatness, characterized as little (1 to 3 mm). Cordão et al. (2012) stated that the desired amount and distribution of fat in the carcass is between the scales of 2.5 (slightly lean) to 3.5 (slightly fat), a minimum thickness of 2 to 5 mm. These authors found a fat thickness of 3.25 mm in Dorper × mixed-breed animals at 14 months of age, and 2.62 mm in Santa Inês × mixed-breed sheep at the same age. They also mentioned that carcass fatness is an important tool to typify carcasses in a refrigerator and to prevent the shortening of muscle fibers due to cold. Coupled with intramuscular fat, these traits give tenderness to the meat.

The animals with access to shade were on scale 3 of conformation, with 2.56 mm, whereas those finished in the environment where shade was not available were on scale 2, with 2.33 mm. Conformation, as well as the other traits evaluated in the carcass, is designed to meet the needs of the market, which generally requires carcasses with good conformation, muscle distribution, and proportions of intramuscular fat.

Motta et al. (2016) found values very close to the present study in Corriedale animals fed native field and ryegrass, describing an average conformation of 2.3 mm. This result did not differ statistically from the analyzed treatments and fit into conformation scale 2 (1-5), which is lower than desired for the animals.

In the present study, the conformation and SFT data were lower than those obtained by Hermes et al. (2015) (3.34 and 3.23, respectively), whereas the texture and marbling results in both treatments were higher than those found by Hermes et al. (2015) (3.15 and 2.60, respectively) in Santa Inês lambs.

The homogeneity of the obtained data may be correlated with the breeds under study, which have great aptitude for meat production, in addition to having been slaughtered at similar weights.

The pH is an extremely important factor when we consider the quality of meat traits, as it influences the color, appearance, texture, and shelf life of the final product. As such, it should be evaluated both immediately after slaughter and after the establishment of *rigor mortis*, 24 h after slaughter. According to Lima et al. (2018), the rate at which pH levels drop is as important as the final pH value. The initial pH value averaged 6.41 and 6.35 for the groups with and without access to shade, respectively, and 24 h *postmortem* the pH set at an average of 5.5 and 5.7 in the meat of animals reared with and without access to shade, respectively.

These values were close to those found by Fernandes et al. (2012), who reported an initial pH of 6.5 and a final pH of 5.7. The initial and final pH results in both treatments were within the desired range for ruminants, indicating that it was possible to obtain quality carcasses regarding this variable. According to Leão et al. (2012), the pH is between 6.5 and 6.7

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shortly after slaughter and drops to 5.4 to 5.8 twenty-four hours *postmortem*.

In this study, the average initial temperature of the carcasses of the lots with and without shade was 30.77 °C and 32.13 °C, respectively. Twenty-four hours *postmortem*, the carcass temperature in the respective groups was 8.50 °C and 8.75 °C. For Lima et al. (2018), the initial and final temperatures of the muscle should be around 35 °C (45 min *postmortem*) and 7 °C (with *rigor mortis* established).

Subcutaneous fat thickness measured directly on the muscle, 30 min after exposure to the oxygenated environment, averaged 1.77 mm in the sheep with access to shade and 2.31 mm in the animals without it.

Loin-eye area measured directly by outlining the *Longissimus dorsi* muscle averaged 14.11 and 13.61 cm² in the shaded and unshaded treatment groups, respectively. Oliveira et al. (2017) observed a LEA of 12.16 cm² in feedlot Santa Inês sheep, a result lower than those obtained in this study.

Almeida et al. (2015) examined the performance, morphometric measurements, and meat quality of Santa Inês × mixed-breed crossbred lambs and observed an average LEA of 15.77 cm², demonstrating that the carcasses showed a considerable pattern of muscularity.

There was no difference in meat color as measured on the hindquarter and directly on the striploin cut between treatments with and without access to shade (Table 5).

Table 5. Results for L*, a*, and b*, corresponding to carcass color and the *Longissimus dorsi* muscle of sheep confined with and without access to shade.

Color	Shade		p[1]	CV (%)[2]	SD[3]
	Available	Unavailable			
L* – Hindquarter	34.31	37.41	0.1083	10.91	3.91
a* – Hindquarter	15.07	14.51	0.5342	12.57	1.86
b* – Hindquarter	4.67	4.63	0.9637	13.49	0.63
L* – Striploin	37.04	37.55	0.6568	6.36	2.37
a* – Striploin	16.90	17.67	0.3314	9.35	1.62
b* – Striploin	4.48	5.20	0.0805	17.08	0.83

[1] Probability value of the F test in analysis of variance. [2] Coefficient of variation.

The color of meat is one of the characteristics that consumers most analyze, as it denotes the quality of the product. It can vary in shades from light pink to bright red or dark red, which indicate the tonality, intensity, and brightness of the product (Marin, 2014).

Costa et al. (2011) analyzed the physical and sensory quality of the meat of lambs of different genotypes. In Santa Inês × Dorper crossbred lambs, after 24 h of carcass refrigeration and later exposure of the muscle to the oxygenated environment for 30 min, the authors found L* = 23.8, a* = 8.9, and b* = 21.4, which are very different values from those observed in the present study.

In the objective analysis of color, Fernandes et al. (2012) observed mean L*, a*, and b* values of 36.52, 6.96, 10.46, respectively. Gallo et al. (2015) evaluated the meat characteristics of Dorper and Texel crossbred lambs and found the following mean color values

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in the former breed, using a colorimeter directly on the *Longissimus dorsi* muscle: L* = 36.80, a* = 5.99, and b* = 6.75. These values were similar to those obtained in the Texel lambs, which may be related to the similar performance between the breeds.

Issakowicz et al. (2014) evaluated quantitative carcass traits and qualitative meat traits in lambs of various genotypes and found the following values for muscle color 30 min after exposure to oxygen, in Santa Inês sheep: L* = 31.70, a* = 12.90, and b* = 3.73, respectively. These results are close to those found in this study in the assessment performed directly on the animals' hindquarter. However, in the present evaluation, the average color values were higher.

The present color results, whether obtained in the hindquarter region of the carcass or directly on the *Longissimus dorsi* muscle, were within the desired range for lambs. According to Madruga et al. (2005), desirable color ranges would be L* between 31.36 to 45.61; a* from 12.27 to 17.06; and b* from 3.34 to 6.51.

The similar results found for carcass and meat traits suggest that the animals had similar development and were not influenced by the availability or unavailability of shade during confinement.

CONCLUSIONS

The use of artificial shading in the feedlot did not influence the production performance or carcass and meat quality of the sheep.

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