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ANIMAL SCIENCE

Effects of corn straw on meat characteristics of lambs in the Brazilian semi-arid region

ANA B. DE OLIVEIRA, TALITA A. DE PAULA, WANDRICK HAUSS DE SOUSA, MARCELO A. FERREIRA, FELIPE Q. CARTAXO, MARCÍLIO F. CEZAR, MARIA LUCIANA M. WANDERLEY NEVES, LÍGIA MARIA G. BARRETO, FLÁVIO G. DE OLIVEIRA, RAYANE N. GOMES & ANTONIA SHERLÂNEA C. VÉRAS

Abstract: The present study aimed to evaluate the influence of increasing levels of corn straw replacement of sorghum silage on average daily gain, loin eye area, subcutaneous fat thickness, weight of commercial cuts, leg tissue composition, and physico-chemical characteristics of the meat from F1 Santa Inês × Dorper lambs maintained in a feedlot system. Treatments consisted of 0, 33, 66 and 100% corn straw replacement of sorghum silage. There were thirty-six 150-day-old male lambs. Corn straw replacement of sorghum silage in lamb feed reduced the average daily gain and weight of the ribs, besides promoting a quadratic influence on leg fat content. However, there was no influence on commercial carcass cuts, leg muscle index, leg tissue composition, and physico-chemical characteristics of the meat. Thus, corn straw can be used as alternative feedstuff for sheep rations to improve the production of high-quality sheep meat in semi-arid regions.

Key words: Alternative foods, dorper, nutrition, Santa Inês.

INTRODUCTION

Sheep farming is one of the main economic and social activities in Brazil, especially in the semi-arid region, and has been growing in recent years due to the increasing meat consumption in the large urban centers, behavior that has encourage lamb production (Raineri et al. 2015).

This increase in demand for sheep meat has inevitably led to an increase in consumer pressure for higher quality products (Monte et al. 2012). However, in Brazil, the commercialized meat is generally still relatively low quality, mainly due to late slaughter of the animals and due to poor planning and precarious production conditions (Grandis et al. 2015), especially in relation to the availability of food in semi-arid regions. This phenomenon occurs because livestock productivity in the tropics is influenced by seasonal forage availability. In general, the ruminants in those regions are intensily dependent on crop residues. Although corn straw is a crop residue that contains low amounts of protein and has low digestibility (Safari et al. 2011), it is an ingredient available to ruminants in northeastern Brazil. For these areas, it is necessary to use alternative foods to maintain an adequate supply of the product at low costs, especially during drought periods (Campos et al. 2017).

The modern meat market is demanding in terms of quality and can be influenced by hygienic and sanitary conditions in which the food is produced, handled, and marketed, factors that directly interfe with quality. This reality imposes the need to standardize the offered product and to identify the effects of management, feeding, and breeding techniques on quality characteristics, although consumers from different countries and regions have demonstrated specific preferences for different types of carcasses and meats (Monte et al. 2012, Realini et al. 2013).

The quality of meat can be evaluated by color, water-holding capacity (WHC), softness, cooking losses, and health and nutritional aspects (Guerrero et al. 2013). These characteristics can be used to determine the price of products with different qualities and to target these products to specific market types (Pinheiro et al. 2010).

Lamb production can be improved in terms of quality and profitability by using alternative feed resources. The use of agricultural residues in lamb feed becomes an alternative to guarantee a food supply. These residues can be used to feed ruminants without increasing production costs, especially in periods of low forage availability (Santos et al. 2014).

Given that a large area in Brazil is used to cultivate corn, corn residues deserve attention as a potential animal feed source. In 2017, corn cultivation occupied 4.98 million ha, with a production of 26.18 million tons in the first harvest. In the second harvest, it occupied 12.11 million ha, with a production of 67.17 million tons (Companhia Nacional de Abastecimento 2018). Watson et al (2015) verified that in corn cultivation, for every 0.55 kg of grains harvested, 0.45 kg of residue are produced.

Although ruminants living in semi-arid regions are usually well-adapted to the environment and poor quality of available forage (El-Meccawi et al. 2009), when introducing a new ingredient in animal diets, besides the acceptability and quality of the chemical composition, it is important to observe its effect on the development of the animal body as well as on the chemical and nutritional characteristics of the meat produced. Thus, it was hypothesized that there is a relationship between sorghum silage and corn straw plus urea that maximizes the performance of lambs receiving 70% concentrate diets.

In this context, the objective of this study was to evaluate the influence of increasing levels of corn straw replacement for sorghum silage on average daily gain, loin eye area, subcutaneous fat thickness, weight of commercial cuts, leg tissue composition, and physical-chemico characteristics of the meat of F1 Santa Inês × Dorper lambs fed in feedlot.

MATERIALS AND METHODS

Management and care of the experimental animals were carried out in accordance with the recommendations of the Ethics and Animal Use Committee (Process 23082.026501/2017-13) of the Universidade Federal de Pernambuco, Recife, Brazil.

Location

The experiment was carried out at the Benjamim Maranhão Experimental Station (Empresa Estadual de Pesquisa Agropecuária da Paraíba - EMEPA-PB), located in the municipality of Tacima, PB, Brazil, in the Agreste Paraibano mesoregion, located at the geographic coordinates 06°29’18’’S 35°38’14”W. at an elevation of 168m above sea level. Mean annual temperature is 23°C.

Experimental animals and diets

Thirty-six 150-day-old F1 Santa Inês × Dorper lambs—uncastrated, with an average body weight of 24.44 ± 2.93 kg—were housed in individual pens (0.80m × 1.2 m) equipped with a feeder and a drinker. The animals were distributed in four treatments consisting of different corn straw replacement levels (0%, 33%, 66%, and 100%, on a dry matter basis) for sorghum silage, in a completely randomized design.

The diet was composed of sorghum silage and/or corn straw and concentrated with ground corn grain, soybean meal, urea, common salt, and mineral supplement, according to the recommendations of the National Research Council (2007) (Tables I and II).

The ingredients of the diets were evaluated for DM, crude protein, mineral matter, organic matter contents, according to AOAC (2005), methods 934.01, 990.13, 942.05, 942.05, respectively; ether extract was determined according to AOCS (2004). Neutral detergent fiber and acid detergent fiber were analyzed according to Van Soest et al. (1991), using α-amylase AOAC (2005) method 973.18. The neutral detergent insoluble nitrogen was analyzed using the Kjeldahl method (Licitra et al. 1996) and, the non-fiber carbohydrate were calculated according to Hall (2003). Total digestible nutrients was obtained according to Weiss (1999).

The experimental period lasted 89 days, of which the initial 21 days were for adaptation to management and facilities. At the beginning of the adaptation period, the animals were treated against endo- and ectoparasites with 200 mg/kg body weight 1% ivermectin (Ivomec®, injected, Merial, São Paulo) and were vaccinated (3 mL) against clostridia (Hertamax-10®, Hertape Calier Saúde Animal SA, Minas Gerais).

The animals were weighed after 16 h of solids food fasting at the beginning of the experimental period. Food was provided *ad libitum* twice a day, at 08:00 h and 15:00 h The daily adjustment of the dietary intake was done according to the orts in the troughs; it was kept around 10%.

Carcass quality analysis

At the end of the experimental period, animals were transported to the Experimental Station of Pendência, 142 km away from the experimental location, for slaughter. After 16 h of solid food fasting and immediately before slaughter, they

Table I. Chemical composition of ingredients.

Chemical composition	Feed			
	CW	SS	SM	Corn
Dry matter (g/kg NM)	911.5	372.8	914.4	905.0
Mineral matter (g/kg DM)	85.8	76.1	78.2	12.5
Organic matter (g/kg DM)	825.7	296.7	836.2	892.5
Crude protein (g/kg DM)	47.3	56.3	536.0	94.0
Ether extract (g/kg DM)	4.8	16.3	15.2	30.6
NDF_{ap} (g/kg DM)	790.0	653.0	156.0	138.0
NFC (g/kg DM)	72.1	198.4	214.6	725.0
Lignin (g/kg DM)	120.0	63.0	13.0	11.6

CW= Corn straw.
SS= Sorghum silage.
SM= Soybean meal.
NDFap= neutral detergent fiber corrected for ash and protein.
NFC= non-fibrous carbohydrates.
NM= natural matter.
DM= dry matter.

were weighed to obtain body weight at slaughter. The slaughter followed Normative Instruction no. 3, 01/17/2000, of the Ministry of Agriculture, Livestock, and Supply (Brasil 2004) it comprised stunning through cerebral concussion, followed by bleeding, skinning, evisceration, and the removal of the head and legs.

Immediately after evisceration, the carcasses were identified, washed, and hung by the metatarsal tarsal joints, spaced 17 cm apart. They were then submitted to refrigeration in a cold room at 4 °C for 24 h.

At the end of the cooling period, cold carcass weights were recorded. The carcass was then sectioned longitudinally using an electric saw. In the left half of the carcass, five commercial cuts were performed: neck, shoulder, rib, loin, and leg, which were individually weighed after separation (Colomer-Rocher 1986).

Table II. Proportion of ingredients and chemical composition of the diet.

Ingredients	Replacement levels (%)			
	0	33	66	100
Sorghum silage	39.00	26.00	13.00	0.00
Corn straw	0.00	12.92	25.84	38.76
Corn grain	43.50	43.50	43.50	43.50
Soybean meal	16.00	16.00	16.00	16.00
Urea	0.00	0.08	0.16	0.24
Common Salt	0.50	0.50	0.50	0.50
Mineral mix[a]	1.00	1.00	1.00	1.00
Chemical composition				
DM (g/kg NM)[b]	582.2	661.6	766.1	909.8
Organic matter[c]	837.5	840.2	842.8	845.5
Mineral matter[c]	61.5	62.7	63.9	65.1
Crude Protein[c]	148.6	149.7	150.8	151.9
Ether extract[c]	22.1	20.6	19.1	17.6
NDFap[cd]	339.7	356.8	374.0	391.2
ADF[ce]	169.7	178.3	187.0	195.6
TC[cf]	766.7	767.4	768.1	768.9
NFC[cg]	427.1	410.6	394.1	377.7
TDN[ch]	596.5	617.7	654.1	605.1

[a] Mineral Composition: Calcium (min.) 110.00 g/kg, Calcium. (max)140.00 g/kg, Phosphorus (min.) 87.00 g/kg, Sulfur (min.) 18.00 g/kg, Sodium (min.) 147.00 g/kg, Cobalt (min.) 40.00 g/kg, Copper (min.) 590.00 mg/kg, Chromium (min.) 20.00 mg/kg, Iron (min.) 1,800.00 mg/g, Iodine (min.) 80.00 mg/kg, Manganese (min.) 1.300,00 mg/kg, Molybdenum (min.) 300.00 mg/kg, Selenium (min.) 15.00 mg/kg, Zinc (min.) 1.800,00 mg/kg, Fluorine (max) 870.00 mg/kg, Monensin Sodium 1,300.00 mg/kg, 1= g/kg MS.
[b] DM: dry matter, g/kg of natural matter.
[c] g/kg DM.
[d] NDFap: neutral detergent fiber corrected for ash and protein.
[e] ADF: acid detergent fiber.
[f] TC: total carbohydrates.
[g] NFC: non-fibrous carbohydrates.
[h] TDN: total digestible nutrient.

After weighing the individual cuts, the left legs and loins of each animal were packed in a polyethylene bag. Six loins were randomly separated from each treatment, identified, and kept at -20°C for further analysis of leg tissue composition and physico-chemical parameters of lamb meat.

Meat quality analysis

The tissue composition of the legs was dissected as described by Cezar & Sousa (2007). A scalpel and tweezers were used to separate the different tissues, subcutaneous fat, intermuscular fat, muscles, bones, and other tissues. Yields were calculated relative to the weight of the reconstituted leg. The following relationships were obtained: muscle: bone and muscle: fat. The five main muscles involving the femur (Biceps femoris, Semimembranosus, Semitendinosus, Quadriceps femoris, and Adductor) were removed and later weighed to calculate the leg muscle index (LMI), according to the formula proposed by Purchas et al. (1991): $LMI = \sqrt{(W5M/FL)}/FL$, where W5M represent the weight of the five muscles (g) and FL indicates the femur length (cm).

Determination of color, WHC, cooking losses, and shear force were performed according to the methodology described by Wheeler et al. (1995). One day prior to analysis, the loins were removed from the freezer and refrigerated at 4°C for slow thawing.

Cooking losses were quantified in the *longissimus thoracis* steaks, which were divided into three approximately 2.5 cm samples, obtained by previous dissection. The samples were wrapped in aluminum foil and baked in a preheated oven at 200°C until reaching 70°C in the geometric center; temperature was monitored with a meat thermometer (AcuRite®, Lake Geneva, WI, USA). Losses during cooking were calculated as the difference in the weight of the samples before and after cooking and expressed as percentages.

Meat color was evaluated using a Minolta CR300 colorimeter (Konica Minolta Sensing Americas, Inc., Ramsey, NJ, USA) operating in the CIE (L*, a*, b*) system, in which L* represent lightness, a* represents the intensity of the color red, and b* represents the intensity of the yellow color. The colorimeter was calibrated with a white ceramic plate and illuminant C, 10° for standard observation, and it was operated using an open cone. Before analysis, samples were exposed to room temperature for 30 min for the formation of oxymyoglobin, the main pigment responsible for the bright red color of meat (Cañeque & Sañudo 2000). After this time, and as described by Miltenburg et al. (1992), the L*, a*, and b* coordinates were measured in three distinct points of the internal muscle surface, and the average of the triplicates for each coordinate was calculated per animal sample.

Shear force was evaluated in the remaining cooked samples from the cooking loss determination. Three cylindrical samples with a 1.27 cm diameter were drawn in the longitudinal direction of the fiber. The force needed to cross-cut each cylinder was measured using the Warner–Bratzler shear force (G-R MANUFACTURING CO., Model 3000, Kansas, USA) method with a 25 kgf load cell, operating at a speed of 20 cm/min. The average shear force of each cylinder was used to represent the hardness value of each sample.

WHC (%) was determined according to the methodology proposed by Sierra (1973), in which 300 mg samples taken from the *longissimus thoracis* muscle were placed between two pieces of previously weighed filter paper (W1), the top and bottom being isolated with Petri dishes and pressed for 5 min, using a 3.4 kg weight. The WHC was calculated using the following formula: WHC

(%) = [(W2-P1)/W] × 100, where W represents the weight of the sample.

The chemical composition was determined in a sample of the *semimembranosus* muscle, which was ground, homogenized in a blender, and freeze-dried for determination of moisture, crude protein (CP), ether extract (EE), and mineral matter (MM), according to the methodology described by Detmann et al. (2012).

Statistical analyses

The study was conducted according to a completely randomized design with covariate (initial weight or final carcass weight) as shown in the following statistical model: Yij = β0 + β1Xij + Ti + εij, where Yij = observation j in treatment i, β0 is the intercept, β1 is the regression coefficient, Xij is the covariate, Ti is the fixed treatment effect I (I = 1 - 4) and εij is the random error. Polynomial orthogonal contrasts were used to test the effect of increasing levels of corn straw replacement of sorghum silage in the diet. Linear or quadratic equations that best fit the data were adjusted. Average daily gain was adjusted to lamb initial weight; carcass and meat data were adjusted to cold carcass weight. All data were analyzed using PROC GLM (SAS Institute Inc., Cary, NC, USA). Each animal was considered to be an experimental unit.

RESULTS

The dry matter and its component intake are reported in Oliveira et al. (2020).

Commercial cut and carcass characteristics

The average daily gain decreased linearly as the corn residue inclusion increased (P = 0.035) from 0.23 kg/day with 0% corn straw to 0.20 kg/day with 100% replacement. However, the reduction was not enough to show an effect on loin eye area (cm^2) and subcutaneous fat thickness (P > 0.05, Table III).

Corn straw inclusion resulted in a reduction only in the rib (P = 0.029) there was no significant influence (P > 0.05) on reconstituted half carcass, shoulder, neck, loin and leg weights. The animal growth rate did not affect the loin eye area and subcutaneous fat thickness. Thus, corn straw replacement had no effect on carcass cuts (P > 0.05, Table III).

Except for the leg fat (kg), there was no effect (P > 0.05) of increasing levels of corn straw replacement of sorghum silage. Leg fat showed a quadratic effect with corn straw inclusion, with a critical value of 0.37 kg with 45% inclusion level.

The muscle: bone and the muscle: fat relationships, were not influenced by the replacement of sorghum silage by corn residue in sheep feed (P > 0.05, Table IV).

The average weights of the five main leg muscles of the femur, subcutaneous, intramuscular, and pelvic fat, as well as the muscle index were not affected (P > 0.05, Table V).

Meat quality

Corn straw replacement of sorghum silage did not affect the physico-chemical parameters of the meat (P > 0.05, Table VI).

The red content (a*) and yellow contents (b*) were similar for the evaluated treatments (P > 0.05, Table VI).

The corn straw replacement levels did not affect the cooking loss variable (P > 0.05). Sorghum silage replacement levels had no impacts on the variable moisture, ash, protein, and fat contents (P > 0.05). The replacement had no influence on the ethereal meat extract contents (P > 0.05).

Table III. **Daily average gain, loin eye area, fat thickness and commercial cuts of lamb carcasses according to the levels of replacement of sorghum silage by corn residue.**

Variables	Replacement levels (%)				SEM[b]	*P-value*		
	0	33	66	100		L[c]	Q[d]	CCW[e]
Daily average gain (kg/day)	0.23	0.23	0.19	0.20	0.0064	0.0353	0.9121	0.9125[f]
Loin eye area (cm^2)	12.76	13.06	12.40	12.99	0.2799	0.9988	0.7772	0.0500
Fat thickness (mm)	1.59	1.69	1.75	1.26	0.0854	0.2698	0.0904	0.3332
Absolute weights								
HRC (kg)[a]	10.31	9.86	9.16	9.12	0.1813	0.5390	0.8597	<0.0001
Shoulder (kg)	1.78	1.75	1.63	1.63	0.0345	0.9406	0.8911	<0.0001
Neck (kg)	1.30	1.14	1.18	1.16	0.0192	0.4386	0.3462	<0.0001
Rib (kg)	2.92	2.64	2.42	2.37	0.1260	0.0294	0.3892	<0.0001
Loin (kg)	1.17	1.29	1.10	1.12	0.0310	0.5733	0.0829	<0.0001
Leg (kg)	3.13	3.04	2.83	2.84	0.1352	0.8877	0.9320	<0.0001
Yield								
Shoulder (%)	17.34	17.72	17.83	17.91	0.1433	0.5326	0.7098	0.0731
Neck (%)	12.56	11.61	12.86	12.75	0.2801	0.1856	0.3455	0.8614
Rib (%)	28.34	26.77	26.43	25.93	0.2053	0.0078	0.3095	0.0582
Loin (%)	11.36	13.01	11.93	12.37	0.1968	0.3179	0.1049	0.5874
Leg (%)	30.40	30.90	30.94	31.04	0.2201	0.4731	0.6983	0.5012

[a] **HRC: half reconstituted carcass.**
[b] **SEM: standard error of the mean.**
[c] **L: probability value for linear contrasts.**
[d] **Q: probability value for quadratic contrasts.**
[e] **CCW= cold carcass weight.**
[f] **Initial weight with covariate.**

DISCUSSION

According to Osório et al. (2002), when the carcass weight increases in absolute value, the weights of the commercial cuts also increase. This statement explains the relationship of direct dependence between cut and carcass weights.

Regarding the reconstituted half carcass, considering the value of the commercial cuts and according to the description of Cezar & Sousa (2007), the sum of first category cuts, namely leg and loins, was 4.30, 4.33, 3.93, and 3.55 kg, respectively, for the 0%, 33%, 66%, and 100% replacement levels, yielding 41.76%, 43.91%, 42.87%, and 40.38%, respectively. The sum of the shoulder, rib, and neck, considered second category cuts, in the different experimental diets was 6.00, 5.53, 5.23, and 5.22 kg, yielding 58.23%, 56.08%, 57.12%, and 59.61%, respectively. There was, however, an ample advantage of the leg compared to the other cuts.

Except for the rib yield, the absence of an effect of corn straw replacement on the yield of the cuts emphasizes the proportionality between the anatomical regions and reaffirm the law of anatomical harmony (Boccard & Dumont 1960). When evaluating the dietary responses of crossbred Dorper, Somalis, and Santa Inês sheep, Nascimento et al. (2012) observed a

Table IV. Tissue composition of the lamb leg as a function of sorghum silage replacement levels by corn straw in the diet.

Variables	Replacement levels (%)				SEM [b]	*P-value*		
	0	33	66	100		L [c]	Q [d]	CCW[e]
Leg R (kg)[a]	3.08	3.00	2.82	2.80	0.0545	0.5660	0.5949	<0.0001
Muscle (kg)	2.04	1.95	1.84	1.88	0.0416	0.4156	0.5948	<0.0001
Muscle (%)	67.49	66.13	66.63	68.49	0.5070	0.4030	0.1392	0.9445
Bone (kg)	0.55	0.54	0.52	0.52	0.0090	0.1506	0.8197	<0.0001
Bone (%)	18.17	18.26	19.12	19.15	0.1968	0.2334	0.9024	0.0088
Fat (kg)	0.33	0.38	0.32	0.27	0.0156	0.4965	0.0355[f]	0.0139
Fat (%)	10.96	12.78	11.68	9.78	0.5056	0.4035	0.0723	0.5997
Others tissue (kg)	0.10	0.08	0.07	0.07	0.0047	0.1692	0.4254	0.0026
Muscularity	3.72	3.63	3.50	3.58	0.0467	0.6480	0.4662	0.0382
Adiposity	6.42	5.46	6.43	7.06	0.2878	0.4272	0.1650	0.3912
Carnosity	4.33	4.33	4.13	4.09	0.0520	0.3099	0.7015	0.0154

[a] **Leg R: Leg Reconstituted.**
[b] **SEM: standard error of the mean.**
[c] **L: probability value for linear contrasts.**
[d] **Q: probability value for quadratic contrasts.**
[e] **CCW= cold carcass weight.**
[f] **$y = -0.00002x^2 + 0.0018x + 0.3313$; R2 = 0.91; Y_0 = 0.37 (Y_0: Plateau - maximum value for quadratic parameter); X_c = 45.0 (Critical value - optimum inclusion level of corn straw for quadratic parameter).**

significant difference only for the rib weight of the Santa Inês animals.

Silva Sobrinho et al. (2008) reported that animals with similar body conditions at the time of slaughter and of the same genetic grouping probably have similarities in their tissue composition, a phenomenon that could also be observed in this study for most of the leg tissues. According to Osório et al. (2002), several factors such as genotype, age, slaughter weight, sex, and diet may influence the amounts of bone, muscle, and carcass fat. Most of these factors were similar in the present study, and thus the feed used did not influence the leg tissue composition of the experimental animals.

An increase in the maturity of the animals leads to an increase in the proportion of fat, a decrease in the proportion of bones and little changes in the proportion of muscles in the carcass, and modifications of these relationships are important in determining carcass quality (Santos et al. 2001). The amount of fat is the most variable component in a sheep carcass. When studying the amount of fat on the legs among ovine genotypes, Costa et al. (2011) reported a value of 7.2%, which is lower than those observed in the present study.

Muscularity and adiposity are estimated by the muscle: bone and the muscle: fat relationships, which were not influenced by corn residue the replacement of sorghum silage in lamb feed. This outcome may be reflecte in the observed responses to loin eye area and fat thickness, as well as the lack of changes in the amounts of bone and muscle. In addition, the average weights of the five main leg muscles of the femur, subcutaneous, intramuscular, and pelvic fat, as well as the muscle index, obtained by dissection of the leg, were not affected by the

Table V. Components and muscle index values of the lamb legs as a function of the levels of sorghum silage replacement by corn straw in the diet.

Variables	Replacement levels (%)				SEM [a]	*P-value*		
	0	33	66	100		L [b]	Q [c]	CCW [d]
Leg reconstituted (kg)	3.08	3.00	2.82	2.80	0.0545	0.0045	0.6974	<0.0001
Biceps (kg)	0.22	0.23	0.20	0.21	0.0052	0.3033	0.5704	<0.0001
Semimembranosus (kg)	0.27	0.25	0.24	0.25	0.0070	0.3322	0.2394	<0.0001
Semitendinosus (kg)	0.18	0.15	0.16	0.15	0.0057	0.9267	0.5101	0.0010
Quadriceps (kg)	0.40	0.38	0.37	0.37	0.0078	0.3798	0.6388	<0.0001
Adductor (kg)	0.11	0.11	0.10	0.10	0.0026	0.9402	0.8162	0.0470
Othersmuscle (kg)	0.86	0.84	0.76	0.79	0.0195	0.5392	0.8078	<0.0001
Femur (kg)	0.16	0.15	0.14	0.15	0.0028	0.8885	0.1157	<0.0001
Fat Subcutaneous (kg)	0.22	0.21	0.23	0.17	0.0121	0.5583	0.2422	0.2145
Fat Pelvic (kg)	0.01	0.02	0.01	0.02	0.0022	0.6021	0.5039	0.2022
Bone (kg)	0.55	0.54	0.52	0.52	0.0090	0.2352	0.7168	0.0005
W5M [e] (kg)	1.185	1.110	1.070	1.05	0.0023	0.3607	0.4496	<0.0001
LMI [f]	0.46	0.46	0.45	0.46	0.0039	0.9748	0.5750	0.0622

[a] SEM: standard error of the mean.
[b] L: probability value for linear contrasts.
[c] Q: probability value for quadratic contrasts.
[d] CCW = cold carcass weight.
[e] W5M = weight of the 5 legs muscle.
[f] LMI = leg muscle index.

different levels of corn residue replacement of sorghum silage.

However, according to Safari et al. (2011), the use of low-quality roughage such as straw fed to goats allowed animal production during dry season in Tanzania while supporting at least a minimum level of fattening to the animals.

The leg muscle index, which indicates the amount of muscles in the carcass, was not influenced by the levels of corn straw replacement of sorghum silage, this finding is consistent with the absence of an effect on tissue composition observed for the same meat cut.

Color is one of the main sensory characteristics that affects consumers' purchasing decisions. Consumers associate red color with meat quality (Kerry et al. 2000). The reason consumers choose bright red meat is that they associate it to the age of the animals, considering bright red as coming from young animals and dark and tough from animals slaughtered at an advanced age (Cruz et al. 2016).

In fact, meat color is directly related to muscle fibers, myoglobin pigment and hemoglobin present in the blood (Gao et al. 2014) and can be influenced by several factors such as muscle type, diet, pH, and intramuscular fat concentration (Sañudo et al. 2013). It is noteworthy that no level of corn straw replacement influenced this characteristic.

The red (a*) content in sheep meat may vary and is related to the genetic group or diet, which will influence the proportion between the forms of myoglobin (deoxymyoglobin and oxymyoglobin). The similar results among treatments was probably due to the similarity among animals and diets and the adoption of the production

Table VI. Physicochemical parameters of sheep meat as a function of sorghum silage replacement levels by corn residue in the feed.

Variables	Replacement levels (%)				SEM [a]	*P-value*		
	0	33	66	100		L [b]	Q [c]	CCW [d]
Lightness (L*)	34.41	33.98	33.79	32.48	0.5547	0.2783	0.7587	0.8392
Red intensity (a*)	12.52	11.17	11.98	11.91	0.2397	0.7621	0.2345	0.4144
Yellow intensity (b*)	6.45	5.89	6.17	6.11	0.1676	0.6073	0.4616	0.9452
WHC [e] (%)	37.28	36.10	37.94	37.58	0.6312	0.3948	0.9657	0.7167
Cooking loss (%)	38.70	40.49	39.25	35.89	1.1423	0.0950	0.5326	0.1492
Shear force (N[f]/cm²)	22.16	28.92	25.69	24.12	0.1363	0.5042	0.0893	0.3634
Moisture (%NM[g])	74.97	75.25	75.40	75.14	0.1227	0.5712	0.3797	0.0153
Ash (%DM[h])	1.38	1.38	1.43	1.40	0.0263	0.1930	0.5862	0.1643
Protein (%DM)	21.80	21.53	21.19	21.46	0.1572	0.8849	0.5249	0.0531
Lipids (%DM)	2.40	2.17	2.15	2.16	0.0437	0.1754	0.1868	0.1112

[a] SEM: standard error of the mean.
[b] L: probability value for linear contrasts.
[c] Q: probability value for quadratic contrasts.
[d] CCW = cold carcass weight.
[e] WHC= water holding capacity.
[f] N=Newton.
[g] NM = natural matter.
[h] DM = Dry matter.
L*: Lightness.
a*: Red intensity.
b*: Yellow intensity.

system, because the animals in feedlots perform fewer to activities. As a consequence, myoglobin synthesis is reduced because of the lower need for muscle oxygenation. This, in turn, promotes a less intense meat color, which is normally pink (Urrutia et al. 2016).

According to Leão et al. (2012), diets with low carotenoid concentrations, such as grains, hay, and silage, reduce the yellow color of the meat fat due to the dilution of the fat color. According to Prache et al. (2003a), the intensity of light absorption by the carotenoid stored in feedlot lamb fat is negatively correlated with the feedlot period, this finding prove that this effect is mediated by the dilution of white fat (Prache et al. 2003b).

WHC is the ability of the meat to retain water during heating, cutting, grinding, or pressing (Pearce et al. 2011). The absence of any effects on these variables is a reflection of the responses obtained for pH after slaughter of 5.74, 5.74, 5.76, and 5.72 for the treatments with 0%, 33%, 66%, and 100% corn straw replacement of sorghum silage, respectively (Oliveira 2018). The absence of any effects on these variables is a reflection of the responses obtained for pH after slaughter of 5.74, 5.74, 5.76, and 5.72 for the treatments with 0%, 33%, 66%, and 100% corn straw replacement of sorghum silage, respectively (Oliveira. 2018). According to Della Malva et al. (2016), the menasured pH values can be considered within the ideal range to avoid altering the physical and chemical characteristics of the meat.

According to Zeola et al. (2007), the WHC values observed in the present study are considered satisfactory for meat tenderness. In this context, the use of corn straw in the diet may not alter the meat tenderness, and, as a consequence, may not lead to losses of soluble proteins, lipids, vitamins, and minerals, along with water. Thus, corn straw replacement of sorghum silage does not interfere with the physicochemical properties of sheep meat. In addition, the shear force values observed for all treatment made the meat considered as soft according to Boleman et al. (1997).

The mean meat property values were as follows: 75.19% of moisture, 1.40% of MM, 21.75% of CP, and 2.22% of lipids. These values are within the range reported by Sañudo et al. (1992) for the chemical composition of sheep meat, that author stated that the values can vary in humidity between 65.5% and 80%, in protein between 16% and 22%, in lipid concentration between 1.5% and 13%, and in mineral content between 0.5% and 1.5%. Tshabalala et al. (2003) reported that possible variations of these levels are dependent on factors such as animal age, genotype, sex, diet, and pre-slaughter procedures.

The water content is the component with the greatest participation in the composition of the meat and has a direct influence on quality attributes such as succulence, color, texture, and taste, as well as on the processes during storage and packaging (Cruz et al. 2016).

According to Prata (1999), sheep meat contains about 19% protein, which is lower than the values found in the present study. It is worth emphasizing that the diet replacement had no effect on the protein content of the meat, which is a positive result because meat is a crucial source of protein valuable macromolecule for human nutritione.

Campos et al. (2017) reported that a relevant factor is the nutritional value of the diets, especially the protein content, which can provide a significant increase in animal performance, because the concentration and the quality of the protein can influence dry matter intake and, consequently, carcass characteristics and the chemical composition of the muscular tissues.

The average value for the mineral content was 1.4%, which is higher than the 1% value observed by Prado (2004) and the 1.03% value reported by Guimarães et al. (2016). This value is within the range reported by Sañudo et al. (1992) for the chemical composition of sheep meat, which can vary between 0.5% and 1.5%.

The fat contents ranged from 2.15% to 2.40, which, according to Bezerra et al (2016) characterizes the meat as lean (5% fat). Pinheiro et al. (2012) reported that the fat content in sheep meat may be due to feed, muscle type, slaughter weight, as well as the physiological stage of the animal. Guimarães et al. (2016) when studying the replacement of corn by cassava husk in sheep feed, observed a linear decrease in the fat contents of sheep meat.

CONCLUSION

Corn straw replacement of sorghum silage in lamb feed had no effect on the physicochemical characteristics, tissue, and chemical composition of sheep meat, but influenced the absolute weight of the rib and the daily average gain. Corn straw replacemet could be recommended for finishing F1 Santa Inês × Dorper lambs to provide a regular supply of quality meat, especially in semi-arid regions.

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ANA B. DE OLIVEIRA[1]
https://orcid.org/0000-0002-4136-0972

TALITA A. DE PAULA[1]
https://orcid.org/0000-0003-4902-9341

WANDRICK HAUSS DE SOUSA[2]
https://orcid.org/0000-0001-8761-0626

MARCELO A. FERREIRA[1]
https://orcid.org/0000-0002-9155-4388

FELIPE Q. CARTAXO[3]
https://orcid.org/0000-0002-2378-0420

MARCÍLIO F. CEZAR[3]
https://orcid.org/0000-0003-3746-3917

MARIA LUCIANA M. WANDERLEY NEVES[1]
https://orcid.org/0000-0003-0077-4041

LÍGIA MARIA G. BARRETO[4]
https://orcid.org/0000-0002-8011-0335

FLÁVIO G. DE OLIVEIRA[5]
https://orcid.org/0000-0002-0948-7543

RAYANE N. GOMES[1]
https://orcid.org/0000-0003-1571-624X

ANTONIA SHERLÂNEA C. VÉRAS[1]
https://orcid.org/0000-0002-7673-0654

[1]Universidade Federal Rural de Pernambuco, Departamento de Zootecnia, Rua Manuel de Medeiros, s/n, Dois Irmãos, 51171-900 Recife, PE, Brazil

[2]Empresa Estadual de Pesquisa Agropecuária da Paraíba, Rodovia BR 230, Km 13,3, s/n, Parque Esperança, Morada Nova, L-26, 58108-502 Cabedelo, PB, Brazil

[3]Universidade Federal de Campina Grande, Departamento de Ciência Animal, Campus Patos, Avenida Universitária, s/n, Santa Cecilia, 58708-110 Patos, PB, Brazil

[4]Universidade Federal de Sergipe, Núcleo de Graduação em Zootecnia, Campus do Sertão, Rodovia Engenheiro Jorge Neto, Km 3, 49680-000 Silos Nossa Senhora da Glória, SE, Brazil

[5]Universidade Federal da Paraíba, Departamento de Zootecnia, Campus II, Areia, Rodovia 12, PB-079, 58397-000 Areia, PB, Brazil

Corresponding to: **Talita Almeida de Paula**
E-mail: talitaalmeidap@gmail.com

Author contributions

W.H de Souza and M. de A. Ferreira - conceived of the presented idea. W.H de Souza, M. de A. Ferreira and A.S.C. Véras - supervised the project. A.B. De Oliveira, F.G. De Oliveira, T.A. de Paula and R.N. Gomes- carried out the experiment, wrote the manuscript with support from L.M.G. Barreto, M.L.M.W. Neves, F.Q. Cartaxo, M. de A. Ferreira, M.F. Cezar and A.S.C. Véras. L.M.G. Barreto and M.L.M.W. Neves - performed the statistical analysis. All authors provided critical feedback and helped shape the research, analysis and manuscript.