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Corn straw replacing sorghum silage in lamb diets in semiarid regions: growth performance, apparent digestibility, and economic viability. Substituição de palha de milho por silagem de sorgo em dietas para cordeiros em regiões semiáridas: desempenho, digestibilidade aparente e viabilidade econômica.

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Abstract

The objective of this study was to evaluate the effect of replacement of sorghum silage at 0, 33, 66, and 100% by corn straw on growth performance, apparent digestibility, and economic viability of lambs in feedlots. Thirty-six Santa Inês x Dorper male lambs were used. The replacement decreased linearly dry matter, organic matter, non-fibrous carbohydrate, and total digestible nutrient intakes. The coefficients of apparent digestibility of dry matter, organic matter, and total carbohydrates increased linearly. Total and daily weight gain decreased linearly. The substitution of sorghum silage by corn straw promotes a positive economic indicator and a significant weight gain, which justifies its use in lamb feeding in semiarid areas.
Keywords: Alternative food. Agricultural residue. Corn residue crop. Santa Inês. Semiarid.

Resumo
O objetivo do estudo foi avaliar o efeito da substituição da silagem de sorgo a 0, 33, 66 e 100% por palha de milho no desempenho, digestibilidade aparente e viabilidade econômica de cordeiros em confinamento. Foram utilizados 36 cordeiros machos Santa Inês x Dorper. A substituição diminuiu linearmente os consumos de matéria seca, matéria orgânica, carboidratos não fibrosos, nutrientes digestíveis e ganhos de peso total e diário. Coeficientes de digestibilidade aparente da matéria seca, matéria orgânica e carboidratos totais aumentaram linearmente. Substituição da silagem de sorgo pela palha de milho promove indicador econômico positivo e ganho de peso significativo, o que justifica seu uso na alimentação de cordeiros em áreas semiáridas.
Palavras-chave: Alimento alternativo. Resíduo de agricultura. Resíduo de plantio de milho. Santa Inês. Semiárido.

Introduction

Sheep farming is one of the main economic and social activities, especially in semiarid regions. However, despite their importance, sheep production systems are extensive, generating low zootechnical indices and low profitability. The low productivity is a reflection of the variation in the supply and quality of forage throughout the year, with concentrated production in the rainy periods and a deficit in the dry period.

An alternative to mitigate climatic effects in the production of sheep from semi-arid regions on the quality and supply of meat to the market would be in feedlots. However, in general, there is a significant increase in food expenditures, besides the need for specific infrastructure, which may make such an approach unfeasible (ARAÚJO FILHO et al., 2015).

The use of alternative feed in lamb nutrition, such as by-products of agriculture, may be an appropriate option for producers wishing to reduce feed costs, particularly in feedlot (SENA et al., 2015). Thus, the adequate use of relatively inexpensive agricultural and agro-industrial by-products is important for profitable livestock production.

The residues from corn production deserve attention due to the size of the cultivated area. It is estimated that in the year 2016, corn crops occupied 5.4 million hectares in Brazil, with an estimated production of 73.5 million tons (IBGE, 2016). A study by Watson et al. (2015) indicates that in the cultivation of corn, there is a generation of waste of the order of 0.45 kg for each 0.55 kg of harvested grains.

Although it is presented as an alternative to the substitution of traditional roughage such as sorghum and/or corn silages, the inclusion of corn straw should be evaluated. Thus, it is important to identify the characteristics of alternative foods in order to recommend their use as a substitute for conventional foods.

In this context, the objective of this study was to evaluate the impacts of the substitution of sorghum silage by corn straw on growth performance, apparent digestibility, and economic viability of F1 Santa Inês x Dorper lamb finishing in feedlot in the semiarid area of Brazil.

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 Federal Rural University of Pernambuco, Recife, Brazil.

Location

The research was conducted at the Benjamim Maranhão Experimental Station, belonging to the State Agricultural Research Company of Paraíba (EMEPA - PB), located in the municipality of Tacima - PB, Brazil. It is located in the Agreste Paraibano mesoregion, at the geographic coordinates 06º 29' 16' L and 35º 38' 13" W. Gr. at an elevation of 168 m above sea level. The average annual temperature is 24,8°C, with an average relative humidity of 68% (SOUZA et al., 2019).

Animals and experimental design

Thirty-six non-castrated with 150-day-old, F1 Santa Inês x Dorper lambs, and average initial body weight (BW) of 24.44 ± 2.93 kg were used. The animals were housed in individual pens (0.80 x 1.20 m) provide with a feeder and drinker. The experimental period lasted 89 days, of which 21 were allocated to the adaptation to management and facilities. The experimental design was completely randomized, the initial BW was used as a co-variable.

At the beginning of the adaptation period, the animals were treated against endo- and ectoparasites with 200 mg/kg body weight of 1% ivermectin (Ivomec®, injected, Merial, São Paulo) and vaccinated (3 mL) against subcutaneous clostridia (Hertamax-10®, Hertape Calier Saúde Animal SA, Minas Gerais).

The diets were formulated to meet the nutritional requirements of lambs with an estimated daily gain of 250 g/day (NRC, 2007). The experimental diets consisted of replacement of 0, 33, 66, and 100% of sorghum silage by corn straw. The sorghum silage was prepared at the Benjamim Maranhão Experimental Station. The corn straw was obtained from regional corn producers (mechanized harvesting) and consisted of the plant, the cob, and some remaining grains. The chemical composition of individual diet components is shown in table 1, while table 2 shows the composition of the diets and the chemical composition of each mixture.

Table 1 - Chemical composition of diet ingredients

Item	Feeds			
	CS	SS	SM	Corn
Dry matter (g/kg NM)	911.5	372.8	914.4	905.0
Ash (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
NDFap (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

CS= Corn straw; SS= Sorghum silage; SM= Soybean meal. NDFap= neutral detergent fibre corrected for ash and protein; NFC= non-fibrous carbohydrates; NM=natural matter

The animals were weighed after 16 hours of solids fasting at the beginning of the experimental period and every 14 days. Food was provided *ad libitum*, twice a day (8:00 a.m. and 3:00 p.m.), aiming at 10% orts.

The feed was weighed and adjusted daily according to the orts. Dry matter intake was determined by quantifying the supply and remaining and the difference between them.

Sampling

Samples of the ingredients that made up the diet and of the orts of each animal were taken weekly, stored in plastic bags, labeled, and frozen at -15ºC. Prior to the determination of their chemical composition, they were oven-dried at 55 °C for 72 hours.

At the end of the sampling period, the samples of each animal were homogenized to obtain one composite sample and ground to pass through a 1-mm mesh to determine their chemical composition and through a 2 mm mesh for *in situ* ruminal incubation.

Table 2 - Proportion of ingredients and chemical composition of the diets

Item	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
Ground 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*	1.00	1.00	1.00	1.00
Chemical composition				
DM (g/kg MN)	582.2	661.6	766.1	909.8
Organic matter[1]	837.5	840.2	842.8	845.5
Mineral matter[1]	61.5	62.7	63.9	65.1
Crude Proteín[1]	148.6	149.7	150.8	151.9
Ether extract[1]	22.1	20.6	19.1	17.6
NDFap[1]	339.7	356.8	374.0	391.2
ADF[1]	169.7	178.3	187.0	195.6
TC[1]	766.7	767.4	768.1	768.9
NFC[1]	427.1	410.6	394.1	377.7
TDN[1]	596.5	617.7	654.1	605.1

*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; DM= dry matter; NDFap= neutral detergent fibre corrected for ash and protein; ADF= acid detergent fibre; TC= total carbohydrates; NFC= non-fibrous carbohydrates; TDN= total digestible nutrient.

Apparent digestibility assay

In the apparent digestibility test over five consecutive days, five samples were taken of the ingredients, orts and feces. Feces spot samples were collected from the animals' rectums at different times each day (7:00 a.m., 9:00 a.m., 11:00 a.m., 1:00 p.m., and 3:00 p.m.), according to the methodology described by Ferreira et al. (2009).

For determination of indigestible neutral detergent fiber (NDFi), 0.8 g of roughage, feces, and orts sample and 1 g of the concentrate feed sample were packed in labeled TNT (non-woven-fabric) bags, dried and weighed, and incubated for 288 hours in the rumen of a fistulated cow (VALENTE et al., 2011). After this period, the bags were removed and washed in running water until completely bleached. Subsequently, they are dried and autoclaved for 1 hour in neutral detergent solution (VAN SOEST; ROBERTSON, 1985) and then washed with hot water and acetone, dried, and weighed; the residue was considered the NDFi.

Fecal dry matter production (FDMP) was determined using the following formula: FDMP= indicator intake (g)/indicator concentration in feces (%) (FERREIRA et al., 2009).

Performance

The performance of the animals was verified by weighing after the fasting of solids for 16 hours. The Total weight gain (TWG) was calculated as the difference between the final BW and the initial BW, while the average daily gain (ADG) was obtained by the ration between TWG and the confinement period, in days. Feed conversion (FC) was calculated as the ratio between dry matter intake (DMI, g/day) and ADG (g/day); feed efficiency (FE) was obtained from the ration between ADG (g/day) and DMI (g/day).

Chemical analyses of diets, orts, and feces

Dry matter (DM, 950.46), ash (MM, 920.153), crude protein (CP, 928.08), and ether extract (EE, 960.39) analyses were performed according to the AOAC (2000). Neutral detergent fiber (NDF) was analyzed according to Van Soest et al. (1991) using α-amylase, as recommended by AOAC (2005) method 973.18. The non-fibrous carbohydrates (NFC) values were obtained by the equation proposed by Detmann & Valadares Filho (2010): NFC = 100% - [(%CP – CP_{urea} + %Urea) + %NDF + %EE + %MM)]. Total carbohydrates (TC) were calculated according to Sniffen et al. (1992): TC= 100 - (%CP + %EE + %MM). The total digestible nutrient content (TDN) was calculated according to Weiss (1999): TDN (%) = CPD% + NDFD% + NFCD% + (EED%*2.25).

Economic indicators

The economic analysis consisted of the determination of the cost to purchase the animals, the ingredients, and labor costs. The cost of labor was based on the temporary hiring of an employee for the days of feedlot. The costs of vermifuge and vaccines were also considered. The sum of these expenses represented the total Effective Operational Cost (EOC).

The Gross Income (GI) was obtained through simulation of the value of the live animal sale, while the Gross Margin (GM) was determined based on the difference between the GI and the EOC: GM= GI - EOC. The Return Rate (RR) was defined as the ratio of GM to EOC: RR= GM/EOC. The Safety Margin (SM) was the result of the difference between EOC and GI, divided by GI, expressed as a percentage: SM = (GI - EOC)/GI * 100. The Cost-benefit (CB) was calculated by dividing GI by EOC: CB = GI/EOC. The results were obtained through calculations in spreadsheets prepared in Excel MICROSOFT CORPORATION. The costs were converted considering R$ 3.83 (Brazil) equal to US$ 1.00, quote to the same period of the experiment.

Statistical analyses

The experimental design was completely randomized, with initial body weight as covariable, according to the following model: $Y_{ij} = \beta_0 + B_1X_{ij} + T_i + \varepsilon_{ij}$, where: Yij = observation j in treatment i, β0 = intercept, B1= regression coefficient, X_{ij} = initial weight covariate, T_i = fixed treatment effect I (I = 1 to 4), ε_{ij} = random error. Data were submitted to analysis of variance and regression, considering a level of probability of 5% for type I error, using the procedures PROC GLM and PROC REG of the statistical package SAS version 9.2.

Results

Dry matter intake and its components

For the dry matter (DM), organic matter (OM), non-fibrous carbohydrates (NFC), and total digestible nutrient (TDN) intakes, expressed in kg/day, there was a linear decreasing effect ($P < 0.05$) with substitution by the corn straw; however, when the DM intake was expressed as a percentage of BW and metabolic weight, there was no effect of the treatments. The crude protein intake (CPI) was not influenced by the substitution of sorghum silage by corn straw ($P > 0.05$), and we observed no influence on the intakes of neutral detergent fiber corrected for ash and protein (NDFap), as shown in table 3.

Table 3 - Dry matter and its component intakes by lambs as a function of sorghum silage replacement levels by corn straw

Item	Replacement levels (%)				SEM	*P-value*		
	0	33	66	100		L	Q	COV
DMI (kg/dia)	1.30	1.27	1.18	1.16	0.0263	0.0176	0.9480	0.0047
DMI (g/kg PC)	39.00	39.00	38.00	37.00	0.0006	0.2246	0.7139	0.0401
DMI (g/kg $PC^{0,75}$)	90.0	90.0	90.0	90.0	0.7073	0.7897	0.8403	0.6408
OMI (kg/day)	1.09	1.07	1.00	0.97	0.0216	0.0150	0.9413	0.0042
CPI (kg/day)	0.20	0.20	0.19	0.19	0.0038	0.2443	0.7928	0.0021
NFCI (kg/day)	0.47	0.45	0.44	0.38	0.0102	0.0011	0.3193	0.0194
NDFIcp (kg/day)	0.39	0.40	0.41	0.41	0.0080	0.2777	0.8564	0.0028
TDNI (kg/day)	0.78	0.79	0.77	0.70	0.0157	0.0496	0.1641	0.1641

DMI = dry matter intake; OMI = organic matter intake; CPI = crude protein intake; NDFIap = neutral detergent fibre intake corrected for ash and protein; NFCI = non-fibrous carbohydrates intake; TDNI = total digestible nutrient intake; SEM = standard error of the mean; L = linear; Q = quadratic; COV = covariate.

Apparent digestibility coefficient

The substitution of sorghum silage at levels of 0, 33, 66, and 100% of the corn straw in confined sheep feed resulted in a linear increase in the apparent digestibility coefficients of DM, OM, and total carbohydrate (TC) (table 4). The treatments exerted a quadratic effect on the apparent digestibilities of CP and NFC. The highest apparent digestibility coefficients of CP (65.11%) and NFC (90.63%) were observed at the replacement levels of 60.18 and 65.11%, respectively.

The lowest apparent digestibility of CP was 55.04%, observed for a diet with no substitution of sorghum silage for corn straw. A reduction in the apparent digestibility coefficient of CP from the maximum 60% substitution point was observed. Replacement levels did not influence the apparent digestibility of NDF.

Table 4 - Apparent digestibility coefficients of experimental lamb diets as a function of sorghum silage replacement levels by corn straw

	Replacement levels (%)					*P-value*		
Item (%)	0	33	66	100	SEM	L	Q	COV
ADDM	53.94	54.57	56.07	61.11	1.2178	0.0251	0.3405	0.0941
ADOM	56.29	56.94	58.53	64.43	1.3925	0.0307	0.3329	0.2665
ADNDF	46.70	48.64	48.60	45.43	0.7956	0.5380	0.1194	0.3141
ADCP	55.04	64.33	63.83	61.17	1.1630	0.0758	0.0075	0.6267
ADTC	58.91	60.12	60.15	66.82	1.2717	0.0269	0.2587	0.2070
ADNFC	84.14	85.64	93.76	87.62	0.7235	<0.0001	<0.0001	0.1874

IBW= initial body weight; ADCDM= apparent digestibility coefficient of dry matter; ADCOM= apparent digestibility coefficient of organic matter; ADCNDF= apparent digestibility coefficient of neutral detergent fibre; ADCCP= apparent digestibility coefficient of crude protein; ADCTC= apparent digestibility coefficient of total carbohydrates; ADCNFC= apparent digestibility coefficient of non-fibrous carbohydrates; SEM= standard error of the mean; L= linear; Q= quadratic; COV= covariate.

Performance

The levels of sorghum silage substitution by corn straw had a linear decreasing effect ($P < 0.05$) on total weight gain and average daily gain (table 5). However, there was no effect ($P > 0.05$) of treatments on slaughter weight, conversion, and feed efficiency.

Table 5 - Performance of sheep as a function of the levels of sorghum silage replacement by corn straw

Variáveis	Replacement levels (%)				SEM	*P-value*		
	0	33	66	100		L	Q	COV
BWI (kg)	24.97	24.65	24.04	24.12	0.5181	-	-	-
Weight at slaughter (kg)	40.47	40.42	37.27	37.77	0.6734	0.0060	0.7009	<.0001
TWG (kg)	15.50	15.77	13.22	13.65	0.3856	0.0007	0.3495	0.8560
AWG (kg)	0.228	0.231	0.194	0.200	0.0065	0.0410	0.8855	0.6694
FC (kg/kg)	5.380	5.566	6.155	5.364	0.1731	0.9713	0.9272	0.0152
FE (g/kg MS)	0.175	0.183	0.163	0.175	0.0048	0.5914	0.7986	0.0033

IBW= initial body weight; TWG= total weight gain; ADG= average daily gain; FC= feed conversion; FE= feed efficiency; SEM= standard error of the mean; L= linear; Q= quadratic; COV = covariate.

Economic indicators

There was a reduction in the cost per kg of dry matter of the rations as sorghum silage was replaced by corn straw (table 6). Effective operating costs decreased with increasing substitution levels. For the gross margin, with a substitution of up to 33% of sorghum silage for corn straw, the gross profit margin presented higher averages. In terms of the rate of return, safety margin, and cost benefit, the highest average values were observed for treatments with 33 and 100% substitution of sorghum silage.

Table 6 - Economic indicators depending on the levels of replacement of sorghum silage by corn straw

Item	Replacement levels (%)			
	0	33	66	100
Cost of diet (US$)/Kg/MS	0.31	0.30	0.29	0.27
Effective operating cost (US$)	464.16	454.18	438.31	432.23
Gross Income (US$)	687.43	686.58	633.08	651.34
Gross margin (US$)	223.27	232.40	194.77	219.11
Return rate (US$)	0.127	0.135	0.116	0.135
Safety margin (%)	8.619	8.983	8.166	8.927
Cost benefit (US$/dia)	0.392	0.400	0.382	0.400

Discussion

Among the factors involved in the regulation of intake in animals are the energy intake by the animal and the NDF concentration of the diet, the last one being considered limiting due to its slow degradation and a lower rate of passage through the rumen. The intake of diets with high fiber content is controlled by physical factors such as ruminal filling and passage rate. Sampaio et al. (2009) reported that one of the main barriers to voluntary intake is the high participation of neutral detergent fiber, especially when the forage is of low quality.

Geron et al. (2014) affirmed that dietary fiber is the fraction of the structural carbohydrate which is difficult to digest due to its chemical composition, therefore limiting dry matter intake. However, for ruminants, fiber is necessary for the adequate digestion of dry matter and other nutrients.

Grandis et al. (2015) reported that even when comparing diets with similar nutritional values, the characteristics of the roughage can exert an important influence on dry matter intake. In this context, in contrast to the results observed in the present study, Carmo et al. (2016) have reported an increase in intake when the level of substitution of *Cynodon* spp. hay for hay of banana farming byproducts in the diet of confined sheep was increased.

Parente et al. (2009) evaluated the performance of confined sheep with mean body weight (BW) of 25kg fed diets based on Tifton 85 hay, with 19% cashew or passion fruit residue, and observed a mean DMI value of 1.557 kg/day. According to the authors, this high dry matter value can be explained by the fact that the concentrate and the roughage used were finely milled, resulting in a higher flow rate.

Although, means dry matter intakes were 1.23 kg/day, 38.25g/kg BW, and 90.00 g/kg$^{0.75}$, according to NRC (2007), those values are adequate for sheep with a mean weight of 30 kg.

Sheep with moderate growth, with an average weight gain of 250 g/day and a BW over 20 kg, require an intake of 167 g of CP (NRC, 2007). The animals fed the diets containing the different levels of corn straw had a CP intake higher than the recommended value (table 3).

As a consequence of an intake decreasing, the food remains in the rumen for a longer period and is, therefore, more degraded. This occurs through a compensatory effect found at lower throughput rates. In such situations, ruminal microorganisms use the feed more efficiently, resulting in better apparent nutrient digestibility coefficients (VAN SOEST, 1994).

According to Santos et al. (2009), the addition of 8% canola residue to sheep diet resulted in similar values for apparent nutrient digestibility. The authors explained that the decrease in the rate of passage in animals fed diets containing higher levels of canola residues led to an increase in digestion time in the gastrointestinal tract, resulting in longer food exposure to ruminal microorganisms and thus increasing apparent dry matter digestibility.

Cunha et al. (2009) reported a mean value of 63.8% for the apparent digestibility of DM in sheep fed diets containing pineapple residue. Similarly, Leite et al. (2013) evaluated the nutritional value of cashew residue in sheep feed and found an average apparent DM digestibility value of 61.43%. Thus, the observed values for the apparent digestibility of DM in diets containing corn residue are within the range observed in previous similar studies.

The apparent digestibility of CP showed a quadratic effect with the inclusion of corn straw (table 4), which is probably a result of the addition of urea to the concentrate of the diets that were constituted by corn straw instead of sorghum silage.

According to Leite et al. (2013), the average apparent CP digestibility of diets containing cashew, wheat, and soybean meal was 42.53%, which was lower than the value found in the present study. The high crude protein intake found in the present study may be due to the use of urea.

According to Van Soest (1994), a possible explanation for the observed results for apparent digestibility of NDF is that for diets with high fiber contents, the residence time in the digestive tract is controlled by physical factors such as the rate of passage and filling, allowing the rumen microorganisms more time to degrade the food.

In addition, the small particle size of the corn straw, associated with the longer residence time in the rumen, offered the microorganisms having a larger surface area and a longer time to degrade the material.

Deriving the equation, a maximum point was observed for the apparent digestibility of the NFC in 65% of substitution of sorghum silage by corn straw, with a decrease from this substitution level. This fact can be partly explained by the reduction in the levels of NFC in the diets as the substitution level increased.

The reduction in the apparent digestibility of NFC can be attributed to the increase of lignin concentrations in the diets with sorghum silage substitution, which was gradual and accentuated at the level of 65% corn straw. The lignin content is closely related to the apparent digestibility of food because it involves the food particles, which prevent the access of microorganisms to NFC (OLIVEIRA et al., 2010; BAURHOO et al., 2008).

According to Van Soest (1994), the dry matter intake is related to the nutrient intake and the nutritional requirements of the animals, being considered the main variable that determines animal performance. Mertens (1994) has reported that 60 to 90% of differences in animal performance are directly related to intake; this statement is consistent with the results obtained in the present research, in which the effect observed for the dry matter intake was reflected in the weight gain.

Lower dry matter intake leads to lower availability of nutrients for metabolic processes of maintenance and production, thus negatively influencing animal performance (ARAÚJO FILHO et al., 2015). However, it is worth noting that even with the reduction of ADG with the substitution of sorghum silage for corn straw, the 100% substitution treatment provided an ADG value of 200 g/day, demonstrating that corn straw can be an excellent alternative in times of food shortages.

Turino et al. (2007) found gains of 233 g/day for confined Santa Inês animals that received diets with high levels of concentrate (88%). It should be noted that for the 200 g/day gain observed in the present study, the level of concentrate in the diet was lower than that used by the author.

The TDN intake followed the observed behavior for dry matter intake and was reflected in animal performance. The animals did not consume the levels recommended by the NRC (2007), a fact that justifies the ponderal performance below the expected value in the present research. The observed results for conversion and feed efficiency is also another consequence of the dry matter intake (kg/day) and total weight gain.

Several factors can affect feed conversions, such as the nature and composition of the feed, age, genetic group, and production system (GRANDIS et al., 2015). Except for the composition of the diet, these factors were similar among the animals used, explaining the absence of an effect for this variable. Alves et al. (2003) have reported feed conversion values between 7 and 10 for confined Santa Inês animals fed different energy levels and diets based on Tifton hay, soybean meal, and corn. Even in the diet with a higher energy density, the feed conversion was lower than that obtained in this study.

The kilogram prices of the rations were US$ 0.31, US$ 0.30, US$ 0.29, and US$ 0.27 for the treatments with 0, 33, 66, and 100% replacement of sorghum silage per corn straw, respectively (table 6). A decrease in the price of the feed is observed as the silage is replaced by corn straw, which may be explained by the higher costs of sorghum silage compared to corn straw. In the treatment with 0% corn straw, a higher DM intake was also observed (table 3), resulting in a higher effective operating cost (US$ 464.16). This demonstrates that the use of agroindustrial residues, which can be obtained at low costs, do not significantly compromise the animal performance and can be an important alternative for finishing lambs in confinement, especially in semi-arid regions.

In an economic analysis of a production system, it is necessary to account for the values of revenues from the activities carried out, since when the Gross Income is less than or equal to the production costs, it implies that this variable is not sufficient to cover the expenses with the production (SANTOS, 2014). Even with the increase in the value of the treatment ration without substitution of the massive and, consequently, higher effective operating cost, this treatment provided higher Gross Income and Gross Margin (table 6). This fact can be explained with the significant weight gain of the animals submitted to this treatment (table 5), the production costs.

According to Barros (2008), the Cost-benefit ratio (C:B) has to be positive. If it is below 1, it indicates that the revenues were below the investment. All treatments showed a positive C:B ratio, with the best values, found for the treatments with 33 and 100% substitution (0.400 US$/day), followed by the treatment with 0% substitution (with 0.392 US$/day).

When sorghum silage was replaced by corn straw, animal performance decreased (table 5). However, the economic viability of the substitution was feasible because, even with lower animal performance, the treatments with corn straw showed a lower Operating Cost Effective of production and a better cost-benefit ratio for the treatments with substitution, thus justifying the use of corn straw in feeding lambs in confinement, when the available material is available in the region.

Conclusion

The use of corn straw in finished goats in feedlot is recommended when the material is available in the region since it is possible to obtain satisfactory animal performance with relevant economic indicators.

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