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Article

Productive performance of sheep fed buffel grass silage in replacement of corn silage

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Abstract:

This study aimed to evaluate the productive performance and nutritional status of crossbred sheep fed a diet containing buffel grass silage (BGS) in substitution of corn silage (CS). Thirty-two male Santa Inês sheep with an average body weight of 20.09 ± 2.0 kg were distributed in a completely randomized block design with four treatments (0, 33.3, 66.6, and 100 % of substitution of corn silage with buffel grass silage) and eight animals per treatment. Dry matter intake, apparent nutrient digestibility, water balance, nitrogen balance, and productive performance of animals were evaluated. The different levels of substitution of corn silage by buffel grass silage promoted a linear decrease in the consumption of ether extract (*P*=0.001) and non-fibrous carbohydrate (*P*<0.001), apparent digestibility of non-fibrous carbohydrate (*P*=0.019), water intake via food (*P*<0.001), total water intake (*P*=0.008), water excretion via urine (*P*=0.004), total water excretion (*P*=0.001), among which the highest values were observed in animals fed 100% corn silage. Water excretion via feces (*P*=0.017) and nitrogen balance (*P*=0.047) showed a quadratic function, increasing as substitution with buffel grass silage increased from 0 to 33.3 %. No significant differences (*P*>0.05) were observed in sheep productive performance, with an average daily weight gain of 140.16 g/d. The replacement of 66.6 % of CS for BGS provides satisfactory results for dry matter and nutrients intake, and water intake, with weight gain of up to 155 g/d for Santa Inês crossbred sheep in Brazilian semi-arid.

Key words: Animal nutrition, Confined sheep, Santa Inês, Semiarid.

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Introduction

In semi-arid regions, the dry season is a major obstacle to animal production due to food shortages and reduced nutritional value of available pastures(1). Caatinga is an important food source for ruminant herds in the semi-arid regions of Brazil(2). However, in most cases, native vegetation is not sufficient to meet the nutritional requirements of the animals, resulting in poor animal performance(3). Thus, the planning of food production has a significant impact on the animal production in these regions.

Confinement systems are used to increase herd productivity and improve the quality and supply of products in the off-season. However, the success of the intensive confinement of ruminants depends on the availability and cost of the feed. Alternative dietary strategies are necessary to obtain satisfactory results and make this activity more profitable because the animal feed is the costliest component of production and affects profitability(3).

The use of forage plants adapted to semi-arid regions by efficiently using water combined with silage production increase food supply, especially in the dry season, making sheep farming sustainable(4). Corn is the standard crop for silage in the Northeast region of Brazil, being one of the main agricultural products in the region, due to its tradition in cultivation, productivity, and nutritional value. The use of corn cultivars, well adapted and of high productivity, as is the case of Caatingueiro, Gorutuba, and São Francisco, is important to increase the improvement of the activity yield in the semiarid[5]. However, alternative food crops with a lower cost and stable production under adverse climatic conditions have been proposed[6,7].

In this respect, buffel grass (*Cenchrus ciliaris* L.) outperforms other cultivars because of its easy adaptation to adverse climatic conditions, good silage production, and maintenance of the productive capacity even after long periods of drought[8]. However, buffel grass is rarely exploited for silage production despite the presence of large cultivated areas; therefore, further studies on the use of this grass as ruminant feed are necessary[9].

The objective of this study was to evaluate the productive performance and nutritional status of crossbred sheep fed a diet containing buffel grass silage (BGS) in replacement of corn silage (CS) in a semi-arid region of Brazil.

Material and methods

Study site

The study was carried out in the Caatinga Experimental Station, in the Animal Metabolism Unit of Embrapa Semiárido, located in Petrolina, Pernambuco State, Brazil. The local mean annual rainfall is 433 mm, and averages of maximum and minimum annual temperatures are 33.46 and 26.96 ºC, respectively. This study was approved by the Research Ethics and Deontology Committee of the Federal University of Vale do São Francisco (UNIVASF), under Protocol No. 0007/131014.

Animals, treatments, and experimental diets

Thirty-two (32) non-castrated male Santa Inês sheep (6-mo-old and 20.09 ± 2.0 kg of body weight) were distributed in individual stalls (1.2 × 0.8 m) equipped with feeding and drinking troughs for the diets and water supply. The experimental design was a completely randomized block design with four treatments and eight animals per treatment. The initial bodyweight was used to define the blocks.

The experiment lasted 71 d, comprising 10 d of animal adaptation to the experimental diet and treatments. At the beginning of the adaptation period, the animals were identified, weighed, treated against endo- and ectoparasites, and randomly allocated to the stalls previously identified according to the treatment.

The silages of corn (*Zea mays*; variety Caatingueiro, around 90 d of maturity) and buffel grass (*Cenchrus ciliaris* L.; variety Biloela, aged about 120 d regrowth) were made in barrel silos with a 200 kg capacity and presented an average density of 113.94 kg and 65.97 kg, respectively. Forage material was processed through a PP-35 forage harvester to an average particle size of about 2.0 cm and then ensiled.

Four diets were formulated by substituting corn silage (CS) by buffelgrass silage (BGS) at increasing levels: 1) 100% CS and 0% BGS, 2) 66.6% CS and 33.3% BGS, 3) 33.3% CS and 66.6% BGS, and 4) 0% CS and 100% BGS. These diets were formulated with a roughage: concentrate ratio of 60:40 based on dry matter and composed of corn silage, buffelgrass silage, ground corn, soybean meal, limestone, common salt, and mineral supplement (Tables 1, 2), being balanced for allowing an average weight gain of 200 g/d, as National Research Council(10) recommendations.

Table 1: Chemical composition of ingredients used in experimental diets (g/kg DM)

Item	Ingredients							
	CS	**BGS**	**Ground corn**	**Soybean meal**	**C1**	**C2**	**C3**	**C4**
Dry matter[a]	225.6	506.4	893.7	908.5	889.7	889.4	890.2	892.9
Organic matter	857.8	844.7	975.3	919.9	946.1	946.4	946.3	942.4
Mineral matter	142.2	155.3	24.7	80.1	53.9	53.6	53.7	57.6
Ether extract	19.0	15.3	64.2	17.9	38.6	38.4	34.0	34.0
Crude protein	60.7	53.0	99.3	498.9	290.9	310.0	320.8	352.5
NDF	533.6	688.1	213.9	186.1	216.3	218.9	219.0	221.8
ADF	292.3	419.9	37.9	135.8	96.1	100.2	103.2	111.3
NFC	248.2	84.6	597.3	217.0	400.3	379.1	372.5	334.1
TDN	621.7	531.9	800.8	731.9	759.8	757.0	754.8	749.1

CS= corn silage; BGS= buffel grass silage; C1, C2, C3 and C4= diets concentrate.

[a]In g/kg fresh matter.

NDF= neutral detergent fiber; ADF= acid detergent fiber; NFC= Non-fibrous carbohydrates; TDN= Total digestible nutrientes.

Table 2: Proportion of ingredients and chemical composition of experimental diets in dry matter basis

Proportion of ingredients in the diets (%)	Substitution of corn silage by buffel grass silage (%)			
	0	33.3	66.6	100
Corn silage	60.00	39.99	19.99	0.00
Buffel grass silage	0.00	19.99	39.99	60.00
Ground corn	24.00	22.40	20.90	19.40
Soybean meal	15.90	17.50	19.00	20.50
Limestone	0.03	0.03	0.03	0.03
Common salt	0.05	0.05	0.05	0.05
Premix mineral[1]	0.02	0.02	0.02	0.02
	Chemical composition (% dry matter)			
Dry matter, % fresh matter	49.12	54.72	60.37	66.10
Organic matter	89.31	89.04	88.78	88.38
Mineral matter	10.69	10.94	11.20	11.62
Ether extract	2.46	2.53	2.43	2.50
Crude protein	15.28	15.89	15.16	15.28
Neutral detergent fiber	40.67	43.85	46.94	50.16
Acid detergent fiber	21.38	24.09	26.76	29.65
Non-fibrous carbohydrates	30.90	26.78	23.24	18.44
Total digestible nutrients	67.70	65.77	63.89	61.88
Metabolizable energy, MJ/kg	10.245	9.856	11.794	11.422

[1]Premix mineral: phosphorus – 45 g; calcium – 90 g; chloro-240 g; sodium-156 g; sulfur – 10 g; magnesium – 8 g; zinc-2,800 mg; iron-1,300 mg; manganese – 2,300 mg; copper -150 mg; iodine – 40 mg; cobalt – 35 mg; selenium – 15 mg and fluorine – 450 mg.

Food was offered daily at 0830 and 1530 h. The amount of food offered was calculated according t o the consumption of the previous day, not allowing leftovers higher than 10 % of the offered quantity. Weekly samples of foods offered and leftovers were collected for chemical analyses.

Nutrient intake and digestibility

The daily dry matter intake (DMI) was obtained by the difference between the total DM of the consumed diet and the total DM present in the leftovers. Nutrient intake was determined as the difference between the total nutrients present in the consumed diet and the total nutrients present in the leftovers, on a total DM basis.

A digestibility test was performed in the final third of the experimental period, with a duration of 10 days, 5 d for adaptation followed by 5 d for collection. The animals were distributed in metabolism cages provided with feeders and drinking fountains. Feces were sampled using collection bags fixed to the animals, which were attached to the animals before the sampling period. The bags were weighed and emptied twice daily and a sub-sample of 10 % of the total amount was collected for further analysis.

Nitrogen balance

Urine was collected and weighed using plastic buckets containing 100 mL of 2 N hydrochloric acid in order to avoid nitrogen volatilization and sampled for nitrogen content determination. Nitrogen balance (NB) was determined according to the method described by Silva & Leão[(11)].

Water balance

Water intake was evaluated daily. The water was supplied in buckets and weighed before being supplied and again 24 h later. Three water-filled containers were placed close to the cages to measure daily evaporation. Water balance was evaluated using the following equations: total water intake = (supplied water – evaporated water) + dietary water; total water excretion = water excreted in the urine + water excreted in the feces; water balance = total water intake – total water excretion[(12)].

Productive performance

The animals were weighed every 15 d after a solid-feed deprivation period of 12 h (with access to water) to obtain the initial body weight, final body weight, total weight gain (TWG= final body weight at fasting − initial body weight at fasting), and daily weight gain (DWG= total weight gain/experimental period). At the end of the experimental period, the feed conversion (FC) was calculated by the following equation: FC= dry matter intake/mean daily gain.

Laboratory tests

Feed, leftover, and fecal samples were pre-dried in a forced ventilation oven at 55 °C for 72 h and ground to 1 mm particles (Wiley Mill, Marconi, MA-580, Piracicaba, Brazil). Laboratory analyses were performed using the methods described by Association of Official Analytical Chemists[(13)] for dry matter (DM; Method No. 967.03), mineral matter (MM; Method No. 942.05), crude protein (CP, Method No. 981.10) and ether extract (EE, Method No. 920.29). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined as described by Van Soest *et al*[14]. Total carbohydrates (TC) were measured using the equation proposed by Sniffen *et al*[15], as follows: TC (% DM) = 100 – (CP + EE + ash). Non-fibrous carbohydrate (NFC) content was measured as proposed by Hall[16]: NFC = %TC – %NDF.

The apparent digestibility coefficient (ADC) of nutrients was calculated as described by Silva & Leão[11]: ADC = {[Nutrient intake (kg) – nutrients excreted in the feces (kg)]/nutrient intake (kg)} * 100. Total digestible nutrient (TDN) was measured using the equation of Harlan *et al*[17], as follows: 82.75 – (0.704 × ADF). TDN intake was estimated using the following formula: %TDN= (TDN intake/DM intake) * 100. TDN of the diet was converted into metabolizable energy (ME) using the following equation proposed by NRC[18]: Digestible energy (DE)= (TDN/100) x 4.409, metabolizable energy= DE x 0.82

Statistical analysis

The data were submitted to Shapiro-Wilk and Levene tests to verify the normality of the residues and homogeneity of the variances, respectively. Once that the assumptions were met, the data were submitted to analysis of variance (ANOVA) using the PROC GLM (General Linear Models). Linear and quadratic regression analyzes were performed using PROC REG. Probability values less than 0.05 (P<0.05) were considered statistically significant. Statistical analysis was performed using SAS version 9.0 (SAS Institute, Cary, NC, USA). The following statistical model was used:

$$Y_{ij} = \mu + T_i + \beta_j + E_{ij},$$

Where:
Yij= value observed for the study variable referring to the i-th treatment in the j-th repetition;
μ= general constant;
Ti= effect of the level of substitution of corn silage by buffel grass silage in the diet;
βj= block effect (i = 1, 2, 3, 4);
Eij= random error associated with the Eij observation.

Results

EE (P=0.001) and NFC (P<0.001) intakes decreased linearly due to the substitution levels of CS with BGS. However, no effect of the diets was found on the intake (in grams/day) of DM (P=0.180), CP (P=0.111), NDF (P=0.078), ADF (P=0.221), TC (P=0.220), and

TDN (*P*=0.267) (Table 2). The digestibility coefficient of NFC (*P*=0.019) was influenced by the diets, with a linear decreasing effect according to inclusion levels of BGS. No significant differences were observed in the digestibility coefficients of DM (*P*=0.425), OM (*P*=0.637), CP (*P*=0.715), EE (*P*=0.065), NDF (*P*=0.536), and TC (*P*=0.112) among the treatments (Table 3).

Table 3: Daily intake of nutritional components and apparent digestibility of nutrients in sheep fed buffel grass silage in replacement of corn silage

Variables	**Substitution of corn silage by buffel grass silage (%)**				**SE**[1]	***P* value**
	0	**33.3**	**66.6**	**100**		
	Intake(g/d)					
Dry matter	768.04	878.06	835.61	701.02	50.88	0.180
Crude protein	168.52	195.30	184.83	161.75	10.25	0.111
Ether extract[2]	26.30	25.27	21.77	18.53	1.35	0.001
Neutral detergent fiber	236.99	305.93	311.44	284.06	20.85	0.078
Acid detergent fiber	144.10	161.29	177.29	171.81	11.60	0.221
Total carbohydrates	529.59	604.47	601.26	437.65	31.91	0.220
Non-fibrous carbohydrates[3]	314.75	273.98	216.30	154.66	11.44	<0.001
Total digestible nutrients	649.68	724.64	740.58	538.92	56.81	0.267
	Digestibility (%)					
Dry matter	71.39	73.74	73.95	68.41	1.80	0.425
Organic matter	72.04	74.92	75.33	69.03	1.73	0.637
Crude protein	65.43	72.06	72.47	71.25	1.99	0.715
Ether extract	72.23	76.65	73.34	65.37	2.07	0.065
Neutral detergent fiber	57.10	61.87	61.93	59.85	2.63	0.536
Total carbohydrates	74.19	75.35	75.92	68.38	1.70	0.112
Non-fibrous carbohydrates[4]	93.43	91.67	88.17	87.35	1.08	0.019

[1]SE= standard error of the mean; Equations: [2]$\hat{Y}$=29.66– 2.68x (SED=0.60, R^2=0.26, *P*=0.0001); [3]$\hat{Y}$=374.41–53.79x (SED=5.12, R^2=0.99, *P*<0.001); [4]$\hat{Y}$=77.67–1.68x (SED=0.76, R^2=0.95; *P*=0.038). Significant at the 5% probability level.

As BGS increased in the diet, a linear decreasing effect was observed in water intake via food (*P*<0.001), total water intake (*P*=0.008), water excretion via urine (*P*=0.004), total water excretion (*P*=0.001). While water excretion via feces showed a quadratic response (*P*=0.017) as substitution levels increased from 0 to 33.3 %, and then decreased, with the lowest values in diets with 100 % BGS (Table 3). No significant effect of substitution of CS with BGS was found on water intake via drinking fountain (*P*=0.266) and water balance (*P*=0.900) (Table 4).

Table 4: Water balance and nitrogen balance in sheep fed buffel grass silage in replacement of corn silage (g/day)

Variables	Substitution of corn silage by buffel grass silage (%)				SEM[1]	***P* value**
	0	**33.3**	**66.6**	**100**		
Water intake via drinking fountain	3078	2748	2716	2587	153.51	0.266
Water intake via food[2]	951	726	548	359	0.07	<0.001
Total water intake[3]	4029	3474	3264	2946	177.95	0.008
Water excretion via urine[4]	2054	974	921	849	258.25	0.004
Water excretion via feces[5]	487	510	420	335	47.36	0.017
Total water excretion[6]	2542	1484	1341	1184	138.79	0.001
Water balance	1811	2227	2072	1808	196.67	0.900
Nitrogen ingested	27.51	32.13	29.57	25.96	2.91	0.385
Nitrogen excreted via feces	6.27	5.47	5.67	6.77	0.32	0.529
Nitrogen excreted via urine	6.87	7.34	8.20	8.57	0.66	0.360
Nitrogen balance[7]	14.36	19.31	15.68	10.62	2.98	0.047

[1]SEM - Standard error of the mean; Equations: [2]$\hat{Y}=1.58-0.29x$ (SED=0.032, $R^2=0.99$, $P<0.001$); [3]$\hat{Y}=6.35-0.78x$ (SED=0.206, $R^2=0.84$, $P=0.001$); [4]$\hat{Y}=2028.62-331.35x$ (SED=115.49, $R^2=0.56$, $P=0.009$); [5]$\hat{Y}=440.96+80.11x-26.96x^2$ (SED=23.68, $R^2=0.96$, $P=0.018$); [6]$\hat{Y}=2.60-0.39x$ (SED=0.123, $R^2=0.67$, $P=0.005$); [7]$\hat{Y}=-2.50x^2+11.03x+6.19$ (SED=1.22, $R^2=0.93$, $P=0.008$). Significant at the 5% probability level.

Nitrogen balance showed a quadratic response (*P*=0.047) as substitution levels increased from 0 to 33.3 % BGS and then decreased, with the lowest values in diets with 100% BGS (Table 3). The amounts of nitrogen ingested (*P*=0.568), nitrogen excreted via feces (*P*=0.529) or via urine (*P*=0.360), were not affected by the substitution levels of BGS in diet (Table 4).

No significant differences were encountered on final weight (*P*=0206), daily weight gain (*P*=0.513), total weight gain (*P*=0.513), and feed conversion (*P*=0.605) of Santa Inês sheep fed different levels of BGS, and the mean daily weight gain was 140.16 g/d (Table 5).

Table 5: Productive performance of sheep fed buffel grass silage in replacement of corn silage

Variables	Substitution of corn silage by buffel grass silage (%)				SE	***P* value**
	0	**33.3**	**66.6**	**100**		
Initial weight, kg	20.54	21.29	20.64	18.09	0.62	0.179
Final weight, kg	28.69	29.95	29.94	25.62	0.95	0.206
Daily weight gain, g/d	135.83	144.40	155.00	125.42	8.66	0.513
Total weight gain, kg	8.15	8.66	9.30	7.53	0.52	0.513
Feed conversion	5.93	6.27	5.47	5.73	0.24	0.605

SE= standard error of the mean; Significant at the 5% probability level.

Discussion

One of the main influencing factors for the productive efficiency of animals is nutrient intake. The observed mean DMI was 795.68 g/animal/d, that was lower than that recommended (1 kg/animal/d) by the NRC(10) for animals of 20 kg of body weight. Low dry matter intake directly affected daily gain. The animals showed, on average, a of 140.16 g/d, reaching 70.1 % of the expected daily gain, according to the recommendations of the NRC(10). A greater control of DMI and lower values of weight gain found in the treatment with 100 % BGS, in relation to the other diets tested, seem to be related to the greater amount of ADF present in this diet. Mertens(19) reports that DMI is controlled by physiological, physical and psychogenic factors. When high quality diets are offered, the animal consumes to meet its nutritional demand, this consumption being limited by its genetic potential to use the nutrients absorbed. However, when low quality diets are offered (high fiber and low soluble carbohydrates content), feed intake occurs until reaching the maximum level of gastrointestinal capacity(19).

The decrease in EE and NFC intakes and in the digestibility coefficient of NFC can be explained by the lower concentration of these components associated with high concentration of NDF and ADF in BGS compared to CS (Table 1). The higher concentration of fibrous fractions provided lower energy concentration to the diets with increasing levels of BGS. According to Allen(20), the use of fiber-rich foods limits DMI, as a consequence of the amount of indigestible material that occupies space inside the rumen, causing physical distension of the rumen. Ruminal microorganisms depend on fermentable energy and nitrogen sources for their metabolic activity, strongly influencing ruminal digestibility and nutrient flow(21). Synchronization between energy and protein is essential in order to maximize microbial efficiency, promoting an improvement in dry matter digestibility(22).

The increase in BGS levels in diets had no significant effect on TDN intake. Even the mean value was higher than that recommended by the NRC(10), that is 0.55 kg TDN/d for an animal gaining 200 g/d. This finding can be explained by the absence of significant differences in DMI and NDF intake, within the recommended standards, maintaining the ingestion of TDN and meeting animal requirements (Table 2).

The linear decreasing response of water intake via food and total water intake in this study, probably it is due to the increase of the dry matter content according to the increase in BGS levels in diets (Table 2) allied to the low DMI that the animals presented. Thus, the low DMI reduced water intake via food and the water excretion via feces; so the animals sought to hydrate themselves through the water intake via drinking fountain, thus increasing the water excretion via urine. This suggests that the animals tried to maintain a certain level of water flow for metabolic functions to balance the lower physiological demand for water caused by lower dietary intake(23). Souza *et al*(24) in a study with Biloela buffel grass silages offered to sheep in the Brazilian semiarid region, found that the animals had lower DMI and this influenced the reduced water intake via food and water excretion via feces. The reduction in DMI and water intake via food was also observed by Carvalho *et al*[8] when offering buffel grass silage in diets for sheep in the Brazilian Semiarid Region. These results corroborate our findings.

The increase in NB was higher in the replacement of corn silage by buffel grass silage at the level of 33.3 % (19.31 g/d) and 66 % (15.68 g/d) in the sheep diets, which indicates that the animals retained dietary protein achieving the main objective of nutritional planning. According to Tosto *et al*[25], this result can be explained by the efficient recycling of N performed by ruminants, under conditions of low protein availability in the diet.

According to Lindberg[26] the levels of N excreted via urine should be on average up to 45 % of the N ingested. In the present study, large amounts of urinary N were not eliminated, which demonstrates that the use of N was efficient by the ruminal microorganisms converting to digestible microbial protein[27], which can be observed in the CP digestibility values (Table 3) of the formulated diets. Thus, the results of NB obtained demonstrate that there is synchronism between the supply protein and energy in diets that possibly used ammonia, promoting greater microbial protein synthesis and greater use of N supplied[25].

Conclusions and implications

Under the experimental conditions, the replacement of 66.6 % of corn silage for buffel grass silage provides satisfactory results for dry matter and nutrients intake, and water intake, with weight gain of up to 155 g/d for Santa Inês crossbred sheep in Brazilian semi-arid.

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