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Nutritive value of hay from sorghum-sudangrass hybrids (*Sorghum sudanense* vs. *Sorghum bicolor*)

Valor nutritivo do feno de híbridos de sorgo com capim-sudão (*Sorghum sudanense* vs. *Sorghum bicolor*)

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ABSTRACT
This study aimed to evaluate the nutritive value of hay from ten sorghum-sudangrass hybrids. A randomized block design with ten treatments and three replicates was used. The chemical composition was analyzed 57 days after germination. Hay from hybrids BRS 810 and BRS 802 showed similar dry matter content, although it was lower compared to other genotypes (86.98; 86.47%). Ash content was highest for the hybrid BRS 810 (6.46%). The highest crude protein content was found in hybrids BRS 810, 1013020, and BRS 802 (14.01; 12.84 and 11.96%, respectively). The lowest neutral detergent fiber (NDF) concentrations were observed in hybrids 1134029 and BRS 810, ranging from 57.72 to 58.57%. The acid detergent fiber (ADF) concentration was least in hybrids BRS 810 and 1013029 (30.30 and 30.31%). The highest lignin content was found in hybrids 1013020 and 1134023 (5.82 and 5.41%, respectively). Values of dry matter digestibility were higher than 50%. Hay from all hybrids was of good quality, but hybrids 1013020, BRS 810, BRS 802 were better in terms of nutritive value.

Keyword: Cutting and grazing, Digestibility, Fodder, Genotype, Haymaking.

RESUMO
Este estudo teve como objetivo avaliar as características nutricionais do feno de dez híbridos de sorgo com capim-Sudão. O delineamento utilizado foi em blocos ao acaso, composto por 10 tratamentos com 3 repetições. As características nutricionais dos respectivos fenos foram analisadas 57 dias após a germinação. Os híbridos BRS 810 e BRS 802 apresentaram teores semelhantes de matéria seca e inferiores aos demais fenos (86,98; 86,47). Para a variável matéria mineral o maior valor obtido foi de 6,46% para o híbrido BRS 810. Quanto a proteína bruta os maiores teores foram apresentados pelos genótipos BRS 810, 1013020, BRS 802 (14,01; 12,84 e 11,96%, respectivamente). Os menores valores de fibra insolúvel em detergente neutro (FDN) variaram de 57,72 a 58,57% para os genótipos 1134029 e BRS 810. Para a fibra insolúvel em detergente ácido (FDA) os menores valores foram dos híbridos BRS 810 e 1013029 de 30,30 e 30,31%. Em relação a lignina os maiores valores encontrados foram para os genótipos 1013020 e 1134023 (5,82 e 5,41%, respectivamente). Os valores de digestibilidade da matéria seca foram superiores a 50%. Os híbridos avaliados demonstraram fenos de boa qualidade, no entanto os híbridos, 1013020, BRS 810, BRS 802 apresentaram melhor valor nutricional.

Palavras-chave: Corte e pastejo, Forragem, Genótipo, Fenação, Digestibilidade.

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1 INTRODUCTION

The seasonality of forage production in Brazil is one of the reasons why most livestock systems become dependent on planning their feeding program based on conserved forages or species with improved drought resistance (AGUILAR *et al.*, 2015).

The continuity of milk and meat production based on feeding high-quality forage as the main dietary component throughout the year has been a challenge in the tropical regions during the dry season. Then, feeding strategies have been proposed to minimize production costs and to overcome the lack of high-quality forage sources.

The grown and use of high-quality conserved forages is an alternative to fill the gap in forage production during the dry season, aiming at improving the low productivity of the herds, reducing the expenses with supplementation, and maintaining the profitability of the livestock enterprise (DANIEL *et al.*, 2011; SANTIN *et al.*, 2020).

Sorghum-sudangrass hybrids are a cross between *Sorghum bicolor* (L.) Moench and *Sorghum sudanense* (Piper) Stapf, also known as 'sorghum grown for cutting and grazing'. These hybrids have been used as an alternative for maintaining the forage supply and, consequently, milk and meat production during the year. There are still few cultivars available in the Brazilian market, but they have been well-accepted by farmers as an available option to extend the period of use of green forage with high nutritive value (FERREIRA *et al.*, 2015).

The use of sorghum-sudangrass hybrids has increased in livestock feeding due to their ease of cultivation, rapid establishment and growth. In addition to their ease of handling for cutting or grazing, these hybrids have good nutritive value and high forage production, making them a feasible option to supply green forage of high nutritional value (LIMA *et al.*, 2017).

The nutritive value of sorghum grown for cutting and grazing does not vary considerably among genotypes in the market, but the productivity depends on adequate climatic conditions and soil fertility. Improvements in productivity are found when sorghum is harvested at more advanced phenological stages (SIMILI *et al.*, 2011).

This study aimed to evaluate the nutritive value of hay from ten sorghum-sudangrass hybrids.

2 MATERIAL AND METHODS

The experiment was conducted at the State University of Southwest Bahia (UESB), in the municipality of Vitória da Conquista, in the state of Bahia, Brazil (15.95ºS, 40.88ºW and 839 meters above sea level). According to Köppen's classification, the climate of the region is classified as humid subtropical climate (Cwa), with an average annual rainfall of 733.9 mm, mainly falling between November to March.

After the first rains from October to December 2016, ten sorghum-sudangrass hybrids for haymaking were sown: 1013020, 1013021, 1013026, 1013029, 1134023, 1134027, 1134029, 1013016, BRS 810, BRS 802. The seeds were provided by the National Center for Research on Corn and Sorghum (Embrapa).

At sowing, 20 kg ha^{-1} of N as urea + 70 kg ha^{-1} of P_2O_5 as single superphosphate were used. For top dressing, 75 kg ha^{-1} of K_2O as potassium chloride + 90 kg ha^{-1} of N as urea (divided into three applications) were used.

Three replicates (blocks) were set for each treatment (hybrid), constituted by four rows of five-meter long spaced 0.5 m apart (total area of $10m^2$), totaling ten treatments with 30 experimental plots in a randomized block design. Cutting was carried out at 57 days after germination. The two central rows (useful plot) were considered for analyzes, disregarding the two outer rows of the plots.

Sorghum-sudangrass hybrids were harvested manually using sickle and scattered over the floor of a shed for drying. The material was turned over every two hours for standardization of dehydration. After drying, the sampled hay was placed into nylon bags and stored in a ventilated area. Hay samples were chopped, homogenized and placed in identified paper bags.

Samples were immediately transported to the Laboratory of Animal Nutrition of the State University of Southwest Bahia (UESB) - Campus Vitória da Conquista, Bahia. The samples were weighed and dried in a forced ventilation oven at 65ºC for 24 hours. After drying, the material was left at room temperature for 1 hour to constant weight and weighed to determine the dry matter (DM) content. The dried samples were ground using a Wiley mill to pass a 1-mm sieve and stored in polyethylene flasks for further analysis.

Whole-plant hay samples were used to evaluate the following nutritional parameters: dry matter content (DM), crude protein (CP), ether extract (EE), ash, cellulose, hemicellulose, lignin, ash and protein-free neutral detergent fiber (aNDF), acid detergent fiber (ADF), according to Detmann *et al.* (2012). Hemicellulose was determined by the difference between the concentrations of NDF and ADF.

The *in vitro* DM digestibility (IVDMD) was determined on the Daisy^{II} digestion apparatus (ANKOM® Technology Corp., Fairport, NY). Ruminal fluid was collected from crossbred cannulated Holstein x Zebu cows with a mean body weight of 550 kg. Cows were fed a diet comprising commercial concentrate and sorghum hay, which started 15 days before the sampling to ensure gradual adaptation of the ruminal microbiota to the diet.

The *in vitro* DM digestibility was determined using the ANKOM® methodology (ANKOM TECHNOLOGY, 2010), after incubation in an artificial rumen (TE-150, TECNAL). A total of 0.5 g of dried sample was placed into filter bags (F-57 ANKOM®), which were subsequently heat-

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sealed. The filter bags with 30 samples corresponding to each treatment and their replicates were placed in an incubation digestion jar for 48 hours.

The buffer solution was prepared in preheated (39°C) flasks. Solution A (g/liter) was composed of 10.0 g KH_2PO_4; 0.5 g $MgSO_4.7H_2O$; 0.5 g NaCl; 0.1 g $CaCl_2.2H_2O$ and 0.5 g urea; and solution B (g/100 mL) was composed of 15.0 g Na_2CO_3; 1.0 g $Na_2S_9.H_2O$. The solutions were mixed by adding 266 mL of solution B to 1330 mL of solution A (ratio 1:5), at a final pH of 6.8 and a temperature of 39°C. Approximately 1600 mL of the combined mixture was added to each digestion jar, then 400 mL of ruminal liquid was added to each incubation digestion jar containing the ANKOM F57 filter bags. After incubation, filter bags were washed and treated with neutral detergent (NDF) solution following the procedures described by Detmann et al. (2012).

The digestible dry matter production of hay (DDMH) was obtained by multiplying hay production (kg) by its dry matter content and digestibility.

Data were submitted to analysis of variance, and the means were compared by the Scott-Knott's test at 5% significance using the ASSISTAT v.7.7 Beta software (SILVA and AZEVEDO, 2016).

3 RESULTS AND DISCUSSION

Sorghum-sudangrass hybrids were different for dry matter content, ash and crude protein concentration (P<0.05) (Table 1). The highest dry matter contents were found in hay from hybrids 1013016, 1134027, 1134029, 1134023, 1013021, 1013029, 1013026, 1013020, which did not differ from each other (P<0.05). The hybrids BRS 810 and BRS 802 showed similar dry matter content, although it was lower compared to other genotypes (86.98 and 86.47%, respectively).

Table 1. Mean values of dry matter (DM), ash, crude protein (CP), and ether extract (EE) of hay from ten hybrids of sorghum-sudangrass.

Hybrids	DM	Ash[1]	CP[1]	EE[1]
1013020	88.31a	5.27b	12.84a	2.01a
1013021	88.60a	5.21b	11.26b	1.53a
BRS 810	86.89b	6.46a	14.01a	2.24a
1013026	88.52a	4.90b	9.88b	2.11a
1013029	88.53a	4.57b	10.06b	2.05a
1134023	88.71a	4.95b	10.17b	2.29a
1134027	89.23a	5.26b	9.53b	1.98a
1134029	88.75a	5.10b	10.33b	2.07a
1013016	89.38a	4.63b	11.18b	1.86a
BRS 802	86.47b	5.22b	11.96a	1.84a
Mean	88.34	5.15	11.13	2.00
CV (%)	0.65	10.90	11.01	9.54

Means followed by similar lowercase letters within rows are not significantly different at P<0.05 (Scott-Knott's test); CV = coefficient of variation; [1]Dry matter basis.
Data source: Authors.

According to Neres and Ames (2015), hay with a maximum moisture content of 15% can be stored over a long period without fermenting, mold growing or even spontaneous combustion. Therefore, dry matter losses are reduced.

The results found in the present study were lower than that found by Athayde *et al.* (2012) evaluating the chemical composition of hay from coastcross grass at different stages of growth. The authors obtained values of 96.65; 96.81; 92.46; 92.63% DM for cuttings at 20, 40, 60 and 80 days.

Ash content was highest for the hybrid BRS 810, averaging 6.46%. For other hybrids, the values ranged from 4.57 to 5.27%, which did not differ from each other (P>0.05).

The highest crude protein content was found in hybrids BRS 810, 1013020, BRS 802, reaching 14.01, 12.84 and 11.96%, respectively, although they did not differ from each other. For other hybrids, the values ranged from 9.53 to 11.26% CP. In a study conducted to evaluate the hay from nineteen hybrids of sorghum-sudangrass, Lima *et al.* (2017) reported crude protein levels ranging from 11.84 to 15.57%, averaging 12.98%.

Several factors can alter the protein content of hybrids of sorghum-sudangrass, including harvest frequency, plant spacing and nitrogen fertilization (PENNA *et al.*, 2010). According to Edward Junior *et al.* (1971), the main factors are plant cutting height and cutting age. As plant progresses through several growth stages, its constitution is markedly changed, with greater fiber accumulation and a higher proportion of stem, which reduce the protein content.

Crude protein levels in hay from the ten hybrids were above the minimum of 7% nitrogen required by the rumen flora to ensure adequate ruminal fermentation (SAMPAIO *et al.*, 2009).

For the ether extract, there was no difference between hybrids (P>0.05). Hybrids 1134023, BRS 810, 1013026, 1134029, 1013029, 1013020, 1134027, 1013016, BRS 802, 1013021 had 2.29; 2.24; 2.11; 2.07; 2.05; 2.01; 1.98; 1.86; 1.84 and 1.53% EE, respectively, with an average value of 2.0% (Table 1).

When analyzing the hay from Tifton-85 grass, Ataíde Junior *et al.* (2000) reported values below than that observed in the present study (1.17 and 1.48% EE, respectively). As recommended by the NRC (2001), in most situations, total lipids in ruminant diets should not exceed 6 to 7% of the total dry matter because it may cause reductions in ruminal fermentation, fiber digestibility and passage rate.

There was a difference between hybrids (P<0.05) for neutral detergent fiber, acid detergent fiber, and lignin concentrations. Sorghum hybrids were similar (P>0.05) for hemicellulose and cellulose (Table 2).

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Table 2. Mean values of neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM), cellulose (CEL), and lignin (LIG) of hay from ten hybrids of sorghum-sudangrass.

Hybrids	NDF[1]	ADF[1]	HEM[1]	CEL[1]	LIG[1]
1013020	63.59a	36.38a	27.20a	30.22a	5.82a
1013021	61.81a	34.50a	32.18a	26.77a	3.87b
BRS 810	58.57b	30.30b	28.27a	26.81a	3.18b
1013026	61.52a	34.86a	26.66a	30.10a	4.61b
1013029	57.63b	30.31b	27.33a	26.35a	3.66b
1134023	62.80a	36.12a	26.67a	30.52a	5.41a
1134027	62.58a	35.86a	26.72a	31.33a	4.37b
1134029	57.72b	33.11a	24.60a	29.50a	4.07b
1013016	63.48a	32.44b	31.04a	27.75a	4.47b
BRS 802	61.80a	32.47b	29.33a	28.36a	4.10b
Mean	61.15	33.63	28.00	28.77	4.35
CV (%)	3.80	7.51	10.39	7.35	16.90

Means followed by similar lowercase letters within rows are not significantly different at $P<0.05$ (Scott-Knott's test); CV = coefficient of variation; [1]Dry matter basis.
Data source: Authors.

Hybrids were different for NDF concentration, with higher values ($P<0.05$) for hybrids 1013026, BRS 802, 1013021, 1134027, 1134023, 1013016, 1013020, ranging from 61.52 to 63.59%. The lowest NDF concentrations were observed in hybrids 1134029, 1134023 and BRS 810 (57.63, 57.72 and 58.57%, respectively), which did not differ between from each other. The mean NDF concentration was 61.15%.

The mean NDF concentration of 59.30% reported by Lima *et al.* (2017) when evaluating hay from sorghum hybrids grown for cutting and grazing was similar to that found in the present study (61.15%). The NDF values observed in hybrids in the present study and the study of Lima *et al.* (2017) are associated with early haymaking (57 days and 52 days), respectively.

Determining the fibrous fractions is essential for the characterization of the nutritive value of forage since these components are associated with the regulation of intake, digestibility, passage rate, and chewing activity of ruminants. In a high-fiber diet, the energy density tends to be low, with intake limited by rumen fill; then, animal performance may be compromised. On the other hand, low fiber contents increase the risk of metabolic disorders (LIMA *et al.*, 2017).

The NDF concentration is directly associated with factors such as cultivar cycle, night temperature, soluble carbohydrate content, among others (OLIVEIRA *et al.*, 2010).

Regarding the ADF concentration, there was a significant difference ($P<0.05$) between hybrids. Hybrids BRS 810, 1013029, 1013016, and BRS 802 had the lowest ADF levels, reaching 30.30; 30.31; 32.44 and 32.47%, respectively, although did not differ between from each other.

Regarding hemicellulose, sorghum hybrids grown for cutting and grazing were not significantly different ($P>0.05$). The values ranged from 24.60 to 32.18%, with an average value of 27.43%. For cellulose, sorghum hybrids were also similar ($P>0.05$), and the values ranged from 26.35 to 31.33%, averaging 26.93%.

As reported by Van Soest *et al.* (1991), cellulose corresponds to the most important component of the cell wall structure. The nutritional availability of cellulose varies from total indigestibility to complete digestibility depending on the degree of lignification.

In this study, the mean hemicellulose content was 28.00%, which is similar to the mean cellulose content (28.77%). Hemicellulose content should be higher or similar to that of cellulose since NDF fraction consists predominantly of hemicellulose. This cell wall component is calculated by the difference between NDF and ADF, with higher digestion rate than cellulose.

Hybrids 1134023 and 1013020 had the highest lignin levels (5.41 and 5.82%, respectively). The other hybrids had lower, but similar values for lignin, ranging from 3.18 to 4.61%, which correspond to that found in hybrids BRS 810 and 1013026. The mean lignin concentration was 4.35%.

The low values found in hybrids BRS 810 and BRS 802 is associated with the fact that they were developed to have a lower lignin content, resulting in lower fiber content and higher digestibility.

The lignin concentration of tropical grasses has been reported by Leonel *et al.* (2009) as the depreciative fraction of feedstuffs. Consequently, lower lignin contents result in better use of fiber by ruminal microorganisms.

Hybrids were significantly different ($P<0.05$) for ash and protein-free neutral detergent fiber and *in vitro* dry matter digestibility (Table 2).

The highest aNDF levels were observed in hybrids 1013016, 1134027, 1013020, 1013021, 1013026, 1134023, 1134029, and BRS 802 (61.37, 60.49, 59.88, 59.06, 59.02, 58.49, 57.93, 57.88%, respectively). The lowest aNDF values were reported in hybrids 1013029, and BRS 810 (54.45 and 56.06%, respectively).

The hybrids BRS 810, 1013029, 1013021, BRS 802, and 1013020 had the highest IVDMD values, which did not differ between from each other.

The high digestibility of the BRS 810 and BRS 802 hybrids is directly associated with their low amount of fiber and lignin (3.18 and 4.10% of lignin, respectively). These two hybrids are mutant plants characterized by a brown midrib in the leaves, resulting in low lignin content and better digestibility rates. Consequently, it can lead to higher feed intake and animal performance (LEDGERWOOD *et al.*, 2009; ASTIGARRAGA *et al.*, 2014; SANTIN *et al.*, 2020).

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Table 3. Mean values of ash and protein-free neutral detergent fiber (aNDF), *in vitro* dry matter digestibility (IVDMD) and digestible dry matter production of hay (DDMH) of hay from ten hybrids of sorghum-sudangrass.

Hybrids	aNDF[1]	IVDMD[1]	DDMH[2]
1013020	59.88a	65.66a	3.22a
1013021	59.06a	66.79a	1.96a
BRS 810	56.06b	72.00a	1.97a
1013026	59.02a	64.21b	1.83a
1013029	54.45b	68.73a	2.43a
1134023	58.49a	61.75b	2.45a
1134027	60.49a	62.24b	2.01a
1134029	57.93a	62.93b	2.14a
1013016	61.37a	58.91b	2.21a
BRS 802	57.88a	65.91a	1.99a
Mean	58.46	64.91	2.22
CV (%)	2.98	4.83	20.50

Means followed by similar lowercase letters within rows are not significantly different at $P<0.05$ (Scott-Knott's test); CV = coefficient of variation; [1]Dry matter basis. [2](t ha-[1]).
Data source: Authors.

The stage of development in plants has a strong relationship with the chemical composition and forage digestibility. With the advancement of physiological maturity, there is an increase in the contents of structural carbohydrates and lignin, and a decrease in the cellular content, reducing the digestibility. The digestibility of the hybrids can be associated with the early cutting age (57 days after germination).

Regarding the digestible dry matter production of hay, no statistical difference ($P>0.05$) was observed between hybrids. The values ranged from 1.96 to 3.22 t ha^{-1}, with an average value of 2.22 t ha^{-1} of DDMH. Penna *et al.* (2010), evaluating six sorghum-sudangrass hybrids under three cuttings and two sowing seasons, reported mean digestible dry matter yields of 2.67 t ha^{-1} and 3.64 t ha^{-1} for the first and second season, respectively. These values are higher than those found in the present study, but the authors performed three cuttings per season.

4 CONCLUSION

Hay from all hybrids was of good quality, with dry matter digestibility higher than 50%. However, hybrids 1013020, BRS 810, BRS 802 were better in terms of nutritive value.

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