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Nutritional characteristics of Sorghum hybrids hay (*Sorghum sudanense* vs. *Sorghum bicolor*)

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ABSTRACT. This study evaluated the nutritional characteristics of hay of nineteen hybrids between sorghum and Sudan grass. The experimental design was a randomized block with nineteen treatments and three replications. The chemical characteristics of the respective hays were analyzed 52 days after sowing and 45 and 49 regrowth days. Data were analyzed by analysis of variance, and when the F test was significant, the treatment means were compared by the Scott and Knott test at 5%. Genotypes 1013026 and 1014020 showed similar dry matter content. As for ether extract content, the highest values ranged from 2.20 to 2.66%. Higher values of minerals were observed in hybrids 1013026 and 1011005. In relation to crude protein, higher content values were reported for hybrids 1013021 and 1013020 (14.59 and 15.47% CP). When evaluating the neutral detergent fiber content, lower values varied between 56.05 and 57.07% for hybrids 1013016 and 1011009. Considering the content of acid detergent fiber, values ranged from 32.70 to 35.78%. Values of dry matter digestibility were higher than 50%. All hybrids provide quality hay, however the hybrid 1014019 showed the best nutritional value.

Keywords: sudan grass, chemical composition, digestibility.

Características nutricionais de feno de híbridos de sorgo (*sorghum sudanense* x *sorghum bicolor*)

RESUMO. Este trabalho foi realizado para avaliar as características nutricionais de feno de 19 genótipos de sorgo com capim-sudão. O delineamento experimental utilizado foi em blocos casualizados composto por 19 tratamentos com três repetições. As características bromatológicas dos respectivos fenos foram analisadas após 52 dias de semeadura e 45 e 49 dias de rebrota. Os dados foram interpretados pela análise de variância e, quando o teste de F foi significativo, as médias dos tratamentos foram comparadas pelo teste de Scott e Knott em nível de 5%. Os genótipos 1013026 e 1014020 apresentaram teores semelhantes de matéria seca. Para a variável extrato etéreo os maiores valores oscilaram de 2,20 a 2,66%. Valores superiores de minerais foram evidenciados nos híbridos 1013026 e 1011005. Quanto à proteína bruta, os maiores teores foram reportados pelos híbridos 1013021 e 1013020 (14,59 e 15,47 % de PB). Ao avaliar os valores de fibra em detergente neutro, os menores teores variaram de 56,05 a 57,07% para os híbridos 1013016 e 1011009. A fibra em detergente ácido variou de 32,70 a 35,78%. Os valores de digestibilidade da matéria seca foram superiores a 50%. Todos os híbridos apresentaram feno de qualidade, no entanto o híbrido 1014019 apresentou melhor valor nutritivo

Palavras-chave: capim-sudão, composição bromatológica, digestibilidade.

Introduction

In Brazil, the cultivation of sorghum (*Sorghum bicolor* L.) has increased considerably. This is due to the increase of the planted area, use of new technologies for cultivation and use of more productive genotypes adapted to soil and climatic conditions (Terra et al., 2010).

Sudan grass (*Sorghum bicolor* cv. Sudanese) has been gaining increasing importance in aniaml feed, due to its ease of cultivation, rapid establishment and growth and, mainly, the ease of handling for cutting and grazing, besides good nutritional value and of high forage production, which makes it a viable alternative to offer green forage of high nutritional value. The nutritive value of the sorghum hybrids with *sorghum bicolor* has shown little variation between the different materials (Wall & Ross 1975).

The nutritional value of hybrids between sorghum and Sudan grass for cutting and grazing has little variation among the materials available in the market, however the productivity depends on suitable climatic conditions and soil fertility, and an increased productivity is found in cuts at more advanced stages. The combination of these factors is essential for hybrids to express their potential, because the occurrence of water deficit negatively influences the production of forage dry matter in order to achieve productivity and avoid losses due to animal trampling when used for grazing (Simili et al., 2011). In Brazil, hybrids between sorghum and Sudan grass have been widely used in the state of Rio Grande do Sul for the formation of temporary summer pastures, when there are high temperatures and low rainfall. In this context, the aim of this study was to evaluate the nutritional value of hay from sorghum-Sudan grass hybrids

Material and methods

The experiment was conducted at Embrapa - National Center for Maize and Sorghum Research, located at Km 65 of the highway MG 424, in the municipality of Sete Lagoas, state of Minas Gerais, between coordinates 19º 28' South latitude and 44º 15' West longitude. The region has an average altitude of 732 m, average annual rainfall of 1340 mm with a concentration of 86% between the months of November and April, and AW climate (savannah climate with dry winter and average temperature above 18°C in the coldest month) according to classification from Köopen.

In the period november/december 2013, as a result of the first rainfall events, nineteen sorghum hybrids for cutting and grazing were sown: 1013020, 1013021, 1011009, 1013026, 1013028, 1013029, 1013030, 1014020, 1014021,1013019, 1014029, 1013016,1011005, 1014006, 1014009, BRS800, 1014015, 1014016, 1014019.

For each treatment (hybrid), 3 repetitions (blocks) were set, consisting of 6 rows, 6 m long, and 70 cm apart, totaling 19 treatments with 57 experimental plots in a randomized block design. Sowing fertilization was made with 300 kg ha^{-1} of the 04-30-10 (NPK) formulation and topdressing at 35 days (60 kg ha^{-1} N as urea) according to soil analysis and crop requirements.

Two central and two intermediate rows (useful plot) were used for analyses, disregarding the two external rows of the plots. The cuts were made at 52 days after sowing, 45 and 49 regrowth days at 15 cm from the ground, in which the sorghum genotypes were collected manually with the use of haymaking, and dried in the field, turning the material over every two hours for standaddization and dehydration of plants. After drying, the sampled hay were placed in nylon bags and stored in a ventilated area. For nutritional analyses, samples of hay were chopped, homogenized, placed in identified paper bags and transported to the Food Analysis Laboratory, State University of Montes Claros (Unimontes) – Campus Janaúba, state of Minas Gerais. Subsequently, samples were weighed and dried in a forced ventilation oven at 55ºC for 72 hours (Detmann et al., 2012). After drying, the material was left at room temperature for 2 hours to weight stabilization and weighed to determine dry matter (DM) content. The dried samples were ground in a Wiley mill with 1 millimeter sieve and stored in polyethylene containers for further analysis.

For nutritional assessment, hays were evaluated for the parameters: total dry matter content (DM) in an oven, ash, crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), neutral detergent insoluble nitrogen (NDIN), acid detergent insoluble nitrogen (ADIN) and lignin, according Detmann et al. (2012). Cellulose was determined by the weight difference between ADF and lignin, hemicellulose by the difference between the NDF and ADF. The *in vitro* dry matter digestibility was calculated according to procedure described by Tilley and Terry (1963) modified by Silva and Queiroz (2006), using *in vitro* incubator Tecnal® (TE-150), with modification of the material of the bag used (5.0 x 5.0 cm), made with non-woven fabric (TNT -100 g m^{-2}), according to Casali et al. (2008). The experiment consisted of a randomized block design, with nineteen genotypes (treatments) and three replications (blocks), totaling 57 experimental plots. Because the number of plants is classified as a discrete quantitative variable, resulting from count data, additivity was tested using the GLM (General Linear Models) procedure, by means of analysis of covariance of the squared predicted values, resulting in $p = 0.0596$, normality by univariate procedure, with W statistics (Shapiro-Wilk test), with $p = 0.0584$ and the homogeneity of variance by Bartlett's test ($p = 0.0624$). Once confirmed the non-significance of these tests, we accepted the transformation, indicating that the assumptions of the residual analysis, residual normality and homogeneity of variances, were accepted, the variables were tested by analysis of variance, and when F-test was significant, the treatment means were compared by the Scott-Knott test at 5% probability. The analysis was performed using the software Sisvar (Ferreira, 2011), according to the following model a Equation 1:

$$Yij: \mu + Gi + Bj + eij \quad (1)$$

where:

Yij = observed value of genotype i in block j;
μ = overall mean;
Gi = effect of genotype i, with i = 1, 2, 3,... 19;
Bj = effect of block j, with j = 1, 2 and 3.
eij = experimental error associated with observed values (Yij).

Results and discussion

Table 1 shows that sorghum hybrids evaluated in this experiment were significantly different ($p < 0.05$) from each other considering the content of dry matter, crude protein, ether extract and mineral matter.

Table 1. Mean values of crude protein (CP), dry matter content (DM), ether extract (EE) and mineral matter (MM) of hay of nineteen sorghum hybrids for cutting and grazing.

Hybrids	DM[1](%)	CP(%)	EE[1](%)	MM[1](%)
1013020	91.37^C	15.47^A	2.32^A	7.94^D
1013021	91.73^B	14.59^A	2.02^B	9.28^B
1011009	91.12^C	11.84^C	2.03^B	9.33^B
1013026	92.19^A	12.54^C	2.66^A	11.12^A
1013028	91.08^C	12.53^C	2.20^A	9.28^B
1013029	90.93^C	12.38^C	2.30^A	9.62^B
1013030	91.23^C	13.80^B	2.59^A	8.55^C
1014020	92.32^A	13.36^B	2.32^A	6.65^E
1014021	91.68^B	12.16^C	2.04^B	9.07^B
1013019	91.25^C	13.37^B	2.02^B	8.19^C
1014029	91.40^C	11.93^C	1.89^B	8.84^B
1013016	91.14^C	12.51^C	1.84^B	7.37^D
1011005	91.54^C	12.35^C	1.54^B	11.13^A
1011006	91.60^B	13.51^B	1.98^B	8.96^B
1014009	91.33^C	12.65^C	2.33^A	8.36^C
BRS800	91.68^B	13.29^B	2.23^A	8.88^B
1014015	91.57^B	12.55^C	2.05^B	8.36^C
1014016	91.56^B	12.90^C	2.27^A	8.74^C
1014019	91.90^B	12.38^C	2.08^B	8.53^C
Mean	91.50	12.98	2.14	8.85
CV (%)	6.31	0.33	0.33	6.31

For the same variable, mean values followed by different uppercase letters, in the same column, are significantly different by Scott-Knott test ($p > 0.05$). CV – Coefficient of variation.

Hybrids 1013026 and 1014020 were superior ($p < 0.05$) to the others considering the dry matter content and similar to each other ($p > 0.05$), with mean values of 92.19 and 92.32%, respectively. The values obtained herein were higher than those described by Neumann et al. (2010), who evaluated four sorghum-Sudan grass hybrids and reported DM content of whole plant ranging from 10.2 to 13.1% when the cutting was done 40 days after sowing and from 16.9 to 21.7% when the cutting was done 110 days after sowing, with a linear increase over time. The timing of cuts is the main responsible for changes in DM content, by the greater participation of leaves and consequent anticipation of the crop reproductive stage, to keep the plant at the vegetative stage and allow successive cuts.

The hybrids were different ($p < 0.05$) considering crude protein content, and the highest values were presented by genotypes 1013021 and 1013020 (14.59 and 15.47% CP). Beck et al. (2007) observed CP content of 12.6; 9.7; 6.9; 5.0 and 4.3% when a sorghum-Sudan grass hybrid was subjected to cutting at 34, 41, 48, 55 and 63 days after planting, respectively. Nineteen hybrids analyzed had ideal values of CP content to meet the requirements of nitrogen by rumen flora and for a good rumen functioning (7% minimum). Tomich, Rodrigues, Tomich, Gonçalves, and Borges (2004) investigated the same hybrids with the cut at 57 days and found similar values, ranging between 12.6 and 14.5%.

For ether extract, there were differences between hybrids ($p < 0.05$), whose highest values ranged from 2.20 to 2.66%. Forages with higher EE content tend to have higher values of total digestible nutrients, because fat supplies 2.25 times more energy than carbohydrates, but should not exceed 6-7% in DM, as it may cause reductions in ruminal fermentation, in fiber digestibility and rate of passage.

With respect to mineral matter, there were differences between hybrids ($p < 0.05$) (Table 1), with the highest values observed for genotypes 1013026 and 1011005 (11.12 and 11.13% MM), which were not different from each other ($p > 0.05$). And the lowest content was verified for hybrid 1014020, with 6.65% MM. Values close to those of sorghum-Sudan grass hay studied in this work were reported by Aguiar et al. (2010), who studied hay of IPA-Bulk-1 millet, Sudan-4202 sorghum, Cameroon elephant grass, IPA-SF-25 forage sorghum and IPA-467-4-2 forage sorghum (10.53; 11.03; 10.98; 8.77 and 8.71% MM). Ash content indicates the amount of minerals in the forage, however high values may also be represented by quantities of silica, which is not favorable in ruminant feeding.

There were differences between hybrids ($p < 0.05$) for both neutral and acid detergent fiber content (Table 2).

NDF content of hybrids ranged from 58.52 to 61.27. Genotypes 1013016, 1011009, 1011005, 1013029 and 1013021 showed lower values, although within the acceptable limit of 50 to 60%. The determination of the fiber fractions content is very important in characterizing the nutritional value of the forage, because of the relationship of these components with the regulation of intake, digestibility, rate of passage and chewing activity in ruminant feed. In fiber-rich diet, the energy density tends to be low, with intake limited by rumen fill and animal performance may be compromised, however, the low fiber content increases the risk of metabolic disorders. NDF content is directly related to factors like the cultivar cycle, night temperature, soluble carbohydrate content, among others (Oliveira et al., 2010). The low NDF content of genotypes tested herein can be because the sorghum hybrids studies have been hay early (52, 45 and 49 days after regrowth). Regarding ADF, there were differences ($p < 0.05$) between hybrids that were greater than 30%. The ADF analysis is an estimate of the total content of cellulose and lignin, acid detergent insoluble nitrogen, acid-insoluble ash and silica, and is related to the potential digestibility of a given forage, while the NDF content is more related to the intake of the sample and is inversely related to the DM digestibility (Van Soest, Robertson, & Lewis, 1991). The content of NDF and ADF increases in the composition of plants during the vegetative stage, and this is due to greater participation of plant cell walls with the passage of time. Von Pinho, Vasconcelos, Borges, and Resende (2007) reported values lower than those observed in this work for NDF (42.9%) and ADF (26.6%) for dual purpose sorghum. Sánchez, Cruz, Gil, Corona, and Wong (2010) studied a sorghum-Sudan grass hybrid subjected to cutting at 106 days after sowing and observed NDF content of 64.6% and ADF of 45.6%.

Table 2. Mean content of neutral detergent fiber (NDF), acid detergent fiber (ADF), celulose (CEL), hemicellulose (HEM) and lignin (LIG).

Hybrids	NDF (%)	ADF (%)	CEL(%)	HEM	LIG
1013020	59.04^{A}	34.79^{B}	25.81^{A}	29.85^{B}	4.47^{B}
1013021	58.52^{B}	32.88^{B}	21.21^{A}	31.23^{A}	4.33^{B}
1011009	57.07^{B}	34.50^{B}	20.78^{C}	26.26^{D}	4.39^{B}
1013026	60.11^{A}	38.78^{A}	19.51^{C}	26.91^{C}	4.13^{B}
1013028	58.95^{A}	38.12^{A}	25.33^{A}	27.41^{C}	4.98^{B}
1013029	57.92^{B}	35.21^{B}	23.81^{B}	29.39^{B}	6.18^{A}
1013030	62.38^{A}	39.52^{A}	19.48^{C}	25.33^{D}	5.81^{A}
1014020	60.01^{A}	38.38^{A}	20.07^{C}	25.51^{D}	5.77^{A}
1014021	59.57^{A}	37.28^{A}	21.23^{C}	27.79^{C}	5.68^{A}
1013019	60.44^{A}	35.08^{B}	21.69^{C}	31.20^{A}	4.86^{B}
1014029	59.04^{A}	34.57^{B}	24.41^{B}	28.73^{B}	6.84^{A}
1013016	56.05^{B}	32.70^{B}	21.20^{C}	27.95^{C}	6.48^{A}
1011005	57.15^{B}	33.53^{B}	26.25^{A}	29.14^{B}	5.82^{A}
1011006	60.28^{A}	38.51^{A}	23.18^{B}	27.24^{C}	6.21^{A}
1014009	60.74^{A}	37.69^{A}	25.18^{A}	28.87^{B}	6.26^{A}
BRS800	59.08^{A}	37.60^{A}	25.96^{A}	26.77^{C}	5.18^{B}
1014015	59.11^{A}	35.78^{B}	23.21^{B}	28.84^{B}	6.17^{A}
1014016	61.27^{A}	35.43^{B}	21.32^{C}	31.48^{A}	6.77^{A}
1014019	60.03^{A}	34.10^{B}	24.55^{B}	27.80^{C}	7.07^{A}
Mean	59.30	36.02	22.85	28.30	5.66
CV (%)	2.41	3.55	5.48	3.94	16.46

For the same variable, mean values followed by different uppercase letters, in the same column, are significantly different by Scott-Knott test ($p > 0.05$). CV – Coefficient of variation.

Sorghum hybrids evaluated differed ($p < 0.05$) as for contents of cellulose, hemicellulose and lignin (Table 2). Cellulose contents ranged from 20.78 to 26.95%. The high or low cellulose content found in sorghum hybrids is directly related to the participation of ADF, once cellulose is a major component of this fraction. Regarding hemicellulose, there were differences between sorghum-Sudan grass genotypes ($p < 0.05$). Genotypes 1013019 (31.20%), 1013021 (31.23%) and 1014016 (31.48%) showed higher values ($p > 0.05$) than the others. The lowest results were observed for hybrids 1013030, 1014020 and 1011009, with HEM content of 25.33; 25.51 and 26.26%, respectively. The hemicellulose integrates the neutral detergent fiber (NDF) and is calculated as the difference between NDF and acid detergent fiber (ADF), and is more digestible than cellulose. Therefore, it becomes interesting to raise the hemicellulose content and decrease the cellulose content, as the bacterial flora of ruminants break down these components into fatty acids. In relation to lignin, values of the hybrids ranged from 4.13 to 7.07% ($p < 0.05$) (Table 2). Lignin is the component most negatively correlated with digestibility, because it limits the digestion of cell wall polysaccharides and reduces the nutritional value of plants for ruminants. Therefore, the selection of sorghum genotypes for cutting and grazing with low lignin content can be considered relevant to improve the diets offered to ruminants, since they have higher digestibility, favoring increased intake by animals. Penna et al. (2010) found no difference between three cuts for the lignin content (5.39% in the first season and 6.32% in the second season).

Values of neutral detergent insoluble nitrogen content were similar ($p > 0.05$) between sorghum genotypes studied, with a mean value of 0.11% NDIN, based on CP (Table 3).

Considering the acid detergent insoluble nitrogen (ADIN), there was variation between genotypes, in which the values ranged from 0.09 to 0.15% ADIN and were superior to other data obtained ($p < 0.05$), being within the range of variation from 3 to 15% total nitrogen. Aguiar et al. (2010) demonstrated mean of 0.09% ADIN of whole plant of Sudan sorghum. The concentration of ADIN in forage has a high negative correlation with the apparent digestibility of protein. This protein fraction corresponds to the proteins associated with lignin, tannin-protein complexes and Maillard reaction products, highly resistant to microbial enzymes and indigestible along the gastrointestinal tract. IVDMD values were significantly different between sorghum genotypes for cutting and grazing ($p < 0.05$) (Table 3). IVDMD of genotypes 1011009, 1013026, 1014020, 1014021, 1013019, BRS800, 1014015, 1014016 and 1014019 were higher than the others. The plant development stage has strong relationship with the chemical composition and digestibility of forages. With the growth of forage, there is an increase in structural carbohydrates and lignin contents and reduced cellular content, which invariably cause decline in digestibility. In this way, the higher IVDMD value may be related to the low age of hay of sorghum genotypes for cutting and grazing used in this study (52 days after planting, 45 and 49 regrowth days). Also in relation to digestibility, sorghum-Sudan grass hay, as they were used in this study, may be an option to overcome the reduction in the quality of pastures. However, further studies are required with animals and on the economic viability of this practice.

Table 3. Neutral detergent insoluble nitrogen (NDIN), acid detergent insoluble nitrogen (ADIN) and in vitro dry matter digestibility (IVDMD).

Hybrids	NDIN[1] (%)	ADIN[1] (%)	IVDMD (%)
1013020	0.18^{A}	0.11^{A}	53.94^{B}
1013021	0.20^{A}	0.12^{A}	55.62^{B}
1011009	0.18^{A}	0.12^{A}	59.16^{A}
1013026	0.19^{A}	0.10^{B}	57.90^{A}
1013028	0.19^{A}	0.12^{A}	54.30^{B}
1013029	0.18^{A}	0.09^{B}	53.76^{B}
1013030	0.19^{A}	0.10^{B}	56.87^{B}
1014020	0.17^{A}	0.13^{A}	59.13^{A}
1014021	0.19^{A}	0.13^{A}	61.04^{A}
1013019	0.21^{A}	0.10^{B}	58.81^{A}
1014029	0.19^{A}	0.13^{A}	52.68^{B}
1013016	0.17^{A}	0.11^{A}	56.39^{B}
1011005	0.17^{A}	0.07^{B}	55.97^{B}
1011006	0.18^{A}	0.12^{A}	54.62^{B}
1014009	0.18^{A}	0.15^{A}	53.88^{B}
BRS800	0.16^{A}	0.10^{B}	59.05^{A}
1014015	0.18^{A}	0.14^{A}	60.54^{A}
1014016	0.18^{A}	0.12^{A}	59.52^{A}
1014019	0.17^{A}	0.12^{A}	63.29^{A}
Mean	0.18	0.11	57.18
CV (%)	9.43	14.95	5.85

For the same variable, mean values followed by different uppercase letters, in the same column, are significantly different by Scott-Knott test (p > 0.05). CV – Coefficient of variation.

Conclusion

In summary, considering the aspects evaluated, all hybrids provide quality hay, however the hybrid 1014019 showed the best nutritional value.

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