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Nutritional value of sorghum silages

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ABSTRACT. This study aimed to evaluate the nutritional characteristics and quality of silages of five sorghum genotypes, namely: Volumax, AG2005E, Qualimax, BRS610 and AG2501. The study was conducted at the Experimental Farm Unimontes, in the municipality of Janaúba, state of Minas Gerais. The treatments were distributed in a randomized block design with four replicates. Data were tested by analysis of variance and means were compared by Scott-Knott test at a significance level of 5%. The pH values ranged from 3.93 and 4.10. Genotypes differed in all studied nutritional characteristics ($p < 0.05$). For the acid detergent fiber, differences were detected between the genotypes, AG2501 (35.66%), Volumax (34.89%), AG2005E (34.53%), Qualimax (32.39%) and BRS610 (33.60%). The high participation of lignin was verified in all genotypes except for Volumax (4.14%). All silages were within the recommended range 50-65% for *in vitro* dry matter digestibility and classified as having good quality, however only the AG2005E genotype met nitrogen requirements for microbial fermentation, with 7.06% crude protein.

Keywords: preserved food, genotypes, nutritional quality.

Valor nutritivo das silagens de sorgo

RESUMO. Objetivou-se avaliar as características nutricionais e qualidade das silagens de cinco genótipos de sorgo, sendo eles: Volumax, AG2005E, Qualimax, BRS610 e AG2501. O estudo foi conduzido na fazenda experimental da Unimontes, situada no município de Janaúba-MG.Os tratamentos foram distribuídos em blocos ao acaso com quatro repetições. Os dados foram submetidos às análises de variância e para a comparação das médias foi utilizado o teste de Scott-Knott ao nível de significância de 5% de probabilidade. Os valores de pH variaram entre 3,93 e 4,10. Os genótipos diferiram entre si em todas as características nutricionais avaliadas ($p < 0,05$). Para a fibra em detergente ácido foi encontrado diferença entre os genótipos avaliados, AG2501 (35,66%), Volumax (34,89%), AG2005E (34,53%), Qualimax (32,39%) e BRS610 (33,60%). A alta participação da lignina foi verificada para todos os genótipos, exceto o Volumax (4,14%). Todas as silagens encontraram-se dentro da faixa recomendada de 50 a 65% para digestibilidade *in vitro* da matéria seca, sendo classificadas como de boa qualidade, no entanto somente o genótipo AG2005E atendeu aos requisitos de nitrogênio para uma fermentação microbiana, com 7,06% de proteína bruta.

Palavras-chaves: alimento conservado, genótipos, qualidade nutricional.

Introduction

In semi-arid regions, production of food for herds becomes the biggest challenge for producers due to climatic conditions. Thus, the problems caused by seasonality of forage can be minimized through food preservation practices. The lack of adapted cultivars that have desirable characteristics, such as high forage production, with high nutritional value, is the major difficulty faced by ranchers in the region in implementing the cultivation system.

Ensiling is the process of converting soluble carbohydrates of the forage into acids, mainly lactic and acetic acids, carried out by lactic acid bacteria under anaerobic conditions and is intended to maintain the quality and nutritional value of fresh forage.

The productive behavior of a forage used for silage production is one of the main characteristics to be used in the economic assessment of the activity. Estimating the nutritional value of forage is important, whether to allow for proper management of diets based on roughage or to guide the breeding or selection of forage, once the market provides a wide variety of sorghum cultivars (Moraes, Jobim, Silva, & Marquardt, 2013). For the production of good silage, it should be considered the percentage of grain in ensiled mass and high biomass productivity, participation of other fractions of the plant, and mainly the digestibility of neutral detergent fiber. Thus, studies comparing hybrids becomes important tools to contribute to breeding programs and to recommend hybrids or cultivars whose silages have the best production/nutritional value ratio (Antunes et al. 2007).

Therefore, the goal of the present study was to evaluate the nutritional value of silage of five sorghum genotypes grown in the winter.

Material and methods

The study was conducted at the experimental farm of the State University of Montes Claros - Unimontes, in the municipality of Janaúba, state of Minas Gerais, in the northern region of the state, in the Brazilian semi-arid region.

Five sorghum genotypes were analyzed, including three forage genotypes (Volumax, BRS 610 and Qualimax), a dual-purpose genotype (AG2005E) and the other for cutting and grazing (AG 2501).The planting was carried out in June 2014, in a randomized block design, with four replicates per genotype, totaling twenty plots with six rows of six meters each spaced 70 cm apart. Before planting, twenty soil samples were taken to a depth of 20 cm randomly throughout the experimental area using a Dutch auger. Soil portions were collected and mixed in a plastic container, comprising a composite sample; from this, a subsample was taken for physical and chemical analysis in the laboratory of the Department of Agricultural Sciences of Unimontes.

The result of chemical analysis was as follows: pH = 6.3; Ca^{2+} (cmol$_c$ dm^{-3}) = 1.6; Mg^{2+} (cmol$_c$ dm^{-3}) = 0.5; P (mg dm^{-3}) = 3.7; K^{1+} (mg dm^{-3}) = 126; $H1^{++}Al^{3++}$ (cmol$_c$ dm^{-3}) = 2.6; Al (cmol$_c$ dm^{-3}) = 0.1; SB (cmol$_c$ dm^{-3}) = 2.6; t (cmol$_c$ dm^{-3}) = 2.7; T (cmol$_c$ dm^{-3}) = 5.2; m (%) = 4.0; V (%) = 50; Organic matter (dag kg^{-1}) = 1.5; Sand (dag kg^{-1}) = 65; Silt (dag kg^{-1}) = 20; Silt (dag kg^{-1}) = 15.

Based on the soil analysis, it was performed correction and fertilization of the soil. At planting, fertilization was made with 300 kg ha^{-1} of the formulation 04-30-10 (N-P-K). The topdressing was made at 35 days, using 60 kg ha^{-1} N, with urea as a source. For each plot, 20 seeds were planted and, after emergence, seedlings were thinned to adjust the number of plants per linear meter.

Harvest was held in November, totaling an experimental period of 119 days. We disregarded 1 m from the ends of each row and the two lateral rows of each plot (borders). The two middle rows of each plot were used for ensiling when each genotype showed dry matter content between 30 and 35%. For ensiling, we used laboratory silos made of PVC pipes 100 mm in diameter, 500 mm length, with average density 600 kg m^{-3}. The forage was minced using a stationary shredder and pressed with wooden socket. Silos were sealed immediately after filling, with PVC caps fitted with Bunsen valves and sealed with tape, and were weighed before and after ensiling.

There were made four replicates per treatment and three replicates per plot; a total of 60 silos were filled, which were opened after 56 days of ensiling. Nutritional assessment of silages was carried out at the Food Analysis Laboratory of Unimontes.

Four replicates per treatment and three replicates per plot were made and a total of sixty (60) silos were made, which were opened after 56 days of ensiling. The nutritional evaluation of the silages was carried out at the Laboratory of Food Analysis of Unimontes.

Upon silo opening, the material was homogenized and part of the ensiled material was placed in paper bags, weighed and pre-dried in a forced ventilation oven at 55°C for 72 hours or until constant weight. Pre-dried samples were ground in a stationary mill with a 1 mm mesh sieve and then placed in glass vials with screw cap and identified for food chemical analysis. The variables analyzed were: dry matter (DM), ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, hemi cellulose and lignin, according methodologies described by Detmann et al. (2012).

The evaluation of *in vitro* dry matter (DM) digestibility was performed in samples pre-dried in a forced ventilation oven at 55°C for 72 hours, and ground with 5 mm mesh sieve. IVDMD was determined according to the method described by Tilley and Terry (1963), modified by Holden (1999), through the use of *in vitro* incubator Tecnal® (TE-150), with modification of the bag (7.5 x 7.5 cm) material, which was made using non-woven fabric (TNT - 100 g m^{-2}) according to Casali et al. (2014). The rumen fluid necessary for the evaluation was collected from two adult crossbred steers, castrated, fitted with rumen cannula, approximately 400 kg body weight. Animals were housed in a pen, fed with forage (sorghum silage), concentrate, mineral salt and water *ad libitum* for 15 days prior to the collection. Data were tested by analysis of variance using the software Sisvar (System for analysis of variance) and means were compared by Scott-Knott grouping test at a significance level of 5%, according to the following statistical model a Equation 1:

$$Yij = \mu + ti + bj + eij \quad (1)$$

In which:
Yij= value related to the observation of hybrid j in blocki
μ = overall mean;
ti = effect of treatment on hybrid j (j = 1, 2, 3, 4, 5);
bj = effect of blocki (i = 1, 2, 3, 4);
eij = experimental error associated with the experiment.

Results and discussion

The results on the quality of silage of five sorghum genotypes are listed in Table 1. The mean values of pH ranged between 3.93 and 4.10, and showed no significant differences ($p > 0.05$). In this study, all silages had pH near 4.0 and can be classified as excellent. Thus, the obtained pH values indicated that all treatments had sufficient availability of soluble carbohydrates for adequate fermentation.

Table 1. Mean values of pH, ammonia nitrogen/total nitrogen (NH_3/TN), lactic acid, acetic acid and *in vitro* dry matter (DM) digestibility of silage of five sorghum genotypes grown in the winter.

Parameters	Volumax	AG2005E	Qualimax	BRS610	AG2501	CV%
pH	4.08[a]	4.04[a]	4.08[a]	3.93[a]	4.10[a]	2.84
NH_3/NT (%)[1]	5.78[b]	7.74[a]	7.01[b]	8.00[a]	8.53[a]	12.23
Lactic Ac. (%)[1]	5.47[b]	5.87[b]	5.86[b]	6.82[a]	4.40[c]	8.82
Acetic Ac. (%)[1]	1.48[b]	1.49[b]	1.50[b]	1.10[c]	2.28[a]	17.13
DIVMS (%)[1]	52.22[b]	54.66[a]	56.46[a]	56.38[a]	51.38[b]	2.75

Mean values followed by different lowercase letters, in the same row, are significantly different ($p < 0.05$). [1]On a drymatterbasis.

In relation to NH_3-N/TN content, all silages can be considered as of good quality, because all the values were below 10% (Table 1). For this characteristic, differences ($p < 0.05$) were detected between the genotypes AG2501 (8.53), BRS610 (8.00) and AG2005E (7.74), which did not differ to each other and were superior to Qualimax (7.74) and Volumax (5.78), which were similar, at 5% probability. The NH_3-N/TN content values are related to DM content. Although AG2005E, BRS610 and AG2501 presented high DM content, the NH_3 content values were higher, which indicates that there must have been some experimental error at the time of ensiling that favored a clostridial fermentation and consequently high proteolysis, raising the ammonia nitrogen content.

The percentage mean value of lactic acid for BRS610 was 6.82, which exceeded ($p < 0.05$) all the other genotypes, in which Qualimax (5.86), AG2005E (5.87) and Volumax (5.47) were similar and exceeded AG2501 (4.40) ($p > 0.05$) (Table 1). Variations occur depending on the type of stem, dry or wet. All tested genotypes have wet stem and very similar concentration of carbohydrates. BRS610 is a hybrid obtained from crossing BR601, of wet stem, with BR700, of dry stem. Thus, the genes of stem trait should have had dominance and produced higher content of soluble carbohydrates, providing more substrate to lactic acid bacteria, increasing the lactic acid content. With respect to AG2501, inferiority in lactic acid content seems to be associated with the characteristics of this genotype, since there are changes in the patterns of use of soluble carbohydrates for production of these compounds.

Table 1 also shows the percentages of acetic acid, in which AG2501 (2.28) surpassed all others; while Volumax (1.48), AG2005E (1.49) and Qualimax (1.50) did not differ to each other, but exceeded the BRS610 (1.10). AG2501, for cutting and direct grazing, has its point of harvest at 50 days; and as the cut for silage was late, at 80 days, increased the DM content (34.99%) by changing the profile of soluble carbohydrates and hence the proliferation of hetero fermentative bacteria, raising the content of acetic acid. BRS610 was inferior to others, because it is an early hybrid harvested at the optimal time, allowing a good lactic fermentation and, consequently, minimizing the presence of hetero fermentative bacteria, which kept low the acetic acid content. A high acetic acid content may restrict the lactic fermentation, as observed with genotype AG2501, wherein the percentage of acetic acid (2.28) exceeded the others and consequently lowered the lactic acid content (4.40), which was lower than the others. The opposite was observed with BRS610, where the acetic acid content was 1.10%, lower than the others, and the lactic acid content was 6.82%, exceeding all the others.

The mean values of the nutritional characteristics of five sorghum genotypes are listed in Table 2.

Table 2. Mean contente of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (Hcel), cellulosse (Cel), lignin (Lig) and *in vitro* dry matter digestibility (IVDMD).

Parameters	Volumax	AG2005E	Qualimax	BRS610	AG2501	CV%
MS total (%)	31.01[b]	33.33[a]	31.75[b]	33.84[a]	34.99[a]	4.92
PB (%)[1]	6.46[b]	7.06[a]	5.94[c]	5.92[c]	5.84[c]	4.51
NDF (%[1])	60.94[a]	61.32[a]	59.75[a]	59.08[a]	61.85[a]	2.70
ADF (%)[1]	34.89[a]	34.53[a]	32.39[b]	33.60[b]	35.66[a]	3.74
Hcel (%)[1]	26.04[a]	26.79[a]	27.36[a]	25.48[a]	26.19[a]	5.34
Cel (%)[1]	27.75[a]	27.23[a]	26.05[b]	25.69[b]	28.45[a]	4.39
Lignin (%)[1]	7.14[b]	7.30[b]	6.34[c]	7.91[a]	7.21[b]	5.95
IVDMS (%)[1]	52.22[b]	54.66[a]	56.46[a]	56.38[a]	51.38[b]	2.75

Mean values followed by different lowercase letters, in the same row, are significantly different ($p < 0.05$) by Scott-Knott test. [1]On a dry matter basis.

In relation to dry matter, genotypes AG2501 (34.99), BRS610 (33.84) and AG2005E (33.33) were similar to each other ($p > 0.01$) and superior to Volumax (31.01) and Qualimax (31.75), which were not different to each other ($p > 0.01$).

AG2005E stood out as it is a dual-purpose genotype, presenting higher percentage of panicle that contributed to the higher dry matter content. As for BRS610, the superiority in the dry matter content is because it is an early hybrid, which completes early the vegetative cycle and thus was at a more advanced stage of maturity at the time of cutting, raising the dry matter content.

AG2501 is a hybrid for cutting and grazing, has greater height, which raises the stem percentage (81.44%). Volumax and Qualimax were inferior to the others because they are late genotypes, but had normal content for ensiling at the time they were cut.

The optimal dry matter content for ensiling is estimated at 30-35% (Dias et al., 2010) to avoid losses by the formation of effluents and biological processes that produce gas, water and heat, as well as provide adequate lactic fermentation to maintain the nutritive value of the silage.

Tolentino et al. (2016) reported values of 37.12% for sorghum of Volumax and 39.48% DM for BRS610, with values higher than those found in the present experiment for the same genotypes.

For crude protein content (CP; Table 2), the AG2005E genotype (7.06%) was superior to the other genotypes, Volumax (6.46), Qualimax (5.94), BRS610 (5.92) and AG2501 (5.84). The superiority of AG2005E is because it is a dual-purpose hybrid that contains higher proportions of grains and leaves.

A food and/or diet should contain at least 7% CP to provide sufficient nitrogen for effective microbial fermentation in the rumen (Church, 1988). The percentage of crude protein is not modified with the ensiling process, although different proportions of nitrogen fractions may be altered. It is known that fermentation causes changes in the composition of nitrogen fractions, reducing the true protein content and increasing the content of free amino acid, or products from the breakdown of these of amino acids, including ammonia, CO_2 and amines (Ohshima & McDonald, 1979).

Thus, the low nitrogen content of silages is a limiting factor for the use of forage of these genotypes mainly for animals with high nutritional requirements.

Tolentino et al. (2016) found CP content above 9.06% when evaluated silages of twenty-four different genotypes of sorghum, values higher than those presented in this study.

Values of neutral detergent fiber (NDF) content of the silages did not differ to each other ($p > 0.05$), ranging from 59.08 to 61.85% (Table 2). For the microbial balance in the rumen, it is important to have a minimum amount of fiber to maintain the fermentation and stimulate salivation, which are indispensable for the fermentation process and prevent metabolic disorders. NDF and ADF contents are indicative of the amount of fiber in the forage; NDF is related to the amount of fiber that is in the roughage, while the FDA, to the amount of less digestible fiber. In this sense, the lower the content, the better the quality of the silage produced and the higher the DM intake by the animal (Santos, Galvão, Silva, Miranda, & Finger, 2010). NDF values above 60% are negatively correlated with dry mater intake by the animal, as for the ADF fraction, high content values hinder the fragmentation of food and digestion by ruminal bacteria.

Considering the content of acid detergent fiber (ADF), differences ($p > 0.05$) were observed between genotypes, genotypes AG2501 (35.66%), Volumax (34.89%) and AG2005E (34.53%) were similar to each other ($p < 0.05$) and superior to Qualimax (32.39%) and BRS610 (33.60%), at 5% probability. The superiority of AG2501 and Volumax is a function of their height, 2.40 and 1.91 m, respectively, while for AG2005E, the result is related to the higher participation of panicle.

The ADF is related to the forage digestibility, because it contains the higher proportion of lignin, which is the completely indigestible fiber fraction, thus indicating its indigestibility. The ADF content should not exceed 30%, thus high levels, as found in this study, hinder the absorption of nutrients.

Values of hemi cellulose content of the silages were not different to each other ($p > 0.05$) and ranged from 25.48 to 27.36%. In forage at later stages, hemicellulose appears more associated with lignin by covalent bonds than others polysaccharides, making them unavailable.

For the cellulose content found in silages, in percentage of DM, there were differences between genotypes ($p > 0.05$). Volumax (27.75), AG2005E (27.23) and AG2501 (28.45) were similar to each other ($p < 0.05$) and superior to Qualimax (26.05) and BRS610 (25.69) (Table2). These values are directly related to ADF values, since cellulose is an important component of this fiber fraction.

As it is the main component of ADF, the superiority in the cellulose content of AG2501 and Volumax is similarly explained by their height, 2.40 and 1.91, respectively, while inAG2005E, the result is explained by the greater participation of panicle. Cellulose represents the greater part of ADF and hemicellulose, more digestible than cellulose, integrates the NDF. Higher content of hemicellulose and lower content of cellulose are interesting, since the bacterial flora of ruminants breakdown these components into short chain fatty acids (SCFA), mainly acetic, propionic and butyric acids, which represent the largest source of energy when the feeding the animals is forage-based.

With respect to lignin content in silages, there were differences ($p > 0.05$) between genotypes (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.

In the Brazilian Table of Food Composition for Cattle, the average lignin content of sorghum silage is 5.87% (Valadares Filho, Pina, Berchielli, Pires, & Oliveira, 2006). The mean values found in the present study were 4.14 (Volumax); 7.30 (AG2005E), 6.34 (Qualimax); 7.91 (BRS610); 7.21 (AG2501). The superiority of BRS610 to the other genotypes is because it is an early hybrid harvested at a more advanced maturity stage and, therefore, with higher lignification of the cell wall.

Regarding Volumax, AG2005E and AG2501, the similarity in lignin content is due to the similarity in the maturity stage at the time of cutting, while Qualimax is a later hybrid. The lignification process is associated with a limitation of dry matter degradation by ruminal microorganisms, thus reducing the nutritional value of forage. This allows to conclude that the smaller the content of lignin in the forage, the more efficient the food degradation in the rumen.

For *in vitro* dry matter (DM) digestibility, in percentage, the genotypes BRS610 (56.38), Qualimax (56.46) and AG2005E (54.66) were similar, and exceeded genotypes AG2501 (51.38) and Volumax (52.22), which were similar, at 5% probability. For Qualimax, BRS610 and AG2005E, high digestibility is due to the increased participation of leaves and panicles, because they have low height (1.63 to 1.75), and lower percentage of stem (Table 2).

Skonieski et al. (2010) determined the nutritional characterization of forage and dual purpose sorghum silages, and found 53.57 and 52.74% IVDMD, with values near to those verified in the present study.

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Conclusion

Based on the assessment of digestibility and fermentation quality of silages, all hybrids were promising for silage production despite the high participation of lignin, except for the genotype Volumax, however, considering the crude protein content, the genotype AG2005 was the most suitable for ensiling process, as it was able to provide sufficient nitrogen for effective microbial fermentation in the rumen.

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