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PASTURE AND FORAGE UTILIZATION

Fermentation characteristics and nutritive values of sorghum silages

Florence Taciana Veriato[1*], Daniel Ananias De Assis Pires[1], Daniella Cangussú Tolentino[1], Dorismar David Alves[1], Diogo Gonzaga Jayme[2] and Marielly Maria Almeida Moura[1]

*[1]Universidade Estadual de Montes Claros, Campus Janaúba, Avenida Reinaldo Viana, 2630, Cx. Postal 91, 39440-000, Janaúba, Minas Gerais, Brasil. [2]Universidade Federal de Minas Gerais, Montes Claros, Minas Gerais, Brasil. *Author for correspondence. E-mail: florenceveriato@yahoo.com.br*

ABSTRACT. The objective of this study was to select sorghum genotypes for silage production. The study was carried out at Embrapa Maize & Sorghum's experimental field. Planting was performed in randomized blocks, with three replicates and the Scott-Knott test at a 5% probability level. The material was ensilaged in laboratory silos opened after 56 days for analysis concerning fermentation and bromatological composition. Only crude protein showed no significant difference ($p > 0.05$), with an overall mean of 8.88%. The other variables presented significant differences ($p < 0.05$): pH (3.34 to 3.94); Aw (0.93 to 0.98); N-NH 3/TN (1.61 to 6.56%); green matter yield (12.05 to 34.14 t ha^{-1}); dry matter yield (6.19 to 11.42 t ha^{-1}); dry matter (26.89 to 49.95%); ashes (4.08 to 6.88%); neutral detergent fiber corrected for ash and protein (47.67 to 65.79%); acid detergent fiber (16.62 to 35.89%); hemicellulose:cellulose (1.07 to 2.71%); lignin (2.03 to 6.52%), digestible dry matter yield (3.70 to 7.41 t ha^{-1}) and dry matter digestibility (56.36 to 72.67%). Based on digestible dry matter yield, the genotypes: male 201191 and hybrids 2012F47484, 2012F47515 and 2012F47525 stood out in relation to the others for showing good yielding, adequate nutritional value, with low dry matter and NDF levels coupled with high digestibility values and good fermentation patterns of the silages.

Keywords: digestibility; genotypes; productivity.

Características fermentativas e valor nutritivo de silagens de sorgo

RESUMO. Objetivou-se selecionar genótipos de sorgo para produção de silagem. O estudo foi conduzido no campo experimental da Embrapa Milho e Sorgo. O plantio foi realizado em blocos casualizados, com três repetições e teste Scott-Knott em nível de 5% de probabilidade. O material foi ensilado em silos laboratoriais, abertos com 56 dias para realização das análises fermentativa e composição bromatológica. Somente a proteína bruta não apresentou diferença significativa ($p > 0,05$), com média geral de 8,88%. As demais variáveis apresentaram diferenças significativas ($p < 0,05$):pH (3,34 a 3,94); Aw (0,93 a 0,98); N-NH3/NT (1,61 a 6,56 %); produção de matéria verde (12,05 a 34,14 t ha^{-1}); produção de matéria seca (6,19 a 11,42 t ha^{-1}); matéria seca (26,89 a 49,95 %); cinzas (4,08 a 6,88 %); fibra em detergente neutro corrigido para cinzas e proteínas (47,67 a 65,79 %); fibra em detergente ácido (16,62 a 35,89%); hemicelulose:celulose (1,07 a 2,71 %); lignina (2,03 a 6,52 %), produção de matéria seca digestível (3,70 a 7,41 t ha^{-1}) e digestibilidade da matéria seca (56,36 a 72,67%). Com base na produção de matéria seca digestível, os genótipos: macho 201191, e os híbridos 2012F47484, 2012F47515 e 2012F47525 se sobressaíram em relação aos demais uma vez que apresenta boa produtividade, adequado valor nutricional, com baixos teores de matéria seca e FDN aliado com altos valores de digestibilidade e bom padrão fermentativo das silagens.

Palavras-chaves: digestibilidade; genótipos; produtividade.

Introduction

The process of preserving chopped organic matter in anaerobic environment – ensilage – undergoes physical-chemical and organoleptic changes derived from microbial fermentation. The use of silage can contribute to increasing animal productivity and, consequently, the profitability of production systems (Simon et al., 2008). To reduce the negative seasonal effects of forage production on performance of the herd, the excess of forage produced in the rainy season needs to be preserved in order to be used in the dry season, guaranteeing good quality and quantity of bulk food throughout the year.

Sorghum (*Sorghum bicolor* (L.) Moench) stands out as a species for food preservation because it is resistant to adverse environmental factors, such as low water availability, high dry matter yield and soluble carbohydrate concentration. Its bromatological characteristics, equivalent to 85 to

90% of the maize silage, allow adequate fermentation and consequent storage of this food in the form of silage, due to higher crude protein content in some varieties and agronomic characteristics (Moraes, Jobim, Silva, & Marquardt, 2013).

The great demand for better quality material has led to the appearance of numerous cultivars, with specific characteristics as to size (tall, medium, short), cycle (early or late) and aptitude (forage, double-purpose or grain). Each of these materials present different agronomic characteristics and nutritive values, with consequent variations in productivity and fermentation patterns, resulting in silages with different qualities (Machado et al., 2011).

The objective of this study was to assess fermentation characteristics and nutritive values of silages, and to select the superior genotypes among the seventeen sorghum genotypes for silage.

Material and methods

The field experiment was conducted at EMBRAPA – *Centro Nacional de Pesquisa de Milho e Sorgo* – [National Center for Research on Maize and Sorghum], located at Km 65 of MG 424 highway, in the municipality of Sete Lagoas, MG. Geographic coordinates are 19°28 'south latitude and 44°15'08"WGrW longitude (Köppen & Geiger, 1928).

Seventeen sorghum genotypes were used, which belonged to Embrapa Maize & Sorghum's genetic enhancement program, being: 3 male forage genotypes: 201191, Santa Elisa and 201187025; 3 female grain genotypes: BRS008B, BR007B and CMSXS222B; 9 hybrids: 2012F47475, 2012F47483, 2012F47484, 2012F47503, 2012F47504, 2012F47515, 2012F47523, 2012F47524, 2012F47525, and 2 commercial hybrids: VOLUMAX and BRS610. Seeding was carried out on February 20, 2013, with 20 seeds per linear meter in each plot. A randomized block experimental design was used, with seventeen genotypes and three replicates (blocks), totaling 51 experimental units. Each plot consisted of 6 rows measuring 6 meters in length and 70 centimeters of row spacing. Fertilization was carried out according to soil analysis and crop requirements; 400 kg of NPK were used for planting (8, 28, 16) and 0.5% of Boron was added and, after 40 days, cover fertilization used 58.5 g of N ha^{-1}.

Harvesting was performed when the plant presented a dry matter content of 30 to 35%, identified through a practical method, by rubbing the sorghum grains with the fingers, which allowed assessing the maturation stage of the grain for the ensiling process. Assessments referring to yielding, bromatological composition, fermentation characteristics and *in vitro* dry matter digestibility were performed in the center and intermediate rows of each plot. Dry matter yield was obtained from green matter yield and DM content; digestible dry matter yield was obtained by means of dry matter yield and digestibility percentage.

For the preparation of the silages, laboratory silos were used, made of PVC caps measuring 100 mm in diameter, 500 mm in length, and with mean density of 600 kg of green matter m^{-3}. The silos were sealed during the ensilage, with PVC caps provided with "Bunsen" valves, and weighed before and after the ensilage. After the 56-day period, the silos were weighed again and sent for analysis.

The nutritional assessment of the silages was carried out at the Laboratory of Food Analysis of the State University of Montes Claros, Campus Janaúba, MG. When the silos were opened, the material was homogenized and extracted for further analyses. Samples collected after the opening of the silos were placed in paper bags, weighed and then pre-dried in a forced ventilation oven at 55°C for 72 hours. The pre-dried samples were milled in a "Willey"-type mill with a 1-mm mesh sieve, then stored in glass containers with a screw cap identified for subsequent analyses of the chemical composition of the food: dry matter, ash, crude protein, neutral detergent fiber corrected for ash and protein, acid detergent fiber and lignin, in accordance with methods described in the INCT-CA (Detmann et al., 2012).

As for the fermentation analyses of the silage, a digital pH meter was used for pH measurement. Ammoniacal nitrogen, expressed as total nitrogen ($N\text{-}NH_3/TN$) was obtained by the sampling of approximately 25 g of silage from each genotype, in accordance with Bolsen et al. (1992). The water activity of the silages was measured using the AquaLab 4TE DUO equipment.

The *in vitro* dry matter digestibility was determined with the samples pre-dried at 55°C and an incubation period of 48 hours, according to methodology described and modified by Holden (1999), who pioneered the use of the Tecnal® (TE-150) *in vitro* incubator, changing the bag material used (7.5 x 7.5 cm), made with non-woven fabric (100g m^{-2}), according to Casali et al. (2008).

IVDMD (%) = ((DM% of the incubated food – (DM% of residue x correction factor))/DM% of the incubated food) x 100, with the correction factor being the result of the ratio of the blank sample weight before incubation by the weight of the same sample after incubation. Where, IVDMD (*in vitro* dry matter digestibility) and DM (dry matter). Digestible dry matter yield (DDMY) for each genotype was calculated with the following equation: DDMY t ha^{-1} = (% DM x % INDMD).

The data obtained in the laboratory were submitted to analysis of variance with the aid of the SISVAR program; when it showed significance for the "F" test, the mean of the genotype factor was compared by the Scott-Knott test at a 5% probability level, according to the statistical model below:

$$Y_{ik} = \mu + G_i + B_k + e_{ik}$$

where:
Yik = Observation concerning genotype i and replicate k;
M = Overall mean;
G_i = Effect of genotype i, where i = 1, 2, 3 ... 17;
B_k = block k effect, where k = 1, 2 and 3;
e_{ik} = the experimental error associated with the observed values (Y_{ik}) that, by hypothesis, has normal distribution with zero mean and σ^2 variance.

Results and discussion

When considering potential of hydrogen (pH), water activity (Aw) and ammoniacal nitrogen/total nitrogen ratio (N-NH3 /TN), there was significant difference ($p < 0.05$) between the silages of the genotypes analyzed (Table 1).

Table 1. Mean values of potential of hydrogen (pH), water activity (aw) and ammoniacal nitrogen/total nitrogen ratio ($N-NH_3/TN$).

Genotypes	pH	Aw	$N-NH_3/TN$[1]
201191	3.56 B	0.97 A	3.61 C
Santa Elisa	3.57 B	0.97 A	2.66 D
201187025	3.80 A	0.96 A	3.55 C
BRS008B	3.94 A	0.93 B	6.56 A
BR007B	3.83 A	0.96 A	3.70 C
CMSXS222B	3.79 A	0.96 A	4.37 B
2012F47475	3.56 B	0.98 A	2.18 E
2012F47483	3.59 B	0.97 A	3.85 C
2012F47484	3.61 B	0.98 A	2.53 D
2012F47503	3.75 A	0.97 A	2.56 D
2012F47504	3.54 B	0.98 A	2.71 D
2012F47515	3.89 A	0.98 A	2.85 D
2012F47523	3.62 B	0.97 A	2.14 E
2012F47524	3.34 B	0.98 A	1.61 E
2012F47525	3.69 A	0.98 A	2.42 D
VOLUMAX	3.53 B	0.97 A	3.89 C
BRS610	3.69 A	0.97 A	4.56 B
CV	4.07	1.04	11.4
Mean (%)	3.69	0.97	3.28

[1]% total nitrogen. Means followed by distinct capital letters, in the same column, differ from each other ($p < 0.05$) by the Scott-Knott Test. CV = Coefficient of variation.

Regarding pH values, the following genotypes: male 201191, Santa Elisa; hybrids 2012F47475, 2012F47483, 2012F47484, 2012F47504, 2012F47523, 2012F47524, and commercial hybrid VOLUMAX showed reduced pH values, which are desirable values for fermentation.

When compared to values obtained in the literature, Ribeiro et al. (2007) determined the fermentation pattern of the silage of five sorghum genotypes and found pH values varying between 3.69 and 4.58. The stability of pH in silage is due to interactions between dry matter concentration, the buffer capacity of the forage, soluble carbohydrate and lactate concentrations, and anaerobic conditions (Borba et al., 2012). Sorghum silages, when well fermented, present minimum pH values around 3 to 7 days after ensilage, which are maintained for long storage times (Fazaeli, Golmohhammadi, Almodares, Mosharraf, & Shaei, 2006). In this way, the silages of the genotypes with reduced pH values can be classified as of good quality.

Regarding water activity (AW), only the female genotype BRS008B presented a lower result, with a value of 0.93. The other genotypes ranged from 0.96 to 0.98. Microorganisms in general are fundamental in the fermentation process of silages and have their activity largely affected by Aw. The development of most bacteria and fungi is restricted to Aw values above 0.90. *Salmonellae* need an Aw greater than 0.92 for growth; as for fungi, the minimum limit for growth is 0.78 Aw; and for the production of aflatoxins this value is 0.86 Aw. The growth of *Clostridium* bacteria, in turn, is inhibited with Aw below 0.94, whereas lactic acid bacteria are less sensitive (Jobim, Nussio, Reis, & Schmidt, 2007). Although the Aw values found in the present study favor microbial growth, the pH can restrict the development of microorganisms, thus preventing undesired fermentation, guaranteeing the preservation and quality of the silages.

The pH is a factor of vital importance in limiting the development of different microorganisms in the silages. At a pH higher than 4.5, there is a varied range of microorganisms, with conditions for the development of most bacteria, including pathogens, molds and yeasts. However, below this value, some do not develop, such as the *Clostridium* genus. In these very acid environments ($pH < 4.0$), the microbiota capable of developing is restricted only to molds and yeasts and, sometimes, to lactic and acetic bacteria (Hoffmann, 2001).

The ammoniacal nitrogen/total nitrogen (N-NH3/TN) ratio of hybrids 2012F47475, 2012F47523 and 2012F47524 obtained similar results, presenting the lowest levels of ammoniacal nitrogen, varying from 1.61 to 2.18%. According to Tolentino et al. (2016), the levels of ammoniacal nitrogen in sorghum silages range from 2.25 to

4.39% of total nitrogen. Thus, the levels found in this study agree with the authors, except for the female genotype BRS008B, which presented a level of 6.65%, higher than that preconized by the authors.

The silage is considered of very good quality when it shows a N-NH_3TN ratio lower than 10%, good between 10 and 15%, medium between 15 and 20%, and bad when higher than 20% (Ribeiro et al., 2007). Accordingly, such silages show desirable values when it comes to anaerobic fermentation in the ensiling process.

The increase in ammonia production caused by proteolysis or by the eventual occurrence of excessive heating in the silo mass can cause the neutralization of desirable acids and “Maillard” reactions, determinant parameters to the final quality of the ensiled material. This ammonia is derived from amino acid catabolism, among other degradation products such as amines, ketoacids and fatty acids, through three biochemical processes: deamination, decarboxylation, and oxidation and reduction reactions (Neumann et al., 2007). The use of this parameter is fundamental in indicating the degree of proteolysis in the silage, because high levels of proteolysis may be related to low voluntary consumptions and lower efficiency of microbial protein synthesis (Neumann et al., 2007).

With respect to the assessments of the nutritional characteristics of the silages, there was significant difference ($p < 0.05$) between genotypes for the following characteristics: green matter yield (GMY), dry matter yield (DMY), dry matter content (DM) and ashes (ASH) (Table 2).

Similar GMY values were obtained for the following genotypes: male 201191, hybrids 2012F47484, 2012F47504, 2012F47515, 2012F47523, 2012F47524 and 2012F47525, with the highest yields ranging from 27.62 to 35.31t ha^{-1}. Lower values were found for the other genotypes, ranging from 12.05 to 24.47t ha^{-1} (Table 2). However, dry matter yield must be taken into account because it is based on a variable that nutrients are concentrated and animal nutrition calculations are performed.

As for dry matter yield (DMY) values, the following genotypes: male 201191, hybrids 2012F47483, 2012F47484, 2012F47504, 2012F47515, 2012F47523, 2012F475524, 2012F47525 and commercial hybrids VOLUMAX and BRS610 were similar and outperformed the others, ranging from 9.33 to 12.59 t ha^{-1}. The ‘Volumax’ sorghum, among all sorghum materials commercially available, is one of the most widely used in the southwestern region of Goiás for ensilage, due to its biomass yield per hectare. Results superior to those of this experiment were found by Pereira, Mizubuti, Pinheiro, Villarroel, and Clementino (2007). For dry matter content among the silages, the female genotypes BRS008B, BR007B, CMSXS222B and the commercial hybrid BRS610 obtained similar results and the highest dry matter contents of the silages, ranging from 46.45 to 59.7%. The other genotypes had the best values, which were lower than the abovementioned values, varying from 26.89 to 41.69%.

Table 2. Green matter yield (GMY), dry matter yield (DMY), dry matter content (DM), ashes (ASH), crude protein (CP), nitrogen unavailable in neutral detergent (NUND) and nitrogen unavailable in acid detergent (NUAD).

Genotypes	GMY[1]	DMY[1]	DM[2]	ASH[3]	CP[3]
201191	35.24 A	12.37 A	35.10 B	4.83 B	7.79 A
Santa Elisa	22.76 B	7.39 B	32.54 B	4.69 B	10.04 A
201187025	17.43 C	6.48 B	39.28 B	5.69 A	9.42 A
BRS008B	13.52 C	8.08 B	59.67 A	6.88 A	8.54 A
BR007B	12.05 C	5.97 B	49.95 A	5.84 A	10.22 A
CMSXS222B	16.38 C	7.64 B	46.46 A	5.56 A	8.75 A
2012F47475	16.48 C	6.37 B	38.98 B	5.53 A	8.09 A
2012F47483	23.24 B	9.53 B	41.69 B	5.19 A	9.28 A
2012F47484	27.62 A	10.28 A	37.17 B	4.08 B	7.81 A
2012F47503	24.47 B	8.82 B	36.01 B	4.69 B	8.95 A
2012F47504	29.95 A	9.33A	31.38 B	4.52 B	9.29 A
2012F47515	35.14 A	12.59 A	35.84 B	4.62 B	8.05 A
2012F47523	27.90 A	10.46 A	37.56 B	4.49 B	8.74 A
2012F47524	35.31 A	9.58 A	26.89 B	4.55 B	9.78 A
2012F47525	33.43 A	12.12 A	36.26 B	5.90 A	8.27 A
VOLUMAX	24.09 B	9.58 A	39.78 B	4.52 B	9.60 A
BRS610	22.76 B	11.38 A	50.89 A	5.32 A	8.27 A
CV	21.52	21.80	15.61	15.6	17.51
Mean (%)	24.55	9.31	39.73	5.12	8.88

[1]tons per hectare (t ha^{-1}); [2]percentage (%); [3]dry matter percentage (DM%). Means followed by distinct capital letters, in the same column, differ from each other ($p < 0.05$) by the Scott-Knott Test. CV = Coefficient of variation.

Araújo et al. (2007) analyzed the quality of the silages of three sorghum genotypes ensiled at five different maturation stages and found DM values ranging from 28.85 to 57.37%. Dry matter content varies according to the age of the cut, being a positive correlation with height; however, it is one of the factors that most influences the quality of the silage. The ideal range goes from 30 to 35% to avoid losses for the formation of effluents and biological processes that produce gases, water and heat, as well as to promote an adequate lactic fermentation to maintain the nutritive value of the silage (Dias et al., 2010).

Silages made from forages with higher DM contents (> 40%) may present greater difficulty in compression and, consequently, a lower quality silage, due to the greater presence of air. Accordingly, materials with a higher moisture content are easier to compress (Tomich et al., 2004).

Among the sorghum plant fractions, the stem is the portion that least contributes to raising DM content, followed by leaves and panicle. Thus, considering these genotypes as double-purpose sorghum, the greater participation of the panicle in the physical structure of the plant may have been the main responsible for changing DM content. In addition to this characteristic, edaphoclimatic conditions during cultivation also contribute to raising the dry matter content of the crop. And in this case, the Indian summer occurred during cultivation possibly contributed to increasing dry matter at the cutting time. Under these conditions, the plant completes the cycle faster and the dry matter content rises, justifying the values found.

For ash content referring to the mineral matter, the male genotype 201187025; females BRS008B, BR007B, CMSXS222B; hybrids 2012F47475, 2012F47483, 2012F47525 and commercial hybrid BRS610 obtained similar results and the highest values, ranging from 5.19 to 6.88%. Magalhães et al. (2010), assessing the chemical-bromatological composition of sorghum silage, observed values similar to those found in this experiment, varying from 2.83 to 4.16%. Cabral et al. (2003), assessing the chemical-bromatological composition of sorghum silage with different proportions of panicles, obtained results superior to those found in this experiment, ranging from 4.99 to 9.71%, and concluded that the higher proportion of seeds influence ash content because the seeds are rich in minerals in order to ensure sufficient supply for the development of the plant at the initial stage. Thus, in line with the authors, the grain sorghum presented the highest ash contents.

About crude protein (CP) levels, there was no significant difference between the assessed genotypes ($p > 0.05$); the mean value was 8.88%. Tolentino et al. (2016), assessing the quality of silages of different sorghum genotypes, found a mean of 8.14%, which characterizes the CP of the sorghum genotypes in the present study as sufficient to guarantee good ruminal fermentation.

When it comes to neutral detergent insoluble fiber corrected for ash and protein (NDFap) and acid detergent insoluble fiber (ADF), cellulose (CEL), hemicellulose (HEM) and lignin (LIG), there was significant difference ($p < 0.05$) between the silages of the analyzed genotypes (Table 3).

The genotypes: male 201187025; female BR007B; hybrids 2012F47503, 2012F47504, 2012F47515, 2012F47523, 2012F47524 and commercial hybrid VOLUMAX were similar, presenting lower levels of NDFap, ranging from 47.67 to 53.62%. The other genotypes obtained the highest values, varying from 56.30 to 64.79%. The NDF correlates negatively with dry mass consumption by the animal. Values above 60% of NDF correlate negatively with dry mass consumption by the animal, compared to the ADF fraction. (Gonçalves et al., 2010) stated that high levels hinder food fragmentation and digestion by ruminal bacteria.

Genotypes 2012F47475, 2012F47515, 2012F47524 and the commercial hybrid VOLUMAX were similar, with the lowest levels of ADF among the analyzed silages, varying from 23.13 to 27.34% (Table 3). As for the ADF fraction, Gonçalves et al. (2010) affirm that high levels of ADF (above 30%) hinder the fragmentation of food and its digestion by ruminal bacteria. NDF levels as well as ADF levels increase in the composition of plants during their vegetative stage, which is due to the greater participation of the cell wall of plants (cellulose and hemicellulose) as their age advances (Gontijo et al., 2010).

Table 3. Mean values of neutral detergent insoluble fiber corrected for ash and protein (NDFap), acid detergent insoluble fiber (ADF), cellulose (CEL), hemicellulose (HEM) and lignin (LIG), based on the DM% of the sorghum silages.

Genotypes	NDFap	ADF	CEL	HEM	LIG
201191	60.86 A	35.89 A	19.10 A	26.78 D	2.82 C
Santa Elisa	57.70 A	30.58 A	20.19 A	29.85 C	2.31 C
201187025	52.66 B	29.62 A	18.32 A	43.89 D	4.29 B
BRS008B	56.30 A	32.66 A	18.83 A	26.13 D	2.68 C
BR007B	53.62 B	32.70 A	17.86 A	23.23 D	2.28 C
CMSXS222B	59.26 A	32.68 A	19.46 A	30.02 C	2.03 C
2012F47475	64.79 A	27.34 B	14.84 B	40.27 A	5.50 A
2012F47483	57.26 A	33.87 A	18.18 A	26.07 D	3.30 C
2012F47484	56.84 A	32.14 A	20.73 A	28.18 C	2.51 C
2012F47503	52.33 B	29.02 A	18.25 A	25.82 D	3.99 B
2012F47504	47.67 B	28.75 A	20.10 A	21.51 D	2.04 C
2012F47515	50.17 B	26.03 B	19.35 A	25.79 D	3.27 C
2012F47523	49.08 B	34.20 A	15.72 B	30.78 C	5.59 A
2012F47524	51.10 B	25.11 B	20.12 A	27.82 C	3.16 C
2012F47525	60.36 A	35.34 A	19.93 A	27.81 C	2.14 C
VOLUMAX	51.39 B	23.13 B	17.71 A	35.81 B	4.45 B
BRS610	63.07 A	35.51 A	15.38 B	30.22 C	6.52 A
CV	11.41	11.41	15.61	9.76	20.78
Mean (%)	55.56	30.09	18.47	29.42	3.46

Means followed by distinct capital letters, in the same column, differ from each other ($p < 0.05$) by the Scott-Knott Test. CV = Coefficient of variation.

NDF and ADF levels are indicative of the amount of forage fiber, with NDF being related to the amount of fiber in the bulk, and ADF to the amount of less digestible and indigestible fiber; thus, the higher the values the better the quality of the silage produced and the greater the DM consumption by the animal (Santos, Galvão, Silva, Miranda, & Finger, 2010). In Table 3, the fibrous fractions present in the plant cell wall, such as cellulose, hemicellulose and the phenolic compound lignin, were different statistically ($p < 0.05$). Regarding cellulose contents, the genotypes: hybrids 2012F47475, 2012F47523 and commercial hybrid BRS610 obtained similar results and the lowest levels, ranging from 14.84 to 15.72%. The other genotypes obtained higher levels: 17.71 to 20.73%.

As for hemicellulose, a higher value was attributed to hybrid 2012F47475 (40.27%); the others ranged from 21.51 to 43.89%.

Cellulose is a homopolysaccharide composed of glucose units, linked together by β-1, 4 glycosidic bonds. Cellulose polymers are distributed parallel to each other, forming layers of plant cell cover (Kozloski, 2011). This arrangement confers greater resistance to the cell, thus hindering degradation at ruminal level by obstructing the attack of fiber-degrading microorganisms, causing the cellulose to be less utilized by the animal (Campos, Lanna, Bose, Boin, & Sarmento, 2002; Carvalho & Pires, 2008). Hemicellulose consists mainly of xyloglucans, contributing approximately to 20-25% of the constituents of the plant cell wall (Paiva, Lima, & Paixão, 2009). Xyloglucans bind to cellulose, pectin and lignin by means of hydrogen bonds, forming cross-links that give stability to the cell wall (Wakabayashi, 2000). The cross-linking of the polymers forming the hemicellulose gives less resistance to the degradation of this carbohydrate at ruminal level, when compared to cellulose.

The hemicellulose: cellulose ratio reports the proportions of these fractions. It would be interesting to raise hemicellulose content and decrease cellulose content, which was observed in the present study, since ruminants use hemicellulose better because it is more degradable than cellulose.

The genotypes: male 201191, Santa Elisa; females BRS008B, BR007B, CMSXS222B; hybrids 2012F47484, 2012F47515, 2012F47504, 2012F47524 and 2012F47525 were similar and had the lowest lignin contents, ranging from 2.03 to 3.27%. Lignin is the component most negatively correlated with digestibility, as it limits the digestion of polysaccharides of the cell wall by microorganisms and reduces the nutritional value of plants for ruminants. In this way, the materials that reported low lignin content favor the consumption and digestibility of the fibrous fraction.

Lignin is a phenolic polymer complex formed basically by three phenolic groups (having the roles of both acid and aldehyde): p-coumaric acid, ferulic acid and synapinic acid. Lignin joins cell wall polysaccharides by covalent bonds, decreasing the rate of ruminal degradation for forming a mechanical barrier to the action of microorganisms (Campos et al., 2002). The structure and arrangement of the plant cell wall determines the rate of degradation and the type of microorganism that will develop. Fiber-degrading microorganisms are cellulolytic bacteria, protozoans and fungi (Carvalho & Pires, 2008).

As for *in vitro* dry matter digestibility (IVDMD) and digestible dry matter yield (DDMY), there was significant difference ($p < 0.05$) between the silages of the genotypes analyzed (Table 4).

About DM digestibility in a 48-hour incubation period, similar results were found in male genotypes 201191, 201187025; female genotypes BRS008B, CMSXS222B and hybrid genotypes 2012F47475, 2012F47483, 2012F47484, 2012F47503, 2012F47504, 2012F47515, 2012F47523, BRS610, ranging from 67.48 to 72.68%. The highest values of digestible dry matter yield (DDMY) were obtained by the genotypes: male 201191 and hybrids 2012F47483, 2012F47484, 2012F47503, 2012F47504, 2012F47515, 2012F47523, 2012F47524, 2012F47525 and commercial hybrids VOLUMAX and BRS610, varying from 6.05 to 8.93 t ha^{-1}.

Table 4. *In vitro* dry matter digestibility (IVDMD) and digestible dry matter yield (DDMY).

Genotypes	IVDMD[2]	DDMY[1]
201191	69.93 A	8.65 A
Santa Elisa	65.03 B	4.82 B
201187025	72.51 A	4.89 B
BRS008B	70.84 A	5.72 B
BR007B	63.95 B	3.83 B
CMSXS222B	67.48 A	5.17 B
2012F47475	72.68 A	4.63 B
2012F47483	69.36 A	6.58 A
2012F47484	68.29 A	6.97 A
2012F47503	68.51 A	6.05 A
2012F47504	68.56 A	6.36 A
2012F47515	70.74 A	8.93 A
2012F47523	67.77 A	7.08 A
2012F47524	62.23 B	6.08 A
2012F47525	56.37 B	6.85 A
VOLUMAX	63.95 B	6.10 A
BRS610	70.42 A	7.98 A
CV	6.75	22.22
Mean (%)	67.56	5.02

[1]tons per hectare (t ha^{-1}) and [2]dry matter percentage (DM%). Means followed by distinct capital letters, in the same column, differ from each other ($p < 0.05$) by the Scott-Knott Test. CV = Coefficient of variation.

DDMY is a way of reconciling productivity with nutritional value, that is, the association between volume and quality. For this reason, digestible dry matter yield is nothing more than the result of the multiplication of dry matter yielding by its digestibility, indicating what is effectively produced in the area and the nutrients provided to animals. Botelho, Pires, and Sales (2010), comparing VOLUMAX and BRS610, both in regrowth (6.40 and 7.20 t ha^{-1}) and in the sorghum of the year (9.10 and 10.30 t ha^{-1}), observed higher digestible dry matter yields for these materials due to their higher dry matter yields.

Conclusion

Based on digestible dry matter yield, the genotypes: male 201191 and hybrids 2012F47484, 2012F47515 and 2012F47525 stood out in relation to the others for showing good yielding, adequate nutritional value, with low dry matter and NDF levels coupled with high digestibility values and good fermentation pattern of the silages.

References

Araujo, V. L., Rodriguez, N. M., Gonçalves, L. C., Rodrigues, J. A. S., Borges, I., Borges, A. L. C. C., & Saliba, E. O. S. (2007). Qualidade das silagens de três híbridos de sorgo ensilados em cinco diferentes estádios de maturação. *Arquivo Brasileiro Medicina Veterinária Zootecnia, 59*, 168-174.

Bolsen, K. K., Lin, C., Brent, B. E., Feyerherm, A. M., Urban, J. E., & Aimutis, W. R. (1992). Effect of silage additives on the microbial succession and fermentation process of alfalfa and corn silages. *Journal of Dairy Science, 75*(11), 3066-3083.

Borba, L. F. P., Ferreira, M. d. A., Guim, A., Tabosa, J. N., Gomes, L. H. d. S., & Santos, V. L. F. (2012). Nutritive value of diferents silage sorghum (*Sorghum bicolor* L. Moench) cultivares. *Acta Scientiarum. Animal Sciences, 34*(2), 123-129.

Botelho, P. R. F., Pires, D. A. A., & Sales, E. C. J. (2010). Avaliação agronômica e nutricional da rebrota anual de quatro genótipos de sorgo para produção de silagem na região norte de Minas Gerais. *Revista Brasileira de Milho e Sorgo, 9*(3), 287-297.

Cabral, L. S., Valadares Filho, S. C., Detmann, E., Zervoudakis, J. T., Pereira, O. G., & Veloso, R. G. (2003). Composição químico-bromatológica, produção de gás, digestibilidade *in vitro* da matéria seca e NDT estimado da silagem de sorgo com diferentes proporções de panículas. *Revista Brasileira de Zoociências, 32*(5), 1250-1258.

Campos, F. P., Lanna, D. P. D., Bose, M. L. V., Boin, C., & Sarmento, P. (2002). Degradabilidade do capim-elefante em diferentes estágios de maturidade avaliada pelo método in vitro/gás. *Scientia Agricola, 59*(2), 217-225.

Carvalho, G. G. P., & Pires, A. J. V. (2008). Organização dos tecidos de plantas forrageiras e suas implicações para os ruminantes. *Archivos de Zootecnia, 57*(1), 13-28.

Casali, A. O., Detmann, E., Valadares Filho, S. C., Pereira, J. C., Henriques, L. T., Freitas, S. G., & Paulino, M. F. (2008). Influência do tempo de incubação e do tamanho de partículas sobre os teores de compostos indigestíveis em alimentos e fezes bovinas obtidos por procedimentos *in situ*. *Revista Brasileira de Zootecnia, 37*(2), 335-342.

Detmann, E., Souza, M., Valadares Filho, S., Queiroz, A., Berchielli, T., Saliba, E., ... Azevedo, J. (2012). *Métodos para análise de alimentos*. Visconde do Rio Branco, MG: Suprema.

Dias, F. J., Jobim, C. C., Soriani Filho, J. L., Bumbieris Junior, V. H., Poppi. E. C., & Santello, G. A. (2010). Composição química e perdas totais de matéria seca na silagem de planta de soja. *Acta Scientiarum. Animal Sciences, 32*(1), 19-26.

Fazaeli, H., Golmohhammadi, H. A., Almodares, A., Mosharraf, S., & Shaei, A. (2006). Comparing the performance of sorghum silage with maize silage in feedlot calves. *Pakistan Journal of Biological Sciences, 9*(13), 2450-2455.

Gonçalves, J. R. S., Pires, A. V., Susin, I., Lima, L. G., Mendes, C. Q., & Ferreira, E. M. (2010). Substituição do grão de milho pelo grão de milheto em dietas contendo silagem de milho ou silagem de capim-elefante na alimentação de bovinos de corte. *Revista Brasileira de Zootecnia, 39*(9), 2032-2039.

Gontijo, M. H. R., Borges, A. L. C. C., Gonçalves, L. C., Rodrigues, J. A. S., Gomes, S. P., Borges, I., ... Campos, M. M. (2010). Potencial forrageiro de seis híbridos de sorgo com capim sudão. *Revista Brasileira de Milho e Sorgo, 7*(1), 33-43.

Hoffmann, F. L. (2001). Fatores limitantes à proliferação de microorganismos em alimentos. *Brasil Alimentos, 9*(1), 23-30.

Holden, L. A. (1999). Comparison of methods of in vitro dry matter digestibility for ten feeds. *Journal of Dairy Science, 82*(8), 1791-1794.

Jobim, C. C., Nussio, L. G., Reis, R. A., & Schmidt, P. (2007). Avanços metodológicos na avaliação da qualidade da forragem conservada. *Revista Brasileira de Zootecnia, 36*(Especial), 101-119.

Köppen, W., & Geiger, R. (1928). *Klimate der Erde*. Gotha: Verlag Justus Perthes. Wall-map 150cmx200cm.

Kozloski, G. V. (2011). *Bioquímica dos ruminantes* (Vol. 1, 3a ed.). Santa Maria, RS: Editora Universidade Federal de Santa Maria.

Machado, F. S., Rodrígues, N. M., Gonçalves, L. C., Rodrigues, J. A. S., Ribas, M. N., Pôssas, F. P., ... Pereira, L. G. R. (2011). Consumo e digestibilidade aparente de silagens de sorgo em diferentes estádios de maturação. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 64*(3), 711-720.

Magalhães, R. T., Gonçalves, L. C., Martins, R. P., Rodrigues, M. J. A., Rodrigues, N. M., Borges, I., ... Araújo, V. L. (2010). Avaliação de quatro genótipos de sorgo pela técnica "in vitro" semi-automática de produção de gases. *Revista Brasileira de Milho e Sorgo, 5*(1), 101-111.

Moraes, S. D., Jobim, C. C., Silva, M. S., & Marquardt, F. I. (2013). Produção e composição química de híbridos de sorgo e de milho para silagem. *Revista Brasileira de Saúde e Produção Animal, 14*(4), 624-634.

Neumann, M., Mühlbach, P. R. F., Nörnberg, J. L., Ost, P. R., Restle, J., Sandini, I. E., & Romano, M. A. (2007). Características da fermentação da silagem obtida em diferentes tipos de silos sob efeito do tamanho de partícula e da altura de colheita das plantas de milho. *Ciência Rural, 37*(3), 847-854.

Paiva, E. P., Lima, M. S., & Paixão, J. A. (2009). Pectina: propriedades químicas e importância sobre a estrutura da parede celular de frutos durante o processo de maturação. *Revista Iberoamericana de Polímero, 10*(4), 196-211.

Pereira, E. S., Mizubuti, I. Y., Pinheiro, S. M., Villarroel, A. B. S., & Clementino, R. H. (2007). Avaliação da qualidade nutricional de silagens de milho (*Zea mays*, L). *Revista Caatinga, 20*(3), 8-12.

Ribeiro, C. G., Gonçalves, L. C., Rodrigues, J. A., Rodriguez, N. M., Borges, I., Borges, A. L. C., ... Ribeiro Junior, G. O. (2007). Padrão de fermentação da silagem de cinco genótipos de sorgo. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 59*(6), 1531-1537.

Santos, M. M., Galvão, J. C. C., Silva, I. R., Miranda, G. V., & Finger, F. L. (2010). Épocas de aplicação de nitrogênio em cobertura na cultura do milho em plantio direto, e alocação do nitrogênio (15N) na planta. *Revista Brasileira de Ciência do Solo, 34*(4), 1185-1194.

Simon, J. E., Lourenço Júnior, J. d. B., Ferreira, G. G. D., Santos, N. F. A., Nahum, B. S., & Monteiro, E. M. M. (2008). Consumo e digestibilidade aparente das frações fibrosas de silagem de sorgo (*Sorghum bicolor* [L.] Moench) por ovinos. *Acta Scientiarum. Animal Sciences, 30*(3), 333-338.

Tolentino, D. C., Rodrigues, J. A. S., Pires, D. A. d. A., Veriato, F. T., Lima, L. O. B., & Moura, M. M. A. (2016). The quality of silage of different sorghum genotypes. *Acta Scientiarum. Animal Sciences, 38*(2), 143-149.

Tomich, T. R., Gonçalves, L. C., Tomich, R. G. P., Rodrigues, J. A. S., Borges, I., & Rodriguez, N. M. (2004). Características químicas e digestibilidade in vitro de silagens de girassol. *Revista Brasileira de Zootecnia, 33*(6), 1672-1682.

Wakabayashi, K. (2000). Changes in cell wall polysaccharides during fruit ripening. *Journal of Plant Research, 113*(3), 231-237.

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