



## The quality of silage of different sorghum genotypes

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**ABSTRACT.** The objective was to select from among 24 sorghum genotypes the superior ones for silage production. The study was conducted in the experimental field of Embrapa Maize & Sorghum, in the municipality of Sete Lagoas, Minas Gerais State. It used 24 forage sorghum genotypes, 21 being hybrids from the crossing of grain sorghum females and forage males (12F38019, 12F38006, 12F40006, 12F40005, 12F40019, 12F37016, 12F37005, 12F37043, 12F39006, 12F39005, 12F39019, 12F38005, 12F38007, 12F37007, 12F39007, 12F40007, 12F38014, 12F37014, 12F39014, 12F40014 e 12F38009) and three witnesses: BRS 610, BRS 655 and Volumax. It estimated productivity per area, *in vitro* dry matter digestibility, and assessed the bromatological and fermentation characteristics of sorghum silage. *In vitro* dry matter digestibility, unavailable protein in neutral detergent, neutral detergent fiber corrected for ashes and protein, acid detergent fiber, hemicellulose and lignin differed as to the genotypes tested. The pH and the ammoniacal nitrogen of the silage also showed differences between genotypes. Most of the genotypes tested are favorable for silage production, except the hybrid with higher lignin content 12F370014, and the hybrids 12F37007 and 12F370014, which showed the highest NDFap values.

**Keywords:** digestibility, grain sorghum, hybrids, fermentation quality, nutritional value.

### Qualidade de silagens de diferentes genótipos de sorgo

**RESUMO.** Objetivou-se selecionar dentre 24 genótipos de sorgo os superiores para produção de silagem. O estudo foi conduzido no campo experimental da Embrapa Milho e Sorgo, município de Sete Lagoas, Estado de Minas Gerais. Utilizados 24 genótipos de sorgo forrageiro, 21 híbridos do cruzamento entre fêmeas graníferas e machos forrageiros (12F38019, 12F38006, 12F40006, 12F40005, 12F40019, 12F37016, 12F37005, 12F37043, 12F39006, 12F39005, 12F39019, 12F38005, 12F38007, 12F37007, 12F39007, 12F40007, 12F38014, 12F37014, 12F39014, 12F40014 e 12F38009) e três testemunhas: BRS 610, BRS 655 e Volumax. Estimada a produtividade por área, digestibilidade *in vitro* da matéria seca, características bromatológicas e fermentativas das silagens de sorgo. A digestibilidade *in vitro* da matéria seca, proteína indigestível em detergente neutro, fibra em detergente neutro corrigido para cinzas, proteína, fibra em detergente ácido, hemicelulose e lignina foram diferentes quanto aos genótipos testados. O pH e nitrogênio amoniacal das silagens também apresentaram diferenças entre genótipos. A maioria dos genótipos testados é favorável à produção de silagem, exceto o híbrido com maior teor de lignina 12F370014 e os híbridos 12F37007 e 12F370014, que apresentaram os maiores valores de FDNcp.

**Palavras-chave:** digestibilidade, gramínea, híbridos, qualidade fermentativa, valor nutricional.

### Introduction

In Brazil, due to climatic conditions, the availability of forage is uneven throughout the year, with alternating periods of excess or shortage of pasture. Aiming at reducing the negative impact of seasonality in the production of forage on the herd performance, the excess of forage produced during rainy periods needs to be stored so it can be used during dry periods, guaranteeing animals a good quality and a substantial amount of food the entire year.

The sorghum crop (*Sorghum bicolor* (L.) Moench) stands out for its rusticity, high biomass production and great tolerance to water deficit. These characteristics, coupled with its energetic efficiency, allow its cultivation in arid and semi-arid zones, with production in different seasons and regions.

Sorghum is a favorable plant for the ensiling process due to its phenotypic characteristics that determine ease of planting, handling, harvesting and storing. It is chemically composed of a high concentration of soluble carbohydrates that are essential for an adequate lactic acid fermentation of

organic matter, a factor responsible for the silage's nutritional quality.

Silage use can contribute to elevating animal productivity and, consequently, the profitability of production systems (Simon et al., 2008). Ensiling is a process aimed at preserving chopped organic matter in anaerobic environment, which suffers physical-chemical and organoleptic changes due to the presence of microbial fermentation.

The objective of this work was to select from among twenty-four sorghum genotypes the best ones for producing silage.

## Material and methods

The study was conducted from February to August 2013 in Embrapa Maize & Sorghum's experimental field located in the municipality of Sete Lagoas, Minas Gerais, Brazil.

A total of 24 forage sorghum genotypes were used, of which 21 were hybrids obtained from the crossing between grain sorghum females and forage males, and 3 were witnesses: BRS 610, BRS 655 e VOLUMAX. The 21 hybrids tested were: 12F38019, 12F38006, 12F40006, 12F40005, 12F40019, 12F37016, 12F37005, 12F37043, 12F39006, 12F39005, 12F39019, 12F38005, 12F38007, 12F37007, 12F39007, 12F40007, 12F38014, 12F37014, 12F39014, 12F40014 and 12F38009.

Sowing was done in February 2013 with 20 seeds per meter in each plot. The harvest of all genotypes was mechanized, held in May, when the sorghum plant had favorable dry matter content for the ensiling process. The ideal dry matter content of the plants was measured through practical method, which is, by rubbing the sorghum grains with the fingers, thus assessing the grain's maturity stage and ensiling moment.

The randomized block design was used, with 24 genotypes sown in 3 blocks, totaling 72 experimental plots. Each plot consisted of 6 rows with 6m in length and 70cm of row spacing. Fertilization was performed according to the analysis of the soil and the requirements of the crop; planting used 400 kg of NPK (8, 28, 16) with the addition of 0.5% of boron, and after 40 days coverage fertilization was done with 100 kg of urea.

Assessments of productivity, bromatological and fermentation characteristics, and *in vitro* dry matter digestibility of the sorghum silage were carried out in the central and intermediate rows of each plot.

Laboratory silos made of PVC pipes were used, measuring 100mm in diameter, 500mm in length, with average density of 600 kg m<sup>-3</sup>. The silos were

sealed at the time of ensiling, with PVC caps fitted with 'Bunsen' type valves, being weighed before and after the ensiling. The silos were opened after 56 days of the ensiling.

The nutritional assessment of the silage was held in the Food Analysis Laboratory of the State University of Montes Claros, Campus Janaúba, Minas Gerais State. Upon the opening of the silos, the material was homogenized and extracted for further analysis.

Sample collected after the opening of the silos was placed in paper bags, weighed; then, pre-drying in forced ventilation oven was carried out, at 55°C, for 72 hours. The pre-dried samples were ground in a 'Willey' type mill with a 1mm mesh sieve, and then packed in glass flasks with screw cap identified for further analysis of food chemical composition: dry matter, ashes, crude protein, neutral detergent fiber corrected for ashes and protein, acid detergent fiber and lignin (Detmann et al., 2012).

The fermentation analyses of the silage were conducted as follows: for the determination of pH, a pH meter was employed in accordance with the methodology described by Silva and Queiroz (2006). The analysis of ammoniacal nitrogen expressed as total nitrogen (N-NH<sub>3</sub>/NT) was performed through the sampling of about 25g of silage of each genotype, as proposed by Bolsen, Lin and Brent (1992). The measurement of the water activity of the silage was performed using the AquaLab 4TE DUO equipment.

The determination of *in vitro* dry matter digestibility was carried out with pre-dried samples at 55°C and determined according to the method described by Tilley and Terry (1963), modified by Holden (1999), who pioneered the use of a Tecnal® *in vitro* incubator (ET-150), with modification in the sachet material used (7.5 x 7.5 cm), made with a nonwoven fabric (100 g m<sup>-2</sup>), in accordance with Casali et al. (2008).

IVDMD (%) = ((% incubated food DM - (% residue DM x correction factor)) / % incubated food DM) x 100, the correction factor being the result of the ratio of the blank sample weight before incubation by the sample weight after incubation, where IVDMD stands for *in vitro* dry matter digestibility, and DM for dry matter.

The digestible dry matter yield (DDMY) for each genotype, in turn, was calculated using the following equation: DDMY ton ha<sup>-1</sup> = (% DM 105°C x % IVDMD).

The data obtained in the laboratory was subjected to analysis of variance through the SISVAR software (Ferreira, 2010), and when it presented significance for the 'F' test the mean

genotype factor was compared through the Scott-Knott test at a 5% probability.

## Results and discussion

When considering the pH of all sorghum silage assessed (Table 1), genotypes 12F40005, 12F40019, 12F39006, 12F39019, 12F38005, 12F37007, 12F40007, 12F37014, 12F38009, VOLUMAX and BRS 610 showed reduced pH values ranging from 3.80 to 4.00, being desirable values for fermentation.

Ribeiro et al. (2007) determined the fermentation pattern of the silage of five sorghum genotypes and found pH values ranging between 3.69 and 4.58.

Sorghum silage, when well fermented, presents minimum pH values around 3 to 7 days after ensiling, which are maintained for a long storage time (Fazaeli, Golmohammadi, Al-Moddares, Mosharraf, & Shoaei, 2008). The pH stability in ensiling is due to interactions between dry matter concentration, the buffering capacity of the forage, the concentrations of soluble carbohydrates and of the lactate, and the anaerobic conditions of the medium (Borba et al., 2012).

In Table 1, the levels present in the silage of 24 sorghum genotypes for water activity were close, the overall mean being 0.97. Aw indicates the level of water in its free form in the material and is expressed in a 0-1.0 scale. The value 0 (zero) is considered for material free of water, and 1.0 for water in its liquid form. Thus, pure water activity is 1.0 and decreases as the concentration of solutes increases.

Microorganisms in general are essential in silage fermentation process and have their activity largely affected by Aw. The growth of most bacteria and fungi is restricted to Aw values greater than 0.90; salmonellae need Aw greater than 0.92 for growth; as for fungi, the threshold for growth is 0.78 Aw, and 0.86 Aw for producing aflatoxins. The growth of bacteria of the genus *Clostridium*, in turn, is inhibited with Aw below 0.94, while lactic acid bacteria are less sensitive (Jobim, Nussio, Reis, & Schmidt, 2007).

Still checking the fermentation quality of sorghum silage, Table 1 displays the values obtained from the N-NH<sub>3</sub>/NT ratio. Lower values for the N-NH<sub>3</sub>/NT ratio were found in genotypes 12F38019, 12F38006, 12F40006, 12F37016, 12F37043, 12F39006, 12F39019, 12F38007, 12F37007, 12F39007, 12F40007, 12F38014, 12F37014, 12F39014, 12F40014, BRS 655 and Volumax, ranging from 2.25 to 3.24, being desirable values

when it comes to anaerobic fermentation in the ensiling process.

Araújo et al. (2007) analyzed the quality of the silage of three sorghum genotypes ensiled at five different maturation stages and found values ranging from 4.09 to 8.02% of N-NH<sub>3</sub>/NT.

**Table 1.** Mean potential hydrogen (pH) levels, water activity (Aw), and ammoniacal nitrogen/total nitrogen (N-NH<sub>3</sub>/NT) ratio in the silage of twenty-four sorghum genotypes.

Genotypes	pH (%)	Aw	N-NH <sub>3</sub> /NT(%)
12F38019	4.12 <sup>A</sup>	0.97	2.68 <sup>C</sup>
12F38006	4.11 <sup>A</sup>	0.96	2.44 <sup>C</sup>
12F40006	4.10 <sup>A</sup>	0.97	3.10 <sup>C</sup>
12F40005	4.00 <sup>B</sup>	0.97	3.52 <sup>B</sup>
12F40019	3.94 <sup>B</sup>	0.97	3.52 <sup>B</sup>
12F37016	4.14 <sup>A</sup>	0.96	2.25 <sup>C</sup>
12F37005	4.25 <sup>A</sup>	0.96	4.37 <sup>A</sup>
12F37043	4.05 <sup>A</sup>	0.97	2.68 <sup>C</sup>
12F39006	3.94 <sup>B</sup>	0.97	3.10 <sup>C</sup>
12F39005	4.17 <sup>A</sup>	0.96	3.48 <sup>B</sup>
12F39019	3.94 <sup>B</sup>	0.97	3.24 <sup>C</sup>
12F38005	3.90 <sup>B</sup>	0.97	4.23 <sup>A</sup>
12F38007	4.06 <sup>A</sup>	0.97	3.24 <sup>C</sup>
12F37007	3.93 <sup>B</sup>	0.97	2.72 <sup>C</sup>
12F39007	4.03 <sup>A</sup>	0.97	2.96 <sup>C</sup>
12F40007	4.00 <sup>B</sup>	0.97	2.72 <sup>C</sup>
12F38014	4.03 <sup>A</sup>	0.97	2.82 <sup>C</sup>
12F37014	3.94 <sup>B</sup>	0.97	2.82 <sup>C</sup>
12F39014	4.15 <sup>A</sup>	0.97	2.96 <sup>C</sup>
12F40014	4.07 <sup>A</sup>	0.97	2.96 <sup>C</sup>
12F38009	3.98 <sup>B</sup>	0.96	4.09 <sup>A</sup>
BRS 655	4.11 <sup>A</sup>	0.97	3.10 <sup>C</sup>
VOLUMAX	3.80 <sup>B</sup>	0.97	2.96 <sup>C</sup>
BRS 610	3.99 <sup>B</sup>	0.96	3.65 <sup>B</sup>
Mean	-	0.97	-
CV(%)	3.16	0.80	15.37

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

The silage is considered of very good quality when it presents an N-NH<sub>3</sub>/NT ratio lower than 10%, good quality when between 10 and 15%, medium quality when between 15 and 20% and bad quality when greater than 20% (Ribeiro et al., 2007).

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

As for dry matter content, Table 2 shows that genotypes 12F37005, 12F39005 and 12F38005 presented the highest values, 46.92, 50.25 and 46.63, respectively. The other genotypes tested presented lower figures as to the DM content of the silage, ranging from 36.31 for genotype 12F39006 to 42.78 for genotype 12F40007.

The optimum DM content for ensiling is estimated between 30 and 35% (Dias et al., 2010) to avoid losses with the formation of effluent and biological processes that produce gases, water and heat, as well as to provide adequate lactic fermentation to maintain the nutritional value of the silage.

Araújo et al. (2007) analyzed the quality of the silage of three sorghum genotypes ensiled at five different maturation stages and found DM values ranging from 28.85 to 57.37%.

Silage made of forage with higher DM content (> 40%) may present greater difficulty of compression and, hence, lower-quality silage due to a greater presence of air. Accordingly, materials with higher moisture content are easier to be compressed (Tomich, 2004).

Among the sorghum plant fractions, the stem is the portion that least contributes to the increase in DM content, followed by leaves and panicle. Thus, considering these genotypes as dual-purpose sorghum, the greater participation of the panicle in the physical structure of the plant may have been the main responsible for the change in the DM content. Coupled with this characteristic, soil and climatic conditions during cultivation also contribute to raising the dry matter content of the crop. And in this case, the dry spell occurred during cultivation possibly helped to increase dry matter at the cutting moment. Under these conditions the plant completes the cycle faster and the dry matter content rises, justifying the values found.

Regarding the IVDMD (Table 2), the greatest digestibility rates observed were found in materials: 12F38019, 12F38006, 12F37016, 12F39006, 12F39005, 12F39019, 12F37007, 12F39007, 12F38014, 12F37014, 12F39014, 12F40014, BRS 655 and BRS 610; 66.99 was the overall mean of the genotypes with higher values.

Pires et al. (2013) assessed the characteristics of the silage of five sorghum genotypes cultivated during the winter and reported IVDMD mean values for Volumax of 52.22, and 56.38% for BRS 610.

Silage with IVDMD between 40 and 55% can be classified as being of satisfactory quality, and silage with 55 to 65% is classified as being of good quality (Paiva, Pizarro, Rodriguez, & Wiana, 2013).

**Table 2.** Mean dry matter (DM) content, *in vitro* dry matter digestibility (DM), and digestible dry matter yield (DDMY) in the silage of twenty-four sorghum genotypes (data expressed in the dry matter).

Genotypes	DM (%)	IVDMD (%)	DDMY (t ha <sup>-1</sup> )
12F38019	38.04 <sup>C</sup>	74.18 <sup>A</sup>	7.58
12F38006	44.46 <sup>B</sup>	68.43 <sup>A</sup>	5.95
12F40006	38.55 <sup>C</sup>	61.38 <sup>B</sup>	5.40
12F40005	39.28 <sup>C</sup>	58.97 <sup>B</sup>	4.76
12F40019	38.01 <sup>C</sup>	56.02 <sup>B</sup>	5.30
12F37016	40.36 <sup>C</sup>	65.37 <sup>A</sup>	6.78
12F37005	46.92 <sup>A</sup>	60.56 <sup>B</sup>	6.57
12F37043	38.76 <sup>C</sup>	56.67 <sup>B</sup>	5.99
12F39006	36.31 <sup>C</sup>	66.10 <sup>A</sup>	6.16
12F39005	50.25 <sup>A</sup>	63.34 <sup>A</sup>	6.59
12F39019	39.53 <sup>C</sup>	64.90 <sup>A</sup>	5.51
12F38005	46.63 <sup>A</sup>	59.61 <sup>B</sup>	5.61
12F38007	43.24 <sup>B</sup>	55.20 <sup>B</sup>	4.89
12F37007	42.56 <sup>B</sup>	64.23 <sup>A</sup>	6.70
12F39007	40.33 <sup>C</sup>	62.71 <sup>A</sup>	4.13
12F40007	42.78 <sup>B</sup>	60.89 <sup>B</sup>	4.84
12F38014	41.40 <sup>C</sup>	67.26 <sup>A</sup>	5.52
12F37014	42.14 <sup>B</sup>	68.74 <sup>A</sup>	6.96
12F39014	43.53 <sup>B</sup>	67.97 <sup>A</sup>	6.11
12F40014	39.37 <sup>C</sup>	66.74 <sup>A</sup>	4.24
12F38009	40.25 <sup>C</sup>	61.00 <sup>B</sup>	6.01
BRS 655	38.89 <sup>C</sup>	67.86 <sup>A</sup>	5.11
VOLUMAX	37.12 <sup>C</sup>	50.46 <sup>B</sup>	4.43
BRS 610	39.48 <sup>C</sup>	66.01 <sup>A</sup>	5.56
Mean	41.12	62.99	5.70
CV(%)	5.65	8.76	24.83

Means followed by distinct capital letters in the same column differ ( $P < 0.05$ ) by Scott-Knott Test. CV = Coefficient of Variation.

Digestibility is an estimate of the capacity the food has of allowing the animal to use its nutrients to a greater or lesser extent. Several factors can interfere with food digestibility coefficients, especially the maturity of the plant, when it comes to forage, exerting a negative effect on the digestibility of nutrients, mainly due to the reduction in protein content and increased cell wall lignification. According to Silva et al. (2011), the lignin forms a barrier that prevents the microbial adherence and the enzymatic hydrolysis of cellulose and hemicellulose, making potentially degradable structural carbohydrates unavailable and lowering the DM digestibility. However, reduced lignin content did not increase the digestibility of the genotypes, which can be probably explained by the low bacterial mass present in the incubation of the materials.

When considering, in Table 2, the digestible dry matter yields of all 24 sorghum genotypes, it is possible to observe that the mean found was 5,695.01 kg ha<sup>-1</sup>. The DDMY is a way to reconcile productivity with nutritional value, that is, the association between volume and quality quantities. Therefore, the digestible dry matter yield is nothing more than the result of the multiplication of the productivity of dry matter by its digestibility, indicating the amount of nutrients that is actually produced in the area and provided to animals (Paziani, 2011).

Gontijo Neto et al. (2002) assessed the productivity of forage sorghum genotypes under increasing levels of fertilization and found DDMY values ranging between 8.0 and 9.2 t ha<sup>-1</sup>.

Considering the ash content present in the 24 sorghum silages shown in Table 3, the overall mean was 5.31%.

Ash content involves the determination of the amount of minerals contained in forage, but high levels may represent high silica content, and the latter does not contribute nutritionally for the animals. The ashes indicate a wealth of minerals in the food, but never which minerals and their content. Generally, foods of animal origin are rich in calcium and phosphorus; plant foods, in turn, have low value of mineral matter, mineral variables (Silva & Queiroz, 2006).

Regarding the CP content (Table 3), it is possible to observe that genotypes 12F38019, 12F40006, 12F37016, 12F39005, 12F38007, 12F37007, 12F37014, 12F39014 and BRS 655 showed the highest CP content, with an overall mean of 9.06 for genotypes with higher values.

Von Pinho, Vasconcelos, Borges, and Rezende (2006) assessed the nutritional characteristics of the silage of forage sorghum genotypes Volumax and BRS610 PB and obtained mean CP values of 8.0%, values similar to those found in this work, using the same genotypes.

A food and/or diet should contain at least 7% of CP to provide sufficient nitrogen for an effective microbial fermentation in the rumen. The CP percentage does not change with the ensiling process, although the different proportions of nitrogen fractions might be changed. It is known that fermentation causes changes in the composition of nitrogen fractions, reducing the levels of true protein and increasing the levels of free amino acids or products from the breakage of these amino acids, including ammonia, CO<sub>2</sub> and amines.

When considering the UPAD content present in the sorghum silage and displayed in Table 3, it is observed that the overall mean found was 0.09. In relation to the UPDN variable, genotypes 12F40006, 12F40005, 12F37016, 12F39005, 12F39019, 12F38005, 12F38007, 12F39007, 12F40007, 12F38014, 12F37014, 12F39014, 12F38009 and BRS 655 presented the lowest values, with 0.06 being the overall mean of the genotypes with the lowest content, which is a desirable characteristic because of the greater availability of the protein present in the food for the animal.

The forms of unavailable nitrogen and unavailable protein are determined based on the content of nitrogen and proteins insoluble in acid

detergent, fractions that are composed by the form of nitrogen associated with lignin, tannin-protein complexes and compounds resulting from the 'Maillard' reaction.

**Table 3.** Mean ash content (ASH), crude protein (CP), unavailable protein in acid detergent (UPAD) and unavailable protein in neutral detergent (UPND) in the silage of twenty-four sorghum genotypes (data expressed in the dry matter).

Genotypes	ASH (%)	CP (%)	UPAD (%)	UPDN (%)
12F38019	5.40	9.56 <sup>A</sup>	0.08	0.95 <sup>A</sup>
12F38006	4.52	8.25 <sup>B</sup>	0.08	0.09 <sup>B</sup>
12F40006	5.61	9.33 <sup>A</sup>	0.09	0.07 <sup>C</sup>
12F40005	5.64	6.58 <sup>B</sup>	0.11	0.07 <sup>C</sup>
12F40019	4.74	7.62 <sup>B</sup>	0.11	0.09 <sup>B</sup>
12F37016	5.80	8.60 <sup>A</sup>	0.09	0.07 <sup>C</sup>
12F37005	5.75	7.97 <sup>B</sup>	0.09	0.09 <sup>B</sup>
12F37043	5.33	8.04 <sup>B</sup>	0.10	0.09 <sup>B</sup>
12F39006	5.68	7.90 <sup>B</sup>	0.09	0.09 <sup>B</sup>
12F39005	5.30	8.98 <sup>A</sup>	0.11	0.06 <sup>C</sup>
12F39019	4.58	8.08 <sup>B</sup>	0.11	0.07 <sup>C</sup>
12F38005	4.66	8.28 <sup>B</sup>	0.10	0.06 <sup>C</sup>
12F38007	5.19	8.90 <sup>A</sup>	0.09	0.06 <sup>C</sup>
12F37007	5.33	8.59 <sup>A</sup>	0.07	0.09 <sup>B</sup>
12F39007	5.35	7.76 <sup>B</sup>	0.08	0.06 <sup>C</sup>
12F40007	4.96	7.42 <sup>B</sup>	0.10	0.07 <sup>C</sup>
12F38014	5.30	7.41 <sup>B</sup>	0.09	0.07 <sup>C</sup>
12F37014	4.86	8.85 <sup>A</sup>	0.09	0.06 <sup>C</sup>
12F39014	6.06	8.90 <sup>A</sup>	0.08	0.05 <sup>C</sup>
12F40014	5.06	6.72 <sup>B</sup>	0.11	0.08 <sup>B</sup>
12F38009	5.58	6.27 <sup>B</sup>	0.10	0.07 <sup>C</sup>
BRS 655	5.53	9.83 <sup>A</sup>	0.10	0.06 <sup>C</sup>
VOLUMAX	5.52	7.62 <sup>B</sup>	0.10	0.08 <sup>B</sup>
BRS 610	5.78	7.60 <sup>B</sup>	0.10	0.09 <sup>B</sup>
Mean	5.31	8.14	0.09	0.11
CV(%)	12.72	13.98	16.92	12.27

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

The components of these fractions are highly resistant to microbial and enzymatic attack; for this reason, they are completely insoluble and/or indigestible in the gastrointestinal tract.

Regarding the NDFap variable (Table 4), lower values were found in genotypes 12F39006, 12F39005, 12F40019, 12F40005 and Volumax, being: 50.48, 48.17, 50.39, 43.68 and 43.10, respectively, desirable values for a good quality fiber. In relation to ADF values, the lower genotypes were 12F40005, 12F40019, 12F37043, 12F39006, 12F39005, 12F38005, 12F38007, 12F40007, 12F38014, 12F39014, Volumax and BRS 610, with 33.91 being the overall mean of the genotypes with lower levels.

Von Pinho et al. (2006) assessed the nutritional characteristics of the silage of dual-purpose and forage sorghum genotypes and recorded NDF percentages of 47.2 and 50.1%, respectively. In relation to the ADF percentages, values varied from 33.1 to 35.4% for dual-purpose and forage sorghum, respectively.

NDF and ADF contents are indicative of the amount of forage fiber, with the NDF being related to the amount of fiber that there is in the

bulky food, while the ADF is related to the amount of less digestible fiber; thus, the lower the content, the better the quality of silage produced and the greater the consumption of DM by the animal (Santos, Galvão, Silva, Miranda, & Finger, 2010).

NDF values above 60% correlate negatively with the dry matter consumption by the animal; as for the ADF fraction, Gonçalves et al. (2010) stated that a high content hinders the fragmentation of the food and its digestion by ruminal bacteria.

Still in Table 4, for the fibrous fraction of cellulose, the overall mean for the 24 genotypes was 23.74. Regarding the hemicellulose fraction only genotype 12F39014 was superior to the other ones, obtaining a value of 40.19. As for the lignin fraction, lower values were found in genotypes 12F39014 and 12F40014, 3.45 and 2.28 respectively.

According to Müller et al. (2006), as a result of the maturity of plants, as the cycle progresses there is an increase in lignin content and an increase in the cell wall of the tissues of vegetables due mainly to decreased leaf/stem ratio. The biggest changes that occur in the chemical composition of forage plants are those that accompany their maturation.

**Table 4.** Mean content of insoluble fiber in neutral detergent corrected for ashes and proteins (NDFap), insoluble fiber in acid detergent (ADF), hemicellulose (HEM), cellulose (CEL) and lignin (LIG) in the silage of twenty-four sorghum genotypes (data expressed in the dry matter).

Genotypes	NDFap (%)	ADF (%)	HEM (%)	CEL (%)	LIG (%)
12F38019	54.35 <sup>A</sup>	35.94 <sup>A</sup>	16.46 <sup>C</sup>	23.18	5.45 <sup>B</sup>
12F38006	58.19 <sup>A</sup>	47.20 <sup>A</sup>	18.86 <sup>C</sup>	23.00	6.99 <sup>A</sup>
12F40006	56.72 <sup>A</sup>	36.96 <sup>A</sup>	30.86 <sup>B</sup>	25.15	7.95 <sup>A</sup>
12F40005	50.48 <sup>B</sup>	33.20 <sup>B</sup>	11.72 <sup>C</sup>	21.75	7.45 <sup>A</sup>
12F40019	48.17 <sup>B</sup>	26.71 <sup>B</sup>	20.48 <sup>C</sup>	27.10	8.35 <sup>A</sup>
12F37016	60.87 <sup>A</sup>	40.63 <sup>A</sup>	21.23 <sup>C</sup>	26.04	5.60 <sup>B</sup>
12F37005	57.04 <sup>A</sup>	38.56 <sup>A</sup>	22.61 <sup>C</sup>	24.06	7.60 <sup>A</sup>
12F37043	57.42 <sup>A</sup>	33.41 <sup>B</sup>	24.01 <sup>C</sup>	27.06	8.48 <sup>A</sup>
12F39006	50.39 <sup>B</sup>	30.13 <sup>B</sup>	18.84 <sup>C</sup>	21.61	5.23 <sup>B</sup>
12F39005	43.10 <sup>B</sup>	31.11 <sup>B</sup>	15.13 <sup>C</sup>	20.05	5.38 <sup>B</sup>
12F39019	60.02 <sup>A</sup>	38.50 <sup>A</sup>	16.04 <sup>C</sup>	20.72	6.03 <sup>B</sup>
12F38005	54.69 <sup>A</sup>	33.66 <sup>B</sup>	19.27 <sup>C</sup>	27.07	8.51 <sup>A</sup>
12F38007	60.16 <sup>A</sup>	31.16 <sup>B</sup>	28.93 <sup>B</sup>	22.66	7.90 <sup>A</sup>
12F37007	61.77 <sup>A</sup>	40.54 <sup>A</sup>	17.11 <sup>C</sup>	20.17	5.41 <sup>B</sup>
12F39007	58.23 <sup>A</sup>	37.79 <sup>A</sup>	14.65 <sup>C</sup>	27.28	5.46 <sup>B</sup>
12F40007	56.47 <sup>A</sup>	28.02 <sup>B</sup>	18.27 <sup>C</sup>	25.76	6.32 <sup>B</sup>
12F38014	57.59 <sup>A</sup>	33.42 <sup>B</sup>	20.89 <sup>C</sup>	28.07	7.12 <sup>A</sup>
12F37014	65.29 <sup>A</sup>	40.16 <sup>A</sup>	25.93 <sup>B</sup>	20.20	7.23 <sup>A</sup>
12F39014	60.43 <sup>A</sup>	33.85 <sup>B</sup>	41.19 <sup>A</sup>	27.78	3.45 <sup>C</sup>
12F40014	65.43 <sup>A</sup>	37.42 <sup>A</sup>	26.17 <sup>B</sup>	16.92	2.28 <sup>C</sup>
12F38009	57.82 <sup>A</sup>	41.44 <sup>A</sup>	17.85 <sup>C</sup>	23.07	5.98 <sup>B</sup>
BRS 655	56.95 <sup>A</sup>	35.32 <sup>A</sup>	22.36 <sup>C</sup>	19.23	5.74 <sup>B</sup>
VOLUMAX	43.68 <sup>B</sup>	24.06 <sup>B</sup>	17.88 <sup>C</sup>	27.92	6.58 <sup>A</sup>
BRS 610	58.17 <sup>A</sup>	34.07 <sup>B</sup>	20.09 <sup>C</sup>	23.95	6.65 <sup>A</sup>
Mean	56.39	34.99	21.20	23.74	6.38
CV(%)	11.17	15.08	25.05	21.96	23.32

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

As the plant ages, the proportion of digestible components tends to decrease, and the proportion of fibers to increase. In addition, bulky foods with high

NDF contents have a greater proportion of the B2 fraction of carbohydrates, which, for providing energy more slowly in the rumen, may affect the microbial efficiency and animal performance.

## Conclusion

Most of the genotypes tested are favorable for silage production except the hybrid with higher lignin content 12F370014, and the hybrids 12F37007 and 12F370014, which showed the highest NDFap values.

## References

- Araújo, V. L., Rodriguez, N. M., Gonçalves, L. C., Rodrigues, J. A. S., Borges, I., Borges, A. L. C. C., & Saliba, E. O. S. (2002). Qualidade das silagens de três híbridos de sorgo ensilados em cinco diferentes estádios de maturação. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, 59(1), 168-174.
- Bolsen, K. K., Lin, C., & Brent, B. E. (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. A., Guim, A., Tabosa, J. N., Gomes, L. H. S., & Santos, V. L. F. (2012). Nutritive value of diferentes silage sorghum (*Sorghum bicolor* L. Moench) cultivares. *Acta Scientiarum. Animal Sciences*, 34(2), 123-129.
- 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. A., Valadares Filho, S. C., Queiroz, A. C., Berchielli, T. T., Saliba, E. O. S., ... Azevedo, J. A. G. (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., Golmohammadi, H. A., Al-Moddares, A., Mosharraf, S., & Shoaci, A. A. (2008). Comparing the performance of sorghum silage with maize silage in feedlot calves. *Pakistan Journal of Biological Sciences*, 9(13), 2450-2455.
- Ferreira, D. F. (2010). *Sisvar Sistema de análise de variância. Versão 5.3* [Software]. Lavras, MG: UFLA.
- Gonçalves, J. R. S., Pires, A. V., Susin, I., Lima, L. G., Mendes, C. G., & 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 Neto, M. M., Obeid, J. A., Pereira, O. G., Cecon, P. R., Cândido, M. J. D., & Miranda, L. F. (2002). Híbridos de sorgo (*Sorghum bicolor* (L.) Moench) cultivados sob níveis crescente de adubação, rendimento, proteína bruta e digestibilidade *in vitro*. *Revista Brasileira de Zootecnia*, 31(4), 1640-1647.
- Holden, L. A. (1999). Comparison of methods of *in vitro* dry matter digestibility for ten feeds. *Journal of Dairy Science*, 82(80), 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(4), 754-762.
- Müller, L., Santos, O. S., Manfron, P. A., Medeiros, S. L. P., Haut, V., Neto, D. D., ... Garcia, D. C. (2006). Forragem hidropônica de milho: produção e qualidade nutricional em diferentes densidades de semeadura e idades de colheita. *Ciência Rural*, 36(4), 1094-1099.
- Neumann, M., Muhlbach, P. R. F., Nornberg, 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, J. A. J., Pizarro, E. A., Rodriguez, N. M., & Wiana, J. A. C. (2013). Silage quality in the metallurgical region of Minas Gerais, Brazil. *National Agricultural Library*, 30(1), 81-88.
- Paziani, S. F. (2011). Produção de milho e sorgo para silagem no estado de São Paulo. *Pesquisa e Tecnologia*, 8(2), 1-4.
- Pires, D. A. A., Rocha Júnior, V. R., Sales, E. C. J., Reis, S. T., Jayme, D. G., Cruz, S. S., ... Esteves, B. L. C. (2013). Características das silagens de cinco genótipos de sorgo cultivados no inverno. *Revista Brasileira de Milho e Sorgo*, 12(1), 68-77.
- Ribeiro, C. G. M., Gonçalves, L. C., Rodrigues, J. A. S., Rodriguez, N. M., Borges, I., Borges, A. L. C. 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.
- Silva, D. J., & Queiroz, A. C. (2006). *Análise de alimentos: métodos químicos e biológicos*. (3a ed.). Viçosa, MG: Editora UFV.
- Silva, M. A., Lira, M. A., Santos, M. V. F., Dubeux Junior, J. C. B., Freitas, E. V., & Araújo, G. G. L. (2011). Rendimento forrageiro e valor nutritivo de clones de *Pennisetum* sob corte, na zona da mata seca. *Archivos de Zootecnia*, 60(229), 64-74.
- Simon, J. E., Lourenço Júnior, J. B., Ferreira, G. D. G., 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 Science*, 30(3), 333-338.
- Tilley, J. M. A., & Terry, R. A. A. (1963). A two-stage technique for the *in vitro* digestion of forage crops. *Journal British Grassland Society*, 18(2), 104-111.
- Tomich, T. R. (2004). Características químicas e digestibilidade *in vitro* de silagens de girassol. *Revista Brasileira de Zootecnia*, 33(6), 1672-1682.
- Von Pinho, R. G., Vasconcelos, R. C., Borges, I. D., & Rezende, A. V. (2006). Influência da altura de corte das plantas nas características agrônômicas e valor nutritivo das silagens de milho e de diferentes tipos de sorgo. *Revista Brasileira de Milho e Sorgo*, 5(2), 266-279.

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