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Chemical composition of sorghum genotypes silages

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ABSTRACT. The objective was to select sorghum genotypes for silage production using its chemical characteristics. The experiment was carried out in the facilities of Embrapa Maize and Sorghum in Sete Lagoas, state of Minas Gerais, to evaluate the agronomic characteristics, and nutritional quality of silage of twelve sorghum genotypes. We used a randomized block design with three replications. In relation to the production of green matter, the genotypes SF15 Volumax and BR610 stood out (52.07; 48.00 and 41.87 ton ha^{-1}). Regarding pH, genotypes 1015339, 1015347, 1016007, SF15, BRS655, Volumax and BR610 averaged 3.68. All genotypes were similar considering the nutritional value, ammonia nitrogen and water activity. The genotypes SF15, Volumax and BRS610 showed the highest productivity per area, representing the best options for silage production.

Keywords: preserved food, seasonality, genotypes and production.

Composição bromatológica de genótipos de silagens de sorgo

RESUMO. Selecionar genótipos de sorgo para produção de silagem por meio de suas características bromatológicas. O experimento foi implantado nas dependências da Embrapa Milho e Sorgo em Sete Lagoas – MG, com o objetivo de avaliar as características agronômicas, nutricionais e qualidade da silagem de 12 genótipos de sorgo. Utilizou-se um delineamento em blocos ao acaso com três repetições. Quanto à produção de matéria verde os genótipos SF15, Volumax e BR610 se destacaram (52,07; 48,00 e 41,87 t ha^{-1}). Em relação ao pH, os genótipos 1015339, 1015347, 1016007, SF15, BRS655, Volumax e BR610 obtiveram média 3,68. Todos os genótipos avaliados foram semelhantes quanto ao valor nutricional, nitrogênio amoniacal e atividade de água. Os genótipos SF15, Volumax e BRS610 destacaram-se pela maior produtividade por área sendo as melhores opções para produção de silagem.

Palavras-chave: alimento conservado, estacionalidade, genótipos e produção.

Introduction

In Brazil, due to climatic conditions, forage availability is irregular throughout the year, with alternating periods of surplus and shortage of pasture (Moreira, Prado, Cecato, Wada, & Mizubuti, 2004). In order to reduce the negative effects of seasonality in forage production on herd performance, it is necessary that the surplus forage is kept for use in the dry season, ensuring the animals a good quality of forage food throughout the year (Moreira et al., 2003; 2004; 2005). In this way, alternatively, there is the production of silage, which is the most widespread technique among producers (Silva, Barros, & Teixeira, 2010).

Several grasses can be used for silage production and sorghum (*Sorghum bicolor* (L.) Moench) is a plant adapted to this process due to the phenotypic characteristics that determine the ease of planting, management, harvesting and storage, combined with the high nutritional value, high concentration of soluble carbohydrates, favorable to an adequate lactic acid fermentation, and high yields of dry mass per unit. Because of all of these strengths, about 30% of the total area planted with sorghum in the country is made up of cultivars of forage sorghum (Neumann et al. (2002).

The identification of agronomic traits related to the proper fermentation process, which provides low loss of dry matter and nutrients during ensiling and high rates of digestibility and consumption, is of great importance in the selection of cultivars most appropriate for ensiling. Therefore, studies should be focused on the selection of hybrids and planting conditions adapted to regional climatic conditions, aiming to optimize the resources available.

Considering the above, this study aimed to evaluate the chemical characteristics of 12 genotypes of sorghum and the nutritional value of silages produced.

Material and methods

The experiment was carried out in the facilities of EMBRAPA - National Center for Maize and Sorghum Research, located at Km 65 of the MG-424 highway, in the municipality of Sete Lagoas, state of Minas Gerais. The climate, according to Köppen and Geiger (1928) is AW (savanna with dry winter). The average annual rainfall is 1271.9 mm, with an average annual temperature of 20.9°C and relative humidity around 70.5%. The predominant soil is Ultisol red, which covers an area from south to north of the municipality.

The experiment was established on December 21st, 2010, because of the first rainfall events. There were sown 13 seeds per meter in each plot. Genotypes were planted in 3 blocks, each block with 12 plots, each plot consisting of 6 rows, 6 meters long, 70 cm spaced apart, totaling 12 treatments using the genotypes of forage sorghum: 1015327, 1015335, 1015339, 1015341, 1015345, 1015347, 1016003, 1016007, BRS655, Volumax, BRS610 and SF15.

Fertilization was performed according to the soil analysis and the requirements of the crop using 350 kg ha^{-1} 08-28-16 (NPK) + 0.5% zinc at planting and 150 kg h^{-1} urea as topdressing, 25 days after planting. Sorghum plants were harvested on the same day with the grain at the pasty milky to milky stage.

Evaluations were made in four rows of each plot, disregarding 1 m at the ends of each row and the two side rows of each plot (the borders). In the two central rows, we evaluated the agronomic characteristics of sorghum plants and the two intermediate rows were used for making silage, for further evaluation of the nutritional characteristics and quality of silages. The two intermediate rows were used for making silage when each genotype had a dry matter content of 30-35%.

For making silage, forage was chopped in a stationary chopper to 1 to 2 cm particle size and homogenized before ensiling. The experimental silos were PVC tubes 10 cm in diameter and 50 cm long, with a capacity of 2.5 kg silage (600 kg m^{-3}). Compaction was performed with wooden sockets, silos were sealed at the time of ensiling, with PVC caps equipped with Bunsen valves and sealed with masking tape, and weighed before and after ensiling.

There were three replicates per treatment and two replicates per plot, totaling 72 silos, which were opened after 56 days of ensiling.

The agronomic characteristics evaluated were: *plant height* (PH) by measuring the height from the ground level to the upper end of the plant, in 20% of the plants in each plot, *production of green matter* (PGM) by weighing all plants of the useful area of the plot, after cutting at 15 cm from the ground, *production of dry matter* (PDM), from the production of green matter and DM content of each genotype at the time of cutting.

Nutritional assessment of silages was performed at the Food Analysis Laboratory of the State University of Montes Claros (Unimontes) - Campus Janaúba, Minas Gerais State. Upon opening the silo, the material was homogenized and 200 mL of silage juice was extracted with the aid of a hydraulic press for determination of pH values, 25 g silage to determine ammonia nitrogen and 20 g to determine the water activity, placed in mini plastic trays. Part of the ensiled material was packed in paper bags, weighed and then pre-dried in a forced ventilation oven at 55°C for 72 hours or until constant weight. The pre-dried samples were ground in a stationary Wiley mill with a 1 mm sieve and then placed in glass vials with lid identified for analysis of food chemical composition: dry matter (DM), ash (CNZ), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin (LIG), neutral detergent insoluble nitrogen (NIDN) and acid detergent insoluble nitrogen (NIDA) according to the methods described by Detmann et al. (2012).

Analysis of silage quality: pH, ammonia nitrogen and water activity were performed with the juice and silage. For the determination of pH, we used a pHmeter; the water activity of the silage was determined using the equipment AquaLab 4TE DUO.

The experiment was a randomized block design with 12 genotypes (treatments) and three replications (blocks), totaling 36 experimental plots. Data were subjected to analysis of variance using the SISVAR statistical software and means were compared using Scott-Knott test at 5% probability ($p < 0.05$).

Results and discussion

Data on plant height (PH), green matter production (PGM) and dry matter production (PDM) were significantly different between genotypes evaluated ($p < 0.05$) (Table 1).

Mean values of plant height varied between 1.78 and 3.30 m ($p < 0.05$). The genotype SF15 showed the highest mean value of height. The obtained plant height values are close to those observed by (Chieza et al., 2008), who evaluated the agronomic aspects of sorghum genotypes, and observed 1.72, 2.16 and 2.52 m plant height for genotypes AG2005E, AG60298 and BR101, respectively. The results found for genotypes evaluated suggest that these are forage genotypes, however genotypes with height up to 2.20 m can be classified as dual-purpose forage and others as modern or silage forage genotypes.

Table 1. Mean number of plants per hectare (thousand Pl ha^{-1}), mean values of plant height (PH) in meters, green matter production (PGM) and dry matter production (PDM).

Genotype	PH (m)	PGM (ton ha^{-1})	PDM (ton ha^{-1})
1015327	1.95 D	30.33 B	9.96 B
1015335	1.78 E	27.13 B	8.38 B
1015339	2.08 D	29.53 B	9.20 B
1015341	1.97 D	28.53 B	10.15 B
1015345	2.02 D	30.93 B	9.61 B
1015347	1.82 E	30.33 B	8.76 B
1016003	2.17 C	34.67 B	10.53 B
1016007	2.55 B	36.53 B	11.54 B
SF 15	3.30 A	52.07 A	15.88 A
BRS 655	2.15 C	33.53 B	11.49 B
Volumax	2.32 C	48.00 A	15.91 A
BRS 610	2.27 C	41.87 A	13.97 A
Means	2.19	32.01	11.28
CV (%)	4.58	35.29	16.24

Mean values followed by different letters, in the same column, are significantly different by Scott–Knott test at 5% probability. CV = coefficient of variation.

Regarding green matter production, there was variation between the genotypes ($p < 0.05$). SF15, Volumax and BRS610 were superior to the others. The differences between the materials evaluated are related to plant maturity stages at the time of ensiling, occurrence of attack by birds and climatic conditions at the cultivation site. Production of DM and GM are in agreement with the height and stand of plants. BRS 610 showed high production and despite not being the tallest genotype, it was compensated for the stand. Similar values were reported by Chieza et al. (2008), who examined the agronomic aspects of sorghum genotypes and determined green matter production for sorghum genotypes AG2005E (42.56 ton ha^{-1}) and AG60298 (39.68 ton ha^{-1}). As for the production of dry matter, SF15, Volumax and BRS610 outperformed the others, as well as for the green matter production ($p < 0.05$). In turn, Perazzo et al. (2013) investigated the agronomic traits of five sorghum genotypes and found results from 10.88 to 12.07 ton ha^{-1} (SIF15 and BRS610).

With respect to the quality of the produced silage, genotypes did not differ as to the water activity and ammonia nitrogen. However, for the pH values, there were differences between the genotypes ($p < 0.05$) (Table 2).

Values of pH of well-preserved sorghum silage vary between 3.6 and 4.2; while for those with low quality, values range from 5.0 to 7.0. Ribeiro et al. (2007) analyzed the fermentation of silage of five sorghum genotypes and reported pH values ranging between 3.69 and 4.58. In relation to ammonia nitrogen, values are between 2.55 and 5.09, with a mean of 3.54. Araújo et al. (2007) evaluated the quality of silages of three sorghum genotypes ensiled at five different stages of maturation and found $N-NH_3/NT$ values ranging from 4.09 to 8.02%. In this study, the mean concentrations of $N-NH_3$ indicate that there was an adequate lactic fermentation.

Table 2. Mean values of pH, ratio of ammonia nitrogen to total nitrogen ($N-NH_3/NT$) and water activity (Aw) of silages of twelve sorghum genotypes grown for silage production.

Genotypes	pH	$N-NH_3/NT$(%)	Aw
1015327	4.10 B	4.47	0.98
1015335	3.92 B	4.18	0.97
1015339	3.50 A	5.09	0.98
1015341	3.99 B	2.57	0.97
1015345	3.93 B	3.43	0.97
1015347	3.75 A	3.63	0.98
1016003	3.98 B	3.23	0.97
1016007	3.71 A	3.52	0.97
SF 15	3.60 A	2.55	0.97
BRS 655	3.68 A	3.60	0.97
Volumax	3.79 A	3.00	0.97
BRS 610	3.76 A	3.27	0.97
Means	3.81	3.54	0.98
CV (%)	5.15	41.55	0.67

Mean values followed by different letters, in the same column, are significantly different by Scott–Knott test at 5% probability. CV = coefficient of variation.

Considering water activity, the mean value was 0.98%. The values verified contributed to the drop in pH, improving the quality of fermentation and preservation of silages evaluated. Values of pH and ammonia nitrogen should be evaluated together, because low content of ammonia nitrogen combined with low pH indicates a rapid stabilization of silage. And for silage quality, the faster the pH decline the better the feed conservation (Van Soest, 1994). For evaluation of ensiled feed, Aw is of great importance for the fermentation quality during ensiling process and for microbial activity during the use of silage. The reduction in Aw may have effect on pH decline, due to the tolerance of lactic acid bacteria to low humidity, assuming a key role in the quality of silage fermentation.

Mean content of dry matter did not vary from each other, averaging 32.01%, listed in Table 3.

Values of dry matter content of the materials used are in a range where it is possible a proper compaction and good development of lactic acid bacteria. To obtain sorghum silage with high nutritional value, the dry matter content of the plant should be within the range 30-35%.

As for crude protein, there was no variation among genotypes, with a mean value of 10.65% CP. The ideal content of CP to meet the nitrogen requirements of ruminal flora and for a good functioning of rumen is at least 7% (Van Soest, 1994). Von Pinho, Vasconcelos, Borges, and Resende (2007) examined the nutritional characteristics of silages of sorghum genotypes (dual purpose), Volumax (forage) and obtained similar PB values compared to this experiment, 8.0 and 9.2% for forage and dual purpose sorghum, respectively.

Table 3. Mean content of dry matter (DM), crude protein (CP), mineral matter (MM), neutral detergent fiber (NDF) and acid detergent fiber (ADF) of twelve sorghum genotypes grown for silage production.

Genotypes	DM (%)	CP (%)[1]	MM (%)[1]	NDF (%)[1]	ADF (%)[1]
1015327	33.02	9.47	3.76	67.63	32.69
1015335	30.97	11.66	3.90	68.42	36.23
1015339	31.02	8.96	3.79	63.77	34.91
1015341	35.74	13.26	3.88	70.05	35.02
1015345	31.12	11.59	4.05	67.90	36.18
1015347	29.12	10.21	4.13	67.10	36.74
1016003	30.68	12.07	4.16	76.13	35.55
1016007	31.54	11.55	3.81	68.45	36.48
SF 15	30.60	10.21	3.10	73.63	40.59
BRS 655	34.27	10.57	3.94	66.68	32.28
Volumax	33.12	9.93	3.89	69.27	35.09
BRS 610	32.95	8.68	3.98	54.96	29.14
Means	32.01	10.65	3.93	67.79	35.07
CV (%)	7.61	18.17	11.13	11.78	13.41

Mean values followed by different letters, in the same column, are significantly different by Scott–Knott test at 5% probability. CV = coefficient of variation

There was no difference ($p > 0.05$) in the content of mineral matter (MM), neutral detergent fiber (NDF), acid detergent fiber (ADF) between the genotypes. Values of mineral matter ranged from 3.1 to 4.2%, being similar for all genotypes tested. Ash content determines the amount of minerals in the forage, but high levels can represent high silica content, which has no nutritional contribution to animals. Generally, animal foods are rich in calcium and phosphorus; plant foods have low value of mineral matter and variable minerals.

Mean values for the 12 genotypes evaluated for NDF and ADF were 67.8 and 35.1%, respectively. NDF analysis is very important for determining the nutritional value of the forage, because this fiber fraction is negatively correlated with intake. Von Pinho et al. (2007) observed values for NDF (42.9%) and ADF (26.6%) for dual-purpose sorghum lower than those found in this experiment. Despite the NDF and ADF fractions are above recommended, the composition of these fractions are more important than the level per se, and it is necessary to evaluate the content of hemicellulose and cellulose.

There was no difference between the content of neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN) between the genotypes, according to results presented in Table 4.

Values of neutral detergent insoluble nitrogen and acid detergent insoluble nitrogen (ADIN) ranged from 0.86 to 1.48% and 1.17 to 1.77%, respectively. The concentration of insoluble nitrogen in forages is highly and negatively correlated with protein digestibility, because this fraction corresponds to protein associated with lignin, highly resistant to microbial enzymes and indigestible along the gastrointestinal tract. Nevertheless, the values observed indicate that the harvest occurred at a physiological maturity stage with little lignification, but enough to compromise part of the availability of protein.

Table 4. Mean content of neutral detergent insoluble nitrogen (NDIN), acid detergent insoluble nitrogen (ADIN), cellulose (CEL), hemicellulose (HCEL) and lignin (LIG) of silages of twelve sorghum genotypes grown for silage production

Genotypes	NIDN (%)	ADIN (%)	CEL (%)	HCEL (%)	LIG (%)
1015327	1.48	1.34	26.39	34.37	6.30
1015335	1.11	1.38	30.26	32.18	5.98
1015339	1.01	1.40	29.87	28.86	5.04
1015341	1.24	1.31	28.77	35.04	6.25
1015345	1.13	1.32	29.16	31.72	7.02
1015347	1.11	1.23	30.39	30.35	6.35
1016003	1.07	1.33	29.50	40.57	6.05
1016007	1.18	1.17	29.00	31.97	7.48
SF 15	0.86	1.49	32.09	33.04	8.50
BRS 655	0.91	1.77	25.47	34.40	6.80
Volumax	0.99	1.34	29.00	34.17	6.08
BRS 610	0.87	1.25	29.66	32.48	5.79
Means	1.08	1.36	29.13	33.26	6.47
CV (%)	16.73	19.66	13.47	16.30	23.91

Mean values followed by different letters, in the same column, are significantly different by Scott–Knott test at 5% probability. CV = coefficient of variation

Analyzing the content of cellulose, hemicellulose and lignin, there was no difference ($p > 0.05$) between genotypes for these traits. The mean values were 29.1; 33.3 and 6.5% for hemicellulose, cellulose and lignin, respectively. The cellulose content found in sorghum genotypes is directly related to the participation of ADF, since cellulose is a major component of this fraction. Regarding the lignin, lignification of structural carbohydrates is associated with the limitation of the dry matter degradation by ruminal microorganisms, thus reducing the nutritional value of forage. Skonieski et al. (2009) measured the production and the nutritional value of silages of forage and dual purpose sorghum and reported values of 21.3% HCEL; 23.9% CEL and 5.2% LIG for forage materials. On the other hand, for dual purpose genotypes, these authors registered values of 24.5% HCEL; 25.3% CEL and 4.8% LIG. The reduced nutritional value of forage with the advance of plant cycle is due to the increase of structural carbohydrates and lignin in the plant supporting tissues, as well as reduction in leaf: stem ratio and to the increase in the percentage of senescent material in the plant, which has low digestibility. Similarly to DM, fiber fractions were close to ideal for a good silage, indicating that genotypes were harvested at the right time. Hemicellulose content suggests that sorghum plants were harvested at the physiological maturity stage, in which the intake would not be reduced. Cellulose and lignin are also within expected for new plants, thus it is suggested that digestibility and utilization of these silages by ruminants will allow a profitable production.

Conclusion

In general, all hybrids showed suitable content for production of high quality silage and chemical composition; however the genotypes SF15, Volumax and BRS610 showed the highest productivity of dry matter per area, representing the best options for silage production.

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