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Assessment of sorghum genotypes for silage: nutritional value

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ABSTRACT. The objective of this study was to determine the agronomic characteristics, chemical composition and *in situ* degradability of different sorghum genotypes. The experiment was conducted at the National Maize and Sorghum Research Center – Sete Lagoas, MG. For agronomic and nutritional characteristics, a randomized block design was used, and for *in situ* degradability, a split-plot design was applied. Genotypes 13F2006, BRS655 and Volumax showed lower dry matter productivity compared to 12F02006 and 12F03033. Genotype BRS655 had the lowest levels of neutral detergent-insoluble fiber (NDF), acid detergent-insoluble fiber (ADF) and lignin. Furthermore, no difference was found for potential degradability (PD), indigestible fraction (IF), and effective degradability (ED) at 2; 5 and 8% hour^{-1} DM among the studied materials. Genotypes 12F03033 and 12F02006 combine higher productivity and nutritional quality.

Keywords: productivity; nutritional quality; silage.

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Introduction

Seasonality in forage production in Brazil is one of the main factors that limit meat and milk productivity throughout the year, making better planning necessary for constant yield (Barbero et al., 2021; Ragazzi, Holmström, Santos, Fragata, & Modesto, 2021). Silage production appears as one of the solutions to this problem, as it allows the nutritional quality of fresh forage to be preserved and guarantees the quantity needed for the herd in unfavorable times.

In this scenario, sorghum is an outstanding crop for silage production, since it has desirable characteristics such as a high content of soluble carbohydrates, which are essential for the fermentation process, and good mass productivity (Tolentino et al., 2016). Furthermore, the crop presents good tolerance to drought and saline soils, as well as good adaptability to different systems, which stimulates an increase in planting areas and drives the development of several genotypes adapted to the forage conservation process.

However, due to Brazil's great climatic diversity, the same behavior is not expected for sorghum hybrids in all regions (Lima et al., 2017). Therefore, information on agronomic characteristics, chemical composition and silage quality is extremely important in characterizing the most promising genotypes for animal feed (Nascimento et al., 2021). However, the study of foods for ruminants aimed only at the quantity of nutrients has been recognized as insufficient, resulting in the search for other methodologies concerning specific assessments of the use of dietary nutrients by animals.

Consequently, *in situ* degradability emerges as an important and essential tool in food assessments, the objective of which is to provide knowledge of the soluble fractions, potentially rumen-degradable fraction, and indigestible fraction of the food, in addition to its degradation rates, effective degradability (ED), and potential degradability (PD) (Simili, Lima, Medeiros, Paz, and Reis, 2014).

In this sense, it is important to intensify studies with an emphasis on technologies that associate productivity and nutritional quality as indispensable factors to achieving satisfactory results in animal production and, consequently, aiming to expand sorghum cultivation for silage production.

In light of the foregoing, the objective was to determine the agronomic characteristics, chemical composition and *in situ* degradability of dry matter and neutral detergent-insoluble fiber of different sorghum genotypes.

Material and methods

Site and climate data

The experiment was conducted on the premises of the National Maize and Sorghum Research Center [*Centro Nacional de Pesquisa de Milho e Sorgo*] – CNPMS, located at geographic coordinates of latitude 19° 28' South and longitude 44° 15' West. The region's climate, according to Koopen, is Aw type (Savannah climate with dry winter). The accumulated rainfall during the experimental period was 829 mm, with an average temperature of 23.64°C (Instituto Nacional de Meteorologia [INMET], 2018).

Planting and tested genotypes

Genotypes 12F02006, 12F03033, 13F26006, BRS655 and Volumax, classified as forage sorghum, were used for comparison. Planting was performed on November 20, 2020, using an arrangement in beds measuring 5 m in length and 3 m in width, with a spacing of 75 cm in between rows. Fertilization was applied during planting and through drop dressing, in accordance with soil analysis and crop requirements. A total of 350 kg ha^{-1} of the 8-28^{-1}6 (N:P:K) + Zinc (0.5 kg ha^{-1}) formula was used at planting, and 150 kg ha^{-1} of urea were used for top dressing, 35 days after planting. Harvesting occurred on March 5, 2017, totaling an experimental period of 106 days.

Agronomic characteristics

The two central rows of each plot were used to determine the flowering age: days for the sorghum flower to emerge after planting; plant height: from ground level to the upper end of the plant, in 20% of the plants in each plot; green matter production: through the weighing of all the plants in the useful area of the plot, determined after a 15 cm cut from the ground; dry matter production: calculated from the green matter production and definitive dry matter content of each genotype; the number of plants per hectare was obtained from the number of plants in the useful area of the plot.

Chemical composition

The two intermediate rows were used; the plants were chopped, homogenized, placed in plastic bags, and previously identified. Still on Embrapa's premises, the samples were weighed, then pre-dried in a forced ventilation oven at 55°C for 72 hours. After the samples were dried, the material was removed from the oven and left at room temperature for weight stabilization, after which the percentage of pre-dried matter was determined.

The pre-dried samples were ground in a Willey mill, with a 1 and 5 mL sieve, and stored in polyethylene containers for subsequent analyses. These samples were then transported to the Food Analysis Laboratory of the State University of Montes Claros [*Universidade Estadual de Montes Claros*] (Unimontes) – Janaúba Campus, Minas Gerais State, where they were subjected to further laboratory analysis.

The analyses conducted referred to dry matter (DM), crude protein (CP), mineral matter (MM), organic matter (OM), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, hemicellulose and cellulose, in accordance with the methodology described by Detmann et al. (2012). To estimate total carbohydrates (TC) and non-fibrous carbohydrates (NFC), the equation proposed by Sniffen, O'Connor, Van Soest, Fox, and Russell (1992) was used, where TC = 100 - (CP% + EE% + MM%) and NFC = 100% - (CP% + NDF% + EE% + MM%). The TDN were estimated using this formula: TDN = 40.2625 + 0.19698CP% + 0.4028*NFC% + 1.903*EE% - 0.1379*ADF% (Weiss, 1998).

In situ degradability

The *in situ* degradability test used six Holstein x Nellore crossbred steers with 400 ± 50 kg of body weight, duly identified and cannulated in the rumen, kept in an intensive breeding system with troughs and drinkers. Using 4 animals, the *in situ* degradability test was carried out in a split-plot scheme, with the genotypes being the plots, and the 11 incubation times being the subplots.

The animals were adapted to the diet for 14 days, through which they received roughage made up of sorghum silage and pre-dried banana peel, and concentrate based on corn and soybean bran, which provided the necessary conditions for the normal functioning of the rumen. The samples were placed in non-woven fabric bags measuring 15 x 7.5 cm, with 52 micron mesh, in the amount of 2.0 g of DM per bag, in order to maintain a ratio close to 20 mg DM cm^2 of surface area of the bag (Nocek, 1988). The nonwoven fabric bags containing the samples were closed in a sealing machine and housed in a tulle bag attached with an 80 cm long nylon thread to the cannula lid at one end, which allowed the tulle bag with the samples to be lodged in the ventral portion of the rumen. The incubation periods corresponded to times 0; 3; 6; 9; 12; 24; 48; 72; 96; 120 and 144 hours, and the nonwoven fabric bags were incubated in the reverse order of times and in quintuplicate, in order to be removed all at the same time, at the end of the period so that, in this way, the material removed from the rumen could be washed uniformly.

After a total incubation period of 144 hours, the nonwoven fabric bags were manually washed in cold running water until it looked clean, and then dried in a forced ventilation oven at 55°C for 72 hours. The *in situ* degradability data for DM and NDF were obtained by the ratio of the difference in weight found for each component, between the weighing carried out before and after rumen incubation, and expressed as a percentage. With the aid of the 2007 Statistical and Genetic Analysis System [*Sistema de Análises Estatísticas e Genéticas*] (Ribeiro Junior, 2001), dry matter degradation rates were calculated using the equation proposed by Ørskov and McDonald (1979):

Dt= A + B x (1 – e-ct), where: Dt = fraction degraded at time t (%); A = soluble fraction (%); B = potentially degradable insoluble fraction (%); c = degradation rate of fraction B ($hour^{-1}$); and t = time (hours).

The NDF degradability was estimated using the Mertens and Loften (1980) model: Rt = B x (1 – e $^{-ct}$), where Rt = fraction degraded at time t; c = degradation rate of fraction B ($hour^{-1}$); and t = time (hour). After the NDF degradation equation was adjusted, fraction standardization was carried out, as proposed by Waldo, Smith, and Cox (1972), using these equations: B_s = B/(B+I) × 100; I_s= I/(B+I) × 100, where: B_s = standardized potentially degradable fraction (%); I_s= standardized indigestible fraction (%); and B, I= indigestible fraction. Nonlinear coefficients A, B and c were estimated using iterative Gauss-Newton procedures. The effective degradability (ED) of dry matter (DM) and crude protein (CP) in the rumen was calculated using this model: ED = A + (B xc/ c + k), where k corresponds to the estimated rate of passage of particles in the rumen, considering 2; 5 and 8 hours, simulating low, medium and high passage rates, respectively. To calculate the effective NDF digestibility, this model was used: ED= B_s xc/(c+k), where BP is the standardized potentially degradable fraction (%).

To estimate the parameters of *in situ* degradation kinetics, the nonlinear regression models were adjusted using the iterative Gauss-Newton method, inserted into the SAS PROC NLIN procedure (SAS Institute, 2005). The level of significance adopted for the estimated parameters is 5% probability. The assessment of the nonlinear models was based on the observation that the estimated parameters do not violate any of the model's assumptions and on the significance of the estimated parameters in relation to the nullity hypothesis for the *in situ* degradation of DM and NDF (Vieira, Tedeschi, & Cannas, 2008).

Statistical analysis of the chemical composition

For agronomic characteristics and chemical composition, the experimental design used consisted of randomized blocks with 5 genotypes (treatments) and 4 replications (blocks), totaling 20 experimental units.

The data obtained were subjected to analysis of variance using the Sisvar program (Ferreira, 2014); when the analysis showed significance for the 'F' test, the means were compared using Tukey's test at a 5% probability level.

Ethics and biosafety committee

The experiment met all the requirements set forth by Unimontes's Ethics and Animal Welfare Committee [*Comissão de Ética e Bem Estar Animal*] (Cebea), under process No. 173/2018.

Results and discussion

Agronomic characteristics

There was a significant difference between genotypes for height, inflorescence, green matter production (GMP) and dry matter production (DMP) ($P < 0.05$). Regarding height, genotypes 12F02006 and 12F03033 were superior to the others, with a mean of 3.71 m, which represents a 26.68% superiority in relation to Volumax and 13F26006, and 34.50% to BRS655 (Table 1).

Assessing the agronomic and nutritional characteristics of sorghum hybrids in different regions, Lima et al. (2017) found a height variation of 2.18 to 2.88 m in the city of Sete Lagoas. In general, height is a decisive characteristic in the distribution of the components of the sorghum plant; taller plants tend to have greater biomass production and lower panicle participation (Perazzo et al., 2014).

Table 1. Agronomic characteristics of different sorghum genotypes.

	Genotypes					SEM[1]	P[2]
	12F02006	12F03033	13F26006	BRS655	Volumax		
Height (m)	3.78 a	3.63 a	2.68 b	2.43 c	2.76 b	0.051	< 0.01
Population	93,750	96,750	87,000	90,500	91,250	5116.8	0.73
Inflorescence	92 b	94 b	85 c	79 d	99 a	1.05	< 0.01
GMP (t ha^{-1})	68.79 a	54.02 ab	43.91 bc	36.97 c	36.22 c	3.50	< 0.01
DMP (t ha^{-1})	20.70 a	16,58 b	12.40 c	10.93 c	9.41 c	0.855	< 0.01

Means followed by different letters differ from each other on the row by Tukey's test at 5% probability. [1]Standard error of the mean; [2]Probability value. Height in meters; Population = Number of plants per hectare; Inflorescence = Count of days from planting to sorghum floral initiation; GMP = Green matter production per hectare; DMP = Dry matter production per hectare.

The genotypes did not differ in terms of the number of plants per hectare, and an average of 91,850 plants ha^{-1} (P > 0.05) could be verified. This density is considered ideal for forage sorghum, as it is between 90 and 110 thousand plants per hectare, as described by Mantovani and Ribas (2015).

Regarding the days to reach inflorescence, genotype Volumax was superior to the others, with an average of 99 days. The BRS655 hybrid reached the flowering phase earlier, at 79 days, which happened 7.06% faster compared to 13F26006, 15.05% compared to genotypes 12F02006 and 12F03033, and 20.20% compared to Volumax. Normally, when sorghum reaches this stage, its growth decreases, as its vegetative development drastically reduces, making panicle development a priority for reproduction purposes.

Genotypes with a longer vegetative phase tend to have a greater increase in their productivity (Menezes et al., 2015); in addition to this factor, the height, stem diameter, selection and improvement of the genotype can also interfere with its productivity. Lima et al. (2017), assessing the chemical composition and agronomic characteristics of sorghum genotypes in different regions, found averages of 90 and 74 days for genotypes Volumax and BRS655 to reach inflorescence, respectively.

Genotype 12F02006 was similar to 12F03033 and superior to 13F26006, BRS655 and Volumax, with a green matter production of 68.79 t ha^{-1} (P < 0.05). A great relationship can be seen between the height of the plants and their GMP, with genotype 12F02006 standing out in both variables. Genotype Volumax, despite taking longer to start flowering, was inferior in terms of productivity, since the height of the plant did not favor GMP.

In relation to DMP, genotype 12F02006 was superior to the others, with a mean of 20.70 t ha^{-1} (P < 0.05). Genotypes 13F2006, BRS655 and Volumax were those with the lowest dry matter productivity – 16% lower compared to 12F02006, and 36.61% compared to 12F03033. Genotype 12F03033 was 19.09% lower in relation to 12F02006.

Genotypes 12F02006 and 12F03033 stood out, as they presented high productivity and higher DM content (Table 2). Lima et al. (2017), assessing different sorghum hybrids in different regions, found, for Volumax and BRS655, means of 13.16 and 17.76 t ha^{-1}, respectively.

Table 2. Chemical-nutritional characteristics of sorghum genotypes[1].

	Genotypes					SEM[2]	P[3]
	12F02006	12F03033	13F26006	BRS655	Volumax		
DM	30.04 ab	30.73 a	31.00 a	29.57ab	26.09 b	0.888	0.013
CP	6.48	7.32	7.10	6.07	7.61	0.512	0.258
MM	4.45 c	4.24 c	4.67 c	8.53 a	6.74 b	0.356	< 0.01
OM	95.56 a	95.76 a	95.33 a	91.48 c	93.26 b	0.356	< 0.01
EE	1.91	1.99	1.68	1.66	1.77	0.089	0.093
TDN	58.39	58.86	56.79	58.07	58.68	0.595	0.18
TC	87.17 a	86.46 ab	86.55 ab	83.75 b	83.88 ab	0.754	0.017
NFC	19.61	20.11	17.49	21.26	19.55	1.378	0.453
NDFap	69.06 a	67.58 ab	66.35 ab	62.49 b	64.33 ab	1.180	0.014
ADF	38.56 ab	38.26 ab	35.42 b	3555 b	41.18 a	1.223	0.031
LIG	8.02 a	7.62 a	7.34 a	4.77 b	3.16 b	0.51	< 0.01
HCEL	29.00 ab	28.09 ab	33.64 a	26.93 ab	23.15 b	1.93	< 0.01
CEL	27.41 b	30.91 ab	30.93 ab	32.39 ab	36.40 a	1.266	0.004

Means followed by different letters differ from each other on the row by Tukey's test at 5% probability. (P < 0.05). [1]Values expressed as a percentage, [2]Standard error of the mean, [3]Probability value. DM = Dry matter; CP: Crude protein; MM = Mineral matter; OM = Organic matter; EE = Ethereal extract; TDN = Total digestible nutrients; TC = Total carbohydrates; NFC = Nonfibrous carbohydrates; NDFap = Neutral detergent-insoluble fiber corrected for ash and protein; ADF = Acid detergent-insoluble fiber; LIG = Lignin; HCEL = Hemicellulose; CEL = Cellulose.

Chemical composition

Genotypes 12F03033 and 13F26006 were 15.51% superior to Volumax in terms of DM content (Table 2). There are several factors that can influence dry matter content, with cutting age being an important one. Furthermore, among the plant fractions, the stem contributes the least to the increase in DM content, followed by the leaves and panicles. Genotype Volumax had the latest inflorescence, just a few days before harvest, so the panicle's participation was lower and resulted in a lower DM content at the time of cutting.

DM levels are associated with quantitative variations of other chemical nutrients, which makes this fraction directly related to increased cell wall and protein levels present in the plant (Silva et al., 2015). Therefore, the constitution of one genotype in relation to another can be variable in this sense. The ideal range recommended for harvesting sorghum in silage production ranges from 30 to 35% DM for adequate lactic fermentation to occur, with genotypes 12F02006, 12F03033 and 13F26006 being suitable for the ensiling process at the time of the assessment.

There was no difference in the CP content of the different genotypes ($P > 0.05$), with a mean of 6.92%. The mean presented by the genotypes studied here did not reach the established minimum of 7% CP in dry matter. Diets for ruminants with protein levels below 7% can limit the activity of microorganisms in the rumen, compromising the use of potentially digestible fibrous energy substrates (Costa et al., 2015).

Moraes, Jobim, Silva, and Marquardt (2013), assessing different sorghum hybrids, found a variation of 8.27 to 9.84% of CP, values higher than those found in this study. These variations in CP content are due to differences between genotypes, mainly in relation to the proportion of stems, leaves and panicles in plants, with the leaves and panicles being responsible for a greater increase in this variable (Moura et al., 2017; Nascimento et al., 2020). Therefore, knowledge of these characteristics is important to determining a better strategy for producing silage with high energy value (Ordoñes, Villalbazo, Córdoba, Bautista, & Villalobos, 2019).

Regarding MM content, genotype BRS655 had a higher value than the others ($P < 0.05$), with a mean of 8.53%. Genotypes 12F02006, 12F03033 and 13F26006 obtained lower values, with a mean of 4.45%. When forage conservation occurs inadequately, it results in losses of organic matter, increasing mineral matter content. Thus, based on the dry matter (DM) value, reduced ash content may indicate well-preserved forage.

Albuquerque, Jardim, Alves, Guimarães, and Porto (2013), assessing the production and chemical composition of sorghum hybrids, reported a mean of 4.87%.

Genotypes 12F02006, 12F03033 and 13F26006 were superior in terms of OM content, with a mean of 95.55% ($P < 0.05$). OM content is inversely proportional to MM content, which thus explains this variation. Assessing the chemical composition of sorghum hybrids, Albuquerque et al. (2013) reported an average content of 94.93%.

The different genotypes were similar in terms of EE content, with a mean of 1.80% ($P > 0.05$) (Table 2). Normally, forages with a higher EE content tend to have a greater increase in TDN, considering that this variable contributes with 2.25 times more energy than the others, but they should not exceed 6 to 7% of DM, as it can harm ruminal fermentation, passage rates, and fiber digestibility (Costa et al., 2015).

No variation was found in total digestible nutrients (TDN) content ($P > 0.05$), with a mean of 58.16%.

There was variation in the contents of total carbohydrates (TC), neutral detergent-insoluble fiber (NDFap), acid detergent-insoluble fiber (FDA), lignin (LIG), hemicellulose (HCEL) and cellulose (CEL) ($P < 0.05$) (Table 2). Genotype 12F02006 was superior to BRS655 in terms of TC content, with a mean of 87.17%. This difference is explained by the superiority in relation to NDFap content, since the TC consider include both cell wall carbohydrates and non-fibrous carbohydrates. According to Simili et al. (2014), differences in chemical composition may be associated with different genotypes, plant height, assessment times, soil and climate conditions, fertilization, among other agronomic and environmental variables. Therefore, the thesis that there are differences in the nutritional characteristics of the genotypes under study is proven.

The nonfibrous carbohydrate (NFC) contents were similar ($P > 0.05$), with a mean of 19.33%. Moraes et al. (2013) observed a variation of 15.55 to 29.09% when assessing sorghum hybrids for silage. Nonfibrous carbohydrates play an important role, as they increase the energy content of food, whereas soluble carbohydrates serve as a substrate for lactic fermentation, maintaining silage conservation.

Genotype 12F02006 showed a superiority of 9.55% compared to BRS655 in terms of NDFap content ($P < 0.05$). According to Van Soest (1994), the NDF content must be between 50 and 60% of the dry matter, as values above this range can compromise the animal's dry matter consumption, as it makes degradation by ruminal microorganisms difficult. This is related to the ruminal degradation rate of NDF components (cellulose, hemicellulose and lignin) and is a determining factor in diet quality assessment (Oliveira, Santana Neto, Valença, Silva, & Santos, 2016).

Decreased NDF with increased cutting height is explained by the basal part of the stalk having higher concentrations of NDF, thus causing a change in the fibrous fraction of the silage. NDF is related to the nutritional quality of the silage and consumption by the animal, being inversely related to intake, that is, the higher its value, the lower the silage intake by the animals (Lopes, Soares, Oliveira, & Melo, 2022).

For hemicellulose, genotype 13F26006 was superior to Volumax, presenting a mean of 33.64%. Values lower than those in this study were reported by Moura et al. (2017), who, while assessing the silages of 5 sorghum hybrids, observed a mean of 26.42% of hemicellulose.

Genotypes 13F26006 and BRS655 were inferior in terms of ADF content compared to Volumax, with a mean of 35.49% ($P < 0.05$). ADF is related to the amount of less digestible fiber, as it represents cellulose and lignin; consequently, the lower the content, the better the quality of the silage produced, and the greater the DM consumption by the animal (Pereira et al., 2017). Assessing the nutritional quality of sorghum hybrids, Costa et al. (2016) observed a variation of 24.06 to 47.20% of ADF, values substantially similar to those in this study.

Genotype 12F02006 was inferior to Volumax in terms of cellulose content ($P < 0.05$), with values standing at 27.41 and 36.40%, respectively. Cellulose is a complex glucose polymer that is joined via a β1-4 bond, which impairs the action of microorganisms in the rumen, reducing the efficiency in the animal's use of this carbohydrate (Oliveira et al., 2016).

Regarding lignin content, genotypes Volumax and BRS 655 were 48.17% inferior in relation to genotypes 12F02006, 12F03033 and 13F26006. Lignin content is related to the plant's cycle, as the more advanced the maturation stage, the greater the reduction in the leaf:stem ratio and the increase in the percentage of senescent material in the plant, which has low digestibility (Soares et al., 2020). Genotype Volumax emitted its inflorescence later than the others, that is, it was at a less advanced stage of maturation, which explains its lower lignin content.

DM *in situ* degradability

There was variation between genotypes for soluble fraction A, potentially degradable fraction B, and the degradation rate of insoluble, potentially degradable fraction C ($P < 0.05$). Genotype Volumax was 18.58% inferior to the others in relation to soluble fraction A, presenting a mean of 20.64%. Soluble fraction A represents sugars and organic acids, being quickly degraded in the rumen, with a degradation rate much higher than the passage rate. Sugars usually represent a small portion of the foods normally used in cattle diets, except in the case of fresh forage (Table 3).

In relation to fraction B, genotypes BRS655 and Volumax were 9.34% superior to the others, with a mean of 49.16% ($P < 0.05$). Fraction 'b' represents the degradation of structural carbohydrates present in the cell wall and which have a slow degradation by the ruminal microbiota (Table 3). The slow degradation is possibly due to the structural arrangement of carbohydrates such as cellulose and hemicellulose with lignin, as this prevents this fraction from being quickly degraded. Genotypes Volumax and BRS655 obtained lower lignin levels, which contributed to greater cellulose and hemicellulose degradation, thus increasing their potentially degradable fraction B.

Table 3. Soluble fraction (A), potentially digestible insoluble fraction (B), degradation rate (C), potential degradability (DP), and effective matter degradability of sorghum genotypes.

	Genotypes					SEM[1]	P[2]
	12F02006	12F03033	13F26006	BRS655	Volumax		
A (%)	24.86 a	25.03 a	23.51 a	24.50 a	20.64 b	0.85	0.009
B (%)	43.93 b	45.18 b	44.60 b	48.85 a	49.47 a	1.49	0.045
C (% $hour^{-1}$)	1.1 b	0.8 b	1.2 b	1.0 b	2.0 a	0.001	0.014
IF (%)	31.20	29.79	31.88	26.64	29.89	1.63	0.233
SD (%)	68.79	70.21	68.12	73.36	70.11	1.63	0.233
ED 2% $hour^{-1}$(%)	40.80	39.00	40.50	42.74	41.38	1.61	0.594
ED 5% $hour^{-1}$(%)	33.08	32.27	32.44	33.91	32.07	1.02	0.71
ED 8% $hour^{-1}$ (%)	30.40	29.91	29.59	30.84	28.57	0.863	0.424

Means followed by different letters differ from each other on the row by Tukey's test at 5% probability. [1]Standard error of the mean; [2]Probability value.

There was no variation in effective degradability at 2; 5 and 8% $hour^{-1}$ for the different sorghum genotypes, with means of 40.88; 32.76 and 29.83%, respectively.

The determination of these food degradability parameters for ruminants is a relevant factor in animal nutrition, being directly related to animal performance and indispensable in diet formulation systems (Garcez et al., 2016).

NDF *in situ* degradability

There was a difference between the genotypes for the potentially degradable fraction (B_s), degradation rate of fraction B (C), indigestible fraction (I_s), and effective degradability ($P < 0.05$) (Table 4.) The highest percentage of potentially degradable insoluble fraction (B_s) was found in genotype BRS655, which presented a value of 73.97%, representing an average superiority of 18.99% in relation to the others. This value may be attributed to the fiber profile of this genotype, as it presented lower lignin and ADF values, while its hemicellulose content was similar, thus allowing greater degradability of this fraction.

Table 4. Standardized potentially degradable insoluble fraction (B_s), degradation rate (C), standardized indigestible fraction (I_s), and effective degradability (ED) of neutral detergent-insoluble fiber of sorghum genotypes.

	Genotypes					SEM[1]	P[2]
	12F02006	12F03033	13F26006	BRS655	Volumax		
B_s (%)	57.20 b	63.63 b	62.19 b	73.97 a	56.66 b	1.943	< 0.01
C (% hour^{-1})	1.1 c	1.4 bc	1.5 bc	1.7 ab	2.0 a	0.001	< 0.01
Ip (%)	42.80 a	36.37 a	37.80 a	26.03 b	43.34 a	1.943	< 0.01
ED 2% hour^{-1}(%)	20.62 c	26.60 b	26.39 b	33.77 a	27.92 b	1.269	< 0.01
ED 5% hour^{-1}(%)	10.66 c	14.22 b	14.27 b	18.64 a	16.01 b	0.849	< 0.01
ED 8% hour^{-1} (%)	7.13 c	9.71 bc	9.79 b	12.88 a	11.23 ab	0.627	< 0.01

Means followed by different letters differ from each other on the row by Tukey's test at 5% probability. [1]Standard error of the mean; [2]Probability value.

Regarding the degradation rate of fraction B (C), genotype Volumax was similar to BRS655 and superior to the others, with a mean of 2% hour^{-1}. The degradation rate of the potentially degradable insoluble fraction is directly linked to lignin, and its degree of interaction, to the other constituents of the plant's cell wall; moreover, the proportion of structural components can influence this variable, with a greater degree of lignification combined with a higher cellulose content making degradation by microorganisms more difficult and consequently slower (Buriol et al., 2020).

Genotype BRS655 presented a 35% lower indigestible fraction value than the others. Costa et al. (2016), assessing the degradability of the fibrous fraction of sorghum silages, observed means of 58.95 and 41.05% for potential degradability and indigestible fraction, values which are higher than those of the present study.

As for effective degradability at 2% hour^{-1}, genotype BRS655 was 20.13% superior to genotypes 12F03033, 13F26006 and Volumax, and 38.93% superior to 12F02006. The same superiority can be seen in degradability at 5% hour^{-1}, with genotype BRS655 being 20.43% superior to 12F03033, 13F26006 and Volumax, and 42.81% to 12F02006. In terms of effective degradability at 8% hour^{-1}, genotype BRS655 was similar to Volumax and superior to the others. The lower ADF and lignin contents provided better effective NDF degradability for genotype BRS655, since these variables are negatively correlated with the use of this variable by rumen microorganisms. Higher values were reported by Costa et al. (2016), who observed a variation from 19.18 to 56.79% in ED at 2% hour^{-1}.

Genotype BRS655, despite obtaining better fiber degradability, had lower productivity, which impaired its performance. Genotype 12F03033, considering dry matter productivity, NDF content and effective degradability at 2 and 5% hour^{-1}, presented a greater degradable fiber per area produced, and in terms of degradability at 8% hour^{-1}, genotype 12F02006 was superior, considering that these two genotypes showed similarities in effective fiber degradability at 8% hour^{-1}.

It is important to highlight that knowledge of the speed of the passage rate can indicate the best method for using forage in animal feed. A degradability of 8% hour^{-1} in silage makes the latter suitable for high production animals, as it allows greater consumption by the animal, considering that this category requires a higher passage rate; regarding degradability of 5% hour^{-1}, because it is an intermediate passage rate, a silage with greater degradability at this speed may be recommended for growing animals, whereas 2% hour^{-1} may be suitable for maintenance animals, since the fiber is slowly degraded in the rumen (Buriol, Torteli, Gallina, Battiston, & Lajús, 2021).

The information from the present study is important to foster the use of intensified systems aimed at overcoming the seasonality of pasture production through silages of high biological value, together with high yield capacity, high nutritional value, and efficient production of nutrients per area.

Conclusion

The genotypes under study presented variations as to their agronomic and nutritional characteristics.

Genotypes 12F03033 and 12F02006 combine greater production and nutritional quality, being recommended for the ensiling process.

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