Chemical composition, kinetics of degradation, and digestibility of forage of different purpose sorghum cultivars

Composição bromatológica, cinética de degradação e digestibilidade de forragem de cultivares de sorgo de distintas aptidões

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Highlights:

Forage of sweet sorghum has potential as a high energy ruminant feed.

Forage quality of sorghum has a different response pattern at the first and second season.

Grain sorghum cultivars have lower *in vitro* dry matter digestibility of the forage than forage sorghum at the first season.

Abstract

The aim of the study was to identify suitability of different purpose sorghum cultivars for silage production and for green chopping, at the first and second season, based on the chemical composition and degradation kinetics. The experiment was based on a randomized block design with four replicates, with sowing in the months of November and March, as the first and second season, respectively. The trial was conducted at the Plant Production Sector of the Federal Institute of Education, Science and Technology of Rondônia, Colorado do Oeste campus, and chemical analyses were performed at the Animal Nutrition Laboratory of the Federal University of Mato Grosso, Cuiaba campus. The treatments comprised six sorghum hybrids of different purposes (BRS 308 and BRS 310, grain sorghum; BRS 655 and BRS 610, forage sorghum; BRS 506 and CMSXS 647, sweet sorghum). The chemical composition, digestibility, and kinetic parameters were evaluated. At the first season, there was a higher digestibility ($P < 0.0001$) for sweet sorghum BRS 506, while for the second season, both grain sorghum BRS 308 and sweet sorghum cultivars BRS 506 and CMSXS 647 presented higher digestibility ($P = 0.0005$). Considering the nutritional value, all sorghum cultivars have the potential to produce silage, or to be used as green chop, at the first and second season.

Key words: Nutritive value. *Sorghum bicolor.* Sweet sorghum.

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Resumo

Objetivou-se identificar, com base na composição bromatológica e cinética de degradação, híbridos de sorgo de diferentes propósitos para produção de silagem e para verde picado em primeira e segunda safra, no sul de Rondônia. O delineamento experimental utilizado foi em blocos casualizados, com quatro repetições. O experimento foi realizado Setor de Produção Vegetal do Instituto Federal de Educação, Ciência e Tecnologia de Rondônia, Campus Colorado do Oeste, e as análises bromatológicas foram realizadas no Laboratório de Nutrição Animal da Universidade Federal de Mato Grosso, Campus Cuiabá, em primeira e segunda safra, com semeadura nos meses de novembro e março, respectivamente. Os tratamentos consistiram em seis híbridos de sorgo de diferentes aptidões (BRS 308 e BRS 310, graníferos; BRS 655 e BRS 610, forrageiros; BRS 506 e CMSXS 647, sacarinos). As variáveis avaliadas foram a composição bromatológica, a digestibilidade e parâmetros cinéticos. Na primeira safra, observou-se maior digestibilidade (P <0,0001) para o sorgo sacarino BRS 506. Na segunda safra, evidenciou-se maior digestibilidade (P = 0,0005) em cultivares de sorgo sacarino e no sorgo granífero BRS 308. As cultivares de sorgo sacarino apresentaram maior digestibilidade, com maior proporção de proteína potencialmente digestível, com bom potencial de uso para ensilagem. Considerando o valor nutritivo, todas as cultivares de sorgo tem potencial para a produção de silagem e para verde picado em primeira e segunda safra.

Palavras-chave: *Sorghum bicolor*. Sorgo sacarino. Valor nutritivo.

Introduction

Seasonality in forage production in the tropics and the need to achieve greater uniformity in production throughout the year have led beef cattle producers to adopt forage conservation practices, including ensiling. This practice comprises the fermentation of soluble sugars in organic acids by anaerobic microorganisms. Acidification and anaerobiosis interrupt the process of degradation of organic matter, which is then conserved (McDonald, Henderson, & Heron, 1991).

Among the forage plants that can be ensiled, sorghum (*Sorghum bicolor* L. Moench) stands out for being a food of high nutritional value, resembling corn in its high soluble carbohydrate content, which is essential for proper lactic fermentation, besides allowing high dry matter (DM) yields per unit area, with the advantage of having greater tolerance to water deficit and greater sowing amplitude compared to maize (Machado et al., 2012).

Despite these advantages, it is necessary to identify which sorghum hybrids have better nutritive value according to the sowing season, which may vary according to the group to which the sorghum belongs. Sorghum cultivars are classified into five groups: grain, forage for silage, forage for grazing/cutting, sweet, and biomass according to their characteristics. The recommendation of using different sorghum genotypes for silage production has been controversial owing to the lack of information regarding the qualitative behavior of different available material (Neumann et al., 2002).

Thus, to evaluate the nutritional value of forage, which is associated with the level of nutrient utilization (Magalhães et al., 2006), it is important to measure the chemical composition, digestibility, and utilization of digestible forage. Sorghum plants with different panicle proportions should possibly have different nutritional quality. Recent studies in China suggest that the forage of sweet sorghum may be a good alternative for ruminant feeding owing to its high energy content (Tang, Yang, & Xie, 2018). In Brazil, there is little information about the use of sweet sorghum in ruminant feed.

Since the ensiling process does not improve the quality of the roughage and maintains only the quality of the original material (Velho et al., 2006), it is important to evaluate the forage of the materials before ensiling, so that they can be recommended

for the production of silage. In addition, it is possible to use the forage of sorghum as green chop in the trough. Thus, the aim of this study was to evaluate the chemical characteristics and kinetic composition of the forage of different purpose sorghum cultivars, to verify the forage potential for silage production and as green chop, at the first and second season.

Material and Methods

The field research was conducted at the Plant Production Sector of the Federal Institute of Education, Science and Technology of Rondônia, Colorado do Oeste campus, and chemical analyses were performed at the Animal Nutrition Laboratory of the Federal University of Mato Grosso, Cuiaba campus. The climate in the experimental area is Awa type, according to the Köppen classification (Alvares et al., 2013), and the soil is a typical Eutrophic Red Ultisol.

The experimental design was a randomized block design, with four replicates. The treatments comprised six sorghum cultivars of different purpose (BRS 308 and BRS 310, grain sorghum; BRS 655 and BRS 610, forage sorghum; BRS 506 and CMSXS 647, sweet sorghum). Two experiments were conducted: at the first and second season, with sowing in November 2011 and March 2012, respectively. The row spacing was 0.60 m, with densities of 170 thousand seeds ha^{-1} for the grain sorghum cultivars and 115 thousand seeds ha^{-1} for the forage and sweet sorghum cultivars.

The plot comprised four lines 5.0 m in length. The useful area comprised two central rows, disregarding 0.5 m at the ends. At sowing, fertilization was performed at doses of 20 kg ha^{-1} N; 40 kg ha^{-1} P$_2$O$_5$, and 60 kg ha^{-1} K$_2$O in the first and second seasons, using urea, single superphosphate, and potassium chloride, respectively.

At five days after sowing, seedling emergence was uniform, and at 25 days after emergence, nitrogen fertilization was performed at a dose of 60 kg ha^{-1}, using urea. It was necessary to apply insecticide based on chlorpyrifos to control armyworm (*Spodoptera frugiperda*), at the dose of 480 mL ha^{-1} of the active principle. Weeds were controlled by hand weeding.

Harvesting was performed when the plants presented grain at the hard dough stage, at 95 days after emergence for grain sorghum cultivars and 105 days after emergence for the forage and sweet sorghum cultivars.

For the analysis of the chemical composition of forage, ten plants per plot were collected inside the useful area, and ground in a stationary chopper up to 2.0 cm. Subsequently, the mass was homogenized, and a sample was pre-dried in a freeze drier at -70 °C until it reached constant mass, with subsequent grinding in a Willey stationary mill, Tecnal model, with 1 mm sieves. The pre-dried forage samples were analyzed for levels of crude protein (CP) according to the Method 954.01 (Association of Official Analytical Chemists [AOAC], 1990); ashes at 600 °C for 4 h according to the Method 942.05 (AOAC, 1990); and neutral detergent fiber (NDF) and acid detergent fiber (ADF) according to the method described by Goering and Van Soest (1970).

Carbohydrate fractionation was performed according to the method described by Sniffen, O'Connor, Van Soest, Fox and Russel (1992), in which the fibrous carbohydrates were obtained from the corrected NDF for their ash and protein content (apNDF); fraction C by indigestible NDF (iNDF) after 240 h *in situ* incubation (Casali et al., 2008); fraction B2, which corresponds to the fibrous fraction with slow degradation rate, was obtained by the difference between apNDF and fraction C; and fractions A and B1 were not estimated, since the non-fibrous carbohydrate + ether extract (NFC+ EE) content was estimated according to the method described by Hall (2015), using the following equation: NFC + EE = 100 - (CP + ashes + aNDF), where aNDF was obtained from the corrected NDF for its ash content.

Protein fractionation was performed according to the Cornell Net Carbohydrate and Protein System (Licitra, Hernandez, & Van Soest, 1996). The fraction A (non-protein nitrogen) was estimated by the difference between total N and trichloroacetic acid insoluble N, which was obtained by mixing 500 mg of the sample with 50 mL of distilled water, remaining at rest for 30 min. Then, 10 mL of 10% trichloroacetic acid was added for a further 25 min. The residue was filtered through a glass filter crucible of porosity 2 (40 to 100 µm), washed with 1% trichloroacetic acid, and residual N determined. The B3 fraction was calculated as the difference between N insoluble in neutral detergent and N insoluble in acid detergent, which were determined by heating a 500 mg sample with neutral and acid detergent solution, respectively, for 1 h in an autoclave. The fraction C was considered as the N insoluble in acid detergent. Fraction B1 + B2 was determined by the difference between total N and the sum of fractions A, B3, and C.

Sample preparation for *in vitro* incubations was performed by taking approximately 500 mg of sample material (450 mg DM), which were placed in penicillin glass vials with a total volume of 100 ml. Subsequently, McDougall's buffer solution (McDougall, 1949) was added with reducing solution comprising 625 mg L^{-1} HCL-cysteine and 1000 mg L^{-1} Na_2SO_3, with pH previously adjusted to 6.9 by sprinkling with CO_2. In each incubation flask, 40 mL of the total solution was added under CO_2 spray so that anaerobic conditions were guaranteed.

The rumen liquid was collected from the rumen of a cannulated cow fed with corn silage and concentrate in a proportion of 60:40, filtered using a triple layer of cheesecloth, stored in a thermal container, and immediately transported to the incubation room. Then, 10 mL of filtered rumen liquid was inoculated into each vial, always under CO_2 spray, immediately sealed with a rubber cap and a metal cap, and then kept in a water bath at 39 °C,

according to methodology described by Malafaia, Valadares, Vieira, Silva and Pereira (1998).

The gas pressure readings were measured using a pressure transducer connected at its end to a needle at 1, 2, 3, 4, 5, 6, 8, 10, 12, 18, 24, 36, 48, 60, 72, 84, and 96 h. To discount the volume of gas from the rumen liquid and buffer solution, four vials were incubated without a sample (blank); thus, for each reading time, the volume of gas from the sample vials was subtracted from the volume of the vials without a sample. The kinetics of cumulative gas production were analyzed using the bicompartmental logistic model developed by Schofield, Pitt and Pell (1994): Vt = V1f/(1 + exp (2-4 × C1 × (T-Lag))) + V2f/(1 + exp (2-4 × C2 × (T-Lag))), where Vt (mL) is the accumulated volume at time t; V1f (mL) is the volume of gas from the rapid degradation fraction; V2f (mL) is the volume of gas from the slow degradation fraction; C (h^{-1}) is the rate of degradation; Lag is the latency (h); and T is the time (h).

To determine the *in vitro* dry matter digestibility (IVDMD), the residue from the incubation was filtered through a previously weighed porosity 2 (40 to 100 µm) sintered crucible with boiling distilled water until the filtrate was cleaned. The crucibles were placed in an oven (105 °C) for drying and residual weight was determined by weight difference.

The statistical model applied was $Y_{ijk} = \mu + B_j + C_i + e_{ij}$, where Y_{ijk} = value observed in sorghum cultivar i in block j; μ = overall mean; B_j = effect of block j; C_i = effect of sorghum cultivar i; and e_{ij} = random plot error.

Data were subjected to analysis of variance and the means compared using the Fisher's Least Significant Difference (LSD) test, adopting a 5% probability level using the statistical program SISVAR, version 5.3 (Ferreira, 2010).

Results and Discussion

First Season

In the sweet sorghum cultivars, in general, there was a higher IVDMD, with higher gas volume and rapid degradation fraction digestion rate, associated with lower lag time (Table 1). Sorghum BRS 308 presented similar characteristics, however, with lower IVDMD.

Table 1
In vitro digestibility of dry matter and kinetic parameters on the forage of different purpose sorghum cultivars at first season

Cultivars	IVDMD	GV1	GV2	TGV	C1	C2	Lag
			Grain				
BRS 308	53.53[d]	3.07[b]	15.76[a]	18.84	15.53[a]	1.66[a]	3.44[c]
BRS 310	54.57[cd]	5.15[b]	12.99[b]	18.14	7.62[b]	1.46[bc]	7.70[a]
			Forage				
BRS 655	57.96[bc]	4.65[b]	16.20[a]	20.85	7.61[b]	1.69[a]	7.02[a]
BRS 610	56.64[bcd]	2.87[b]	15.57[a]	18.44	15.57[a]	1.59[ab]	6.64[a]
			Sweet				
BRS 506	65.20[a]	9.69[a]	11.61[b]	21.30	14.20[a]	1.51[bc]	5.53[b]
CMSXS 647	58.01[b]	8.40[a]	11.38[b]	19.77	14.28[a]	1.41[c]	5.30[b]
P-value	< 0.0001	0.0001	< 0.0001	0.0397	0.0002	0.0042	0.0004
SMD	3.40	2.46	1.66	3.33	3.61	0.14	1.95
CV (%)	3.91	29.00	8.04	7.00	19.20	6.14	20.89

CV: Coefficient of variation. Means followed by the same letter in the column do not differ among themselves by LSD test ($P > 0,05$). IVDMD: In vitro dry matter (DM) digestibility (g 100 g^{-1} DM); GV1: gas volume of the rapidly degrading fraction (mL 100 mg^{-1} DM); GV2: gas volume of the slowly degrading fraction (mL 100 mg^{-1} DM); TGV: total gas volume (mL 100 mg^{-1} DM); C1: digestion rate of fast degradation fraction (% h^{-1}); C2: digestion rate of slow degradation fraction (% h^{-1}); Lag: latency (h); SMD: significant minimum difference.

The higher digestibility of sweet sorghum BR 506 is mainly owing to the lower iNDF content (Table 2). In addition, although low CP content was observed (Table 3), most of it was in the form of non-protein nitrogen, which combined with the high NFC + EE content interfered in the digestion rates of the rapid degradation fraction and lag time. Sweet sorghum cultivars presented lower proportion of indigestible protein (fraction C), owing to the lower proportion of grains, since in the grain sorghum, part of the protein is in the form of a dense protein matrix (J. S Silva et al., 2014).

The sweet sorghum CMSXS 647, presented different IVDMD, although gas volume and digestion rate of the fast degradation fraction were similar to that of BR 506. This is probably owing to the higher absolute value in iNDF and lower absolute value in estimated NFC + EE. T. C. Silva et al. (2014), evaluating the ruminal fermentation kinetics of sorghum hybrids silages, observed the effect of non-fibrous carbohydrate content on the final gas volume.

Lower IVDMD values were observed in the grain sorghum cultivars (Table 1), perhaps owing to the presence of tannin in the higher grain proportion sorghums. Tannins have antimicrobial capacity, promoting negative effects on digestion and absorption of nutrients within the rumen (Scalbert,

1991). In contrast, higher CP content was observed in grain sorghum, possibly owing to their small plant size and higher grain participation. Regarding the NDF, ADF, and aNDF levels, there was no difference between the cultivars, however, the fiber content varies according to panicle proportion (Cabral, Detmann, Zervoudakis, Pereira, & Veloso, 2003; Moraes, Jobim, Silva, & Marquardt, 2013; F. F. Silva et al., 1999), with a lower fiber content being expected in grain sorghum, which was not observed in the present study.

Table 2
Chemical composition (g 100 g⁻¹ DM) of the forage of different purpose sorghum cultivars at first season

Cultivars	Ash	NDF	ADF	apNDF	NFC + EE	Fraction B2	iNDF
Grain							
BRS 308	10.73[ab]	41.23	21.60	37.05	39.31[b]	16.81	20.24[ab]
BRS 310	10.94[a]	41.96	22.28	37.86	37.33[b]	12.83	25.04[a]
Forage							
BRS 655	9.58[abc]	38.14	21.16	34.68	45.41[ab]	14.32	20.36[ab]
BRS 610	9.16[bcd]	46.54	26.42	43.87	38.21[b]	18.41	25.46[a]
Sweet							
BRS 506	7.70[d]	32.60	19.94	31.40	54.09[a]	14.71	16.69[b]
CMSXS 647	8.05[cd]	38.81	24.82	37.35	47.22[ab]	16.09	21.26[ab]
P-value	0.042	0.0919	0.2472	0.1563	< 0.0001	0.3653	0.0396
SMD	1.70	9.13	5.99	9.04	8.05	5.51	5.62
CV	12.40	15.20	17.50	16.20	15.68	23.55	17.30

CV: Coefficient of variation. Means followed by the same letter in the column do not differ among themselves by LSD test (*P* > 0.05). NDF: neutral detergent fiber; ADF: acid detergent fiber; apNDF: neutral detergent fiber corrected for ash and protein; NFC + EE: estimated content of non-fibrous carbohydrate and ether extract, according to Hall (2015); Fraction B2: available fraction of fiber, obtained by the difference between apNDF and iNDF; iNDF: indigestible neutral detergent insoluble fiber; SMD: significant minimum difference.

In all sorghum cultivars, ideal NDF levels were observed, which is closely correlated with dry matter intake, since values above 60% are negatively correlated with forage intake (Mertens, 1987; Van Soest, 1965). Andrade et al. (2019) obtained similar values to those found in this study.

The low NDF content of the forage and sweet sorghum cultivars, besides the amount of fiber, was probably owing to the high amount of sugar present, also explaining a higher estimated NFC + EE value. Sucu, Kalkan, Canbolat and Filya (2016) worked with forage sorghum and obtained higher NDF values than the ones presented in the present study, indicating a good quality of the studied material.

Sweet sorghum cultivars showed lower CP content, with expressive participation of fast degrading protein, comprising protein fraction A (Table 3), while the grain sorghum cultivars presented higher CP content. Probably, the higher proportion of grains in the grain sorghum cultivars provided higher CP content, but with higher protein fraction content B3 and C, owing to the higher proportion of protein matrix in the grain.

The content of CP is a relevant aspect in ruminant diet, and low dietary CP levels result in decreased feed intake and performance in ruminant animals (Detmann, Valente, Batista, & Huhtanen, 2014). According to Minson (1984), the minimum protein

level in feeds must be 7% for proper fermentation to occur. Recent results for low quality forage indicate levels of 8 to 11%, aiming at the full capacity utilization of the fibrous components by ruminal microorganisms and the reduction of ruminal repletion of the iNDF (Lazzarini et al., 2009).

Table 3
Protein fractionation of the forages of different purpose sorghum cultivars at first season

Cultivars	CP	A	B1 + B2	B3	C
			g 100 g^{-1} DM		
			Grain		
BRS 308	11.04[a]	3.37[a]	5.79[b]	1.12[a]	0.76[b]
BRS 310	11.33[a]	1.07[b]	7.73[a]	1.32[a]	1.21[a]
			Forage		
BRS 655	8.00[b]	0.43[b]	5.24[bc]	1.19[a]	1.13[a]
BRS 610	7.24[bc]	1.37[b]	4.36[c]	0.86[a]	0.65[b]
			Sweet		
BRS 506	6.36[c]	3.41[a]	2.50[d]	0.12[b]	0.33[c]
CMSXS 647	6.87[bc]	3.30[a]	3.07[d]	0.11[b]	0.40[c]
***P*-value**	< 0.0001	0.0002	< 0.0001	0.0004	< 0.0001
SMD	1.34	1.26	1.16	0.54	0.24
CV	10.50	38.90	16.04	45.30	21.55
			g 100 g^{-1} CP		
			Grain		
BRS 308		30.08[b]	44.44[bc]	11.17[a]	7.16[cd]
BRS 310		9.29[c]	64.53[a]	13.81[a]	12.37[b]
			Forage		
BRS 655		5.48[c]	45.54[bc]	16.67[a]	16.16[a]
BRS 610		18.83[b]	51.16[b]	11.87[a]	9.07[c]
			Sweet		
BRS 506		53.29[a]	34.40[c]	1.93[b]	5.19[d]
CMSXS 647		48.08[a]	38.68[c]	1.58[b]	5.83[d]
***P*-value**		< 0.0001	0.0014	0.0003	< 0.0001
SMD		12.74	11.99	6.11	2.40
CV		30.72	17.13	42.66	17.11

CV: Coefficient of variation. Means followed by the same letter in the column do not differ among themselves by LSD test (*P* > 0.05). CP: Crude Protein; Fraction A: non-protein nitrogen; Fraction B1 + B2: determined by the difference between total nitrogen and the sum of fractions A, B3 and C; Fraction B3: difference between nitrogen content in samples subjected to neutral detergent fiber analysis and in samples subjected to acid detergent fiber analysis; Fraction C: Nitrogen insoluble in acid detergent; SMD: significant minimum difference.

Thus, considering the nutritional value, all sorghum cultivars could be recommended for silage or as green chop, especially in highly intensive systems, with high grain proportion diets, where the forage has the function of providing fiber to reduce metabolic disturbances. In this system, sweet sorghum stands out, as it has higher digestibility and the low protein content would not be limiting,

considering the diet as a whole. In contrast, for extensive systems, where the only supplementary food used in the dry season is the forage, the use of sweet sorghum is not recommended as it does not meet the protein requirements for adequate fermentation and to reduce ruminal repletion (Lazzarini et al., 2009).

Second season

In the second season, higher IVDMD values were observed for the sweet sorghum cultivars and the grain sorghum BRS 308 (Table 4), possibly owing to the lower absolute NDF values (Table 5). Sweet

sorghum cultivars showed higher gas production from the fast degradation fraction, owing to higher estimated NFC + EE content (Table 5). According to Lourenço, Massa, Palma and Rato (2007), sweet sorghum cultivars can have soluble carbohydrate content of 30 to 40%, being higher than that of grain sorghum cultivars. In addition, although the sweet sorghum cultivars had lower CP content, a higher proportion of protein fraction A was observed, which presents rapid ruminal degradation and in parallel with non-fibrous carbohydrates, probably maximized the protein and carbohydrate synchronization, and consequently, microbial production, which favors digestibility.

Table 4
In vitro digestibility of dry matter and kinetic parameters of the forage of different purpose sorghum cultivars at second season

Cultivars	IVDMD	GV1	GV2	TGV	C1	C2	Lag
Grain							
BRS 308	62.72[a]	3.05[c]	18.51[a]	21.56[ab]	31.09[a]	1.44[a]	7.03
BRS 310	59.03[b]	2.75[c]	17.32[ab]	20.07[bc]	28.35[a]	1.36[a]	5.67
Forage							
BRS 655	59.57[b]	5.17[b]	15.55[c]	20.72[abc]	13.63[c]	1.38[a]	6.93
BRS 610	60.20[b]	3.80[bc]	15.67[bc]	19.47[c]	21.32[b]	1.25[b]	5.29
Sweet							
BRS 506	64.56[a]	8.23[a]	14.08[c]	22.32[a]	16.27[bc]	1.17[b]	5.95
CMSXS 647	63.10[a]	7.40[a]	14.51[c]	21.91[a]	18.13[bc]	1.21[b]	5.75
***P*-value**	0.0005	< 0.0001	0.0004	0.0001	0.0003	< 0.0001	0.4176
SMD	2.29	1.45	1.70	4.29	6.72	0.09	2.09
CV	2.47	18.93	7.08	5.96	20.77	4.35	22.69

CV: Coefficient of variation. Means followed by the same letter in the column do not differ among themselves by LSD test (*P* > 0.05). IVDMD: In vitro dry matter (DM) digestibility (g 100g^{-1} DM); GV1: gas volume of the rapidly degrading fraction (mL 100 mg^{-1} DM); GV2: gas volume of the slowly degrading fraction (mL 100 mg^{-1} DM); TGV: Total gas volume (mL 100 mg^{-1} DM); C1: digestion rate of fast degradation fraction (% h^{-1}); C2: digestion rate of slow degradation fraction (% h^{-1}); Lag: latency (h); SMD: significant minimum difference.

Table 5

Chemical composition (g 100 g^{-1} DM) on the forage of different purpose sorghum cultivars at second season

Cultivars	Ash	NDF	ADF	apNDF	NFC + EE	Fraction B2	iNDF
			Grain				
BRS 308	9.81[a]	48.35[a]	24.58	44.57[a]	33.17[c]	26.89[a]	17.70
BRS 310	9.53[a]	47.12[ab]	24.25	43.60[a]	33.41[c]	23.90[ab]	19.70
			Forage				
BRS 655	8.43[bc]	39.22[d]	23.45	36.57[c]	42.91[a]	16.41[c]	20.20
BRS 610	8.78[b]	44.60[abc]	26.74	42.32[ab]	37.68[bc]	21.61[b]	20.70
			Sweet				
BRS 506	8.18[cd]	40.26[cd]	23.69	38.51[bc]	43.92[a]	20.58[b]	17.90
CMSXS 647	7.71[d]	42.97[bcd]	25.21	41.41[ab]	42.53[ab]	23.21[b]	18.20
P-value	< 0.0001	0.0072	0.2519	0.0155	< 0.0001	0.0002	0.0632
SMD	0.59	4.95	2.97	4.58	4.82	3.36	2.37
CV	4.24	7.51	7.99	7.39	8.43	10.09	8.23

CV: Coefficient of variation. Means followed by the same letter in the column do not differ among themselves by LSD test (*P* > 0.05). NDF: neutral detergent fiber; ADF: acid detergent fiber; apNDF: neutral detergent fiber corrected for ash and protein; NFC + EE: estimated content of non-fibrous carbohydrate and ether extract, according to Hall (2015); Fraction B2: available fraction of fiber, obtained by the difference between apNDF and iNDF; iNDF: indigestible neutral detergent insoluble fiber; SMD: significant minimum difference.

Grain sorghum cultivars showed higher gas volume from the slow degradation fraction (Table 4), possibly owing to the higher content of carbohydrate fraction B2 (Table 5). The high digestibility of BRS 308 may be associated with the synchronization of carbohydrate fraction B2 with CP fraction B1 + B2. Sniffen et al. (1992) suggested that, in the evaluation of food, nitrogen and carbohydrate content should be fractionated, considering the ruminal degradability of these compounds, aiming to minimize nutrient losses and maximizing efficiency of microbial growth by synchronizing carbohydrate and protein degradation.

As at the first season, the sweet sorghum cultivars presented lower CP, but with higher non-protein nitrogen and lower indigestible protein (fraction C), owing to the higher proportion of protein matrix in the grain. However, at second season, the CP level was higher than 7% (Table 6). As for the ash content, the higher content in the grain sorghum is associated with the dilution effect, in which smaller plants have higher ash content.

Table 6
Protein fractionation on the forages of different purpose sorghum cultivars at second season

Cultivars	CP	A	B1 + B2	B3	C
	g 100 g^{-1} DM				
Grain					
BRS 308	10.50[b]	3.15[bc]	5.60[ab]	1.03[a]	0.81[a]
BRS 310	11.71[a]	3.88[abc]	6.06[a]	0.95[ab]	0.81[a]
Forage					
BRS 655	10.60[b]	2.90[c]	6.21[a]	0.61[bc]	0.88[a]
BRS 610	10.13[b]	4.25[ab]	4.79[b]	0.37[cd]	0.72[a]
Sweet					
BRS 506	8.62[c]	5.07[a]	2.78[c]	0.34[cd]	0.43[b]
CMSXS 647	7.76[c]	4.55[a]	2.63[c]	0.24[d]	0.34[b]
P-value	<0.0001	0.0246	<0.0001	0.0006	<0.0001
SMD	0.99	1.33	1.09	0.35	0.17
CV	6.65	22.15	15.43	38.85	16.54
	g 100g^{-1} CP				
Grain					
BRS 308		29.59[c]	52.95[a]	9.75[a]	7.71[a]
BRS 310		32.87[bc]	51.90[a]	8.28[ab]	6.95[a]
Forage					
BRS 655		27.13[c]	50.69[a]	5.72[bc]	8.40[a]
BRS 610		41.95[b]	47.38[a]	3.62[c]	7.05[a]
Sweet					
BRS 506		58.88[a]	32.22[b]	3.96[c]	4.94[b]
CMSXS 647		58.18[a]	34.19[b]	3.20[c]	4.43[b]
P-value		< 0.0001	0.0008	0.0037	0.0005
SMD		11.45	11.54	3.40	1.60
CV		18.33	16.56	39.24	16.1

CV: Coefficient of variation. Means followed by the same letter in the column do not differ among themselves by LSD test ($P >$ 0,05). CP: Crude Protein; Fraction A: non-protein nitrogen; Fraction B1 + B2: determined by the difference between total nitrogen and the sum of fractions A, B3 and C; Fraction B3: difference between nitrogen content in samples subjected to neutral detergent fiber analysis and in samples subjected to acid detergent fiber analysis; Fraction C: Nitrogen insoluble in acid detergent; SMD: significant minimum difference.

There was no difference in the iNDF variable between the forages of different cultivars in the second season. The iNDF is constituted by the fraction of the plant cell wall that is not digested along the gastrointestinal tract (Sniffen et al., 1992). This fraction is related to digestibility (Huhtanen, Nousiainen, & Rinne, 2006).

In general, in both seasons, sweet sorghum cultivars presented higher digestibility, with lower CP content, but with expressive participation of readily and potentially digestible protein, in addition to lower levels of fraction C, which represents the unavailable N in the gastrointestinal tract. In contrast, although the BRS 310 grain sorghum had lower digestibility than the sweet sorghum cultivars

(Table 4), this cultivar presented higher CP content at the second season (Table 6).

For highly intensive systems, with high grain proportion in the diets, where the forage has the function of providing fiber to reduce metabolic disturbances, all sorghum cultivars could be recommended for silage or as green chop, but the sweet sorghum cultivars and grain sorghum BRS 308 stand out. The sweet sorghum cultivars present high digestibility and high estimated NFC + EE content, possibly owing to the higher soluble sugar content present in these cultivars. Grain sorghum BRS 308 has higher digestibility among cultivars of this purpose, but both cultivars of this category have CP content between the levels recommended by Lazzarini et al. (2009), allowing a full capacity utilization of the fibrous components by ruminal microorganisms and the reduction in ruminal repletion. In extensive and highly extensive systems, sorghum cultivars could be recommended for ensiling, as they meet the protein requirements for proper fermentation and reduced rumen repletion in ruminant feeding.

Even though the forage of sorghum cultivars has favorable nutritive value, it is necessary to evaluate the silage of these materials, to verify the maintenance of this nutritive value after fermentation, and to observe the fermentative characteristics in the use of these materials.

Conclusion

The forage of sweet sorghum cultivars presented higher digestibility, with a higher proportion of readily and potentially digestible protein and non-fibrous carbohydrates with ether extract, with good potential for use in ensiling, or to be used as green chop, at the first and second season.

Considering the nutritive value of the forage, all sorghum cultivars have the potential for silage production, at the first and second season.

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