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Fermentation characteristics of different purposes sorghum silage[1]

Características fermentativas da silagem de sorgo de diferentes aptidões

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Abstract

Sorghum stands out among other plants recommended for ensiling due to its forage composition, its resistance to drought, and its planting range. New cultivars of grain and sweet sorghum that can be used for silage production are available, but there is little information regarding their ensiling characteristics. The aim of this study was to evaluate the fermentation characteristics at the ensiling of different purpose sorghum cultivars, at two crop periods. The trial was carried out at the Plant Production Department of the Federal Institute of Education, Science and Technology of Rondônia, Colorado do Oeste campus, Rondônia, Brazil, and chemical analyses were performed at the Laboratory of Animal Nutrition, at the Federal University of Mato Grosso, Cuiabá campus, Mato Grosso, Brazil. The experimental design used was a randomized block, in split-plot design, with four replicates. The plot treatments consisted of six sorghum cultivars grown for different purposes (grain sorghum: BRS 308 and BRS 310; forage sorghum: BR 655 and BRS 610; sweet sorghum: BRS 506 and CMSXS 647). Split-plot treatments consisted of two cropping seasons (first crop and second crop). The grain sorghum cultivar BRS 310 was the only one that had suitable dry matter content for ensiling; however, it was also the only one that did not show ideal water soluble carbohydrate content for ensiling. Nevertheless, all treatments presented pH below than 4.2 and ammonia nitrogen lower than 12% of total N, which indicates that the fermentation inside the silo had proceeded well. For sweet sorghum cultivars, higher ethanol and butyric acid content were observed for the first crop than for the second crop. All evaluated sorghum cultivars can be used for silage production, but the use of sweet sorghum is recommended at the second crop.

Key words: Alcoholic fermentation. Fermentability coefficient. Grain sorghum. *Sorghum bicolor.* Sweet sorghum.

Resumo

O sorgo se destaca entre as plantas recomendadas para a ensilagem em razão de sua composição

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forrageira, além de resistência ao déficit hídrico e amplitude de semeadura. Há no mercado cultivares de sorgo granífero e sacarino que podem ser utilizados para a produção de silagem, porém faltam informações acerca de suas características para ensilagem. Objetivou-se avaliar as características fermentativas na ensilagem de cultivares de sorgo de diferentes aptidões, em duas épocas de cultivo. O delineamento experimental utilizado foi em blocos casualizados, com os tratamentos dispostos em esquema de parcelas subdivididas, com quatro repetições. Os tratamentos da parcela corresponderam a seis híbridos de sorgo de diferentes aptidões (BRS 308 e BRS 310, graníferos; BR 655 e BRS 610, forrageiros; BR 506 e CMSXS 647, sacarinos). Os tratamentos da subparcela corresponderam a duas épocas de cultivo (primeira safra e segunda safra). Todos os tratamentos apresentaram pH menor que 4,2 e nitrogênio amoniacal inferior a 12% do N total, o que indica boa fermentação dentro do silo. Nas silagens das cultivares de sorgo sacarino, observou-se maior teor de etanol na primeira safra em comparação com à segunda, com médias de 5,91 e 0,11%, respectivamente. Todas as cultivares de sorgo avaliadas podem ser utilizadas para a produção de silagem, porém o uso de sorgo sacarino é mais recomendado na segunda safra.
Palavras-chave: Coeficiente de fermentabilidade. Fermentação alcoólica. *Sorghum bicolor*. Sorgo granífero. Sorgo sacarino.

Introduction

Sorghum cultivation is an interesting alternative for silage production, since it presents content of dry matter (DM) and water soluble carbohydrates (WSC) that are ideal for ensiling. Sorghum also has the advantage of having greater tolerance to water deficit and greater sowing amplitude than that of maize (MACHADO et al., 2012). Sorghum cultivars are classified into four groups: grain; forage and/or sweet; grazing/cutting (sudangrass and sorghum-sudangrass hybrids); and broom, according to their proportions of stem, panicle and leaves (RIBAS, 2003).

Grain sorghum has the potential to produce high quality silage, with 40-50 % of grain in the ensiled mass (KAISER et al., 2004), with higher nutritional value than that of forage sorghum (COLOMBINI et al., 2012). The use of forage sorghum provides high yields of DM, in general, with a stem proportion higher than 50 %, and thus a high content of the fibrous fraction. Sweet sorghum is characterized by the high content of non-structural carbohydrates that remain in the stem and in the leaves as soluble sugars (KAISER et al., 2004).

Sweet sorghum can also be a suitable alternative for silage production, due to its high productivity (LOURENÇO et al., 2007) and high WSC content (ZHANG et al., 2016). It therefore has greater potential than that of other sorghum cultivars (SANTOS et al., 2013; VON PINHO et al., 2006). However, the use of sweet sorghum in silage production may promote ethanol production inside the silo, since its high non-structural carbohydrate content provides an ideal environment for yeast activity, which converts WSC to ethanol in anaerobic environment (CAVALI et al., 2010).

According to Weissbach (1996), an ideal relationship between the DM content, WSC content and buffering capacity (BC) is required for proper fermentation inside the silo, which can be determined by the fermentability coefficient (FC). When observing the fermentation inside the silo, the main variables measured are the pH and the ammonia nitrogen content.

Thus, different purpose sorghum cultivars, with different panicle proportions, provide different levels of DM (CABRAL et al., 2003) and WSC (SILVA et al., 1999), which may influence the fermentation inside the silo. In addition, the growing season may influence the grains production and the proportion of panicles in the produced forage.

Heinemann et al. (2009), comparing the maize production in Goiás at the first and second crop, observed greater problems with grain filling and

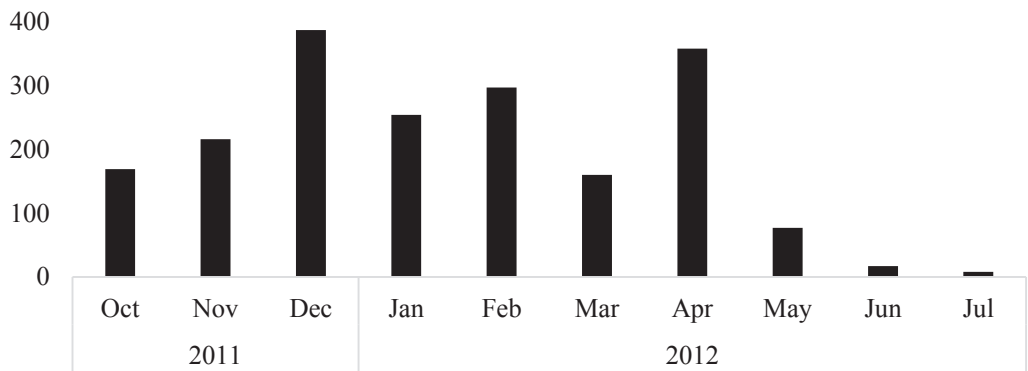
yield for the second crop than for the first. Whilst sorghum is more tolerant to water deficit than maize, there is little information of the growing season effect on the morphological characteristics of sorghum plant, or on its influence on the fermentation.

The aim of this study was to evaluate the fermentation characteristics of different purpose sorghum cultivars ensiled from two crop periods.

Material and Methods

The trial was carried out at the Plant Production Department, Federal Institute of Education, Science, and Technology of Rondônia, Colorado do Oeste campus, Rondônia, Brazil. Chemical analyses were performed at the Laboratory of Animal Nutrition, Federal University of Mato Grosso, Cuiabá campus, Mato Grosso, Brazil. The soil in the experimental area was a typical eutrophic red ultisol (EMBRAPA, 2006). The climate was Awa, based on the Köppen classification system, with an average temperature of 27 °C and annual average rainfall of 1497 mm. The rainfall data (Figure 1) was collected from the meteorological station of Vilhena, Rondônia, Brazil (INMET, 2016), which is located approximately 70 km from the experimental area.

Figure 1. Monthly values of rainfall during the trial period, October 2011 to July 2012.



The experimental design was a randomized block with a split-plot arrangement and four replicates. The plot treatments consisted of six different purpose sorghum cultivars (grain sorghum: BRS 308 and BRS 310; forage sorghum: BR 655 and BRS 610; sweet sorghum: BRS 506 and CMSXS 647). The split-plot treatments comprised two crop periods (first crop and second crop).

The seeds for the first crop were planted on November 3, 2011, while seeds for the second crop were planted on March 22, 2012. The spacing between lines was 0.60 m, with density of 180,000 plants ha^{-1} for grain sorghum cultivars, and 120,000 plants ha^{-1} for forage and sweet sorghum cultivars. The plot consisted of four planting lines 5 m in length. A 0.5 m border was left around the study plot perimeter, reducing the usable area to two central rows, each of them 4 m in length. Fertilizer was applied at planting for both crops, at doses of 20 kg ha^{-1} N, 40 kg ha^{-1} P_2O_5, and 60 kg ha^{-1} K_2O using urea, single superphosphate, and potassium chloride, respectively.

Five days after planting, seedlings showed uniform emergence; 25 days after emergence (DAE), nitrogen fertilizer was applied at approximately 60 kg ha^{-1} N using urea. The insecticide Chlorpyrifos

was applied at a dose of approximately 480 mL ha^{-1} of active ingredient, to control armyworm (*Spodoptera frugiperda*). Weed control was carried out by manual weeding.

The plants were harvested when they showed grain at the 'hard dough' stage, which was at 95 DAE for grain sorghum cultivars, and 105 DAE for forage and sweet sorghum cultivars. For ensiling, forage was chopped to approximately 20 mm in length using a stationary forage cutter. The experimental units were 'experimental silos' (2.5 L glass jars) that were equipped with water-filled air locks on their lids, which enabled the release of fermentation gases during storage without any ingress of air.

The experimental silos were filled manually with enough forage to obtain a density of 550 kg m^{-3}, with approximately 1.375 kg of green mass per silo. After filling, the silos were closed, and a silicone layer applied around the edges of the lids to ensure complete sealing. The silos remained closed for 30 days.

For forage evaluation, ten plants per plot were collected and chopped to approximately 20 mm in length using a stationary forage cutter. Then, the mass was homogenized and a sample freeze-dried at -70 °C for 48 hours. Samples were ground in a Wiley mill until they could pass through a 20 mesh steel sieve.

For silage evaluation, sampling was performed at the geometrical centre of the experimental silo at opening, with the upper and lower portions being discarded. The mass was homogenized, after which two samples were taken: one to obtain an aqueous extract, following the methodology described by Kung Junior (1996), which was stored in a -12 °C freezer; and the other sample for pre-drying in a freeze-dryer at -70 °C for 48 hours. Pre-dried samples were then ground in a Willey stationary mill with a 20 mesh sieve.

The pre-dried forage samples were analyzed for final DM content, in a 105 °C oven for 24 hours, as well as for crude protein (CP) and ash content, according to AOAC (1990). The WSC content was analyzed following the methodology described by Deriaz (1961) and BC, according to Weissbach et al. (1974). The FC was calculated according to the instructions of Weissbach (1996): $FC = MS + 8 \times (WSC/BC)$; where FC: fermentability coefficient; DM: dry matter content (%); WSC: water soluble carbohydrate content (%); BC: buffering capacity (g lactic acid 100 g MS^{-1}) (Table 1).

Table 1. Chemical composition (g 100 g^{-1} of DM) of the forage of different purpose sorghum cultivars for ensiling.

Cultivars	1st Crop			2nd Crop		
	Ash	OM	CP	Ash	OM	CP
Grain						
BRS 308	10.73	89.27	9.86	9.81	90.19	10.5
BRS 310	10.94	89.06	11.32	9.53	90.47	11.71
Forage						
BRS 655	9.58	90.42	10.22	8.43	91.57	10.6
BRS 610	9.16	90.84	9.51	8.78	91.22	10.13
Sweet						
BRS 506	7.70	92.30	6.64	8.18	91.82	8.62
CMSXS 647	8.05	91.95	6.11	7.71	92.29	7.76

OM: Organic matter; CP: Crude protein.

The aqueous extract was used for the analysis of ammonia nitrogen, which was carried out according to the methodology described by Mizubuti et al. (2009), and for pH measurement using a digital pH meter. The pre-dried silage samples were used for the measurement of the DM and WSC content.

For organic acid and ethanol content determination, a mixture of 10 ml of aqueous extract was placed in a falcon centrifuge tube, and centrifuged for 5 minutes at 3000 rpm. Subsequently, an aliquot of 1.5 mL of supernatant was collected and placed in a 2 mL Eppendorf microcentrifuge tube, and then centrifuged again for 20 minutes at 12000 rpm and 4 °C. After centrifugation, the supernatant was transferred to an Eppendorf microcentrifuge tube, and then refrigerated at -12 °C.

Ethanol and organic acids analyses were performed using gas chromatography on Agilent equipment using an Agilent VF-WAXms column (30 m × 250 mm × 0.25 μm). The helium gas flow was set to 0.8 ml min^{-1}, and the sample division ratio was 1:10. The column temperature was programmed for 200 °C, with a rise of 35 to 80 °C at a ratio of 5 °C min^{-1}, and from 80 to 200 °C at a ratio of 40 °C min^{-1}, keeping the final temperature for 5 minutes. The injector temperature was set to 250 °C. Organic acid quantification was accomplished by normalization of the peaks areas, and peaks were identified by the comparison of the sample elution times to that of prepared standards. Ethanol and organic acids content was expressed as mmol per 100 mL and converted to percentage of DM, based on the forage mass used for aqueous extract preparation, and the sample DM content.

Data were subjected to statistical analysis using analysis of variance, and the means were compared using the least significant difference (LSD) test, adopting the probability level of 5%. Analyses were undertaken using the SISVAR statistical program, version 5.3.

Results and Discussion

The higher levels of DM ($p<0.05$) observed for grain sorghum cultivars and forage sorghum BRS 655 (Table 2) are due to the fact that these cultivars, probably, have higher panicle proportions, when compared with the other cultivars studied. Cabral et al. (2003), evaluated the nutritive value of sorghum silages and observed a linear increase in DM content with an increment in panicle ratio, which helps to explain the results obtained.

The ideal forage DM content, which would ensure adequate fermentation inside the silo, is 30 to 35 % (MCDONALD et al., 1991). Values close to these were observed for grain sorghum cultivars and forage sorghum BRS 655. Abdelhadi and Tricarico (2009), evaluating the ensiling of grain sorghum, observed average values of 29.5 % in DM content, while Cattani et al. (2016), evaluated different sorghum hybrids and observed average DM content of 32.4; 24.5 and 24.7 % for hybrids of grain, forage and sweet sorghum, respectively.

The greater levels of WSC ($p<0.05$) observed in the forage (Table 2) of sweet sorghum cultivars are because these cultivars are characterized by high non-structural carbohydrate content that remains in the stem and leaves as soluble sugars (KAISER et al., 2004). In addition, the lower WSC levels in grain sorghum cultivars are due to the possible differences in the panicle proportions present in the mass. According to Lourenço et al. (2007), sweet sorghum can exhibit sugar content of 30-40 % of DM, values similar to those observed in this work. According to McDonald et al. (1991), the minimum content of WSC required in the forage for a good fermentation is 15 % of the DM, which was not observed in either crop in grain sorghum cultivar BRS 310.

Forage BC can be influenced by the concentration of N and by the presence of cations, which neutralize the organic acids produced by the fermentation (JOBIM et al., 2007). Elevated levels of minerals may increase the forage BC and interfere with the silage process (MIRON et al., 2007). Thus, the lower

BC values observed for sweet sorghum cultivars in the first crop may be due to the lower ash and CP content present in these forages, while the higher BC values obtained by the grain sorghum cultivars in the second crop may be due to the higher protein and ash content observed in these cultivars.

Table 2. Chemical composition and fermentability coefficient of the forage of different purpose sorghum cultivars for ensiling.

Crop period	Cultivars						Mean
	Grain		Forage		Sweet		
	BRS 308	BRS 310	BRS 655	BRS 610	BRS 506	CMSXS 647	
	Dry matter (g 100 g^{-1})						
1st crop	25.70	30.27	29.04	22.89	23.66	21.05	25.44
2nd crop	30.20	31.40	28.21	25.61	25.41	21.99	27.14
Mean	27.95 a	30.84 a	28.63 a	24.25 bc	24.54 b	21.52 c	
CV (%)							10.72
	Water soluble carbohydrates (g 100 g^{-1} of DM)						
1st crop	17.27 cA	11.02 dA	17.73 cA	18.44 cA	41.90 aA	38.10 bA	24.08
2nd crop	15.22 cA	12.75 cA	21.16 bA	19.95 bA	34.54 aB	31.36 aB	22.50
Mean	16.25	11.88	19.44	19.19	38.22	34.73	
CV (%)							9.93
	Buffering capacity (g lactic acid 100 g^{-1} of DM)						
1st crop	4.25 cB	4.92 bB	5.32 abA	5.56 aA	4.34 cB	4.13 cB	4.75
2nd crop	6.33 abA	6.76 aA	5.15 cA	5.34 cA	5.95 bA	6.02 bA	5.92
Mean	5.29	5.83	5.24	5.42	5.14	5.08	
CV (%)							6.20
	Fermentability coefficient						
1st crop	58.26 bA	48.19 bA	55.78 bA	49.43 bA	102.85 aA	95.52 aA	68.34
2nd crop	49.48 cA	46.54 cA	61.42 bA	55.54 bA	72.48 aB	63.95 abB	58.24
Mean	53.87	47.36	58.60	52.49	87.67	79.74	
CV (%)							10.88

CV: Coefficient of variation. Means followed by the same capital letter in the column and by small letters in the row do not differ among themselves by LSD test ($p > 0.05$). Fermentability coefficient = DM + 8 × (WSC/BC).

Although some cultivars did not exhibit the required minimum DM and WSC content, all cultivars studied showed pH below 4.2, and ammonia nitrogen ($N\text{-}NH_3$) content below 12 % of total N (Table 3). This indicates that fermentation had proceeded satisfactorily within the silo (MCDONALD et al., 1991). According to Weissbach (1996), forage with a fermentability coefficient (FC) higher than 45, as was observed in all cultivars, would probably enable adequate fermentations. Thus, the low content of WSC observed for grain sorghum cultivar BRS 310 was compensated for by its high DM content, while the low DM content observed for sweet sorghum cultivars was compensated for by their high WSC content.

The higher $N\text{-}NH_3$ content observed for grain sorghum cultivar BRS 308 at the first crop, may

be due to the low average value for forage DM content of this cultivar (25.70 %), while this cultivar presented an average value of 30.20 % for forage DM content in the second crop, higher to the value of 30 % considered ideal by McDonald et al. (1991) for the inhibition of Clostridium bacteria activity. Clostridium can cause proteolysis in the silo, which will increase the N-NH_3 content in the silage aqueous extract. Despite the low DM content, the sweet sorghum cultivars had low N-NH_3 content, probably due to the low levels of CP in the forage.

The lower pH in the silage of sweet sorghum cultivar CMSXS 647 was due to the lower DM content and higher WSC content of this cultivar. Likewise, the higher pH observed for grain sorghum cultivar BRS 310 may be due to its higher DM content and lower WSC content. The bacterial activity that occurs during ensiling decreases as DM content increases (KAISER et al., 2004), which reduces the production of organic acids, such as lactic acid, consequently decreasing the rate of pH reduction. In addition, elevated levels of WSC promote vigorous fermentations within the silo (PINHO et al., 2015). Zhang et al. (2015), evaluated the quality of sweet sorghum silages and observed pH values of 4.16 and N-NH_3 of 7.66 % of total N.

Table 3. Fermentation characteristics of silages of different purpose sorghum cultivar.

Crop period	Cultivars						Mean
	Grain		Forage		Sweet		
	BRS 308	BRS 310	BRS 655	BRS 610	BRS 506	CMSXS 647	
	Dry matter (g 100 g^{-1} of DM)						
1st crop	26.91 abA	34.61 aA	24.72 bB	22.01 bcA	20.02 cB	16.46 dB	24.12
2nd crop	29.92 aA	31.99 aA	29.28 aA	24.58 bcA	25.09 bA	22.00 cA	27.14
Mean	21.42	33.30	27.00	23.30	22.55	19.23	
CV (%)							8.03
	Ammonia-N (g N-NH_3 100 g^{-1} of total N)						
1st crop	11.57 aA	7.81 bA	6.95 bA	6.36 bA	6.82 bA	6.73 bA	7.71 A
2nd crop	6.07 abB	8.87 aA	4.95 bA	8.45 aA	4.54 bA	5.48 bA	6.39 B
Mean	8.82	8.34	5.95	7.41	5.68	6.11	
CV (%)							9.06
	pH						
1st crop	3.97	4.07	3.91	3.92	3.92	3.80	3.93 A
2nd crop	3.85	3.92	3.81	3.73	3.78	3.62	3.78 B
Mean	3.91 b	4.00 a	3.86 b	3.82 b	3.85 b	3.71 c	
CV (%)							2.02
	D-WSC (g 100 g^{-1} of DM)						
1st crop	10.96 bcA	5.33 dA	9.56 cA	13.77 bA	31.50 aA	30.91 aA	17.01
2nd crop	10.68 cdA	7.51 dA	13.77 bcA	15.40 bA	21.73 aB	20.35 aB	14.91
Mean	10.82	6.42	11.67	14.59	26.62	25.63	
CV (%)							15.86

CV: Coefficient of variation. Means followed by the same capital letter in the column and by small letters in the row do not differ among themselves by LSD test ($p > 0.05$). D-WSC: difference in water soluble carbohydrate content between the forage and the silage.

Regarding silages of sweet sorghum cultivars, the lower DM content observed at the first crop than at the second crop may have been due to higher ethanol production (Table 4). The metabolism of WSC, during sugar fermentation and ethanol synthesis by yeast, may have been the cause of a decrease in the silage DM content, due to dry matter losses (AVILA et al., 2009). Pedroso et al. (2008), evaluating sugarcane silage, observed a reduction in DM content in silages with ethanol content of 4.05 % of DM.

The greater levels of WSC observed in the forage of sweet sorghum cultivars may be the cause of the higher ethanol production seen at the first crop in these cultivars than in the second crop. High concentrations of ethanol in the silage is mainly related to high WSC content. It is also affected by the yeast populations, which convert soluble sugars to ethanol, thus decreasing the WSC content of the conserved forage (CAVALI et al., 2010). Silva et al. (2008), when investigating the ethanol content in sugarcane silages that had been reconstituted with water to decrease the WSC content, observed that lower WSC content led to lower ethanol content in the finished silage. In the ensiling of sugarcane with a WSC content of about 41 %, these authors observed average ethanol content of about 15 % of DM.

Table 4. Content of organic acids and ethanol in silages of different purpose sorghum cultivars.

Crop period	Cultivars						Mean
	Grain		Forage		Sweet		
	BRS 308	BRS 310	BRS 655	BRS 610	BRS 506	CMSXS 647	
	Acetic acid (g 100 g^{-1} of DM)						
1st crop	0.65	0.60	0.86	0.92	1.26	1.47	0.96
2nd crop	0.78	1.02	1.05	1.45	0.97	1.11	1.06
Mean	0.72 c	0.81 bc	0.96 abc	1.18 a	1.11 ab	1.29 a	
CV (%)							34.05
	Propionic acid (g 100 g^{-1} of DM)						
1st crop	0.19 deA	0.15 eA	0.22 cdA	0.26 bcA	0.32 bA	0.41 aA	0.26
2nd crop	0.20 bA	0.18 bA	0.21 bA	0.24 abA	0.24 abB	0.30 aB	0.23
Mean	0.19	0.16	0.22	0.25	0.28	0.36	
CV (%)							18.18
	Butyric acid (g 100 g^{-1} of DM)						
1st crop	0.10 bA	0.10 bA	0.12 bA	0.09 bA	0.21 aA	0.27 aA	0.15
2nd crop	0.15 aA	0.15 aA	0.13 aA	0.16 aA	0.19 aA	0.18 aB	0.16
Mean	0.12	0.13	0.12	0.13	0.20	0.23	
CV (%)							31.91
	Ethanol (g 100 g^{-1} of DM)						
1st crop	0.64 bA	0.19 bA	0.55 bA	0.49 aA	6.22 aA	5.59 aA	2.28
2nd crop	0.14 aA	0.12 aA	0.14 aA	0.11 aA	0.12 aB	0.10 aB	0.12
Mean	0.39	0.15	0.34	0.30	3.17	2.85	
CV (%)							99.17

CV: Coefficient of variation. Means followed by the same capital letter in the column and by small letters in the row do not differ among themselves by LSD test ($p > 0.05$).

The values of acetic acid observed in the silages produced were lower than the maximum limits of 2.0 % of DM established by Roth and Undersander (1995) (Table 4). The acetic acid content is related to the lower rates of decrease and higher final pH values in the silages, corresponding mainly to the prolonged action of heterofermentative lactic acid bacteria and enterobacteria (MUCK; BOLSEN, 1991). Cattani et al. (2016) evaluated the silage produced from different sorghum cultivars and found a higher content of acetic acid in sweet sorghum in comparison to grain sorghum, with average values of 2.04 and 1.75 % of DM, respectively, with a similar response pattern to what was observed in this work.

The same response pattern to that of acetic acid content was obtained for propionic acid content (Table 4). Sorghum cultivars with lower DM content produced higher levels of propionic acid, possibly due to the more vigorous fermentations.

Despite the differences in acid content, no sorghum cultivar had propionic acid content higher than the maximum recommended of 0.5 % of DM (ROTH; UNDERSANDER, 1995). According to Pinho et al. (2015), lower levels for these acids are associated with the rapid acidification of the medium, due to its susceptibility to low pH values.

The elevated levels of butyric acid in the silages produced from the sweet sorghum cultivar CMSXS 647 at the first crop, were possibly due to the lower DM content observed in the forage of these cultivars. The butyric acid content reflects the extent of the *Clostridium* bacterial activity on ensiled forage, and is one of the main negative indicators of the fermentation process quality, with a recommended maximum value of 0.2 % of DM (MCDONALD et al., 1991). This value was surpassed by the sweet sorghum cultivars in the first crop. *Clostridium* bacteria are sensitive to low water activity, therefore their performance is higher in conditions of low DM. Machado et al. (2012), studying the quality of forage sorghum hybrids silage, noted good fermentation in the ensiled mass, with average values of acetic acid between 0.53 and 1.45 %, similar to those observed in this study, and butyric acid between 0.00 and 0.06 %, lower than those observed in this study.

It is suggested that there was a higher use of soluble carbohydrates, due to the alcoholic fermentation, which explains the greater difference in the content of WSC between the forage and the silage found in the cultivars of sweet sorghum in the first crop than in the second crop (Table 3). Similarly, the higher content of acetic and propionic acid in sweet sorghum silages, and in forage sorghum cultivar BRS 610, may have influenced the greater consumption of WSC inside the silo, when compared to other cultivars.

In sugarcane ensiling, the intense yeast activity promotes the conversion of soluble sugars to ethanol, carbon dioxide, and water. This can cause up to 70 % reductions in WSC content, as well as increasing cell wall fraction and DM losses (PEDROSO et al., 2008). In this study, the sweet sorghum ensiling at the first crop had a similar behaviour to that of sugarcane, possibly due to the high WSC content in the forage. Thus, the use of sweet sorghum for silage, at the first crop, may be associated with alcoholic fermentation, high ethanol production, and high WSC consumption. This increment DM losses in the silo, increasing the content of fibre and decreasing the digestibility of the silage produced.

Conclusions

Based on the fermentation characteristics, all evaluated sorghum cultivars are suitable for silage production. However, the ensiling of sweet sorghum at the first crop produces elevated levels of ethanol and butyric acid, so its use is recommended at the second crop.

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