Ciência Rural, Santa Maria, v.45, n.2, p.298-303, fev, 2015 http://dx.doi.org/10.1590/0103-8478cr20131532
ISSN 0103-8478

Sorghum cultivars of different purposes silage

Cultivares de sorgo para silagem de diferentes propósitos

Ricardo Martins Araujo Pinho[I*] Edson Mauro Santos[I] Juliana Silva de Oliveira[I] Higor Fábio Carvalho Bezerra[I] Poliane Meire Dias de Freitas[II] Alexandre Fernandes Perazzo[II] Rosângela Claurenia da Silva Ramos[I] Ana Paula Gomes da Silva[I]

ABSTRACT

*This study aimed to assess the fermentation profile, losses and chemical composition of the silages of five sorghum cultivars. A completely randomized design with five replicates was used. The experimental treatments were represented by five sorghum cultivars (**Sorghum bicolor** (L). Moench): 'BRS Ponta Negra', 'BRS 610', 'BRS 655', 'BRS 800' and 'BRS 810'. There was variation (P<0.05) for the pH in the cultivars studied, with highest result of pH by 'BRS 610'. The average percentages of lactic acid, acetic acid and propionic acid, differed (P<0.05) among the cultivars, ranging from 32.9 to 59.5, 19.8 to 39.8, and 0.0 to 1.3g kg^{-1}, respectively. The dry matter recovery varied among cultivars (P<0.05), allowing the identification of BRS Ponta Negra, and 'BRS 810' silages, as those which recovered the lowest dry matter, with values of 757.1 and 776.1g kg^{-1}, respectively. There were differences (P<0.05) for dry matter, crude protein, ether extract, neutral detergent fiber, non-fibrous carbohydrates and total carbohydrates contents among the cultivars. It was concluded that, despite the morphological and chemical differences among cultivars, the resulting silages had good fermentation profile.*

Key words: *conservation, ensilage, quality, **Sorghum bicolor**.*

RESUMO

*Objetivou-se com este estudo avaliar o perfil fermentativo, perdas e a composição bromatológica de silagens de cinco cultivares de sorgo. Foi utilizado um delineamento experimental inteiramente casualizado com cinco repetições. Os tratamentos experimentais foram representados por cinco cultivares de sorgo (**Sorghum bicolor** (L). Moench): 'BRS Ponta Negra', 'BRS 610', 'BRS 655', 'BRS 800' e 'BRS 810'. Houve variação (P<0,05) para o pH nos genótipos estudados, com maior resultado para o genótipo 'BRS 610'. Os valores médios de ácido lático, ácido acético e ácido propiônico, diferiram entre as cultivares (P<0,05), variando de 32,9 a 59,5; 19,8 a 39,8; e 0,0 a 1.3g kg^{-1}, respectivamente. A recuperação de matéria seca variou entre as cultivares (P<0,05), em que as silagens dos cultivares 'BRS Ponta Negra' e 'BRS 810', é que tiveram menor recuperação de matéria seca, com valores de 757,1 e 776,1g kg^{-1}, respectivamente. Houve diferença (P<0,05) para teores de matéria seca, proteína bruta, extrato etéreo, fibra em detergente neutro, carboidratos não-fibrosos e carboidratos totais entre as cultivares. Conclui-se que, apesar das diferenças morfológicas e químicas entre as cultivares, as silagens resultantes tinham adequado padrão de fermentação.*

Palavras-chave: *conservação, ensilagem, qualidade, **Sorghum bicolor**.*

INTRODUCTION

Among the advantages of using sorghum, these are highlighted: high dry matter yield in relation to other grasses and the possibility of use regrowth. Moreover, sorghum can be considered as a plant with xerophilous characteristics, low soil fertility requirements and resistant/tolerant to drought and salinity.

Choosing the most appropriate genotype is fundamental in establishing a more efficient production system. The efficiency in selecting genetic material can be enhanced by observing a set of information for the crop within each region. Among the features to be evaluated, the characteristics of silages produced from plants of different cultivars are very important, since the efficiency of the fermentation during ensiling determines the percentage of dry matter recovered and the nutritional value of the produced

[I]Centro de Ciências Agrárias, Universidade Federal da Paraiba (UFPB), 58397-000, Areia, PB, Brasil. E-mail:ricardo-zootec@hotmail.com. *Corresponding author.
[II]Universidade Federal da Bahia (UFBA), Salvador, BA, Brasil.
Received 11.15.13 Approved 05.29.14 Returned by the autor 09.18.14
CR-2013-1532.R2

silage. Therefore, the evaluation of sorghum cultivars is especially important in the Brazilian northeast, where half of the region, classified as semiarid, is under the influence of adverse factors, some of which the sorghum is adapted to.

Based on the above, studies to evaluate the adaptability of sorghum cultivars, as well as the conservation potential in silage form, should be done in order to determine the genotypes that can be cultivated in production systems in the semiarid region.

Forage sorghum has more sugar content than other purpose sorghum owing to higher stem than other parts of plant (SILVA et al., 2011a). In spite of being more productive, when ensiled losses may occur, since yeast can develop into the silo. Thus, it is very important to evaluate not so agronomic characteristics but also losses and fermentation profile of silages, to indicate the more appropriate purpose sorghum for a given production system.

Thus, the objective was to evaluate losses, fermentation profile and chemical composition of silages of five sorghum cultivars of different purpose.

MATERIAL AND METHODS

The soil in the experimental area had the following chemical attributes (profile from 0-20cm): pH: 6.94; P: 70.38; K^+: 82 (mg dm^{-3}), Na^+: 0.37; $H^+ + Al^{+3}$: 2.06; Al^{+3}: 0.0; Ca^{+2}: 7.45; Mg^{+2}: 2.40 (cmolc dm^{-3}); base saturation: 83.51% and organic matter: 10.55g kg^{-1}. Fertilization was conducted with 50kg ha^{-1} of nitrogen, in the form of ammonium sulfate, 15 days after emergence (DAE).

The experimental area measured 0.5ha, totaling 0.1ha for each variety of sorghum, distributed in a completely randomized block, with four blocks. The spacing of 0.7m between rows was used and a seeding rate of 12 seeds per meter. A completely randomized design with five replicates was used for silages evaluation, once material of all blocks of each treatment was mixed, thus silos were considered the replicates. The experimental treatments were represented by five sorghum cultivars (***Sorghum bicolor*** (L). Moench): 'BRS Ponta Negra', 'BRS 610', 'BRS 655', 'BRS 800', 'BRS 810', with seeds provided by the *Empresa Brasileira de Pesquisa Agropecuária – Embrapa Milho e Sorgo*.

The cultivars 'BRS 810' and 'BRS Ponta Negra' have more forage characteristics; the cultivar 'BRS 610' has dual purpose characteristics; and the cultivars 'BRS 655' and 'BRS 800' have grain sorghum characteristics (Table 1).

The harvest was done manually, and the material was transported in oxcart, when the grains were in milky: pasty stage. For ensiling, plastic buckets of 15L were used – equipped with Bunsen valves for gas exhausting with 4kg of sand at the bottom to catch the effluent. The compression was performed by treading. After 40 days of ensiling, the silos were opened, and the upper and lower portions (5cm) were discarded; of the rest, 300g was taken for laboratory tests together with a composite sample of plants, obtained after chopping.

The agronomic characterization of the sorghum cultivars was conducted through sampling a linear meter at five different spots in the experimental area of each cultivar evaluated, totaling five repetitions. The plants of each linear meter were weighed to determine the yield per linear meter. This weight was multiplied by the total linear meters in a hectare, to determine green matter yield per hectare. Two plants per linear meter were randomly selected for separation into components: leaf, stem, panicle and dead material. The remaining plants were chopped in a stationary machine and, together with samples of plant components, were pre-dried in a forced ventilation oven at 65ºC until they reached constant weight, later to determine the dry matter content. The green matter yield was converted into dry matter yield, and the percentage of the plant components were expressed, based on

Table 1 - Dry matter yield, morphological components and leaf/stem ratio of forage crops harvested at the time of ensiling, based on dry matter.

Cultivars	DMY	Panicle	Leave	Stem	Dead Material	leaf/stem
	kg ha^{-1}	---------- kg $100kg^{-1}$ ----------				
'BRS 810'	18516.90	12.48	7.41	77.00	3.11	0.10
'BRS 800'	9198.65	26.53	13.57	57.16	2.74	0.24
'BRS 655'	11450.47	29.34	7.93	60.20	2.52	0.16
'BRS Ponta Negra'	17799.59	9.37	13.15	72.07	5.41	0.18
'BRS 610'	16144.22	23.20	15.31	53.41	7.99	0.30
CV^2 (%)		37.37	20.90	14.20	65.92	40.37

the dry matter of each component. The results are shown in table 1.

The chemical components evaluated were: dry matter (DM), crude protein (CP), ether extract (EE), organic matter (OM), mineral matter (MM), according to SILVA & QUEIROZ (2002) and FDNcp through the method of VAN SOEST et al. (1991) with adjustments proposed by the Ankon manual (Ankon® Technology Corp.).

A central portion was homogenized in order to proceed to withdraw a sample of about 200g to determine pH and ammonium nitrogen, according to BOLSEN et al. (1992). For the analysis of organic acids, 10g of sample were mixed on an industrial blender with 90ml of distilled water and filtered on a Whatman filter paper type (KUNG & RANJIT JR., 2001). Losses by gases and effluents and dry matter recovery (DMR) were calculated through equations described by SANTOS et al. (2008).

The data were submitted to analysis of variance and the averages were compared by the Scott-Knott test at 0.05 level of probability, using the Statistical Analysis System SAS (SAS INSTITUTE, 2000).

RESULTS AND DISCUSSION

There was variation ($P<0.05$) for the pH in the cultivars studied (Table 2). Values were generally below the values recommended by McDONALD et al. (1991), which is 4.0. This indicates that the fermentation was intense, probably due to high concentrations of water soluble carbohydrates (WSC) in the plants (Table 3).

The average percentages of lactic acid (LA) varied ($P<0.05$) among cultivars. 'BRS Ponta Negra' silages had higher ($P<0.05$) content of lactic acid, 59.5g kg^{-1}, expected result, since this cultivar had higher WSC content (Table 3) and allowed greater fermentation by lactic acid bacteria. On the other hand, 'BRS 655' and 'BRS 610' silages presented lower ($P<0.05$) content of lactic acid, 43.8 and 43.7g kg^{-1}, respectively. These cultivars before ensiling had lower contents of WSC, 125.8 and 133.5g kg^{-1}, respectively, resulting in higher pH values. However, pH and amount of acid lactic are influenced by the content of WSC sorghum. Soluble carbohydrates are major substrates for lactic acid fermentation, who in turn allows pH drop. Due to the different concentrations of WSC for the cultivars variation was observed in the fermentation process (Table 3). Evaluating same cultivars 'BRS 610' and 'BRS 655' FILYA & KARABULUT (2004) and FRANÇA et al. (2011) found values close, but lower than those found by MACHADO et al. (2012). In general the average observed among cultivars under study, 45.92g kg^{-1} of LA, are considered satisfactory according to McDONALD et al. (1991), to ensure appropriate fermentation.

For the average values of acetic acid (AA) there was difference ($P<0.05$) among the cultivars. 'BRS 800' silage presented higher content, 39.8g kg^{-1} and 'BRS Ponta Negra' lower content, 19.8g kg^{-1}. According to McDONALD et al. (1991), high acetic acid production is indicative of enterobacteria action which occurs during to the initial phases of the silage fermentation competing with lactic acid bacteria for nutrients. On the other hand, that acetic acid production can be occur though heterofermentative acid lactic bacteria which to the use pentoses as substrate produce one molecule of lactic acid and one molecule of acetic acid, thus contributing to the fast acidification of the medium (ROTH & UNDERSANDER, 1995). Furthermore acetic acid is highly effective antifungical agent that improve the aerobic stability of silages (KUNG Jr. et al., 2003).

Table 2 - Average values of lactic acid (LA), acetic acid (AA), butyric acid (BA), propionic acid (PA), ammoniacal nitrogen in ratio total nitrogen and pH of silages from sorghum cultivars.

Cultivars	LA	AA	BA	PA	N-NH_3/NT	pH
	----------	----------	g kg^{-1}	----------	----------	
'BRS 810'	32.9d	28.0c	1.1	0.1d	32.5	3.08b
'BRS 800'	49.7b	39.8a	1.0	1.1b	33.5	3.00b
'BRS 655'	43.8c	31.8b	1.0	1.3a	32.2	3.12b
'BRS Ponta Negra'	59.5a	19.8d	1.1	0.0d	28.5	3.02b
'BRS 610'	43.7c	27.6c	1.1	0.9c	30.5	3.44a
CV[2] (%)	6.23	3.84	14.60	13.93	20.41	6.68

[1]Averages followed by the different letter in the column differ by the Scott-Knott test at 0.05 probability.
[2]CV: Coefficient of variation.

Table 3 - Dry matter (DM) values of the silages, dry matter recovery (DMR), losses by effluents (LE), losses by gases (LG), water soluble carbohydrates from the plant (WSC) and water soluble carbohydrates of the silage (WSCs) of different cultivars of sorghum.

Cultivars	DM	DMR	LG	WSC	WSCs	LE
	-------------------	-------------------	g kg^{-1}	-------------------	-------------------	kg Mg^{-1}
'BRS 810'	211.3b	776.1b	39.7	190.5	25.9	12.48b
'BRS 800'	215.0b	895.8a	40.0	136.5	26.5	22.54[a]
'BRS 655'	231.7a	904.0a	40.3	125.8	25.0	8.91b
'BRS Ponta Negra'	208.2b	757.1b	44.8	205.9	27.3	9.32b
'BRS 610'	233.5a	822.8a	49.4	133.5	28.5	5.84b
CV (%)	3.98	4.24	45.81	-	13.11	45.54

[1]Averages followed by the different letter in the column differ by Scott-Knott test at 0.05 probability
[2]CV: Coefficient of variation.

There was no difference (P>0.05) among the cultivars for butiric acid, however there effect (P<0.05) for propionic acid (Table 3). The lower contents for these acids are associated with fast acidification of the medium due to their susceptibility to low pH. Therefore in silages with good fermentation is common to find minimum values for them, which was also observed by FRANÇA et al. (2011) and MACHADO et al. (2012).

The DMR varied among cultivars (P<0.05), allowing the identification of silages of Ponta Negra and 'BRS 810' as those which recovered the lowest dry matter, 757.1 and 775.1g kg^{-1}, respectively (Table 3). The other silages were similar to each other with higher values. These results are very important to be analyzed, because demonstrated that high amount of silage can be lost in forage purpose sorghum. In spite of 'BRS Ponta Negra' and 'BRS 810' being more productive, losses were very high, so that dry matter yield must be adjusted for these losses values. Although the dry matter contents of the silages were not high or lower than 300g kg^{-1} these not disfavored the fermentation process because the pH values of all silages were lower than 4.0.

On the other hand, when the content of WSC from the plant is high, which results in low pH values, the development of yeasts during fermentation may occur, resulting in production of ethanol or even bacteria which convert lactic acid into acetic acid (OUDE ELFERINK et al., 2001). The alcoholic fermentation leads to increased losses, because for each mole of fermented glucose, two molecules of CO_2 are formed and lost in gaseous form, besides the ethanol which is a volatile organic compound.

Observing the values of residual soluble carbohydrates of the silages, it is noted that all silages had the same amount of residual sugar, so those with more sugars in the plant lost more sugars in the fermentation process, leading to losses of DM, probably for production of ethanol.

There were differences (P<0.05) among cultivars for the percentage of DM, which could compromise the quality of silage, because values below 210g kg^{-1} present a higher probability of undesirable secondary fermentations, damaging the quality of silage. However, for the studied cultivars, the pH values were all low, which leads to very acid silages, suggesting that the percentage of dry matter did not favor the development of clostridia and enterobacteria, which require mediums with high water activity (McDONALD et al., 1991) and pH above 5.0, respectively (SANTOS et al., 2013). This proves that there is a relationship between the percentage of dry matter to be ensiled and the amount of soluble carbohydrates, as demonstrated by SILVA et al. (2011b). Otherwise, that low dry matter content had promoted development of undesirable microorganisms the use of moisture absorbents additives would be indicated for to control secondary fermentations.

The crude protein contents (Table 4) differed (P<0.05), approaching the minimum values of 49.1 and 69.4g kg^{-1} of the rate considered adequate for the functioning of ruminal microbiota (VAN SOEST, 1994), confirmed in tropical conditions by LAZZARINI et al. (2009). Anyway, crude protein in sorghum silages is below of value cited above, since sorghum is forage. 'BRS Ponta Negra' silage presented lower crude protein content, 49.1g kg^{-1}. This cultivar was more productive (Table 1), however, result in silages with lower crude protein content and high losses. This information must be concern to decide about its use for silage, once costs with protein concentrate will be elevated as compared to the other cultivars.

The levels of EE and NDF differed (P<0.05) among 'BRS Ponta Negra', 'BRS 610' and 'BRS 655', with higher percentages of NDF, and

Table 4 - Average contents crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), organic matter (OM), ash (MM), non-fibrous carbohydrates (NFC) and total carbohydrates (TC) of sorghum silages

Cultivars	CP	EE	NDF	OM	MM
	------	------	g kg^{-1}	------	------
'BRS 810'	64.1a	69.0a	629.8c	925.2b	74.7a
'BRS 800'	62.6a	40.3b	649.2c	914.0b	86.0a
'BRS 655'	69.4a	36.1b	671.6b	907.0b	92.9a
'BRS Ponta Negra'	49.1b	31.1b	710.5a	966.5a	33.5b
'BRS 610'	54.1b	37.8b	673.7b	909.6b	90.4a
[2]CV (%)	11.04	21.62	2.86	1.49	18.24

[1]Averages followed by the different letter in the column differ by Scott-Knott test at 0.05 probability.
[2]CV - coefficient of variation.

between 'BRS 800' and 'BRS 810' with lower values, which may contribute to the increased dry matter consumption. The increased levels of fiber for the first three cultivars can be explained from the fact that they have forage characteristics. For EE, the opposite occurred: the cultivars that had lower NDF contents, consequently showed higher levels of EE.

It was noted that the chemical compositions of sorghum silages follow their morphological characteristics, that is, the taller and more fodder plant allows for a silage with more fiber content, lower ether extract, less protein, but higher amount of carbohydrates than the less fodder plants which, on the other hand, because they contain more panicles, have higher levels of protein and ether extract.

CONCLUSION

It is concluded that, despite the morphological and chemical differences among cultivars, the resulting silages had high lactic fermentation. The cultivars 'BRS 810', 'BRS Ponta Negra' and 'BRS 610' stood out in relation to the others. Nevertheless, more studies are needed to understand better the fermentation process of forage sorghum silages with higher concentration of sugars and to develop techniques for control of DM losses, to allow farms to explore their higher productive potential.

REFERENCES

BOLSEN, K.K. et al. Effect of silage additives on the microbial succession and fermentation process of alfalfa and corn silages. **Journal of Dairy Science**, v.75, p.3066-3083, 1992. Available from: <http://www.sciencedirect.com/science/article/pii/S0022030292780709>. Accessed: Jun. 18, 2013.

FILYA, I. Nutritive value and aerobic stability of whole crop maize silage harvested at four stages of maturity. **Animal Feed Science and Technology**, v.116, p.141-150, 2004. Available from: <http://www.animalfeedscience.com/article/S0377-8401(04)00123-3/pdf>. Accessed: Jun. 08, 2013.

FRANÇA, A.F.S. et al. Características fermentativas da silagem de híbridos de sorgo sob doses de nitrogênio. **Ciência Animal Brasileira**, v.12, n.3, p.383-391, 2011. Available from: <http://www.revistas.ufg.br/index.php/vet/article/view/540>. Accessed: Jan. 13, 2013.

KUNG JR. L., RANJIT, N.K. The effect of ***Lactobacillus buchneri*** and other additives on the fermentation and aerobic stability of barley silage. **Journal of Dairy Science**, v.84, n.5, p.1149-1155, 2001. Available from: <www.agroteam.it/index.aspx?m=81&f=3&idf=118>. Accessed: May 13, 2013.

KUNG JR. L. et al. The effect of treating alfalfa with Lactobacillus buchneri 40788 on silage fermentation, aerobic stability, and nutritive value for lactating dairy cows. **Journal of Dairy Science**, v.86, n.1, p.336-343, 2003. Available from: <http://www.sciencedirect.com/science/article/pii/S002203020373611X>. Accessed: May 13, 2014.

LAZZARINI, I. et al. Intake and digestibility in cattle fed low-quality tropical forage and supplemented with nitrogenous compounds. **Revista Brasileira de Zootecnia**, v.38, n.10, p.2021-2030, 2009 Available from: <http://www.scielo.br/pdf/rbz/v38n10/24.pdf>. Accessed: Aug. 03, 2013.

MACHADO, F.S. et al. Qualidade da silagem de híbridos de sorgo em diferentes estádios de maturação. **Medicina Veterinária e Zootecnia**, v.64, n.3, p.711-720, 2012. Available from: <http://www.scielo.br/pdf/abmvz/v64n3/24.pdf>. Accessed: May 13, 2013.

McDONALD, P. et al. **The bochemistry of silage**. 2.ed. Marlow: Chalcombe, 1991. 340p

OUDE ELFERINK, S.J.W.H. et al. Anaerobic conversion of lactic acid to acetic acid and 1,2- propanediol by ***Lactobacillus buchneri***. **Applied Environmental Microbiology**, v.67, p.125-132, 2001. Available from: <http://aem.asm.org/content/67/1/125.short>. Accessed: Mar. 01, 2014.

ROTH, G.; UNDERSANDER, D. Silage additives. In: **Corn silage production management and feeding**. Madison: Madison American Society of Agronomy, 1995. p.27-29.

SANTOS, E.M. et al. Composição bromatológica, perdas e perfil fermentativo de silagens de capim-elefante com níveis de inclusão de jaca. **Revista Brasileira de Saúde e Produção Animal**, v.9, n.1, p.64-73, 2008. Available from: <http://revistas.ufba.br/index.php/rbspa/article/view/872/562>. Accessed: Jun. 13, 2013.

SANTOS, E.M. et al. **Lactic acid bacteria in tropical grass silages, lactic acid bacteria** - R & D for food, health and livestock purposes, Dr. J. Marcelino Kongo (Ed.). ISBN: 978-953-51-0955-6, In Tech.

Available from: <http://cdn.intechopen.com/pdfs/42321 /InTech_Lactic_acid_bacteria_in_tropical_grass_silages.pdf>. Accessed: Jun. 17, 2013. doi: 10.5772/50703.

SILVA, D.J., QUEIROZ, A.C. **Análise de alimentos**: métodos químicos e biológicos. Viçosa: Universidade Federal de Viçosa, 2002. 165p.

SILVA, T.C. et al. Agronomic divergence of Sorghum hybrids for silage yield in the semiarid region of Paraiba. **Revista Brasileira de Zootecnia**, v.40, n.9, p.1886-1893, 2011a. Available from: <http://www.scielo.br/pdf/rbz/v40n9/a07v40n9.pdf>. Accessed: Jan. 08, 2013.

SILVA, T.C. et al. Populações microbianas, perfil fermentativo e composição de silagens de capim-elefante com jaca. **Archivos de Zootecnia**, v.60, n.230, p.253, 2011b**.** Available from: <http://scielo.isciii.es/pdf/azoo/v60n230/art9.pdf>. Accessed: Jul. 30, 2013.

STATISTICAL ANALYSES SYSTEM – SAS. SAS/STAT User's guide. Cary: 2000. 1028p.

VAN SOEST, P.J. **Nutritional ecology of the ruminant**. 2.ed. Ithaca: Cornell University, 1994. 476p. Available from: <http://www.cornellpress.cornell.edu/book/?GCOI=80140100037050>. Accessed: Jul. 30, 2013.

VAN SOEST, P.J. et al. Symposium: carbohydrate methodology, metabolism, and nutritional implications in dairy cattle. **Journal of Dairy Science**, v.74, p.3583-3597, 1991. Available from: <http://webpages.icav.up.pt/ptdc/CVT/098487/2008/Van%20Soest,%201991.pdf>. Accessed: Feb. 14, 2013.