BIOMASS SORGHUM SILAGES WITH SUGARCANE

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ABSTRACT

The storage of forage to be offered at different times of the year are viable alternatives for all production systems, and sorghum biomass has been highlighted for this purpose. As preserved forage, it was hypothesized that sugarcane can contribute to the fermentation process. The objective was to evaluate the inclusion of different levels of sugarcane (0, 20, 40 and 60%) in the silage of three biomass sorghum genotypes (B012, B017 and B018). The material was ensiled using PVC silos and after 60 days the silos were opened and the contents of dry matter, mineral matter, organic matter, crude protein, neutral detergent fiber, acid detergent fiber, hemicellulose, lignin, and hydrogen potential were determined. The experiment was conducted in a completely randomized design, in a factorial scheme with four replications. The data were analyzed through the analysis of variance followed by multiple comparison by Tukey's test ($\alpha < 0.05$) and linear regression. The biomass sorghum genotypes responded satisfactorily to the fermentation process, resulting in quality silages. However, the inclusion of sugarcane did not improve the quality of the silages, and its inclusion in the silage of the genotypes evaluated is not recommended.

Keywords: alternative food, genotypes, nutritional composition, shortage

SILAGEM DE SORGO BIOMASSA COM CANA-DE-AÇÚCAR

RESUMO

O armazenamento de forragem a ser ofertada em diferentes épocas do ano são alternativas viáveis para todos os sistemas de produção, e a biomassa de sorgo tem se destacado para este fim. Como forragem preservada, levantou-se a hipótese de que a cana-de-açúcar pode contribuir para o processo de fermentação. O objetivo foi avaliar a inclusão de diferentes níveis de cana-de-açúcar (0, 20, 40 e 60%) na silagem de três genótipos de sorgo biomassa (B012, B017 e B018). O material foi ensilado em silos de PVC e após 60 dias foram abertos e determinados os teores de matéria seca, matéria mineral, matéria orgânica, proteína bruta, fibra em detergente neutro, fibra em detergente ácido, hemicelulose, lignina e potencial de hidrogênio. O experimento foi conduzido em delineamento inteiramente casualizado, em esquema fatorial com quatro repetições. Os dados foram analisados por meio da análise de variância seguida de comparação múltipla pelo teste de Tukey ($\alpha < 0{,}05$) e regressão linear. Os genótipos de sorgo biomassa responderam satisfatoriamente ao processo de fermentação,

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resultando em silagens de qualidade. No entanto, a inclusão da cana-de-açúcar não melhorou a qualidade das silagens, não sendo recomendada sua inclusão na silagem dos genótipos avaliados.

Palavras-chave: alimentos alternativos, composição nutricional, escassez, genótipos

ENSILAJE DE SORGO BIOMASA CON CAÑA DE AZÚCAR

RESUMEN

Los acopios de forrajes para ser ofrecidos en diferentes épocas del año son alternativas viables para todos los sistemas de producción, y para ello se ha destacado la biomasa de sorgo. Como forraje conservado, se planteó la hipótesis de que la caña de azúcar puede contribuir al proceso de fermentación. El objetivo fue evaluar la inclusión de diferentes niveles de caña de azúcar (0, 20, 40 y 60%) en el ensilaje de tres genotipos de sorgo de biomasa (B012, B017 y B018). El material se ensiló en silos de PVC y después de 60 días se abrieron los silos y se determinaron los contenidos de materia seca, materia mineral, materia orgánica, proteína cruda, fibra detergente neutro, fibra detergente ácido, hemicelulosa, lignina y potencial de hidrógeno. El experimento se condujo en un diseño completamente al azar, en un esquema factorial con cuatro repeticiones. Los datos fueron analizados a través del análisis de varianza seguido de comparación múltiple por la prueba de Tukey ($\alpha < 0{,}05$) y regresión lineal. Los genotipos de sorgo de biomasa respondieron satisfactoriamente al proceso de fermentación, dando como resultado ensilajes de calidad. Sin embargo, la inclusión de caña de azúcar no mejoró la calidad de los ensilajes, por lo que no se recomienda su inclusión en los ensilajes de los genotipos evaluados.

Palabras clave: alimentos alternativos, composición nutricional, escasez, genótipos

INTRODUCTION

In tropical countries, cattle production systems are predominantly on pasture, and the study of forage plants becomes rather relevant (1). However, seasonal forage production is one of the main factors that limits animal performance (2). Seasonality impairs the uniform development of forage plants throughout the year, resulting in periods of forage abundance, in contrast to periods of food shortage associated with the reduction of their nutritional value (3). In order to mitigate the instability of forage production, silage stands out as one of the main strategies used to store roughage so that they can be supplied in periods of shortage (4; 5).

Biomass sorghum (*Sorghum bicolor* [L.] Moench) stands out for its potential to produce a large amount of green mass, about 50 t ha^{-1} of dry matter (DM) per cycle that lasts an average of six months, tall structure and fibrous culm. It has a high capacity to adapt to tropical and temperate climates. It is tolerant to drought, efficient in the use of water and high potential for the production of lignocellulosic biomass (6). The characteristics of sorghum biomass make it a fully mechanized crop, from sowing to harvest. Sowing occurs in the spring, as it coincides with the beginning of the rainy season, while the harvest occurs during the inter-crop period of sugarcane (7). Biomass sorghum is a promising crop, due to its qualitative and quantitative characteristics in the supply of raw material for the production of cellulosic ethanol and cogeneration of energy through the burning of biomass for its high lignin values, also known as second-generation biofuel energy (7; 8).

Given the context, biomass sorghum can be an alternative of roughage for supplementation in the period of food shortage, and it can also be used in the feeding of ruminants throughout the year. Despite being considered a promising alternative of forage for animal feeding, the biomass sorghum genotypes are not available for commercialization, as they are still undergoing tests to prove the potential use in the feeding of ruminants.

In order to improve the nutritional quality of biomass sorghum, additives are included to the forage at the time of ensiling, which can be composed by acids, salts, fermentable carbohydrates or lactic bacterial culture, besides enzymes. In addition, the additives have the purpose of influencing the fermentation process and help the food preservation (9). However, it is important to remember that the use of additives does not eliminate daily care to obtain a good silage, such as the adequate cutting season, the compaction of forage and the silo sealing (10).

Thus, the use of sugarcane in the diet of ruminants has been justified by its easy cultivation, high energy production and low cost of dry matter produced per unit of cultivated area. In addition, its harvest period coincides to the shortage of forage and the maintenance of nutritional value for a long time after maturation (11; 12). However, the biggest limitation of sugarcane ensilage is the high production of ethanol. The ensiled material presents a fast proliferation of yeasts that, in anaerobiosis, ferment carbohydrates and produce ethanol (13; 14). On the other hand, the presence of ethanol can reduce the consumption of silage by animals and increase losses due to its volatilization (15).

In times and/or places where water restriction exists, sorghum silage with sugar cane, when available, can be an alternative (16) guaranteeing roughage food for the animals in number. Therefore, the objective of this study was to evaluate the inclusion of different levels of sugarcane (0, 20, 40 and 60%) in three sorghum biomass genotypes (B012, B017 and B018) in silage production.

MATERIAL AND METHODS

Acquisition of ensiled material

The biomass sorghum genotypes (*Sorghum bicolor* [L.] Moench) were sown, cultivated and managed at the Empresa Brasileira de Pesquisa Agropecuária (Embrapa) Milho e Sorgo, located in Sete Lagoas, in the state of Minas Gerais, Brazil. Embrapa is located in the rural area of Sete Lagoas, with geographic coordinates 19°28' south latitude and longitude 44°15'08" W GrW and an altitude of 732 meters. The sugarcane (*Saccharum officinarum* L.) was supplied by Fazenda Resplendor, located in Datas – Minas Gerais, Brazil, with geographic coordinates 18°32' south latitude and longitude 43°38' west Cwb and 1130 meters of altitude.

The biomass sorghum genotypes were cut close to the soil, presenting average height and green matter production of 3.04 centimeters and 56.95 tons per hectare, respectively. The next day after cutting, the sorghum and sugar cane genotypes were properly identified and transported to the Federal University of the Jequitinhonha and Mucuri Valleys (UFVJM), Campus JK, Diamantina - Minas Gerais, Brazil, for tests and laboratory analyzes.

Experimental trial

An experimental trial was conducted at the Animal Science Department in UFVJM. The experiment was performed on a completely randomized design in a 3x4 factorial scheme in which three biomass sorghum genotypes (B012, B017 and B018) and four levels of sugar cane inclusion (0, 20, 40 and 60%) were evaluated with four replications.

Silage

The material to be ensiled was previously cut into particles measuring between 1.0 and 2.0 centimeters (cm), using a previously regulated mincer, brand Nogueira, model EN1146600. The chopped material was weighed on an electronic bench scale, brand SCOUT, model SJX6201BR/E, with an accuracy of 0.01 g and stored in experimental silos. Before the ensiling, a 500-gram sample of the material was collected in order to evaluate the chemical-bromatological composition of the ensiled material (Table I).

Table I. Average values of chemical-bromatological composition of the three genotypes of sorghum biomass and sugarcane before ensiling (fresh material)

Treatment	%DM	%MM	%OM	%CP	%NDF	%ADF	%HEM	%LIG
Sugarcane	25,24	1,82	98,18	2,7	33,30	17,47	15,83	4,4
B012	31,28	5,68	94,32	3,6	54,12	26,36	27,76	4,9
B017	28,9	5,76	94,24	4,3	58,18	29,01	29,17	6,0
B018	29,6	4,94	95,06	3,6	50,08	24,49	25,60	4,4

DM: dry matter; MM: mineral matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; HEM: hemicellulose; LIG: lignin.

The experimental silos were made with PVC with 100 mm of diameter and 450 mm in length, giving a density of 500 kg/m³. The ensiling process of sorghum and sugar cane was carried out shortly after being chopped. The material was compacted manually, with the aid of wooden sockets, to expel oxygen from the ensiled material.

After filling the silos, they were sealed with PVC caps provided with Bunsen-type valves, and subsequently sealed with adhesive tape and identified. The experimental silos were organized randomly and remained sealed for 60 days, protected from indirect sunlight and humidity.

Laboratory Analysis

After opening the silos, the material was homogenized, and 350g of the material from each silo was pressed using a hydraulic press, brand Reinalab, model TE-097, for the extraction of the silage juice to determine the hydrogen potential (pH), using a Tecnopon mPA 21 potentiometer with expanded scale. Another 500-gram sample of silage was collected and then pre-dried in a forced ventilation oven at 55°C for 72 hours (17). Then, the samples were ground in a Wiley mill, which had a 1mm sieve (17), and placed in previously identified plastic bags for further laboratory analysis.

The chemical-bromatological analysis of both the material before ensiling (Table I) and the silages referring to the contents of dry matter (DM), mineral matter (MM) and crude protein (CP) were carried out according to (17) and the content of organic matter (OM) was obtained by difference (% OM = 100 - MM). The components of the cell wall, neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM) and lignin (LIG) were measured sequentially by the method proposed by (18).

Statistical analysis

The statistical analyzes were conducted using the software R (19), always adopting a level of 5% of significance. The data were subjected to analysis of variance (ANOVA), using the following statistical model:

$$\mathbf{Y_{ijk} = \mu + G_i + C_j + (GC)_{ij} + \varepsilon_{ijk}},$$

which Y_{ijk} is the observed value for the variable response in its k-th repetition of the combination of the i-th genotype of biomass sorghum with the j-th level of inclusion of sugarcane, μ is the general average, G_i is the effect of the i-th genotype of biomass sorghum (G = B012, B017 and B018), C_j is the effect of the j-th level of inclusion of sugarcane (C = 0.00; 0.20; 0 , 40 and 0.60), $(GC)_{ij}$ is the effect of the interaction of the i-th genotype of biomass sorghum with the j-th level of inclusion of sugarcane and ε_{ijk} is the experimental error N (0, σ^2).

The assumptions of normality, homoscedasticity and independence of the residues were evaluated sequentially using the Shapiro-Wilk, Bartlett and Durbin-Watson tests, respectively. Once the assumptions were met, the multiple comparison of the genotypes averages by the Tukey test and linear regression for the levels of inclusion of sugarcane was carried out. Were evaluated first and second degree models, as the final model chosen based on its significance compared to a nullity model.

The Box-Cox transformation was utilized in cases that the ANOVA's assumptions did not met. The assumptions were then evaluated again and, if met, the multiple comparison of the means of the genotypes was carried out by the Tukey test on the transformed data and for the levels of inclusion of sugarcane a weighted linear regression by the inverse of the variance was carried out.

In conditions where the assumptions were not met even after the transformation, a nonparametric approach was adopted in the analysis of variance through the *Aligned Rank Transformation*, this being specific to experimental data from a factorial scheme (20). In those cases, the Dunn test, adopting the Benjamini-Hochberg adjustment, was used in the multiple comparison of the means of the genotypes and the quantile regression (semiparametric) was used to assess the levels of inclusion of sugarcane. In a similar way, first and second degree models were evaluated, the final model being chosen based on its significance in comparison to a nullity model.

RESULTS

The silages of the three tested sorghum genotypes presented statistically different dry matter (DM) contents ($P < 0.05$), being the highest value observed on the silage from the B012 genotype (Table II). In addition, a negative linear effect ($P < 0.05$) of the inclusion levels of sugarcane in the DM content was observed (Table II).

Regarding the contents of organic matter (OM), Figure 1 displays the unfolding of the interaction ($P < 0.05$) between the genotypes and the levels of sugar cane (Table II), in which there was no effect of sugar cane levels in the OM content of silage of genotype B012 ($P > 0.05$). The positive quadratic effect ($P < 0.05$) of the sugar cane levels in the OM of the silages of the genotypes B017 (Figure 1b) and B018 (Figure 1c) was observed.

Table II. Dry matter (%DM), organic matter (%OM), mineral matter (%MM), crude protein (%CP), neutral detergent fiber (%NDF), acid detergent fiber (%ADF), hemicellulose (%HEM), lignin (%LIG) and hydrogenionic potential (pH) in sorghum biomass and different sugarcane levels.

Item	Genotype[1]			Sugarcane				SD[2]	Significance[3]		
	B012	B017	B018	0	20	40	60		G	S	G × S
DM	29,3 a	27,3 b	26,4 b	28,4	28,1	27,9	26,2	2,00	< 0,001	< 0,001†	0,52
OM	95,0	94,4	95,1	94,3	94,4	95,0	95,6	0,91	< 0,001	< 0,001	0,001
MM	5,01	5,63	4,94	5,71	5,65	5,00	4,41	0,91	< 0,001	< 0,001	0,001
CP	2,85	3,49	2,86	3,19	3,14	3,15	2,80	0,60	< 0,001	0,12	0,003
NDF	53,2	52,2	55,9	56,0	54,3	53,2	51,5	4,96	0,06	0,10	0,12
ADF	27,7	27,5	30,0	28,9	28,7	28,4	27,7	3,83	0,09	0,83	0,05
HEM	25,5	24,6	25,9	27,1	25,7	24,8	23,8	2,52	0,18	0,002 ††	0,11
LIG	5,05	5,31	5,73	5,27	5,17	5,42	5,60	0,91	0,08	0,63	0,09
pH	4,26 a	4,14 b	4,17 b	4,19	4,20	4,20	4,17	0,08	< 0,001	0,50	0,06

[1] Averages of genotypes followed by different letters in the rows differ statistically ($P < 0,05$); [2] SD = Standard deviation; [3] G = Genotype; S = Sugarcane; G × S = Interaction between genotype and sugarcane; † $\hat{Y} = 28,58 - 3,02X$; $R^2 = 0,12$; P-value = 0,02; †† $\hat{Y} = 26,77 - 4,71X$; $R^2 = 0,23$; P-value = 0,009

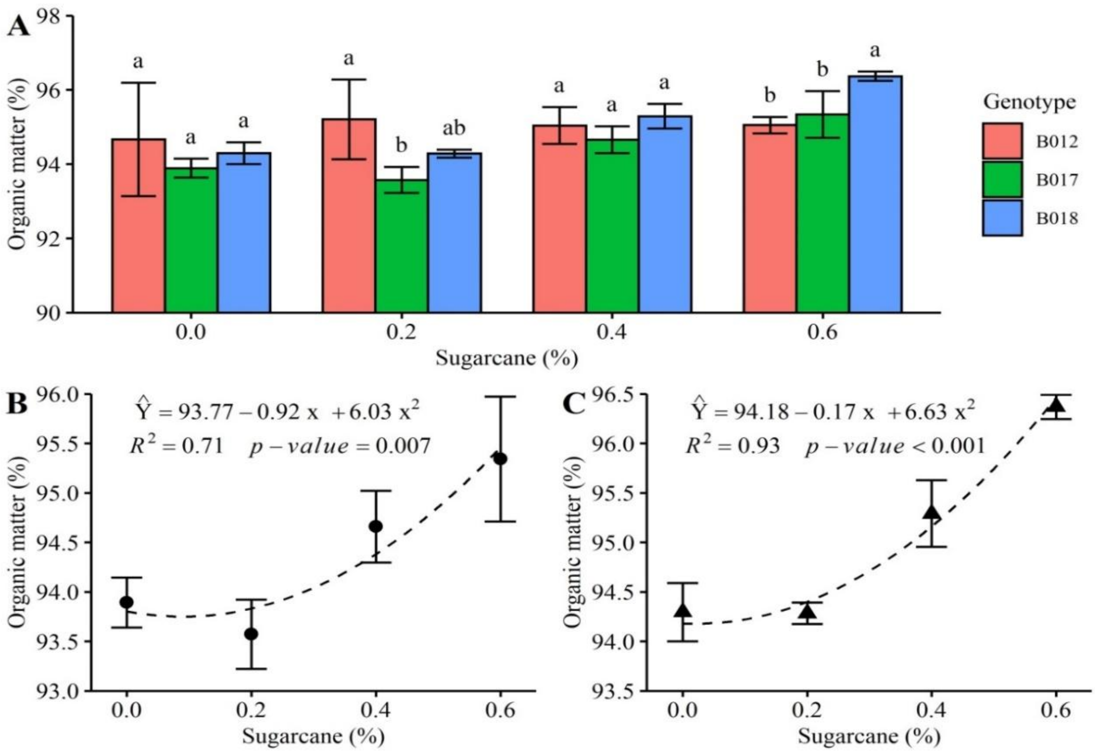

Figure 1. The effect of the interaction between the levels of inclusion of sugarcane (0.00, 0.20, 0.40 and 0.60) and the biomass sorghum genotypes in the organic matter content of the silages. **A.** Effect of different genotypes in the content of organic matter at each level of inclusion of sugarcane. Columns followed by different letters at each level differ statistically (P <0.05) according to Dunn's test. **B.** Average (●) ± standard deviation (bars) of the organic matter content of silages of genotype B017 according to the level of inclusion of sugarcane with a linear regression model and the representation of its respective adjustment (dashed line). **C.** Average (▲) ± standard deviation (bars) of the organic matter content of silages of genotype B018 according to the level of inclusion of sugarcane with a linear regression model and the representation of its respective adjustment (dashed line).

In Figure 1B, there was a minimum value of 7.63% estimated by the model, in which, with the inclusion of 0% to 7.63% of sugarcane, the OM content decreased, and from 7.63 % the inclusion of sugarcane increased the OM content of the silage in the genotype B017. As shown in Figure 1c, the minimum point estimated by the model is 1.28%, in which the inclusion of sugarcane reduced the OM content up to 1.28%, from this point on, the inclusion of sugarcane increased the OM in the silage of the genotype B018.

The levels of mineral matter (MM) presented a statistically significant effect of the interaction ($P < 0.05$) between the genotypes and the levels of sugarcane, with no effect of the levels of sugarcane on the genotype B012 ($P > 0.05$, Figure 2). There was a negative quadratic effect of sugarcane levels on the MM of silages of genotypes B017 and B018 ($P < 0.05$). In Figure 2b, the maximum point was noted, in which the MM increased up to 7.62% and from that point on, there was a reduction in the MM content as the level of inclusion of sugarcane increased in the silage of the genotype B017. In Figure 2c, the maximum point of the genotype B018 was 5.04%. After that point, the MM content decreased as the inclusion of sugarcane increased.

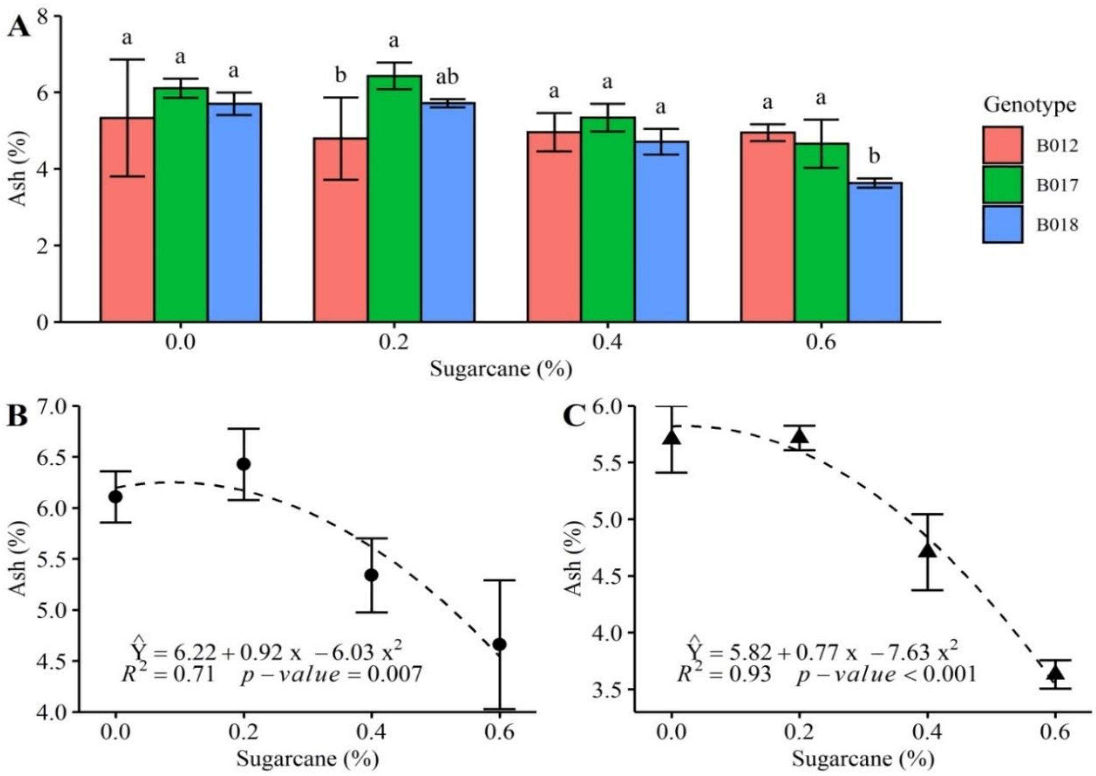

Figure 2. The effect of the interaction between the levels of inclusion of sugarcane (0.00; 0.20; 0.40 and 0.60) and the biomass sorghum genotypes in mineral matter content of the silages. **A.** Effect of different genotypes in the content of mineral matter at each level of inclusion of sugarcane. Columns followed by different letters at each level differ statistically ($P <0.05$) according to Dunn's test. **B.** Average (●) ± standard deviation (bars) of the mineral matter content of silages of genotype B017 according to the level of inclusion of sugarcane with a linear regression model and the representation of its respective adjustment (dashed line). **C.** Average (▲) ± standard deviation (bars) of the mineral matter content of silages of genotype B018 according to the level of inclusion of sugarcane with a linear regression model and the representation of its respective adjustment (dashed line).

In Figure 3, the interaction between the different genotypes and levels of inclusion of sugarcane on the levels of crude protein (CP) can be seen. In the silage of genotypes B012 and B018, there was no effect of the inclusion of sugarcane (P> 0.05). It can be seen that the genotype B017 was the only genotype where sugarcane had a significant effect and negative linear behavior (Figure 3b), showing a higher value compared to the other genotypes at levels 0 and 20% of inclusion of sugarcane (Figure 3a).

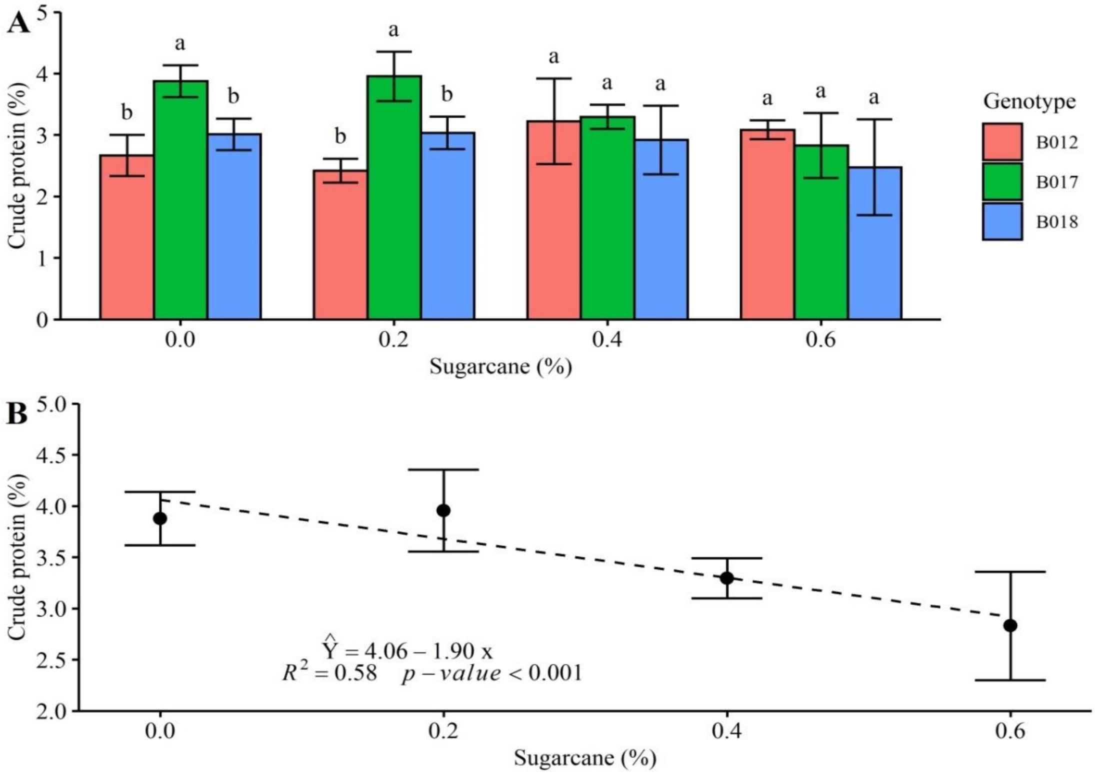

Figure 3. The effect of the interaction between the levels of inclusion of sugarcane (0.00; 0.20; 0.40 and 0.60) and the biomass sorghum genotypes in the crude protein content of the silages. **A.** Effect of different genotypes in the content of crude protein at each level of inclusion of sugarcane. Columns followed by different letters at each level differ statistically (P <0.05) according to Tukey's test. **B.** Average (●) ± standard deviation (bars) of the crude protein content of silages of genotype B017 according to the level of inclusion of sugarcane with a linear regression model and the representation of its respective adjustment (dashed line).

Regarding the cell wall constituents of the sorghum genotypes, referring the content of neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM) and lignin (LIG), a statistically significant effect was observed (P < 0.05) in the levels of inclusion of sugarcane in the HEM content of the silages, in which the effect showed a negative linear behavior (Table I).

A statistically significant effect (P < 0.05) of the genotypes was observed on the pH of the silage juice, in which the genotype B012 had the highest pH value compared to the others. (Table I).

DISCUSSION

Data analysis assessed that the silages of the three biomass sorghum genotypes with the inclusion of sugarcane showed significant differences for the studied variables. It was observed that sugarcane presented a significant effect when added to the sorghum genotypes.

A good quality silage must have a DM content between 30% to 35%, recommended by (21), as the ideal value. High levels can hinder compaction and benefit the action of fungi and yeasts. However, (22) recommends DM values between 28% to 38%. In this study, the DM content of the genotype B012 was within the range recommended by (22). However, a negative effect with the inclusion of sugarcane on the DM content of the silage was observed, regardless the genotype, which may be a consequence of alcoholic fermentation by yeast causing loss of DM and reducing digestibility (23; 24).

Regarding the average contents of OM and MM, there was a significant effect of the interaction and the factor. Neumann et al (25) and Neumann; Restle; Brondani (26), found similar contents to this study, with average OM contents of 94.7 and 95.79%.

For MM contents, the results obtained were lower than those reported by (27) (average MM of 5.30%) when evaluating forage and dual-purpose sorghum silages, and by (28) (average MM of 4.88%), for silage of forage sorghum without additives. Junqueira (29) found a content of 3.6% MM in sugarcane silages. According to (30), the lower content of MM is an indicative of better conservation of forage, because, when there is inadequate fermentation, losses of OM occur, increasing the relative participation of MM in DM. As there were no changes in the contents of DM and OM, the variation in the contents of MM may be related to a possible contamination with the soil at the time of harvesting the material.

In diets of ruminants, according to (31), the recommendation for CP content is 6 to 8% in order to provide adequate development of ruminal microorganisms, because lower contents can affect ruminal fermentation in a negative way, causing the reduction of microbial activity. In this study, the CP contents of the genotypes were lower than that reported by (31), which may be related to the crop variety and vegetative stage of the plant at the time of ensiling which impair the use silage from biomass sorghum as the only source of food in animal feeding (32). In addition, the CP content is considered an obstacle to the adoption of sugarcane as the only forage food. The value found in the current study was lower than what is found in the literature, of 1.91 to 3.81% CP (33; 34). Thus, if the evaluated silages are used to feed the animals, protein supplementation is necessary in order to complement the nutritional demand of the animals.

The NDF measures the total insoluble fiber content of the food and it is the most used parameter for balancing diets since it interferes with their quality (35). Van Soest (31) reports that for satisfactory digestibility, NDF levels must be between 55 and 60%, and that higher values are negatively correlated with voluntary consumption by animals and very low contents might jeopardize the optimal conditions for ruminal fermentation. As reported by (36), the increased NDF content throughout fermentation is relative and occurs due to the loss of cellular content during fermentation.

On average, the NDF content obtained in this study was 53.7%, similar to that observed by (37) (55.54% NDF), in which the authors studied silage of sorghum genotypes. According to (38), silages with NDF content lower than 50% are more desirable, because a minimum amount of fiber is required to have adequate concentrations of microorganisms in the rumen, in order to promote the fermentation process, saliva production and ruminal movements. Therefore, in this study, the NDF content of the silages was similar to the above-mentioned authors.

The ADF content determines the quality of the cell wall and expresses the insoluble and less digestible fraction of it (cellulose and lignin-insoluble or remaining in acid detergent), and it is directly associated with the digestibility of the food (31), in other words, the higher the ADF content of a given food, the greater the indigestible fraction and, as a consequence, a lower the digestibility.

On average, the ADF content obtained in this study was 28.4%, lower than what was found by (37) (30.21 and 31.86% ADF in forage sorghum and dual-purpose sorghum silages, respectively). The fractions of ADF and lignin have a negative relationship with the apparent digestibility of the material and with the ingestion, because the lower the ADF, the greater the energy value of the food. In this sense, high and low fractions of NDF and ADF (above 60% and below 30%, respectively), compromise the consumption and usage of forage (39). So, the ADF content of the silages was similar to the above-mentioned authors.

The HEM contents in this study, on average, 25.3%, were lower than the 36.6% reported by (40) and similar to what was found by (41) (25.0% HEM). HEM is part of the cell wall and, in the absence of substrate, it can be used in the fermentation process (36). Regarding the significant effect with negative behavior of the inclusion of sugarcane, it can be related to the hydrolysis of the hemicellulosic fraction by microorganisms in the medium, which can generate by-products of its metabolism, including ethanol by yeast (14; 42; 43). As sugarcane is rich in sucrose, probably, there was no lack of substrate for the microorganisms in the medium, suggesting that there was a dilution effect of the HEM fraction in the silage of biomass sorghum with sugarcane. Therefore, in this study, the HEM content of the silages is within the range recommended by the above-mentioned authors.

Van Soest (31) states that the LIG acts in a negative way in the digestibility of food, being able to limit the digestion of nutrients and other components of the cell wall. Lignin is made up of macromolecules with a complex structure and high molecular weight. With the development of forage, this compound replaces the spaces in the matrix of the cell wall occupied by water, increasing the rigidity of the cell wall (44). Thus, lignin affects DM digestibility by binding to cell wall components, and the occurrence of this interaction increases with forage maturity, either by increasing LIG concentration and/or by modifying the composition of phenolic compounds (45). According to (46), contents below 7.3% of lignin in silage of sorghum favor the increase of consumption and the digestibility of fibrous fractions.

The average LIG content found in the study was 5.3%, which is higher than what was found by (27) (3.36 to 4.94% LIG) in silage of different sorghum hybrids after 43 days of fermentation. Thus, sorghum genotypes B012, B017 and B018 had an average LIG content within the suggested range, which possibly would not hamper the digestibility of the silages.

Regarding the pH values of the silage juice of the evaluated genotypes, the values found are within the recommended by (36) with pH values between 3.8 and 4.2, the desirable for the silage to be well conserved. The authors (47) and (48) considered adequate pH values between 3.6 and 4.2 for a good quality silage. In the current study, the genotypes B012, B017 and B018 presented average pH levels within the suggested range, which indicates that the evaluated silages were well conserved during the storage period of 60 days.

In view of the above, the biomass sorghum genotypes evaluated had a satisfactory response to the fermentation process resulting in good quality silages. Although, the inclusion of sugarcane did not improve the quality of the silages produced, and its inclusion in the ensilage of the evaluated genotypes is not recommended.

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DECLARATION OF COMPETING INTEREST

The authors declare no competing interests.

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