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Nutritional composition of silage from pearl millet cultivars with the inclusion of soy hulls[1]

Composição bromatológica de silagens de cultivares de milheto com inclusão de casca de soja

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ABSTRACT - The nutritional composition of silages from the millet cultivars BRS 1501, ADR 500 and ADR 8010 was evaluated with the inclusion of soy hulls at 0, 3, 6 and 10%. The experimental design was completely randomized in a 3 x 4 factorial scheme with 3 replications. The dry matter content of the silages was affected by the inclusion of the soy hulls, ranging from 16.20% (ADR 8010) to 23.27% (BRS 1501) for the inclusion of 0 and 10% respectively. The levels of crude protein ranged from 9.46 to 10.79%, with significant differences between varieties being seen with the inclusion of 6% and 10% soy hulls. Inclusion of the hulls reduced the mineral matter content of the silages, with a change of 8.62% in the control treatment, up to an average of 6.38% at the level of 10%. The neutral (NDF) and acid (ADF) detergent fiber content did not differ with treatment. The hemicellulose content differed with the level of soy hulls, and ranged from 22.65 to 26.18%. The cellulose content varied from 24.90% (ADR 500), with the inclusion of 6% soy hulls, to 29.80% (ADR 8010) with the inclusion of 10% hulls. The lignin content showed significant differences for the level of hull inclusion, ranging from 1.37% (ADR 8010) with the inclusion of 10% hulls, to 3.71% (BRS 1501), found in the control treatment. The soy hulls increased the dry matter content of silages from the cultivars under evaluation.

Key words: Fibers. Dry matter. *Pennisetum glaucum*. Crude protein.

RESUMO - Avaliou-se a composição bromatológica de silagens de cultivares de milheto: BRS 1501, ADR 500 e ADR 8010, com a inclusão de casca de soja: 0; 3; 6 e 10%. O delineamento experimental foi inteiramente casualizado, em arranjo fatorial 3 x 4 e três repetições. Os teores de matéria seca das silagens foram influenciados pela inclusão da casca de soja, com variação de 16,20% (ADR 8010) a 23,27% (BRS 1501), para os níveis de inclusão de casca de soja 0 e 10%, respectivamente. Os teores proteína bruta variaram de 9,46 a 10,79% e foram observados diferenças significativas entre os cultivares com a inclusão de 6 e 10% da casca de soja. A inclusão de casca de soja reduziu o teor de matéria mineral das silagens, com variação de 8,62% no tratamento controle, até 6,38%, em média, ao nível de inclusão de 10%. Os teores da fibra em detergente neutro (FDN) e ácido (FDA) não diferiram em função dos tratamentos. Os teores de hemicelulose diferiram em função dos níveis de casca de soja variando de 22,65 a 26,18%**.** Os conteúdos de celulose variaram de 24,90% (ADR 500), com a inclusão de 6% de casca de soja até 29,80% (ADR 8010), no nível de 10%. Os teores de lignina apresentaram diferenças significativas em função dos níveis de inclusão da casca variando de 1,37% (ADR 8010), com a inclusão de 10 até 3,71% (BRS 1501), determinado no tratamento controle. A casca de soja elevou a matéria seca da silagem das cultivares avaliadas.

Palavras chave: Fibras. Matéria seca. *Pennisetum glaucum*. Proteína bruta.

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INTRODUCTION

Pearl millet (*Pennisetum glaucum*) is used as forage, and has the potential for silage production in regions where Indian summers or drought are a problem, or when planted in succession or in the off-season after harvesting the main crop. This is due to its rusticity and adaptation to planting at the end of summer and the beginning of fall (PEREIRA *et al*., 1993).

In Brazil, millet silage is still little studied in relation to maize and sorghum silage; however, some studies have already shown that the production of millet silage in quantity and of satisfactory quality is possible even in the off-season (AMARAL *et al*., 2008; COSTA *et al*., 2011).

Evaluating the nutritional value of silages from three pearl millet cultivars (BRS-1501, NPM-1 and CMS-3) ensiled at 100 days, Guimarães Júnior (2006) found levels of dry matter (DM) that varied from 20.99 to 22.72%, crude protein (CP) from 10.73 to 11.83%, NDF from 70.54 to 71.22% and ADF from 37.70 to 39.71%, cellulose (CEL) from 35.78 to 37.40%, hemicellulose (HEM) from 31.51 to 32.84% and lignin (LIG) from 1.92 to 2.63%. Amaral (2008), evaluating the BRS 1501, BN 1 and Common cultivars, ensiled at 70, 90 and 110 days during the rainy period, and harvested at 70 and 90 days during the dry period, found a DM content ranging from 21.34 to 36.83% and from 20.68 to 29.85%, CP from 9.50 to 8.40% and from 12.65 to 11.91%, NDF from 60.15 to 68,63% and from 68.80 to 75.44%, and ADF from 39.51 to 40.88% and from 38.91 to 41.67%, for the respective periods.

The appropriate time for ensiling millet is when the grain is at the pasty to farinaceous stage, but at that time the plant has a low dry matter content, around 20 to 23% (GUIMARÃES JÚNIOR; GONÇALVES; RODRÍGUES, 2009). It is therefore advisable to include absorbent additives that allow better silage fermentation.

Little work has been done using millet with the inclusion of additives. Ferrari Júnior *et al*. (2009) evaluated silages of *Pennisetum hybridum* cv. Paradise using 5 and 10% citrus pulp, 1% calcium oxide or a commercial additive (Silomax®). The authors concluded that the addition of citrus pulp increased the DM content from 17.22 to 21.59 and 24.95% at levels of 5 and 10% citrus pulp respectively, resulting in silages with more adequate fermentation patterns.

Evaluating elephant grass silages with the inclusion of maize bran and soy hulls at levels of 5 and 10%, Andrade *et al*. (2012) found that including soy hulls increased dry matter in the silages from 21.1 to 24.2 and 28.3%, at levels of 5 and 10% respectively. Whereas, maize bran increased the dry matter of the silages from 21.1 to 23.8 and 28.9%, at levels of 5 and 10% respectively.

Evaluating the inclusion of soy hulls in elephant grass silage, Chagas (2012) concludes that soy hulls are a good additive for the process of ensiling non-standard forage grasses, due to increasing the dry matter content and crude protein, while keeping the NDF and ADF content of the produced silages practically unchanged.

In this context, the aim of this research was to evaluate the nutritional composition of silage from pearl millet cultivars at different levels of soy hull inclusion.

MATERIAL AND METHODS

The experiment was conducted at the Department of Animal Production, School of Veterinary and Animal Science, at the Federal University of Goiás (UFG), located in the town of Goiânia, in the State of Goiás, Brazil, latitude 16º35’00” S and longitude 49º16’00” W, at an altitude of 727 m. The area used for growing the millet has a flat topography, with soil classified as a typic dystrophic red Latosol of clayey texture and medium fertility.

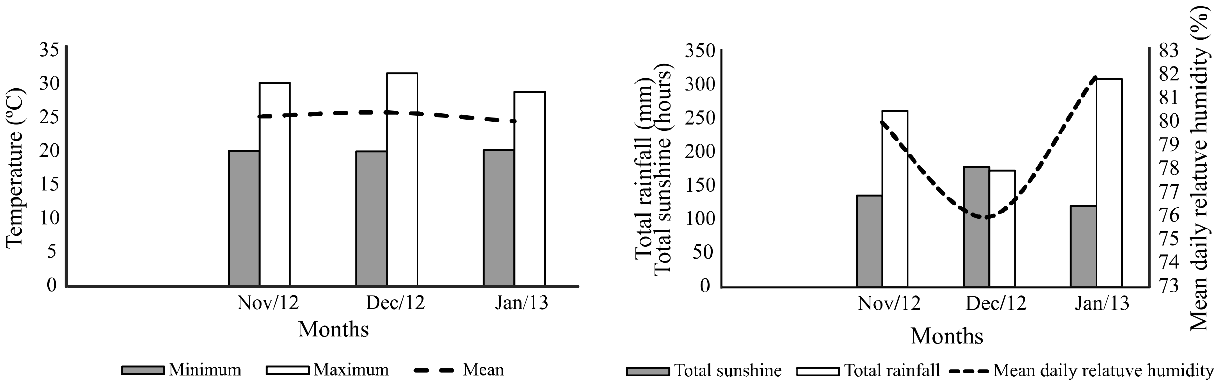
The climate in the region is type Aw, warm and semi-humid, with well-defined seasons, a period of drought from May to October, and a rainy period between November and April.

Climate data for the months of the experiment are shown in Figure 1, and were obtained from the first-class evaporimeter station of the Sector for Biosystems Engineering of the School of Agronomy, UFG.

The treatments consisted of three millet cultivars, ADR 8010, ADR 500 and BRS 1501, and four levels of soy hull inclusion (0, 3, 6 and 10%). A completely randomized experimental design was used in a 3 x 4 factorial scheme with three replications. The data were processed using the R software (2012), and mean values compared by Tukey’s test at a level of 5% probability, with regression analysis used for the levels of soy hull inclusion. Significance of the coefficients by t-test was used as the criterion for choosing the regression model (linear or quadratic). For variables that gave two models with significant coefficients, the adjusted coefficient of determination and the biological explanation were also considered as the criterion of choice.

The soil in the experimental area was collected at a depth of 0.00 to 0.20 m and characterized by the Laboratory for Soil and Leaf Analysis of the School of Agronomy at UFG. The results are shown in Chart 1.

Figure 1 - Monthly rainfall (mm), sunshine (hours), relative humidity (%) and average temperatures (ºC) in the experimental area



Source: First-class evaporimeter station of the Sector for Biosystems Engineering of the School of Agronomy, UFG

Chart 1 - Physical and chemical attributes of the soil in the experimental area

Clay	Silt	Sand	OM	V	pH ($CaCl_2$)	P (Mehl)	K
35.0%	19.0%	46.0%	1,8%	62,5%	5,9	3,8 mg/dm³	69,0 mg/dm³
Ca	Mg	H+Al	Al	CEC	Ca/CEC	Mg/CEC	K/CEC
3.4 $cmol_c/dm^3$	1.1 $cmol_c/dm^3$	2.8 $cmol_c/dm^3$	0,0 $cmol_c/dm^3$	7,5 $cmol_c/dm^3$	45,5%	14,7%	2,4%
Ca/Mg		Mg/K			Ca/K		
3.1		6.2			19.3		

Source: Laboratory for Soil and Leaf Analysis, UFG

Soil preparation was conventional, with harrowing and leveling preceding sowing. According to the soil analysis, liming was not necessary, as per the recommendation of Martha Júnior, Vilela and Sousa (2007).

Sowing was carried out manually, on November 17, 2012, at a density of 20 pure viable seeds (PVS) per linear meter. The plots comprised five rows of 50 m, at a spacing of 0.30 m, giving a total area of 60 m² per cultivar.

The experimental area was fertilized with 60 kg ha^{-1} P_2O_5 (SS), 60 kg ha^{-1} K_2O (KCl) and 30 kg ha^{-1} FTE BR-16 (MARTHA JÚNIOR; VILELA; SOUSA, 2007). Nitrogen fertilizer was applied as cover 20 days after plant emergence, on December 07, 2012, at the equivalent of 80 kg ha^{-1} N (urea).

During the period of cultivation, crop treatments such as weeding were carried out to remove invasive plants from the experimental area.

The cutting and ensiling of the millet cultivars was carried out on January 23, 2013, at 65 days after plant emergence, when the grains were at the pasty to farinaceous stage. The forage in each plot was cut with a backpack brushcutter 0.15 m from ground level and chopped in a forage harvester, with the aim of obtaining particles of approximately two centimeters. A sample of around 500 g of original material was removed and placed in a forced ventilation oven at 65 °C for 72 h to determine the pre-dried matter. The sample was then ground in a Wiley mill with a one-millimeter mesh sieve and stored in a hermetically sealed polyethylene container for later laboratory analysis.

The original material of each millet cultivar under evaluation was divided into four parts that received added soy hull according to the proposed treatments. Plastic buckets with a capacity of 12 L were used as experimental mini-silos; these were equipped with a Bunsen-type valve to allow the gases produced in the fermentation process to escape without allowing air to enter. At the bottom of each mini-silo, an apparatus was installed consisting of a two to three centimeter layer of coarse sand, followed by two layers of cotton fabric to collect the effluents and measure the loss per effluent. Before ensiling, the silos were weighed with the lid and bottom apparatus. The experimental silos were filled manually. A manual press was also used to compact the forage, with the aim of reaching a mean density of 545 kg m^{-3}. After compaction, the mini-silos were closed using the lid, sealed with high-adhesion tape and then weighed.

Table 1 - Mean values for dry matter (DM), crude protein (CP), mineral matter (MM), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM), cellulose (CEL) and lignin (LIG), determined in the original material (OM) of the millet cultivars and soy hulls

Parameter	Cultivar			Soy hulls
	BRS 1501	ADR 500	ADR 8010	
DM (%)	18.31	17.79	18.23	94.47
CP (% of DM)	9.31	7.26	9.62	8.91
NDF (% of DM)	57.24	56.54	58.58	65.35
ADF (% of DM)	30.73	29.17	29.31	31.05
HEM (% of DM)	26.50	27.37	29.26	34.30
CEL (% of DM)	24.84	20.84	24.80	29.91
LIG (% of DM)	3.43	2.45	2.44	0.11
MM (% of DM)	8.25	2.43	8.77	1.93

Thirty days after ensiling, on February 23, 2013, the experimental silos were weighed and opened. The upper and lower parts of the silage was discarded, and a sample of approximately 500 g was taken from the central part and placed in a forced ventilation oven at 65 °C for 72 h to determine the pre-dried matter. The pre-dried samples were then milled in a Wiley knife mill having a one-millimeter diameter mesh sieve, identified and packed into lidded polyethylene containers and stored for chemical analysis.

From the processed samples of original material and silage, an analysis was made to determine the levels of dry matter (DM), crude protein (CP) and mineral matter (MM), following a methodology described by Silva and Queiroz, (2002). Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CEL) and lignin (LIG) by the Klason method, were determined as per the methodology for forage analysis proposed by Van Soest, Robertson and Lewis (1991). Hemicellulose (HEM) was calculated from the difference between the NDF and ADF fractions, as described by Silva and Queiroz (2002).

The analyses were carried out at the Laboratory for Animal Nutrition of the School of Veterinary and Animal Science, Department of Animal Production, at the Federal University of Goiás (EVZ - UFG).

The nutritional composition of the original material from the millet cultivars at the time of ensiling and of the soy hulls is presented in Table 1.

RESULTS AND DISCUSSION

It can be seen that the dry matter content (DM) determined in the silage of the millet cultivars differed (P<0.05) only for the levels of soy hull inclusion, with a variation of from 16.20% (ADR 800) to 23.27% (BRS 1501) (Table 2).

A dry matter content ranging from 25.80 to 28.48%, determined in millet silage harvested at 65 days of vegetative growth, was reported by Costa *et al*. (2012), while Brunette, Baurhoo and Mustafa (2014) found a mean DM content of 25.7%, and Hassanat, Mustafa and Seguin (2006) reported a mean DM content of 22.45% for millet silage at 8 weeks of growth. In the present work, the cultivars displayed a mean DM content of 18.1% at the time of ensiling. This low DM content may be due to the nitrogen fertilizer, which causes an increase in production and a reduction in DM content, and to the high relative humidity during the experimental period, of 76% on average.

Millet silage at various phenological stages (vegetative, flowering, milky grain and pasty grain) was evaluated by Morales *et al*. (2011). The authors concluded that, despite the lower dry matter content and lower dry matter production per area, vegetative-stage silage is beneficial, as it promotes a more vigorous regrowth of the forage.

There was a positive linear correlation between the dry matter content of the silages and the levels of soy hull inclusion, which was determined with Equation 1, thereby reaffirming the efficiency of this additive in raising the dry matter content of the ensiled material.

$$y = 17.23 + 0.579x \ (R^2 = 0.99) \quad (1)$$

CP content did not differ (P>0.05) with the level of soy hull inclusion, however significant differences between the millet cultivars were seen in crude protein content at inclusion levels of 6 and 10%, where the mean value between cultivars was of the order of 10.50% CP.

The values for protein content found in this study are similar to those verified by other authors for millet ensiled at the same phenological stage. Khan *et al*. (2011) reported a CP content of 8.8%, while Morales *et al*. (2011) found a CP content of 9.6% for millet silage.

Based on the average values for CP determined in the original material, which varies from 7.26% (ADR 500) to 10.32% (ADR 8010), and presented in Table 1, it can be said that the fermentation process proceeded appropriately, without causing a loss of CP content in the produced silages (Table 2). A PB content of less than 7% is considered limiting to the activity of ruminal microorganisms, and implies unfavorable conditions for the rumen microbiota, thereby compromising maintenance of microbial growth and usage of fibrous forage compounds (SAMPAIO *et al*., 2009).

The mineral matter content (MM) showed a significant difference (P<0.05) for the level of soy hull inclusion. It is worth noting that the mean value for mineral matter content found in this research is within the normal range quoted in the literature (AMARAL *et al*., 2008; AMER *et al*., 2012), and displayed a decreasing linear equation, represented by Equation 2, for increases in the level of soy hulls.

$$y = 8.3138 - 0.2082x \ (R^2 = 0.89) \qquad (2)$$

Neutral detergent fiber content (NDF) did not differ (P<0.05) for the level of soy hull inclusion, however, there were significant differences among the cultivars under evaluation, varying from 52.14% (BRS 1501) in the control treatment, up to 57.59% (ADR 8010) with the inclusion of 6.0% soy hulls (Table 3).

The values for NDF content found in the original material from the millet cultivars for the different levels of soy hull inclusion showed mean values of from 56.54% (ADR 500) to 61.24% (BRS 1501) (Table 1), higher mean values than those found in the silages. The reduction in NDF content can be explained by the loss of dry matter through the production of effluents. The values for NDF content found in the silages from the millet cultivars in this research are close to those verified by Pinho *et al*. (2014), which ranged from 52.3 to 63.9%, but below that found by Khan *et al*. (2011) of 68.7% in millet at the pre-inflorescence stage.

The acid detergent fiber content (ADF), which is related to the cellulose and lignin, correlates negatively with digestibility, and in this study ranged from 28.57 to 32.59% (Table 3), showing no difference (P> 0.05) for the level of soy hull inclusion. Among the cultivars however, significant differences were seen for the level of soy hull inclusion, with

Table 2 - Dry matter (DM), crude protein (CP) and mineral matter (MM) content determined in the silage of millet cultivars with the inclusion of soy hulls

Parameter	Cultivar	Soy hull inclusion (%)			
		0	3	6	10
DM (%)	BRS 1501	17.09 Ca	19.97 Ba	20.63 Ba	23.27 Aa
	ADR 500	17.79 Ca	19.32 BCa	20.60 Ba	22.85 Aa
	ADR 8010	16.20 Da	18.57 Ca	20.72 Ba	22.75 Aa
	Mean	17.03 D	19.29 C	20.65 B	22.96 A
	CV%	2.84			
CP (% of DM)	BRS 1501	10.53 Aa	10.54 Aa	10.79 Aa	11.13 Aa
	ADR 500	10.14 Aa	9.86 Aa	9.46 Ab	9.93 Ab
	ADR 8010	10.40 Aa	9.62 Aa	10.30 Aab	10.43 Aab
	Mean	10.36 A	10.01 A	10.18 A	10.50 A
	CV%	3.65			
MM (% of DM)	BRS 1501	8.89 Aa	7.46 ABa	6.66 Ba	6.36 Ba
	ADR 500	7.71 Aa	6.96 Aa	7.02 Aa	6.45 Aa
	ADR 8010	9.26 Aa	7.41 Ba	7.37 Ba	6.34 Ba
	Mean	8.62 A	7.28 B	7.02 B	6.38 B
	CV%	9.65			

Mean values followed by the same uppercase letter in a row and lowercase letter in a column are statistically equal by Tukey's test at 5% probability

Table 3 - Values for the nutritional composition of the neutral and acid detergent fibers determined in the silage from millet cultivars with levels of soy hull inclusion

Parameter	Cultivar	Soy hull inclusion (%)			
		0	3	6	10
NDF (% of DM)	BRS 1501	52.14 Ab	53.21 Ab	53.79 Ab	54.90 Aa
	ADR 500	53.99 Aab	56.27 Aab	53.79 Ab	56.68 Aa
	ADR 8010	55.86 Aa	57.47 Aa	57.59 Aa	56.21 Aa
	Mean	54.00 B	55.65 AB	55.06 AB	55.93 A
	CV%	2.25			
ADF (% of DM)	BRS 1501	29.50 Aa	28.57 Ab	28.71 Ab	28.72 Ab
	ADR 500	30.42 Aa	31.18 Aab	31.19 Aab	31.08 Aab
	ADR 8010	30.37 Aa	32.29 Aa	32.59 Aa	31.89 Aa
	Mean	30.10 A	30.68 A	30.83 A	30.56 A
	CV%	3.70			

Mean values followed by the same uppercase letter in a row and lowercase letter in a column are statistically equal by Tukey's test at 5% probability

the exception of the control treatment. Higher results were found by Morales *et al*. (2011) who noted 36.8%, and Khan *et al*. (2011) with 37.7%, for millet ensiled at the vegetative stage. The ADF content, varying from 29.12% (BRS 1501) to 30.98% (ADR 8010) in the original material (Table 1), remained stable due to the soy hulls presenting a value of 31.05% for ADF, very similar to the ensiled forage, and not altering the ADF content of the mixture. Kollet, Diogo and Leite (2006), reported values for ADF in the range of 34.73%, determined at 49 days of vegetative growth, higher than the values quoted in the present study.

The hemicellulose content (HEM) (Table 4) only differed with the various levels of soy hulls included during the ensiling process, showing a variation of 22.65 to 26.18% in the control treatment, and with the inclusion of 10% soy hulls respectively, both in the BRS 1501 cultivar.

There was a difference (P<0.05) and a linear correlation (Equation 3) between the levels of soy hull inclusion, which can be explained by the hemicellulose content of the soy hulls being used (34.30%), and which caused a linear increase in the hemicellulose content of the silages.

$$y = 23.75 + 0.174x \ (R^2 = 0.70) \quad (3)$$

According to Van Soest (1994), hemicellulose is a homogeneous mixture of amorphous polysaccharides with a degree of polymerization much lower than that of cellulose. In the present research, average content is between 23.53 to 25.62%.

In relation to cellulose content, no significant differences were seen (P>0.05) for the level of soy hull inclusion or between cultivars. In Table 4, it can be seen that the cellulose content showed a variation of from 24.90% (ADR 500) with the inclusion of 6% soy hulls, up to 29.80% (ADR 8010) at the level of 10%. This linear increase, $y = 25.85 + 0.317x$ ($R^2 = 0.89$), can be explained as a function of the greater cellulose content of the soy hulls in relation to the forage, with an average of 29.81%.

According to Van Soest (1994), this is a polysaccharide of great abundance in nature, and is therefore the main constituent of most cell walls, where the concentration varies from 2 to 40% in the dry matter of higher plants, corroborating the results found in the present research.

The lignin content (LIG) showed significant differences (P<0.05) only for the different levels of soy hulls included as an additive to the silages, with a variation of 1.37% (ADR 8010) for the inclusion of 10% soy hulls, up to 3.71% (BRS 1501) found in the control treatment (Table 4). The lignin content displayed a decreasing linear correlation, $y = 3.5247 - 0.1867x$ ($R^2 = 0.99$).

According to McKenna, Tolmie and Runions (2014), lignin is a polymer that associates with structural carbohydrates, cellulose and hemicellulose during the process of cell wall formation, negatively influencing the carbohydrate digestibility of forages. Morales *et al*. (2011) report a lignin content of 3.7 to 4.4% for millet ensiled at the vegetative stage, similar to that found in the present work. Without doubt, one of the determinant factors in raising the lignin content of forage is the maturity of the forage plant, among others.

Table 4 - Values for the nutritional composition of hemicellulose, cellulose and lignin determined in the silage from millet cultivars with levels of soy hull inclusion

Parameter	Cultivar	Soy hull inclusion (%)			
		0	3	6	10
HEM (% of DM)	BRS 1501	22.65 Ba	24.65 ABa	25.07 Aba	26.18 Aa
	ADR 500	23.57 ABa	25.09 ABa	22.59 Ba	25.60 Aa
	ADR 8010	24.38 Aa	24.89 Aa	25.19 Aa	25.07 Aa
	Mean	23.53 B	24.88 AB	24.28 AB	25.62 A
	CV%	4.99			
CEL (% of DM)	BRS 1501	25.53 Aa	26.51 Aa	27.90 Aa	28.74 Aa
	ADR 500	25.84 Aa	25.75 Aa	24.90 Aa	29.19 Aa
	ADR 8010	25.90 Aa	29.62 Aa	28.63 Aa	29.80 Aa
	Mean	25.76 B	27.29 AB	27.14 AB	29.24 A
	CV%	7.81			
LIG (% of DM)	BRS 1501	3.71 Aa	2.57 ABa	2.69 ABa	1.71 Ba
	ADR 500	3.62 Aa	2.84 Aa	2.84 Aa	1.89 Aa
	ADR 8010	3.25 ABa	3.47 Aa	1.68 BCa	1.38 Ca
	Mean	3.53 A	2.96 AB	2.40 BC	1.66 C
	CV%	29.43			

Mean values followed by the same uppercase letter in a row and lowercase letter in a column are statistically equal by Tukey's test at 5% probability

CONCLUSIONS

1. Soy hulls proved to be efficient in increasing the dry matter content of silage from the millet cultivars under evaluation;
2. The inclusion level of 10% soy hulls resulted in the greatest increase in dry matter content, keeping the levels of crude protein, neutral and acid detergent fibers, hemicellulose, cellulose, lignin and mineral matter within accepted standards for the nutritional composition of bulky feed for ruminants;
3. Among the silages under evaluation, the BRS 1501 cultivar displayed a higher crude protein content and lower levels of NDF and ADF.

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