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PASTURE AND FORAGE UTILIZATION

Chemical composition and fermentative losses of mixed sugarcane and pigeon pea silage

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ABSTRACT. Adding legumes to sugarcane silage is a strategy used to improve silage quality and reduce losses. This study's objective was to evaluate the chemical composition and fermentation profile of silages sugarcane and pigeon pea. A completely randomized design was used, with five treatments and four replications. The treatments consisted of sugarcane silage with increasing pigeon pea proportions (0, 25, 50, 75 and 100%). The forages were ensiled in experimental microsilos that remained closed for 60 days. Their chemical compositions were evaluated by determining the pH value and dry matter, crude protein, neutral detergent fiber, acid detergent fiber, hemicellulose, cellulose and lignin content. Fermentation profiles were evaluated by determining the effluent, gas, and total dry matter losses and dry matter recovery of the silage. Including pigeon pea in sugarcane silage decreases the hemicellulose content and increases the crude protein, acid detergent fiber and lignin content. Fermentation losses are reduced by adding pigeon pea to sugarcane silage with reduced effluent and gas losses and increased dry matter.

Keywords: ruminant feeding; *Cajanus cajan*; forage conservation; ensiling; *Saccharum officinarum*.

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Introduction

Sugarcane (*Saccharum officinarum* L.) is a forage that is widely used in ruminant feeding, both fresh and as silage. The high dry matter (DM) productivity, low production costs and easy management favors the use of this forage in animal feeding in the form of silage (Ávila, Pinto, Sugawara, Silva, & Schwan, 2008). However, some undesirable characteristics restrict the use of sugarcane silage, including intense alcoholic fermentation when the forage is ensiled pure (Lopes & Evangelista, 2010; Pedroso et al., 2005), dry matter losses and reduced nutritive value (Rezende et al., 2011), and low protein levels and low-quality fiber (Siqueira, Roth, Moretti, Benatti, & Resende, 2012). To control these undesirable characteristics, many additives have been used, including urea (Ribeiro et al., 2010), calcium oxide (Balieiro Neto et al., 2007), virgin lime and limestone (Amaral et al., 2009), sodium chloride (Rezende et al., 2011) and *Lactobacillus buchneri* (Sá Neto, Nussio, Zopollatto, Junges, & Bispo, 2013). However, some additives can raise production costs and impact the environment. The search for sustainable and low-cost alternatives to improve sugarcane silage quality is constant.

Among the alternatives, legumes have shown to be good sources of protein (Copani, Niderkorn, Anglard, Quereuil, & Ginane, 2016; Doyle & Topp, 2004). Legumes can be produced at the farm with reduced inorganic N input due to the biological fixation of N_2 (Fageria, Ferreira, Baligar, & Knupp, 2013), which reduces production costs and environmental impacts. Several studies have been conducted on legumes in sugarcane silage (Contreras-Govea et al., 2011; Mendieta- Araica, Spörndly, Reyes- Sánchez, Norell, & Spörndly, 2009), but few studies have added pigeon pea (*Cajanus cajan* (L.) Millsp.). Pigeon pea is a shrub, semiperent and well adapted to the tropical climatic conditions, it is used in animal feed in exclusive and intercropping pastures and as green fodder, hay and silage (Bonfim-Silva et al., 2014; Provazi, Camargo, Santos, & Godoy, 2007). The inclusion of legumes in grass silage, such as sugarcane, can promote the increase of protein in the bulky. Neres et al. (2012) evidenced the fundamental role of the presence of the legume in the increase of crude protein levels of the forage offered to the animals, reinforcing the positive contributions of the presence of the legume in the quality of the forage. This study hypothesized that including pigeon pea in sugarcane silage would improve the silage’s chemical composition and fermentative profile, with fewer losses.

This study’s objective was to evaluate the chemical composition and fermentation profile of silages sugarcane and pigeon pea.

Materials and methods

The experiment was conducted at the Boa Vista Farm of the Federal University of Viçosa (Universidade Federal de Viçosa – UFV), in the region of Zona da Mata of Minas Gerais, Brazil. The site coordinates are 20°45’20” latitude South and 45°52’40” longitude West of Greenwich, with an altitude of 651 m. According to the Köppen and Geiger (1928) classification, the regional climate is classified as hot temperate, with rainy summers and cold dry winters (Cwb). Mean annual rainfall and relative humidity are approximately 1,268.2 mm and 81%, respectively (Lorenzon, Dias, & Leite, 2013).

A completely randomized design was used with five treatments and four replications, totaling 20 experimental units. The treatments consisted of sugarcane silage with increasing proportions of pigeon pea (0, 25, 50, 75 and 100% on a fresh matter basis). The sugarcane and pigeon pea plants were harvested and ground separately in a stationary forage chopper to particle sizes of 1 to 2 cm. After homogenizing each of the forages, subsamples of sugarcane and pigeon pea were collected, dried in a forced-air oven at 60°C to a constant weight and weighed to determine the dry matter percentage. Samples were ensiled in experimental silos with the capacity of 3.6-liter plastic buckets, with forage addition and compaction. The compaction was performed manually with a custom-made wooden rod, whose base was circular with a radius of 6 cm. The silage was compacted for the purpose of allowing anaerobic fermentation. After ensiling, the silos were sealed with plastic lids, fitted with a Bunsen valve and sealed with adhesive tape. Dry sand (1.5 kg) was placed at the bottom of the silos and covered in cotton cloth to drain the effluent.

The fermentation profile was evaluated by determining dry matter (DM), effluent loss (EL), gas loss (GL), total dry matter loss (TDML) and dry matter recovery (DMR). The chemical composition was evaluated by determining the pH value, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM), cellulose (CEL) and lignin (LIG) contents. When the silos were opened after 60 days, the silage from the ends was discarded, and the remainder was homogenized. Subsamples were then collected to determine the DM content (%) and dried in a forced-air oven at 60° C to a constant weight. To determine the pH, the contents of CP, NDF, ADF, HEM, CEL and LIG were followed by procedures described by Detmann et al. (2012).

The EL was calculated using the equation $\mathrm{EL}\,(\mathrm{kg\,ton} - 1\,\mathrm{FM}) = (\mathrm{Weff} \times 1000)/\mathrm{GMi}$, where Weff = weight of the effluent (weight of empty set after opening - weight of empty set before filling) (kg) and GMi = ensiled forage green mass (kg) and the weight of the set corresponding to the mass of the silo + lid + sand + fabric (Jobim, Nussio, Reis, & Schmidt, 2007). The GLs were estimated using the equation $\mathrm{GL}\,(\%\,\mathrm{DM}) = (\mathrm{WFScl} - \mathrm{Wfsop})/(\mathrm{GMcl} \times \mathrm{DMcl}) \times 10000$, where Wfscl = weight of filled silo at closing (kg); Wfsop = weight of the filled silo at opening (kg); GMcl = green mass of the forage at closing (kg); and DMcl = dry mass of the forage at closing (%) (Jobim et al., 2007).

The total dry weight loss during the ensiling period was determined by the difference between the weight of the initial and final mass in the silos (Jobim et al., 2007). The DMR of the silage was estimated using the equation $\mathrm{DMR}\,(\%) = (\mathrm{FMop} \times \mathrm{DMop})/(\mathrm{FMcl} \times \mathrm{DMcl}) \times 100$, where FMop = forage mass at opening (kg); DMop = DM content at opening (%); FMcl = forage mass at closing (kg); and DMcl = forage DM content at closing (%) (Jobim et al., 2007).

The regression equations were chosen based on the coefficient of determination and the significance of the equation parameters using the statistical program SISVAR (Ferreira, 2011).

Results and discussion

Adding pigeon pea to the sugarcane silage for EL, GL and TDML showed an effect that decreased linearly, while DMR and DM increased linearly (Table 1). The decreases in EL with the increased addition of pigeon pea to the silage were mainly due to the decreases in DM content. Adding 50% pigeon pea promoted a 35% increase in DM and a 53% decrease in EL. According to Ribeiro et al. (2010), nutrients are lost with the effluent when ensiling sugarcane, and these nutrients are transported to the bottom of the silo. The decrease in GL with the increased addition of pigeon pea in sugarcane silage may be related to the decreased soluble carbohydrate content due to increased NDF and ADF. The increased fiber content decreased the amount of substrate available for the yeasts promoting alcoholic fermentation that produces CO_2 and volatilizes alcohol (Balieiro Neto et al., 2007; Lopes & Evangelista, 2010).

The lowest DMR and DM values were observed in sugarcane silage with no pigeon pea added. Soluble carbohydrate consumption during fermentation increases the DM losses in sugarcane silage without additives due to the action of yeasts (Lopes & Evangelista, 2010). Increases in DMR and DM are explained by the lower effluent and gas lost as the portion of pigeon pea added to the sugarcane silage increased.

The increased pigeon pea proportions in the sugarcane silage promoted changes in the pH values and CP, NDF, ADF, HEM and LIG contents (Table 2). The CEL content did not change. The pH value showed a quadratic response ranging from 3.59 to 4.84 for the proportions of 0 to 100% pigeon pea in the silage, respectively. The proportion of 75% pigeon pea yielded a pH within the range of 3.8 to 4.2, which is considered ideal for good quality silage (McDonald, 1981). The other proportions presented pH values near this range. The NDF content presented a quadratic response ranging from 58.87 to 64.53% for the proportions of 50 to 100% pigeon pea in the silage.

The CP, ADF and LIG contents increased linearly, while the HEM content decreased linearly with the increasing addition of pigeon pea to the sugarcane silage. The increase in CP is explained by the pigeon pea's high CP content (Amaefule, Ukpanah, & Ibok, 2011). Intercropping legumes with grass in silage is mainly aimed at increasing the silage CP content, since grasses such as sugarcane have low CP levels (Neres et al., 2012). The minimum protein level in the feed should be 7% CP, so that appropriate ruminal fermentation occurs (Minson, 2012). Thus, including 25% pigeon pea in sugarcane silage provided the minimum CP content for good ruminal functioning.

The growing increase in ADF by adding pigeon pea to the sugarcane silage is explained by this legume's fibrous stems (Pires et al., 2006). The increase in LIG content with the increased pigeon pea proportions in the silage is explained by this legume's high lignin content. The lignin content is an important parameter to be considered in silage because it is the main limiting factor in degrading the fibrous fraction of the forages (Ribeiro et al., 2010). One reason for using additives in sugarcane silage is to reduce lignin content, which was not achieved by adding pigeon pea.

The HEM contents decreased as the pigeon pea proportions increased in the silage. Hemicellulose is an important parameter in evaluating sugarcane silage fermentation (Lopes & Evangelista, 2010). When soluble carbohydrates are depleted, hemicellulose can serve as a substrate for fermenting bacteria (McDonald, 1981). Thus, the silage quality may improve due to higher lactic acid bacterial colonization (Lopes & Evangelista, 2010).

Table 1. Fermentative profile of sugarcane silage with increasing pigeon pea proportions.

Variable	Proportion of pigeon pea (%)					R^2	Regression equation	CV (%)
	0	25	50	75	100			
EL (kg ton^{-1} MV)	44.89	33.32	23.74	16.01	10.30	0.98	$y = 42.950 - 0.346x^{**}$	13.14
GL (% DM)	18.44	13.36	10.73	8.79	6.97	0.94	$y = 17.160 - 0.110x^{**}$	12.49
TDML (%)	32.08	20.50	8.76	0.94	0.01	0.93	$y = 29.199 - 0.335x^{**}$	13.40
DMR (%)	67.92	79.50	91.24	99.06	99.99	0.92	$y = 70.801 + 0.335x^{**}$	1.91
DM (%)	21.10	24.70	28.55	31.90	32.68	0.96	$y = 21.715 + 0.121x^{**}$	2.25

** and ^{ns} indicate, respectively, significance at 1% probability and not significant by the ANOVA F test. R^2 = coefficient of determination. CV = coefficient of variation. EL = effluent losses, GL = gas losses, TDML = total dry matter losses, DMR = dry matter recovery of silage and DM = dry matter.

Table 2. Chemical composition of sugarcane silage with increasing pigeon pea proportions.

Variable	Pigeon pea, %					R^2	Regression equation	CV (%)
	0	25	50	75	100			
pH	3.59	3.52	3.62	3.78	4.84	0.94	$y = 3.651 - 0.016x + 0.001x^{2**}$	2.24
CP (% DM)	4.04	7.39	9.95	11.13	14.12	0.97	$y = 4.55 + 0.095x^{**}$	7.30
NDF (% DM)	60.87	60.12	58.87	61.18	64.53	0.95	$y = 61.119 - 0.101x + 0.001x^{2**}$	3.07
ADF (% DM)	32.18	34.55	37.26	40.02	44.53	0.98	$y = 31.672 + 0.121x^{**}$	4.42
HEM (% DM)	28.69	25.57	21.62	21.16	20.00	0.90	$y = 27.768 - 0.087x^{**}$	4.12
CEL (% DM)	20.88	19.98	19.15	23.75	23.41	-	$y = 21.43^{ns}$	16.14
LIG (% DM)	10.67	13.83	17.73	15.93	20.81	0.84	$y = 11.32 + 0.089x^{**}$	17.30

** and ^{ns} indicate, respectively, significance at 1% probability and not significant by the ANOVA F test. R^2 = coefficient of determination. CV = coefficient of variation. CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, HEM = hemicellulose, CEL = cellulose and LIG = lignin.

Notably, pigeon pea productivity is low relative to sugarcane. Thus, studies are needed to evaluate ruminants' intake of mixed sugarcane and pigeon pea silage to determine the proportion of the mixture required to obtain the best animal performance together with economic viability.

Conclusion

Fermentative losses are reduced by adding pigeon pea to sugarcane silage, with reduced effluent and gas losses and increased dry matter content. Including pigeon pea in sugarcane silage decreases the hemicellulose content and increases crude protein, acid detergent fiber and lignin content.

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