Ruminal in situ degradability of dry matter and neutral detergent fiber of sugarcane silage

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Abstract

The ruminal degradability of dry matter (DM) and neutral detergent fiber (NDF) of 9 sugarcane varieties ensiled 15 months after planting was evaluated, using 3 fistulated Holstein x Zebu cows and incubation periods of 0, 6, 12, 24, 72 and 96 h in a randomized complete block design. Dry matter, crude protein (CP), mineral matter (MM), NDF, pH and in-situ degradability levels were determined. There were significant differences in composition of all evaluated parameters in the silages, except for CP, with the following variations: DM (19.7–23.2%), CP (2.70–3.47%), MM (3.2–5.2%), NDF (67.6–73.8%) and pH (3.8–4.2). The DM fraction 'a' differed among sugarcane varieties, with SP 801816 presenting the highest soluble fraction (26.83%). Effective degradability (ED) of DM (32.7–40.9%) and degradation rate 'c' did not differ among varieties. The ED of NDF and fraction 'a' did not differ among silages, but there were significant differences in fraction 'b', with a variation from 36.4 to 41.2%. Highest NDF ED occurred for the varieties RB 835486 (22%) and SP 791011 (21.1%). Further studies with these two varieties with the addition of inoculants and additives at ensiling are needed along with feeding studies to determine animal performance data.

Resumen

Se evaluó la degradabilidad de la materia seca (MS) y la fibra detergente neutra (FDN) de ensilajes de 9 variedades de caña de azúcar, ensiladas 15 meses después de la siembra, utilizando 3 vacas (Holstein x Cebú) con cánula ruminal. Las muestras se incubaron durante 0, 6, 12, 24, 72 y 96 h y se determinaron los niveles de MS, FDN, proteína cruda (PC), materia mineral (MM), pH y la degradabilidad in situ. El diseño experimental fue bloques al azar con 9 tratamientos y 3 repeticiones. Los resultados mostraron diferencias ($P<0.05$) en la composición química de los ensilajes, excepto para PC, con las variaciones siguientes: MS (19.7–23.2%), PC (2.70–3.47%), MM (3.2−5.2%), FDN (67.6–73.8%) y pH (3.8–4.2). La fracción soluble ('a') de la MS varió entre las variedades de caña, entre ellas la SP 801816 que presentó el valor más alto (26.83%). La degradabilidad efectiva (DE) de la MS (32.7–40.9%) y la tasa de degradación ('c') no difirieron entre variedades. La DE de la FDN y la fracción 'a' no difirieron entre ensilajes, pero se encontraron diferencias en la fracción potencialmente degradable ('b') con variaciones desde 36.4 hasta 41.2%. Los valores más altos de la DE de la FDN ocurrieron con las variedades RB 835486 (22%) y SP 791011 (21.1%). Se sugiere la realización de estudios con estas 2 variedades usando inoculantes y aditivos al ensilar y determinando el desempeño animal.

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Introduction

Sugarcane (*Saccharum officinarum)* is grown in the tropical areas of Brazil, where it is processed into sugar and/or alcohol. Increasingly, because of its high growth rate, it is viewed as a forage source for cattle. However, there are aspects of quality that must be considered before offering it to livestock, as its slow cell-wall digestion results in low metabolizable energy available to the animal, and limits its nutritive value. Due to difficulties presented by the use of freshly cut sugarcane, its conservation as silage is generally necessary to make it useful.

Although sugarcane has a high sugar fraction, which would support rapid microbial growth in the rumen, especially of bacteria, the microflora have a lesser capacity to degrade the potentially degradable fiber (Pereira et al. 2001). The rapid breakdown and loss of soluble carbohydrate fractions in sugarcane silages cause a slight increase in cell-wall components relative to other forage fractions (Schmidt et al. 2007b). The nylon bag technique has been adapted by researchers to estimate these losses. This technique has the advantages of speed, low cost and ease of execution.

As numerous sugarcane varieties are now available, each with certain enhanced characteristics aiming to meet the needs of the sugar/alcohol industry, it is essential to know the quality of these different varieties with respect to fiber content and degradation kinetics for the livestock industry. Further, these factors can be related to animal performance to allow selection of those varieties that can increase production (Azevêdo et al. 2003a).

It is customary to include additives during ensiling to enhance the fermentation process (Schmidt et al. 2007a). In this study, no additives or inoculants were used so that differences between the sugarcane varieties would not be masked. In a later study these same varieties will be assessed along with the use of inoculants and additives.

Therefore, the aim of this study was to assess silages made from different sugarcane varieties by determining the degradation profiles of dry matter and neutral detergent fiber, to help in choosing appropriate varieties for use as animal feed.

Materials and Methods

The experiment was conducted at the Model Dairy Farm belonging to the Animal Production Department of the Veterinary and Animal Science School of the Federal University of Goiás, Goiânia, Goiás state, Brazil. The Model Farm is located in the Cerrado (savanna) biome (16º36' S, 49º16' W; 727 m asl). The climate in the region is Aw according to the Köppen classification (hot semi-humid, with a well-defined dry season from May to October), with average yearly temperature of 23.2 ºC, minimum average temperature of 17.9 ºC and mean annual rainfall of 1,760 mm (INMET 2010).

To assess the in-situ degradability of the ensiled forage, 3 crossbred (Holstein x Zebu) cows were used, each with a rumen fistula, and weighing approximately 450 kg. Animals were kept in individual paddocks with access to shade, water and feed troughs. The animals were fed with chopped sugarcane and a concentrate containing 20% crude protein, in the proportion of 60:40, at 8.00 and 15.00 h each day.

The experimental design was randomized blocks, with 9 treatments and 3 replicates. Nine sugarcane varieties were evaluated as silage: RB 72454, RB 835486, RB 845257, RB 855536, SP 813250, SP 835073, SP 801842, SP 801816 and SP 791011. The cane was ensiled 15 months after planting. Whole cane plants were chopped in a forage shredder into 2-cm pieces and ensiled, using experimental silos consisting of sealed plastic buckets, each with a capacity of 4 kg of forage. The material was compacted by hand and wooden clubs, to obtain a density of approximately 700 kg/m^3. The silos were opened after 45 days, when a 10-g sample was taken to measure pH according to Silva and Queiroz (2002) and a 500-g sample was removed for evaluations. Samples were placed in a forced-air oven at 65 ºC for 72 h. Then a sub-sample was taken, ground and passed through a 5-mm sieve for the degradability tests.

A second sub-sample was prepared to determine the levels of dry matter (DM), crude protein (CP), mineral matter (MM) and neutral detergent fiber (NDF), according to the methods described by Silva and Queiroz (2002).

To assess the ruminal degradability of DM and NDF, we used the nylon bag method as proposed by Meherez and Ørskov (1977). Bags measuring 7 x 14 cm of free area with a mesh size of 50 μm were identified and weighed. Samples of 4.0 g DM of each silage variety were placed in separate bags for incubation.

The nylon bags were closed with small metal rings, tied with elastic bands and affixed to a chain for placement in the rumen of each cow. Incubation times were 0, 6, 12, 24, 72 and 96 h. In each cow, 90 bags were incubated (2 samples of each cultivar for each assessment time – samples of time 0 h were simply immersed and immediately removed from the rumen of animals). The bags were placed in the rumen in reverse order of incubation time but were all removed simultaneously. After retrieval, the bags were placed in buckets containing cold water to stop microbial activity and then were sent to the laboratory for washing. After thorough washing in distilled water, the bags were dried in a forced-air oven at 60 ºC for 72 h and weighed. All residual material was ground in a Willey mill with 1-mm mesh for measurement of DM and NDF, according to the methodology described by Silva and Queiroz (2002).

DM and NDF degradabilities were calculated using the mathematical model proposed by Mehrez and Ørskov (1977). Once the values of fractions ‘a’, ‘b’ and ‘c’ were obtained, they were applied in the equation proposed by Ørskov and McDonald (1979): ED = a + [(b x c)/c + k]**,** where ED is the effective ruminal degradability of the component analyzed and k is the rate of ruminal passage of the food (5%/h), according to ARC (1984).

Variables were submitted to analysis of variance and the means were compared by the Tukey test at 5% probability, using the Sisvar 4.6 program (Ferreira 2008).

Results

Chemical composition and pH of the silage made from the 9 sugarcane varieties are shown in Table 1. There were significant differences ($P<0.05$) among varieties for all characteristics evaluated except for CP.

The CP concentrations ranged from 2.70 to 3.47% ($P>0.05$), MM levels from 3.25 to 5.24% ($P<0.05$) and pH from 3.80 to 4.30 ($P<0.05$). Variety RB 845257 had the highest NDF concentration and SP 801816 had the lowest ($P<0.05$).

The results for the soluble fraction (‘a’), potentially degradable fraction (‘b’), degradation rate of the potentially degradable fraction (‘c’) and effective degradability (ED) of DM estimated for the 5%/h passage rate of the silages made from the different sugarcane varieties are shown in Table 2. Soluble fraction ‘a’ for DM differed ($P<0.05$) among sugarcane silages, with SP 801816 presenting the highest soluble fraction (26.8%). Dry matter fractions ‘b’ and ‘c’ and ED of DM did not vary significantly ($P>0.05$) among the silages, with the potentially degradable DM fraction (‘b’) ranging from 26.7 (SP 801816) to 32.8% (SP 835073) and the degradation rate (‘c’) having an overall average of 3.64%/h. There was no statistically significant difference in ED of DM ($P>0.05$) among tested silages, with a range of 32.7 to 40.9%.

For NDF, fractions ‘a’ and ‘b’ and the degradation rate ‘c’, as well as effective degradability (ED) of NDF of the silages, are shown in Table 3. There was no significant difference ($P>0.05$) in the values of fraction ‘a’ among the varieties, which ranged from 0.63 to 2.22%. The potentially degradable fraction ‘b’ varied ($P<0.05$) from 35.5 to 41.2%, as did the degradation rate (range 2.46 to 5.23%/h; $P>0.05$). Effective degradability varied ($P<0.05$) from 15.3 to 22.0%.

Discussion

This study has provided useful information on the quality of silage made from a range of sugarcane varieties for feeding to cattle. All varieties produced silage with low crude protein and high crude fiber levels plus dry matter degradability of less than 40%, indicating limited nutritive value for livestock unless nitrogen supplements are included to increase rate of passage and hence feed intake.

Table 1. Dry matter (DM), crude protein (CP), mineral matter (MM), and neutral detergent fiber (NDF) concentrations and pH of silages made from 9 sugarcane varieties.

Variety	DM (%)	CP (% DM)	MM (% DM)	NDF (% DM)	pH
RB 72454	21.4b[1]	3.03a	5.07a	73.9ab	4.21a
RB 835486	21.6b	2.91a	3.25c	73.2bc	4.25a
RB 845257	23.2a	3.00a	3.60bc	75.4a	4.30a
RB 855536	22.3ab	2.97a	4.13b	72.3bc	4.20ab
SP 813250	22.1ab	2.91a	5.17a	72.0c	4.11b
SP 835073	21.6b	2.70a	3.74bc	73.4bc	4.10bc
SP 801842	19.7c	3.47a	5.24a	70.3d	3.96bcd
SP 801816	19.7c	3.35a	4.74a	67.6e	3.80d
SP 791011	18.7c	2.71a	3.74bc	68.5de	3.86cd

[1]Means followed by different letters within columns differ ($P<0.05$) by the Tukey test.

Table 2. Soluble fraction (a), potentially degradable fraction (b), degradation rate of fraction 'b' (c) and effective degradability (ED) of dry matter, with their respective coefficients of determination (R^2), of silages made from 9 sugarcane varieties.

Variety	a (%)	b (%)	c (%/h)	ED (%)	R^2
RB 72454	22.0bc[1]	30.3a	4.35a	35.9a	0.98
RB 835486	23.6abc	31.8a	3.71a	37.7a	0.98
RB 845257	19.6c	31.9a	3.69a	33.1a	0.97
RB 855536	21.9bc	31.3a	3.30a	35.3a	0.99
SP 813250	21.3c	29.5a	3.25a	32.7a	0.99
SP 835073	21.9bc	32.8a	3.39a	35.0a	0.98
SP 801842	22.8abc	28.8a	3.35a	35.8a	0.98
SP 801816	26.8a	26.7a	3.30a	37.3a	0.99
SP 791011	26.4ab	30.3a	4.46a	40.9a	0.99

[1]Means followed by different letters within columns differ (P<0.05) by the Tukey test.

Table 3. Soluble fraction (a), potentially degradable fraction (b), degradation rate of fraction 'b' (c) and effective degradability (ED) of neutral detergent fiber, with their respective coefficients of determination (R^2), of silages made from 9 sugarcane cultivars.

Variety	a (%)	b (%)	c (%/h)	ED (%)	R^2
RB 72454	1.54a[1]	37.2bcd	4.71a	19.2ab	0.98
RB 835486	2.22a	40.8a	5.23a	22.0a	0.98
RB 845257	1.55a	38.8abcd	3.43a	17.0ab	0.98
RB 855536	1.32a	39.7abc	3.40a	17.3ab	0.99
SP 813250	0.63a	36.4cd	2.46a	15.3b	0.99
SP 835073	1.12a	41.2a	3.62a	18.3ab	0.98
SP 801842	0.70a	35.5d	4.86a	17.7ab	0.97
SP 801816	0.70a	37.2bcd	3.35a	15.6b	0.99
SP 791011	1.91a	40.4ab	4.66a	21.1a	0.98

[1]Means followed by different letters within columns differ (P<0.05) by the Tukey test.

The dry matter (DM) contents in the silages (18.7–23.2%) were similar to the 22.4 and 20.7% found by Freitas et al. (2006b) in an experiment involving sugarcane ensiled 11 and 13 months after planting, respectively, and lower than the 28.6% found by Freitas et al. (2006a) in sugarcane ensiled 16 months after planting, and the 25.2% reported by Santos et al. (2011). According to McCullough (1977), desirable DM levels for ensilage are between 28 and 34%. Above 28% DM, the proliferation of yeasts is reduced by raising the osmotic pressure (Van Soest 1994), while a DM content above 35% favors the growth of bacteria of the *Clostridium* genus, which produce butyric acid and reduce silage quality.

While stage of maturity and soil moisture levels can affect plant moisture levels, a contributing factor to the low DM levels found in our silages was the failure to use additives in the ensiling process, since effective ensiling of sugarcane requires large amounts of additives (Siqueira et al. 2007). These authors evaluated additives and inoculants for ensiling sugarcane and showed that the inclusion of inoculants increased DM content of silage by more than 4 units (from 27.4 to 31.9%), when *Lactobacillus buchneri* was added.

The low DM levels measured in varieties SP 801842, SP 801816 and SP 791011 were a reflection of the intermediate and late ripening cycles of these varieties, which were less mature than the others at harvest. McDonald et al. (1991) indicated that DM loss in sugarcane silages can exceed 35% of the original level due to alcoholic fermentation caused by epiphytic yeasts in the forage, which are a feature of some varieties. Freitas et al. (2006a) reported a DM reduction of 19.5% relative to the original DM level, when evaluating sugarcane silage with different forms of additives (soybean crop residue, *Lactobacillus plantarum* and *L. buchneri*).

According to Preston and Leng (1978), the crude protein (CP) concentration in sugarcane varieties is naturally low, as we have also shown, a strong case against its use as the sole feed for cattle. This low protein content can be remedied, at low cost, by adding a source of non-protein nitrogen to the diet. Some cattle herders routinely add low levels of urea, following a period of adaptation to its inclusion in the sugarcane forage diet. Without additional N or protein, low CP levels in sugarcane forage can impair the functioning of the ruminal microbiota; as Van Soest (1994) stated, the minimum CP level should be 7% for adequate rumen functioning. Azevêdo et al. (2003b) analyzed sugarcane varieties with different ripening cycles and found CP levels similar to those of our study, with mean values of 2.8, 2.4 and 2.4% for varieties SP 801842, RB 845257 and SP 791011, respectively, levels well below that suggested by Van Soest (1994) as optimal for rumen microbiota.

While sugarcane produces large quantities of DM, it is considered to be poor in minerals. For example, Pinto et al. (2003) reviewed several cultivars and the mineral concentrations ranged from 1.2% DM (cultivar SP 801842) to 3.4% DM (cultivar RB 72454). Therefore, it is necessary to improve the quality through physical and/or chemical techniques, since mineral deficiencies can occur, if sugarcane is the sole feed for livestock. Levels of particular minerals in the silage must be determined, so that appropriate mineral supplements can be fed to the particular class of animals. The mineral matter (MM) levels we recorded (3.25–5.24%) were lower than values reported by Pedroso et al. (2006) of 6.59% and Schmidt et al. (2007b) of 8.10%. A range of factors can affect mineral composition of forages, especially type of soil, level and type of fertilizer applied and species and variety. Lopes and Evangelista (2010), in an experiment conducted to assess the effect of additives on sugarcane silage, reported average ash levels of 4.26% after opening the silos, with no significant differences in this parameter attributed to different additives.

The neutral detergent fiber (NDF) values in this study were higher than those found by Freitas et al. (2006b) (66.3%), Balieiro Neto et al. (2007) (63.3%), Schmidt et al. (2007b) (66.0%) and Queiroz et al. (2008) (53.5%). This is quite significant as Van Soest (1965) indicated that cell-wall constituents above 55–60% in the DM are negatively correlated with the consumption of forage by animals, since rate of digestion is slower and retention time in the rumen is increased. Higher NDF levels in sugarcane silage than in the original green material occur due to the loss of cell contents caused by microorganisms that produce organic acids and alcohol, raising the proportion of fibrous matter, and reducing the nutritive value of the forage (McDonald et al. 1991).

The pH values in this experiment (3.8–4.3) are similar to the figures found by Freitas et al. (2006a) (3.5), Schmidt et al. (2007b) (3.31) and Siqueira et al. (2007) (3.7). According to McDonald et al. (1991), pH of silage should be lower than 4.2, to inhibit development of microorganisms that produce butyric acid, which lowers acceptability and quality of silage.

Compared with silage made from other tropical grasses, sugarcane dry matter's fraction 'a' in this research presented medium values. Pires et al. (2010) evaluated silage from corn (AG 7575), sorghum (BR 700) and *Brachiaria brizantha* and found DM fraction 'a' values of 38.5, 21.4 and 12.5%, respectively. Resende et al. (2003) evaluated forage sorghum and grain sorghum and the DM fraction 'a' values were, respectively, 26.8 and 29.2%. Rossi Jr. and Schogor (2006), in an experiment with silage made of sugarcane variety RB 72474, found a fraction 'a' value of 23.4% in silage without additives, 33.5% when urea was added (1% of silage fresh matter) and 35.3% when urea (1% of silage fresh matter) and corn grain (2.5% of silage fresh matter) were added. Since the fraction 'a' values did not differ between the urea treatment and the urea + corn grain treatment, the increase was possibly due to an increase in available nitrogen for the microbes. The higher soluble sugars fraction (26.8%) in SP 801816 in our study suggests that this would promote greater microbial growth in the rumen than the other cultivars.

It is of interest that fraction 'b' and its degradation rate 'c' and the effective degradability (ED) of DM did not differ among varieties. Values for the potentially degradable fraction (26.7–32.8%) were similar to those reported by Rossi Jr. and Schogor (2006) (31.4%) and Schmidt et al. (2007b) (27.5%). In silages such as corn and sorghum, which contain large quantities of starch because of the grain content, values for this fraction are substantially higher, averaging around 50%; thus they are potentially better feed sources for livestock. The overall average figure (3.64%/h) for degradation rate 'c', which represents the fermentation rate of fraction 'b', was similar to the rates observed by Rossi Jr. and Schogor (2006) of 3.29%/h (sugarcane cultivar RB 72-474), and Schmidt et al. (2007b) of 3.27%/h (sugarcane cultivar RB78-5841).

According to Martins and Loyola (1999), factors such as DM, type of fermentation and concentration of soluble carbohydrates can affect the ruminal degradability rates of silages. Schmidt et al. (2007b), in an experiment with sugarcane (cultivar RB78-5841), found the ED of DM to be 41.2%, compared with our findings of 33.1–40.9%. Balieiro Neto et al. (2007) found in vitro digestible DM concentrations in pure sugarcane silage (cultivar IAC86-2480) of 62.1%.

Our values of NDF fraction 'a' (0.63–2.22%) were much lower than the 10.9% for fraction 'a' for sugarcane (variety RB78-5841) silage reported by Schmidt et al. (2007b). They did not state the age of the cane at ensiling, so there is no way to judge whether the lower value for ‘a’ in our experiment was due to the increase in the fibrous fraction caused by greater age of the cane at ensiling.

The low values for the ED of NDF (15.3–22.0%) were similar to the 14.1 to 17.3% for sugarcane silage (variety not mentioned) without additives reported by (Santos et al. 2008) and 13.8% for silage of cultivar SP 801816 without additives (Santos et al. 2011).

Conclusions

Effective degradability of DM of all analyzed varieties ranged around 35.9%, indicating that the silage would be of limited value for feeding to livestock as the sole diet. The results of this study suggest that varieties SP 791011 and RB 835486 are more suitable for animal feed due to higher NDF degradability. As a preliminary study, these two varieties should be evaluated under laboratory conditions with the use of additives and inoculants and evaluation of in vitro digestibility. This should be followed by assessment of animal performance with nitrogen supplements. Other factors such as DM yield, susceptibility to lodging and time to maturity of all evaluated varieties should be investigated in further studies to provide sufficient data for decision making.

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