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Chemical composition and fermentation characteristics of sugar cane silage enriched with detoxified castor bean meal

[*Composição químico-bromatológica e características fermentativas de cana-de-açúcar ensilada com farelo de mamona destoxificado*]

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ABSTRACT

This experiment was designed to evaluate the effects of the inclusion of detoxified castor bean meal (CM) content on the chemical-bromatological composition, as well as the fermentation characteristics and dry matter losses of sugarcane silage. The treatments consisted of four levels (0, 7, 14 and 21% natural matter) of addition of castor bean meal. The design was completely randomized, with five replicates. The material was ensiled in PVC silos of 50-cm in height and 10-cm in diameter, which were opened after 60 days. The density of fodder maintained in the silos was equal to 750kg of natural matter/m^3. In order to quantify the gas and effluent losses, the silos were weighed at the beginning and at the end of the experiment. The addition of castor bean meal has increased the levels of DM and crude protein and reduced the levels of neutral detergent fiber, $N\text{-}NH_3$, ethanol, and gas and effluent losses from silages, but did not affect pH values. During ensiling, alcoholic fermentation was controlled with the inclusion of the additive.

Keywords: by-product, ethanol, gases, *Saccharum officinarum* L, silage

RESUMO

O experimento foi desenvolvido para avaliar os efeitos da inclusão de níveis de farelo de mamona destoxificado sobre a composição químico-bromatológica, as características fermentativas e as perdas de matéria seca da silagem de cana-de-açúcar. Os tratamentos consistiam em quatro níveis (0, 7, 14 e 21% da matéria natural) de inclusão do farelo de mamona. O delineamento foi inteiramente ao acaso, com cinco repetições. Foram usados silos de PVC, com 50cm de altura e 10cm de diâmetro, para a produção das silagens, que foram abertos após 60 dias. A densidade de forragem nos silos foi correspondente a 750kg de matéria natural/m^3. Os silos foram pesados no início e ao final do período experimental para quantificar as perdas por gases e efluentes. A inclusão de farelo de mamona elevou os teores de MS e proteína bruta e reduziu os teores de fibra em detergente neutro, $N\text{-}NH_3$, etanol e as perdas por gases e efluentes das silagens, não ocasionando efeito nos valores de pH. A fermentação alcoólica durante a ensilagem foi controlada com a inclusão do aditivo.

Palavras-chave: etanol, gases, Saccharum officinarum *L, silagem, subproduto*

INTRODUCTION

The daily use of fresh sugarcane is traditional and widely known among farmers. However, this handling demands day-to-day manpower for cutting, unpacking the straw, transporting and milling, and may lead to operational limitations when it is intended to provide the supplement to large herds (Lopes and Evangelista, 2010).

The ensiling of sugarcane can be an interesting alternative to optimize the daily work in the fields. However, a major constraint for the

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conservation of this grass plant is directly associated with dry matter losses (DM) resulting from intense alcoholic fermentation when the forage is ensiled without additives. This grass hosts a large yeast population that is naturally present in sugarcane at the time of ensiling. As a consequence of this undesirable fermentation, sugarcane silage presents low nutritional values.

The search for information on technologies designed for the production of sugarcane silage so as to reduce the production of ethanol and thereby improve the nutritional quality of forage has been the subject of numerous studies nationwide. To this end, various additives have been studied, including quicklime and sodium chloride (Rezende *et al*., 2011), calcium oxide (Cavali *et al*., 2010), bacterial inoculant (Schmidt *et al*., 2011); soybean crop residue (Freitas *et al*., 2006), urea (Lopes and Evangelista, 2010), among others.

The additives with absorbent and nutritive properties are a promising alternative for the production of silage, as the addition of carbohydrate sources leads to a reduced demand for soluble carbohydrates, ensuring a satisfactory fermentation process, preventing the development of undesirable microorganisms and making the silage of tropical grass a nutritionally adequate food (Balsalobre *et al*., 2001).

Thus, the detoxified castor bean meal has a great adoption potential, since the generation of this residue has been stimulated by government programs aimed at generating clean energy through biodiesel. Furthermore, this by-product has a high protein value and absorbing characteristics that could improve the nutritive value and the fermentation profile by correcting the low protein values of sugarcane and reducing effluent losses on silages without additives.

The aim of this study was to evaluate the influence of different levels of detoxified castor bean meal on the chemical-bromatological composition of silages, as well as the losses and fermentation characteristics of sugarcane silages.

MATERIAL AND METHODS

The experiment was conducted at the Laboratory of Forage-growing and Pasture of UESB, *Campus* Juvino Oliveira, located in the municipality of Itapetinga-BA.

The sugar cane (*Saccharum officinarum L.*) variety used was the RB72454, with a brix level of 17 degrees. In order to obtain particles of an average size of 2cm, the canes were manually harvested and processed in a stationary shredder. After disintegration, the cane was ensiled without additives, or enriched with detoxified castor bean meal (DCM) at levels of 7%, 14% and 21%, based on natural materials. The used castor bean meal was purchased at agro-industries from the metropolitan region of Salvador-BA; the meal has been detoxified with the use of lime solution (CaOH), each kg being diluted into 10 liters of water and applied in the amount of 60 grams of lime per 1kg of meal, on a base of natural material, as recommended by Oliveira *et al*. (2007). After the meal and the lime solution were mixed, the material remained undisturbed for a period of twelve hours (overnight), and was afterwards dried. The drying time varied according to the weather conditions and lasted about 48-72 hours. The experimental design adopted was four treatments and five replicates.

In order to determine the chemical composition presented in Table 1, samples were collected from sugarcane *in natura* and fresh castor bean meal.

Table 1. Chemical composition of *in natura* sugar cane and detoxified castor bean meal

Item	Sugar cane	Castor bean meal
DM[1]	262.0	918.0
Ethereal extract[1]	18.0	17.7
Ashes[1]	20.0	141.1
Crude Protein[1]	19.0	388.8
INND[1]	0.7	16.3
INAD[1]	0.6	6.4
INND[2]	230.3	100.2
INAD[2]	190.7	40.0
NDFap[1]	490.0	300.0
ADF[1]	319.0	290.3
Lignin[1]	54.0	70.1

[1]g/kg of dry matter (DM), [2]g/kg of total nitrogen, insoluble nitrogen in neutral detergent (INND), insoluble nitrogen in acid detergent (INAD), neutral detergent fiber corrected for ashes and protein (NDFap), acid detergent fiber (ADF).

Immediately after the cane was cut and shred it was enriched with castor bean meal in a proportion determined on a base of natural materials.

After the amount of castor bean meal was mixed to the sugarcane on a base of natural materials (weight/weight), the material was stored for 60 days in silos of 50-cm in height and 10-cm in diameter, fitted with a Bunsen valve for the output of fermentation gases. Each silo contained 1.5kg of sand in the bottom, which was separated by a screen fitted with a mesh properly designed to prevent contact with the silage and thereby quantify effluents.

Compression was performed with the aid of concrete sockets with the arrangement of layers of approximately 5cm in thickness, thus providing a specific mass with a density of 750kg of green material/m^3; after compression the silos were sealed and weighted.

After 60 days the silos were weighed and opened, proceeding to the collection of samples, which were frozen for later analysis.

Before analysis the samples were thawed at room temperature, packaged in paper bags and pre-dried in an oven, for 72 hours, at a temperature of 65°C. After that, the samples were ground in a Willey-type mill equipped with 1 mm mesh sieves, and submitted for analysis of dry matter (DM), total nitrogen (TN), ether extract (EE), neutral detergent fiber without ash and protein (NDFap), acid detergent fiber (ADF), cellulose, hemicellulose, lignin, nitrogen insoluble in neutral detergent (NIND), nitrogen insoluble in acid detergent (NIAD) and ashes, according to the methodologies described by Silva and Queiroz (2002).

The analyses of insoluble fiber in neutral (NDF) and acid detergent (ADF) (Van Soest *et al.*, 1991) were performed in an autoclave, as proposed by Pell and Schofield (1993).

Part of the silage *in natura* (50 g) was triturated with 200mL of water in an industrial blender and filtered through cheese-cloth layers for extraction of the aqueous medium to be used in the analysis of ammonia nitrogen ($N\text{-}NH_3$) and pH. A percentage of the total nitrogen (TN,) the $N\text{-}NH_3$ content is forthwith measured using magnesium oxide and calcium chloride, according to Cunniff (1995).

In order to determine the organic acids, approximately 25g of thawed silage were diluted into 250mL of distilled water and homogenized in an industrial blender for one minute. The resulting aqueous extract was filtered through filter paper, and 100mL of the extract were acidified with H_2SO_4 (50%), and thereupon filtered using a fast filter paper (Ranjit and Kung Jr., 2000). As an internal standard, 1mL of 20% metaphosphoric acid and 0.2mL of 1% carbolic acid have been added to 2mL of this filtrate. The determination of lactic, acetic, propionic and butyric acids was performed by high-performance liquid chromatography (HPLC), using a Schimadzu SPD-10 detector with a wavelength of 210 nm, a C18 Reversed-Phase Column, pressure of 168kgf and flow of 1.5mL/minute. Ethanol analysis was performed by high performance liquid chromatograph (HPLC) using a SHIMADZU RID – 6A detector (SCR-101P Column), at a pressure of 31kgf and a flow of 1.2mL/min.

The dry matter loss in the form of gases was calculated based on the weight of the silos during their opening and closure and by deducting the weight of the empty silo. The amount of effluents was calculated as the difference between the initial and the final weight of the silos containing sand and plastic screen. In turn, the total loss of DM (DML) during ensiling was calculated by the difference between the weight of the initial and the final dry matter content in the silos, as described by Jobim *et al*. (2007).

Data were assessed by analysis of variance and regression, using the Statistical and Genetic Analysis System - SAEG (System…, 2000). The models were selected in line with the determination coefficients (R^2) and the observed significance of the regression coefficients, using the F test at a probability level of 0.05.

RESULTS AND DISCUSSION

DM values have been influenced ($P<0.05$) by the inclusion levels of detoxified castor bean meal (Table 2). The addition of castor meal into the sugarcane ensilage has affected the DM content of silages in an increasing and linear order. The increases found for this variable were of 0.76 percentage units for each unit of castor bean meal added.

Table 2. Average contents of dry matter (DM), crude protein (CP), insoluble protein in neutral detergent as a function of CP (IPND/CP), insoluble protein in acid detergent as a function of CP (IPAD), ether extract (EE), ashes, neutral detergent fiber corrected for ashes and protein (NDFap), acid detergent fiber (ADF), hemicellulose (HEM), cellulose (CEL), lignin and fiber in indigestible neutral detergent (NDFi) of sugarcane silages with additives (or not), with detoxified castor bean meal

Variable	Levels of castor beans meal (g/kg MN)				Regression equation	R^2	CV (%)
	0	7	14	21			
DM[1]	199.3	261.0	311.0	353.0	$\hat{Y} = 200.0046 + 7,57933x$	0.97	3.1
DM[1]	28.0	119.0	161.0	200.0	$\hat{Y} = 43.32614 + 7,96863x$	0.92	6.8
IPND[2]	469.0	336.0	295.0	303.0	$\hat{Y} = 466.823 – 22.7621x + 0.7163x^2$	0.86	8.1
IPAD[2]	205.0	236.0	238.0	225.0	$\hat{Y} = 226.0$	-	10.7
EE[1]	17.0	15.0	16.0	18.0	$\hat{Y} = 14.88 + 0.20428x$	0.92	2.6
Ashes[1]	32.0	48.0	55.0	61.0	$\hat{Y} = 34.628 + 1.3556x$	0.90	4.8
NDFap[1]	682.0	538.0	495.0	471.0	$\hat{Y} = 648.191 – 9.66869X$	0.85	4.8
ADF[1]	498.0	414.0	405.0	403.0	$\hat{Y} = 494.404 – 12.924x + 0.4151x^2$	0.78	4.6
HEM[1]	194.0	123.0	80.0	54.0	$\hat{Y} = 182.278 – 6.5687x$	0.91	11.5
CEL[1]	373.0	244.0	200.0	192.0	$\hat{Y} = 340.697 – 8.4104x$	0.77	7.4
Lignin[1]	74.0	79.0	85.0	92.0	$\hat{Y} = 73.0025 + 0.896786x$	0.99	3.0
NDFi[1]	370.0	328.0	358.0	330.0	$\hat{Y} = 346.7$	-	3.7

[1] g/kg DM, [2] % CP, NM: natural material

The increased DM content of enriched silages can be explained by the fact that the castor bean meal has a high DM content (918.0 g/kg) (Table 1). The highest values found for DM were 311.0 and 353.0 g/kg for silages enriched with 14 and 21 g/kg of NM, respectively.

Silages with DM content below 300g/kg are prone to undesirable fermentations due to excess moisture; this condition hinders the rapid lowering of pH, which is a precondition for ensuring a proper fermentation.

The lowest value observed in the control sugarcane silage was 193.0g/kg of DM, probably as a result of the increased production of gases and effluents (Table 3) resulting from the largest expanse of undesirable fermentations, especially by yeasts.

Corroborating the results obtained in this experiment, Freitas *et al*. (2006), assessing the inclusion of 10% of soybean crop residue on the nutritional quality of silage from sugar cane, found elevated levels of MS, with values of 286.0 and 324g/kg DM respectively for the control silage doped with 10% soybean crop residue.

Similarly, Lopes and Evangelista (2010) also observed increases in DM content with the addition of urea 0.5 + 4% corn and 0.5% urea + 4 cassava, which showed average values of 270.0 and 249.0g/kg of DM, respectively.

The CP and NDIP / PB were influenced (P<0.05) by the inclusion of castor meal in the ensiling of sugar cane. When evaluating the values of PB, there was positive linear correlation with the addition of castor bean meal. For each unit of added castor meal, CP levels increased 0.79 percentage units. The castor bean meal is a protein additive (387.0g/kg CP), which explains the results found in this study.

The increase in crude protein content of silage cane sugar control in relation to sugarcane in nature (Table 1) is associated with the concentration of this nutrient in MS, mainly due to the loss of soluble carbohydrates by respiration in the fermentation process of silage.

As for neutral detergent insoluble protein as a percentage of CP (NDIP / PB), the negative quadratic function of the level of castor bean meal added, with minimum point of 286g/kg was 15.9g/kg addition of castor meal.

In contrast, the ADIP values /BP were not influenced (P>0.05) by adding the by-product which had a mean value of 226.0g/kg (Table 2). This result was possibly due to the low levels of this protein fraction (Table 1) in castor meal, not promoting change of silages.

The levels of EE and ash were influenced (P<0.05) by the inclusion of castor meal in a linear way with increases of 0.02 and 0.13 percentage units for each unit of castor bean meal added. The elevated content of EE was not expected since the product used has low concentrations of EE due to the solvent extraction method, by which it is subjected. The likely explanation for these results is a possible concentration effect due to the decrease in soluble carbohydrates during the fermentation process. An elevation was expected in the ash contents since the detoxification castor bran increases the ash due to the addition of minerals in the chemical treatment.

The fiber fraction of silages of cane sugar was influenced (P<0.05) by castor bean meal. The contents of NDF, hemicellulose and cellulose were linearly reduced with the inclusion of the product used. The reductions were 0.97, 0.65 and 0.84 percentage units respectively for each unit meal of castor added (Table 2). On the other hand, the ADF values showed a negative quadratic response, with a minimum of 39.4% at a castor bean meal level of 15.6%. Despite the NDFap concentrations having been reduced with the use of a by-product, the value of this control silage was superior to that of the sugarcane *in natura*. This result is commonly encountered in the literature, since the loss of soluble carbohydrates (highly fermentable components) promotes such elevation. On the other hand, the enriched silages showed reduced NDFap values, possibly because the DM loss of these silages was inferior to that of the control silage (Table 3); this has probably reduced the intense use of soluble carbohydrates, thus diminishing the effect of concentration. Furthermore, the castor bean meal showed a lower NDFap (Table 1), which may have produced a dilution effect.

Despite the NDFap values having decreased with the inclusion of a by-product, the NDF levels increased (Table 1) after ensiling. This finding is in line with the results obtained by Schmidt *et al.* (2011), who observed an average increase of 17.8 and 12.7 percentage units in the NDF and ADF levels of sugarcane before and after ensiling.

A different response pattern for the fiber fraction has been observed for the lignin content of silages, which were observed to increase with the inclusion of castor bean meal. The increases found for this variable were of 0.09 percentage units for each unit of castor bean meal added. The observed increases might have been due to the presence of the studied oleaginous seed coat. The results are explained by the fact that the seed coat has high lignin and cutin levels.

As for NDFi, the addition of castor bean meal to enriched silages was not observed to exert any influence (P <0.05), showing an average percent value of 34.7% (Table 2).

The inclusion of castor bean meal in the sugarcane ensiling had an influence (P<0.05) on total DM losses, losses in gases and effluents, and recovery of DM (RECPDM) (Table 3).

Table 3. Losses and recovery of DM (RECPMS) from sugarcane silages enriched (or not) with detoxified castor bean meal

Variable	Levels of castor beans meal (g/kg NM)				Regression equation	R^2	CV (%)
	0	7	14	21			
Total DM losses[1]	313.0	261.0	213.0	162.0	Ŷ= 31.6120 – 0.739337x	0.92	6.1
Losses in gases[1]	179.0	108.0	62.0	44.0	Ŷ= 16.5507 – 0.641911x	0.91	6.7
Losses in effluents[2]	192.4	183.2	153.7	120.2	Ŷ= 199.287 – 3.51537x	0.95	3.5
RECPDM	69.5	73.9	78.7	83.8	Ŷ= 69.2985 + 0.683590x	0.98	1.0

[1] g/kg of DM; [2]kg/t NM ; NM: natural material

The percent values of total DM losses were linearly reduced (P<0.05) with the inclusion of the byproduct. Possibly, the increased DM content of enriched silages has favored the reduction of losses by reducing the moisture content of the control silage. Silages with DM content below 30% of DM favor the development of secondary fermentations responsible for increased nutrient losses in silages. From a nutritional standpoint, the reduction of 0.73 percentage units per unit of castor bean meal represents an interesting result, since it can provide the nutrients that would be wasted by leaching or by gases. The largest reduction in total DM losses was obtained at a level of inclusion of 21%, showing an average value of 16.2%, whereas the control silage showed a loss percentage of 31.3%, i.e., 48.2% higher than that of the silage enriched with 21% of castor bean meal.

The findings of this study regarding DM loss were on average similar to those found by Freitas *et al*. (2006) and Rezende *et al*. (2011); when studying sugarcane silages enriched with 10% soybean crop residue and 0.5% sodium chloride, these authors have observed DM losses of about 22.4% and 24.9 %, respectively. The authors believe that this reduction in losses has occurred due to the increased DM content of enriched silages, as a result of the lower ethanol concentration of these silages.

Castor bean meal levels have linearly decreased ($P<0.05$) losses in the form of gases from sugarcane silages. There were reductions of 0.64 percentage units for each unit of castor bean meal added. On average, DM losses in the form of gas accounted for 57.1% of the total DM losses. Losses in the form of gases are the major path of fermentation loss in sugarcane silages (Baliero Neto *et al*., 2009).

Similarly, losses in the form of effluents were linearly decreased with the inclusion of the byproduct (Table 3). The observed reductions were of 3.51 percentage units for each unit of castor bean meal added. High effluent production indicates a reduction in the nutritional value of silages, since the nutrients that could be potentially used by the animals are carried to the bottom of the silo through a leaching process. In this regard, the use of additives with an absorbent potential - such as the one used in this study - favors the ensiling process, since it increases the DM content and reduces nutrient losses via effluents.

The greatest reduction in effluent production (37.5%) was observed in the silage with 21% of CM (Table 3). The production of effluents was superior when compared with the results reported by Santos *et al*. (2008); Schmidt *et al*. (2011) and Rezende *et al*. (2011), who found average values of 29.7%, 9.8% and 54.9% of losses in the form of effluents in studies comprising microbial inoculants, quicklime, sodium chloride and calcium oxide, respectively.

RECPDM values were linearly influenced ($P<0.05$) by the addition levels of castor bean meal. The increases were of 0.68 percentage units for each unit of castor bean meal added (Table 3). These results are consistent with those found for losses, since the reduction in losses due to increased DM levels via additives provides higher recoveries and has beneficial effects from the fermentative, nutritional and economical standpoints.

The fermentative characteristics of sugarcane silages are presented in Table 4. The addition of castor bean meal to sugarcane ensiling has not affected ($P>0.05$) the pH value, which had an average value of 3.6 (Table 4).

Table 4. Fermentative characteristics of sugarcane silage with (or without) detoxified castor bean meal

Variable	Levels of castor bean meal (%NM)				Regression equation	R^2	CV (%)
	0	7	14	21			
pH	3.5	3.6	3.6	3.7	$\hat{Y} = 3.58$	-	3.1
NH_3[2]	66.0	16.0	16.0	15.0	$\hat{Y} = 63.395 – 7.413x + 0.2496x^2$	0.93	3.7
Latic acid[1]	9.0	11.0	13.0	12.0	$\hat{Y}= 8.757 + 0.470x – 0.01515x^2$	0.96	11.8
Acetic acid[1]	2.0	2.0	1.0	1.0	$\hat{Y} = 2.01625 – 0.050142x$	0.96	12.9
Propionic acid[1]	0.9	0.6	0.5	0.5	$\hat{Y} = 0.8697 – 0.0484x + 0.00157x^2$	0.84	14.0
Butyric acid[1]	0.07	0.06	0.05	0.05	$\hat{Y} = 0.0661060 – 0.00111837x$	0.85	10.9
Ethanol[1]	75.0	57.0	49.0	36.0	$\hat{Y} = 72.747 – 1.77350x.$	0.97	2.2

Ammoniacal nitrogen (NH3), 1g/kg of DM, 2g/kg of total nitrogen

Despite the pH values being low, these were not enough to reduce DM fermentative losses. These data corroborate the assertions that lactic acid is not a good inhibitor of yeast activity and that it serves as a substrate for its metabolism.

The variable NH_3 was affected ($P<0.05$) by the inclusion of castor bean meal in sugarcane ensiling and showed a quadratic response. The estimated minimum value was 0.83% at a 14.8% level. The highest NH_3 value found was that of the control silage (6.6%), which is below the 10% reported in the literature as indicative of poor quality silage (Van Soest, 1994).

The ammonia nitrogen is associated with the fermentative quality of silage, as it derives from the degradation of the protein fraction by clostridia (McDonald *et al*., 1991). Yet, this degradation is expected in sugarcane ensiling and is inhibited by the rapid decrease in pH as a result of the low buffering capacity and abundant presence of soluble carbohydrates. The low pH values (Table 4) found in these silages allow one to infer that the studied silages had a good fermentation profile.

The VFA profile of silages was influenced ($P<0.05$) by the addition of castor bean meal during the ensiling process. Lactic and propionic acids showed positive and negative quadratic responses, with maximum and minimum values of 2.0% and 0.05%, at levels of 15.6% and 15.4% of castor bean meal inclusion, respectively.

It should be noted that the lactic acid content obtained from silages does not necessarily represent the amount of acid produced in the fermentation process, since part of it can be converted into ethanol by the silage yeasts (Moon, 1983).

The acetic and butyric acid concentrations, in turn, have linearly decreased ($P<0.05$) with the inclusion of castor bean meal. There were reductions of 0.005 and 0.00015 percent units for each castor bean meal unit added (Table 4). The acetic acid concentrations found in all treatments were found to be lower than those recorded by Freitas *et al*. (2006), who noted an average concentration of 3.1%.

The ethanol values of silages have linearly decreased ($P<0.05$) in 0.2 percentage units for each castor bean meal unit added. The addition of castor bean meal has significantly contributed to reduce the ethanol content of the silages showing decreases of 23.4%, 35.2% and 53.3% in relation to the control, for the levels of 7%, 14% and 21%, respectively. The lowest and the highest values were observed for the control silage, and with 21% of CM with average values of 7.5% and 3.6%, respectively. According to Andrade *et al*. (2001), the ethanol reduction with the addition of absorbent additives can be attributed to the low tolerance of yeasts to the high osmotic potential of silages with additives. This fact may explain the lower ethanol production observed for the level of 21% of castor bean meal.

The results found in this study for the control treatment (7.5%) were greater than those observed by Amaral *et al*. (2009) and lower than those obtained by Freitas *et al*. (2006), who identified ethanol levels of 4.3% and 17.8%, respectively. According to the authors, the difference in ethanol production observed for the control silage is related to the concentration of soluble carbohydrates of the forage used at the time of ensiling.

According to McDonald *et al*. (1991), ethanol production represents a loss of 48.9% of DM from substrates, which majorly consists of soluble carbohydrates. This assertion is consistent with the findings of this study, which revealed major losses (Table 3) in silages containing higher ethanol concentrations (Table 4).

CONCLUSION

The addition of detoxified castor bean meal to sugarcane ensiling promotes better nutritional results, since it increases the crude protein levels and reduces the cell wall. The use of castor bean meal as an additive in sugarcane ensiling reduces alcoholic fermentation and losses in the form of gases and effluents, thus favoring the fermentation process.

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