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FERMENTATIVE LOSSES AND LACTIC ACID CONTENT OF ELEPHANT GRASS SILAGES ADDED WITH MACAÚBA CAKE

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Abstract
Elephant grass is indicated for silage production but requires additives to increase dry matter content because it reduces the production of effluents, potentially improves the fermentation pattern, and preserves the nutrients of the silage. This study aimed to evaluate the effects of including macaúba cake in elephant grass ensilage on dry matter content, lactic acid bacteria population, lactic acid production, pH values, losses by gases and effluents, and dry matter recovery. The experimental design was completely randomized, in a 3x6 factorial scheme, with three levels of inclusion of macaúba cake (0, 10, and 20%) and six opening times (1, 5, 10, 20, 40, and 60 days after ensilage), with four repetitions. Macaúba cake was an effective moisture-absorbing additive, increasing dry matter content, lactic acid bacteria population, and lactic acid content and reducing the pH. The losses by effluents and gases decreased, and dry matter recovery increased with the addition of this biodiesel co-product. The 20% level of inclusion of macaúba cake in elephant grass ensilage allowed for better preserving the ensiled material.

Keywords: Additives. Animal feed. Biodiesel. Co-products. Fermentation.

1. Introduction

The variation in the availability of growth factors for forages throughout the year determines the seasonality of forage production, which may compromise animal performance (Mochel Filho et al. 2016). Thus, using forage conservation techniques is indispensable to ensure feed supply in sufficient quantity and quality in critical times of the year, highlighting the ensilage technique (Azevedo et al. 2017; Guimarães et al. 2018).

Elephant grass (*Pennisetum purpureum* Schum.) is indicated for silage production due to its productive potential, animal acceptability, and resistance to adverse climatic conditions. However, this forage presents low nutrient levels and high moisture content during the harvest period, making the environment more conducive to developing unwanted microorganisms, potentially causing secondary fermentation that compromises the quality of the ensiled material (Cardoso et al. 2016). Thus, grass ensilage without additives favors significant losses by effluents, in which large amounts of organic compounds are carried, thus reducing the nutritional value of silages (Andrade et al. 2012).

The cakes are co-products of biodiesel production generated from the extraction of oil from oleaginous crops that, when discarded in the environment, can contaminate natural resources such as water and soil. In this context, using co-products in animal feed would be an alternative, adding value to the final product and reducing the costs of both biodiesel production and animal feed (Bonfá et al. 2018; Teixeira et al. 2014). Co-products can increase dry matter content, improve the nutritional value of silages, and reduce the fermentation caused by undesirable microorganisms (Bonfá et al. 2020).

Macaúba cake has a high dry matter content that allows using it as an additive in silage to improve fermentative characteristics by absorbing moisture. Among other characteristics, this biodiesel co-product has a competitive advantage compared to other biodiesel-producing oil crop cakes because it does not suffer from a direct price influence.

Considering the need to understand the potential of macaúba cake added to elephant grass silage, this study aimed to evaluate the effects of including macaúba cake in elephant grass silage.

2. Material and Methods

The experiment was conducted at the Federal University of Jequitinhonha and Mucuri Valleys (UFVJM), Campus JK, located in Diamantina, Minas Gerais, Brazil. Laboratory analyses were performed in the Microbiology Laboratory of the Graduate Program in Biofuels and the Animal Nutrition Laboratory of the Department of Animal Science, both at UFVJM.

The experimental design was completely randomized with four repetitions. The treatments were arranged in a 3x6 factorial scheme, with three levels of inclusion of macaúba cake (0, 10, and 20%, based on the green forage weight) and six silo openings (1, 5, 10, 20, 40, and 60 days after silage). The statistical model was:

$$Y_{ij}K = \mu + N_i + T_j + NT_{ij} + e_{ij}k$$

where, $Y_{ij}K$ = observation of level i of macaúba cake at opening time j in repetition k; μ = overall mean; N_i = effect of level i of macaúba cake (i = 1, 2, and 3); T_j = effect of opening time j (j = 1, 2, 3, 4, 5, and 6); NT_{ij} = effect of the interaction between level i of macaúba cake and opening time j; $e_{ij}k$ = experimental error associated with each observation that received level i of macaúba cake at opening time j in repetition k.

The elephant grass (*Pennisetum purpureum* Schum.), a Cameroon cultivar, was purchased from a rural property located in Lavras, Minas Gerais, Brazil. A uniform cutting was previously made, and the fertilization maintenance consisted of the formulated fertilizer NPK 8-28-16 at 400 kg ha^{-1}. Cutting was performed 10 cm from the ground level, and the grass was approximately 1.60-m high and had grown for 70 days, with an average dry matter yield of 16 t ha^{-1}. The co-product from the biodiesel production chain was the macaúba cake [*Acrocomia aculeata* (Jacq.) Lood. ex Mart.] (pulp and peel) obtained from Indústria DBIO, located in Dores do Indaiá, Minas Gerais, Brazil.

Subsamples were separated from the raw material of elephant grass, macaúba cake, and homogenized mixtures of elephant grass and macaúba cake with the respective levels of inclusion of macaúba cake (0, 10, and 20%) before the silage process for analyzing dry matter (DM), the microbial population of lactic acid bacteria (LAB), and pH (Table 1).

Table 1. Dry matter (DM) content (%), lactic acid bacteria (LAB) population (log CFU g^{-1}), and pH values of elephant grass, macaúba cake, and the respective additions before ensilage.

Raw material	DM	LAB	pH
Elephant grass	22.00	5.30	5.34
Macaúba cake	88.20	-	-
Elephant grass + 10% Macaúba cake	27.68	6.68	5.06
Elephant grass + 20% Macaúba cake	31.61	6.71	4.90

The elephant grass was chopped in a regulated stationary silage machine to obtain particles of approximately 2 cm. Then, the macaúba cake was added to the elephant grass with the respective levels of inclusion, and homogenization was performed. The silage was made in experimental silos of polyvinyl chloride (PVC) tubes of 100 mm in diameter and 450 mm in length, with PVC lids with a Bunsen valve, to allow the escape of gases produced in the fermentation inside the silos. A cloth bag with 0.8 kg of dry sand was deposited at the bottom of each silo to capture the effluents and subsequently estimate the losses during fermentation.

Each silo received 1.6 kg of material, and compaction was performed aided by wooden sockets, obtaining an average specific mass of 600 kg m^{-3} of green forage weight. The silos were sealed with a PVC lid, the entire set was weighed at the time of ensilage, and the lid was sealed with adhesive tape. The silos were stored in a covered area at room temperature. The silos were opened at the respective times, in days, according to the treatments aforementioned. The entire set was weighed at the opening times to estimate losses.

Losses by effluents (LE) were based on the differences in the weights of sand and cloth bags deposited at the bottom of the silos at closing and opening (Jobim et al. 2007), represented by the equation:

$$LE = (Wo – We)/ (GMef) \times 1000$$

where, LE = Losses by effluents (kg/ton of green mass); Wo = Weight of the set (silo, sand, and cloth bag) at opening (kg); We = Weight of the set (silo, sand, and cloth bag) in ensilage (kg); GMef = Green mass of ensiled forage (kg).

Losses by gases (LG) in ensilage were based on the weights of the silos at closing and opening relative to the stored forage mass, discounting the tare weight of the experimental silo, as described by Jobim et al. (2007), and represented with the following equation:

$$LG = [(Wfe – We) * DMe] – [(Wfo – We) * DMo] \times 100/ [(Wfe – We) * DMe]$$

where, LG = Losses by gases (% DM); Wfe = Weight of the silo filled in the ensilage (kg); We = Weight of the set (silo, sand, and cloth bag) in ensilage (kg); DMe = Dry matter content of the forage in the ensilage (%); Wfo = Weight of the silo filled at opening (kg); DMo = Dry matter content of the forage at opening (%).

The following equation was used to estimate the dry matter recovery (RDM) index, according to Jobim et al. (2007):

$$RDM = (MFo \times DMo)/ (MFc \times DMFc)*100$$

where, RDM = Dry matter recovery index (%); MFo= Forage mass at opening (kg); DMo= Dry matter content at opening (%); MFc = Forage mass at closing (kg); DMFc = Forage dry matter content at closing (%).

After opening the silos, the material was separated into two parts. One subsample was reserved for analyzing DM content and LAB population, and the other subsample was pressed to extract liquid from the silage for analyzing pH and lactic acid content.

To determine DM content, weighing and pre-drying were performed in a forced-air ventilation oven at 55°C for 72 hours. Then, DM was taken to an oven at 105°C (Detmann et al. 2012). For analyzing the LAB population, a 25-g aliquot was removed from each silo immediately after opening and placed in an Erlenmeyer flask with 225 mL of phosphate buffer solution. This sample was sent to the shaker for 20 minutes at 28°C, representing a 10^{-1} dilution (Kung Jr 1996). Subsequently, dilutions were made until reaching a 10^{-6} dilution. The MRS Agar Lactobacilli (MRS) from the brand Himedia was used as the culture medium, and the microbial population was counted on dishes with up to 300 colony-forming units (CFU) and transformed into log 10 base (log CFU g^{-1}).

The pH values were obtained using a potentiometer with an expanded scale from the brand Tecnopon, mPA 210. The lactic acid content with the liquid extracted from the silage was analyzed with high-performance liquid chromatography (Kung Jr 1996), using the C18 column (Reverse Phase) from the brand Biorad.

The data were subjected to the analysis of variance with the Genes statistical software (Cruz 2013). If there were significant effects regarding inclusion levels, opening times, and the interaction between them, a regression analysis was applied.

3. Results

There was a significant effect ($P<0.05$) on the dry matter (DM) content of elephant grass silages according to the levels of inclusion of macaúba cake (MC) and level/time interaction, with a quadratic behavior in the interaction (Table 2).

Table 2. Dry matter content (%) of elephant grass silages according to the levels of inclusion (LI) of macaúba cake and silo opening times, in days, after ensilage, with the respective means, regression equations, and coefficients of determination (R^2).

LI	Opening time						Mean	Regression equation	R^2
(%)	1	5	10	20	40	60			
0	19.3	18.4	18.5	18.9	19.0	19.7	19.0	$Y_0=18.9 - 2.4x10^{-2}X + 6.0x10^{-4}X^2$	0.79
10	25.1	26.0	25.7	24.9	24.8	25.0	25.3	$Y_{10}=25.7 - 3.4x10^{-2}X + 4.0x10^{-4}X^2$	0.63
20	29.9	30.1	29.8	29.2	30.1	30.0	29.9	$Y_{20}=30.0 - 2.4x10^{-2}X + 4.0x10^{-4}X^2$	0.50
Mean	24.8	24.8	24.7	24.3	24.6	24.9	24.7		

There was a significant effect ($P<0.05$) on the lactic acid bacteria (LAB) population of elephant grass silages according to MC levels of inclusion and level/time interaction, with a quadratic behavior in the interaction (Table 3).

Table 3. Lactic acid bacteria population (log CFU g^{-1}) in elephant grass silages according to the levels of inclusion (LI) of macaúba cake and silo opening times, in days, after ensilage, with the respective means, regression equations, and coefficients of determination (R^2).

LI	Opening time						Mean	Regression equation	R^2
(%)	1	5	10	20	40	60			
0	6.4	5.6	5.4	5.9	5.8	6.7	6.0	$Y_0=6.1 - 4.1x10^{-2}X + 9.0x10^{-4}X^2$	0.80
10	7.2	7.0	6.8	7.1	6.8	7.2	7.0	$Y_{10}=7.1 - 2.0x10^{-2}X + 3.0x10^{-4}X^2$	0.65
20	8.1	7.9	7.5	7.8	7.6	8.0	7.8	$Y_{20}=8.0 - 3.0x10^{-2}X + 5.0x10^{-4}X^2$	0.75
Mean	7.2	6.8	6.6	6.9	6.7	7.3	6.9		

There was a significant effect ($P<0.05$) on the lactic acid content of elephant grass silages according to MC levels of inclusion and level/time interaction, with a quadratic behavior in the interaction (Table 4).

Table 4. Lactic acid content (%) of elephant grass silages according to the levels of inclusion (LI) of macaúba cake and silo opening times, in days, after ensilage, with the respective means, regression equations, and coefficients of determination (R^2).

LI	Opening time						Mean	Regression equation	R^2
(%)	1	5	10	20	40	60			
0	2.2	3.6	4.0	4.9	3.3	4.2	3.7	$Y_0=2.9 + 8.5x10^{-2}X - 1.1x10^{-3}X^2$	0.59
10	1.8	4.1	4.3	4.4	3.9	5.6	4.0	$Y_{10}=3.0 + 5.9x10^{-2}X - 4.0x10^{-4}X^2$	0.70
20	1.0	3.7	4.5	4.5	4.5	7.3	4.2	$Y_{20}=2.4 + 0.1X - 5.0x10^{-4}X^2$	0.84
Mean	1.7	3.8	4.3	4.6	3.9	5.7	4.0		

There was a significant effect ($P<0.05$) on the pH values of elephant grass silages according to MC levels of inclusion and level/time interaction, with a quadratic behavior for the interaction (Table 5).

There was a significant effect ($P<0.05$) on losses by effluents of elephant grass silages according to MC levels of inclusion, opening times, and level/time interaction. There was an increasing linear behavior in the interaction (Table 6).

Table 5. The pH values of elephant grass silages according to the levels of inclusion (LI) of macaúba cake and silo opening times, in days, after ensilage, with the respective means, regression equations, and coefficients of determination (R^2).

LI	Opening time						Mean	Regression equation	R^2
(%)	1	5	10	20	40	60			
0	5.2	4.3	4.1	3.9	3.9	3.8	4.2	$Y_0=4.9 – 6.0x10^{-2}X + 7.0x10^{-4}X^2$	0.85
10	4.9	4.2	4.1	4.1	4.0	3.8	4.2	$Y_{10}=4.7 – 3.9x10^{-2}X + 4.0x10^{-4}X^2$	0.84
20	4.6	4.1	3.8	3.7	3.8	3.8	4.0	$Y_{20}=4.4 – 4.1x10^{-2}X + 5.0x10^{-4}X^2$	0.86
Mean	4.9	4.2	4.0	3.9	3.9	3.8	4.1		

Table 6. Losses by effluents (kg ton^{-1} of green mass) of elephant grass silages according to the levels of inclusion (LI) of macaúba cake and silo opening times, in days, after ensilage, with the respective means, regression equations, and coefficients of determination (R^2).

LI	Opening time						Mean	Regression equation	R^2
(%)	1	5	10	20	40	60			
0	25.8	49.8	57.6	66.1	66.7	89.3	59.2	$Y_0=40.8 + 0.8X$	0.89
10	6.4	6.4	5.9	17.7	18.1	31.0	14.2	$Y_{10}=4.8 + 0.4X$	0.95
20	3.0	3.8	6.2	5.1	16.4	28.3	10.5	$Y_{20}=0.9 + 0.4X$	0.97
Mean	11.7	20.0	23.2	29.6	33.7	49.5	28.0		

There was a significant effect ($P<0.05$) on losses by gases of elephant grass silages according to MC levels of inclusion, opening times, and level/time interaction, with a quadratic behavior in the interaction (Table 7).

Table 7. Losses by gases (%) of elephant grass silages according to the levels of inclusion (LI) of macaúba cake and silo opening times, in days, after ensilage, with the respective averages, regression equations, and coefficients of determination (R^2).

LI	Opening time						Mean	Regression equation	R^2
(%)	1	5	10	20	40	60			
0	12.0	16.8	15.3	14.3	14.3	11.3	14.0	$Y_0=13.8 + 0.1X – 2.9x10^{-3}X^2$	0.70
10	10.2	7.8	9.6	11.9	12.7	11.1	10.6	$Y_{10}=8.5 + 0.2X – 2.5x10^{-3}X^2$	0.79
20	6.9	5.8	6.4	7.8	6.6	9.1	7.1	$Y_{20}=6.6 – 1.0x10^{-2}X + 8.0x10^{-4}X^2$	0.79
Mean	9.7	10.1	10.4	11.3	11.2	10.5	10.5		

There was a significant effect ($P<0.05$) on dry matter recovery (RDM) of elephant grass silages according to MC levels of inclusion, opening times, and level/time interaction. There was a quadratic behavior in the interaction for the exclusive elephant grass silage and a linear decreasing behavior for silages with 10 and 20% levels of inclusion of MC at silo openings (Table 8).

Table 8. Dry matter recovery (%) of elephant grass silages according to the levels of inclusion (LI) of macaúba cake and silo opening times, in days, after ensilage, with the respective means, regression equations, and coefficients of determination (R^2).

LI	Opening time						Mean	Regression equation	R^2
(%)	1	5	10	20	40	60			
0	85.5	79.6	79.0	80.1	79.3	81.5	80.8	$Y_0=83.2 – 0.3X + 4.5x10^{-3}X^2$	0.68
10	90.5	93.6	91.2	90.4	86.2	83.9	89.3	$Y_{10}=92.6 – 0.2X$	0.94
20	94.6	95.1	93.8	90.5	93.4	90.3	92.9	$Y_{20}=94.4 – 6.0x10^{-2}X$	0.72
Mean	90.2	89.4	88.0	87.0	86.3	85.2	87.7		

4. Discussion

The minimum dry matter (DM) content of the exclusive elephant grass silage (0% MC) was obtained 20 days after ensilage, with 18.2% of DM, by adding 10 and 20% of macaúba cake (MC). The minimum DM contents occurred 43 and 30 days after ensilage, with DM contents close to 25.0 and 29.6%, respectively.

All opening times showed the lowest DM content in elephant grass silages, followed by silages with 10% of MC. Silages with 20% of MC had the highest DM content in all silo openings, which allowed inferring that MC incremented the DM content of elephant grass silages added to this biodiesel co-product. According to Evangelista et al. (2004), Vilela and Veiga (2003), grasses have a low dry matter content in the growth stages, in which they present good nutritional value, risking the conservation process with silage due to potential secondary fermentation. This justified adding the biodiesel co-product in this study.

The average DM content obtained for levels of inclusion of 0, 10, and 20% of MC were 19.0, 25.3, and 29.9%, respectively. This increase relates to the high DM content in the MC at ensilage (Table 1). Adding MC increased the DM content of elephant grass silages by 33.2 and 57.4%, considering the levels of inclusion of 10 and 20% of MC, respectively (Table 2).

Thus, the contribution of increasing MC levels to increase DM content is remarkable, meaning that MC can be considered a moisture-absorbing additive in the ensiled material. Other authors have also found increases in the DM content of elephant grass silages by using agro-industry co-product additives (Andrade et al. 2012; Viana et al. 2013; Cardoso et al. 2016; Barcelos et al. 2018; Furtado et al. 2019).

In the treatment without co-product addition, the ensiled material had a DM content of 19.0%, which could compromise silage quality. In silages with MC, the DM content agrees with the study by Zopollatto et al. (2009), in which this content provided good-quality silage.

The LAB population in the exclusive elephant grass silage (0% MC) was lower in all opening times than silages added with 10 and 20% of MC. Only at 60 days, the LAB population was 6.7 log CFU g^{-1} in the exclusive elephant grass silage. In the other inclusion levels, this LAB count was higher since the first day of ensilage (Table 2).

The behavior of this microbial population according to MC levels of inclusion followed the increase in the DM content of elephant grass silages, which contributed to fermentation and favored the development of LAB. The quantification of this microbial population is important because the lactic acid production by the LAB reduces the pH and environment acidification, preserving the ensiled material.

The LAB population ranged from 6.0 to 7.8 log CFU g^{-1} with the addition of MC. This increase with the addition of MC can be explained by the epiphytic population before ensilage (Table 1). The increments were 16.7 and 30.0% at the 10 and 20% levels of inclusion of this biodiesel co-product, respectively, compared to the exclusive elephant grass silage (Table 3).

There was an increase in lactic acid content at all levels of inclusion of MC when comparing the first and last days after ensilage (Table 4). The highest lactic acid production from elephant grass silages occurred at 60 days with 10 and 20% levels of inclusion of MC. The production rate of lactic acid is essential to inhibit the growth of unwanted bacteria and reduce losses during fermentation. The production of this acid depends on the initial lactic acid bacteria population at the time of ensilage and the amount of substrate (Mcdonald et al. 1991).

The exclusive elephant grass silage (0% MC) had an average lactic acid content (3.7%) similar to that of several studies (Zanine et al. 2010; Silva et al. 2011) that also required additives in the silage to improve fermentation. Adding MC in elephant grass silage increased lactic acid content, which justifies the importance of adding the biodiesel co-product in the silage.

In the first days of fermentation, the pH values were higher in the exclusive elephant grass silage (0% MC), followed by 10 and 20% levels of inclusion, according to the initial pH values of the raw material before ensilage (Table 1). Thus, there was a rapid decline in the pH values of elephant grass silages according to MC levels of inclusion and silo opening times, in days, after ensilage, which stabilized later (Table 5).

The minimum pH value for the 0% level of inclusion of MC was 3.6 at 43 days. However, when adding 10% of MC, the lowest pH value was 3.7 at 49 days, and for a 20% increment, the lowest pH was 3.5

at 41 days. The lowest pH value was verified with the highest level of MC (20%), emphasizing that MC was effective in reducing pH, which, in turn, is directly related to the conservation of the ensiled material (Table 5).

The pH values obtained at the levels of inclusion of MC 20 days after ensilage agree with McDonald et al. (1991). These authors proposed pH values below 4.0 for a satisfactory fermentation of the ensiled material, promoting well-preserved silage.

The results suggest that MC increases dry matter content (Table 2), favors the development of lactic acid bacteria (Table 3), and produces lactic acid (Table 4), consequently decreasing the pH (Table 5). Overall, the increase in MC allowed preserving the ensiled material and improved the fermentation profile (according to the complementary data presented by Guimarães et al. (2018). These findings corroborate Vilela and Veiga (2003), as the authors report that using additives in the silage rapidly reduces the pH of the ensiled material, prolongs the stability of the silage in the feeding phase, or even reduces losses in the silo.

The losses by effluents in the exclusive elephant grass silage (0% MC) ranged from 25.8 to 89.3 kg ton^{-1} of green mass at silo openings, and in silages with 10 and 20% levels of inclusion of MC, the effluent production ranged from 6.4 to 31.0 kg ton^{-1} of green mass and 3.0 to 28.3 kg ton^{-1} of green mass, respectively, over the times studied (Table 6).

As for opening times, as fermentation occurred, the losses by effluents of elephant grass silage increased at all levels of inclusion of MC. Higher losses by effluents were also observed in elephant grass silages in the last opening time studied (Andrade et al. 2012).

Regarding the levels of inclusion, the data confirm that elephant grass silages added with a biodiesel co-product have a high potential to become a moisture-absorbing additive due to the increased proportion of DM in the treatments, which is directly related to the lower production of effluents according to the addition of MC. A similar result was verified with lower losses by effluents from elephant grass silages using moisture-absorbing additives than the exclusive elephant grass silage (Furtado et al. 2019).

The high humidity of the ensiled forage produces excess effluents, which complicate management and leach digestible nutrients, lowering the increase in silage values and favoring the increase of proteolysis in the ensilage material (Oude Elferink et al. 2000). Silage effluents carry nutrients in the water, nitrogen compounds, sugars, organic acids, and mineral salts, which reduce the nutritional value of silages (Andrade et al. 2012). In this study, including MC reduced the escape of highly digestible nutrients via effluents.

The exclusive elephant grass silage at silo openings showed higher losses by gases, with a maximum of 14.0%, and these losses decreased to 10. 6% and 7.1% when adding 10 and 20% of MC at silo openings (Table 7). This can be explained by the increased DM content with the addition of MC, potentially favoring the lower incidence of undesirable fermentation with the reduction of gas-producing microorganisms and consequent prevalence of lactic fermentation (Table 4). This resulted in minimal losses in silages with MC additives, considering that losses by gases are associated with the fermentation occurring in the ensiled material.

The exclusive elephant grass silage (0% MC) and with a 10% level of inclusion of MC presented maximum losses by gases of 15.0 and 13.0% at silo openings of 17 and 40 days, respectively, and these losses later decreased. However, in the silages added with 20% of MC, the minimum losses by gases were 6.6%, which occurred six days after ensilage.

High moisture content in the ensiled material is associated with losses by gases and effluents, in which *Clostridium* bacteria are benefited in humid and high-pH environments, increasing losses by gases, as they produce CO_2 and butyric acid instead of lactic acid (Zanine et al. 2010).

The buffering power of grass silages favors the growth of enterobacteria, which produce gases such as CO_2, as well as ethanol, acetic acid, and ammonia. However, in this study, the DM contents of elephant grass silages added with MC were high, not characterizing a wet material. The pH values were satisfactory for preserving the ensiled material, which did not favor the development of these unwanted microorganisms. There was also a prevalence of lactic fermentation, which emphasizes that the losses in silages with added MC were minimal.

In elephant grass silages (0% MC), the minimum RDM was 78.2% at 33 days, and after this period, the dry matter recovery (RDM) indexes increased. In silages with 10 and 20% levels of inclusion of MC, the RDM decreased at silo openings, ranging from 90.5 to 83.9% and 94.6 to 90.3% (Table 8), respectively, which is consistent with losses by effluents.

The dry matter recovery rate is highly affected by production losses by effluents and gases from elephant grass silages, and the calculation is determined according to these two variables, meaning that the treatments with higher losses by gases and effluents showed a lower dry matter recovery index (Pacheco et al. 2014). The silage with the highest DM content tends to result in an increased dry matter recovery index, which was found in the present study and justified the use of MC.

In summary, including MC increased the RDM, with indexes of 80.8, 89.3, and 92.9% in silages with additions of 0, 10, and 20% of MC, respectively. This is evidenced by the increased DM content and reduced losses by gases and effluents by adding this biodiesel co-product.

5. Conclusions

Macaúba cake was effective as a moisture-absorbing additive in elephant grass silages, with increased dry matter content, lactic acid bacteria population, and lactic acid content, and reduced pH values. Losses by gases and effluents decreased and dry matter recovery increased with the addition of this biodiesel co-product. Both results were satisfactory to preserve the ensiled material, showing higher expressiveness at the 20% level of inclusion of macaúba cake in elephant grass ensilage.

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