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Macauba palm cake as additive in elephant grass silage

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ABSTRACT. The aim of this study was to evaluate the addition of macauba palm cake (*Acrocomia aculeata*) on the chemical composition, fermentation and aerobic stability of elephant grass silages (*Pennisetum purpureum*). The experiment was performed in a completely randomized design with four replicates. The treatments were composed of six levels of macauba palm cake (0, 6, 12, 18, 24, 30%) as additive to elephant grass silage. Dry matter and ethereal extract content of the silage increased linearly with the inclusion of the additive. Addition levels of 15.54% would provide 35% of dry mass, and the limit of 7.00% of ethereal extract in the silage could be obtained with 10.47%. The neutral detergent fiber content reduced linearly from 68.97 to 52.59%, but lignin increased linearly from 6.56 to 7.70%. There was a reduction of 0.17% in the ammoniacal nitrogen content for each 1% of cake. The minimum value of dry matter losses (1.33%) was estimated to the inclusion level of 23.70%. The aerobic stability increased with inclusions between 18 and 24% of cake. The use of levels between 10 and 15% of macauba palm cake are sufficient to optimize dry matter and ethereal extract contents of the silages and to provide a high aerobic stability with minimum losses.

Keywords: *Acrocomia aculeate*; aerobic stability; chemical composition; dry mass losses; effluent production; pH.

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Introduction

Pastures present low cost and provide high nutritional value for herds, especially in tropical climates where grasses and perennial forage legumes are adopted. These plants pass through seasonal climate variations, which affect their growth, quality and forage availability.

Ensiling is a conservation technique defined as the anaerobic fermentation of moist forage conditioned in silos (Santos et al., 2011). Elephant grass (*Pennisetum purpureum* Schum.) is considered one of the most suitable tropical grasses for silage since it presents great adaptability to tropical environments, yield of up to 50 t ha^{-1} year, good nutritional value (crude protein from 9.1 to 14.2%; around 70% of neutral detergent fiber and 55% of *in vitro* dry matter digestibility) and good acceptance by the animals (Voltolini et al., 2010; Flores et al., 2012; Rengsirikul et al., 2013; Pereira et al., 2017). Besides, it presents low dry matter and water-soluble carbohydrate content and high buffer capacity during the vegetative growth, when it presents the best nutritive value. These characteristics hamper the conservation process due to the possibility of undesirable fermentation (Andrade et al., 2012; Pires et al., 2009).

The wilting process and the use of moisture sequestering additives (hygroscopic products) aim to reduce forage moisture (Oliveira et al., 2010; Teixeira et al., 2008). Biodiesel byproducts are alternatives that can be used as moisture absorbing additives. Among them, macauba palm (*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.) cake presents some intrinsic characteristics such as high contents of dry matter (from 87 to 89%) and ethereal extract (from 8 to 20 %) and high concentration of non-fibrous carbohydrates (Fonseca et al., 2012; Santos et al., 2015; Silva et al., 2015). These characteristics highlight its potential as an ingredient in ruminant diets or as a moisture sequestering additive in tropical grass silages.

The use of additives in silage (physical, chemical or microbiological) is adopted for only 27.7% of the dairy farmers in Brazil (Bernardes & Rêgo, 2014). So, the association of elephant grass to the use of macauba palm cake can improve the results of tropical forage conservation and contribute to increase the adoption of this method, reducing the production costs.

The aim of this study was to evaluate the effects of the addition of increasing levels of macauba palm cake on the chemical composition, dry matter losses, effluent production and aerobic stability of elephant grass silages.

Material and methods

The experiment was carried out in Montes Claros, located in the northern region of Minas Gerais state at 16°50'52.7"S and 43° 50' 26.9" W and 646.3 m altitude. According to Köppen's classification, the climate is Aw, which is considered tropical of savannah with dry winter and rainy summer with average temperatures around 25 to 35°C (Sá Júnior. et al., 2012).

The experiment was performed in a completely randomized design with six treatments and four replicates. The treatments were composed of six levels of macauba palm cake (MPC) based on the fresh matter of elephant grass forage. The levels were: 0, 6, 12, 18, 24, 30%.

Elephant grass was harvested in pasture areas in the experimental farm of UFMG and MPC was obtained from small farmers cooperative in the municipality of Montes Claros, Minas Gerais, Brazil. The palm coconut was peeled, pulped and the oil was partially extracted by a mechanized method. The byproduct resulting from this process and the forage were previously analyzed for their chemical characteristics (Table 1).

Table 1. Chemical composition of elephant grass forage and macauba palm cake before ensilage.

Item	Elephant grass forage	Macauba palm cake
Dry matter (%)	22.98	85.49
Mineral Matter (%DM)	7.95	5.65
Crude protein (%DM)	8.07	5.89
Ethereal Extract (%DM)	1.03	23.93
NDF (%DM)[1]	73.13	38.87
NDFap (% DM) [2]	66.36	33.36
ADF (% DM) [3]	42.13	22.05
Lignin (% DM)	6.95	9.43
NFC (% DM) [4]	16.59	31.17

[1]NDF (neutral detergent fiber); [2]NDFap (neutral detergent fiber corrected for ash and protein); [3]ADF (acid detergent fiber); [4]NFC (non-fibrous carbohydrate).

The forage was manually harvested ten centimeters above the soil surface when the elephant grass reached 2.00 meters. Then the material was chopped in a stationary forage harvester adjusted for particle sizes of 0.5 to 2.5 cm. The forage was homogeneously mixed with the MPC according to the treatments and then stored in experimental silos. The material was compacted using wooden sockets.

The experimental silos were made with PVC pipes with 10 cm in diameter and 50 cm in length. Each silo has a fixed lid on the bottom and a mobile lid on the top. The top lid had a "Bunsen" valve that allows the gas escape. The silos were equipped with effluent reservoir made with 700 g of washed sand (around 5 cm of the bottom of the silo). The sand was pre-dried in forced ventilation oven at 65°C for three days and covered with a mesh plastic sheeting.

Each experimental silo received the mixture of forage and MPC up to a specific mass of 700 g dm^{-3} and then were sealed with silicone and adhesive tape, weighed and stored.

After 90 days of storage, the silos were weighed again to check the weight loss and to quantify the fermentative (gas) losses. After opening, the silage was removed and the silo was weighed with the sand and the mesh plastic sheeting to determine the effluent accumulation in the reservoir. With these values, dry matter (DML) and effluent production (EFP) were quantified by weight difference using the equations 1 and 2 respectively (JOBIM et al., 2007):

Equation 1:

$$\text{DML (\%DM)} = \frac{(\text{WSi} - \text{WSf})}{(\text{FMef} \times \text{DMef})} \times 100$$

where:

DML – Dry matter losses;

WSi – initial weight of full silo at the beginning of storage (kg);
WSo – final weight of the full silo after the storage period (kg);
FMef – fresh mass of ensiled forage (kg);
DMef – dry matter content of ensiled forage (%).

Equation 2:

$$\text{EFP (g kg}^{-1}\text{FM)} = \frac{(\text{WSa} - \text{WSb})}{\text{FMef}} \times 1000$$

where:
EFP = Effluent production (kg t^{-1} fresh mass);
WSa = Weight of empty silo + wet sand + sheeting after storage (kg);
WSb = Weight of empty silo + dry sand + sheeting before the storage period (kg);
FMef = fresh mass of ensiled forage (kg).

The silage on the top of each experimental unit (around 5 cm with visible molds) was discarded and the remaining was removed and homogenized. Samples were collected to perform chemical analysis and aerobic stability evaluation.

Chemical analyses were performed according to analytical procedures of the National Institute of Science and Technology in Animal Science (Detmann et al., 2012). The contents of dry matter (DM), neutral detergent fiber (NDF), neutral detergent insoluble ash (NDIA), neutral detergent insoluble protein (NDIP), acid detergent fiber (ADF), mineral matter (MM), crude protein (CP), ethereal extract (EE), lignin and non-fibrous carbohydrates (NFC) were determined. NDAI and NDIP values were used only to determine neutral detergent fiber content corrected for ash and protein (NDFap). The NFC was determined by: NFC = 100 – (NDFap + CP + MM + EE).

For pH analysis, samples of approximately 0.015 kg were collected during the opening of the silos, and they were immersed in 0.060 L distilled water. After resting for half an hour, pH was read, using Beckman Expandomatic SS-2 potentiometer. For the determination of ammoniacal nitrogen ($N\text{-}NH_3$), an aqueous extract of the silage was obtained, where 0.030 kg sample was mixed with 0.270 L distilled water with subsequent stirring in a homogenizer (Stomacher 400, Seward, London, UK). The ammoniacal nitrogen was determined using a selective combined electrode for the determination of ammonium ion (95-12 Thermo Scientific Orion Star), using the multi-parameter apparatus (A214 pH / ISE Thermo Scientific Orion Star).

To evaluate aerobic stability, 2.5 kg of silage from each experimental unit was packed in plastic buckets with capacity of 5.0 kg, where it remained for ten days in air-conditioned room at 25°C. The temperature of each sample was monitored with a digital thermometer which was inserted into the ensiled mass (0.10 m deep), four times a day, at 0, 6, 12 and 18h. After each temperature measurement, the silage mass in the buckets was homogenized. The room temperature was measured with a thermometer located in the heated room; the average was 24.5°C and the variation was between 23.8 and 26.0°C.

The aerobic stability was estimated as the time necessary for the silage to elevate 2°C in relation to the room temperature after opening the silos (Kung Júnior et al., 2000). The maximum temperature, the time to reach the maximum temperature, the maximum difference between silage and the room temperature, sum of the differences between the silages and room temperatures and time for the silage temperature to show a tendency of elevation were evaluated according to Jobim et al. (2007).

Data were submitted to analysis of variance at 5% critical probability level. Data were submitted to regression analysis adopting 5% as critical level when there was effect of inclusion levels of MPC. All the analyses were performed using statistical software GENES version 1990.2018.71 (Cruz, 2013).

Results and discussion

The DM, CP, EE, MM, NDF, NDFap, ADF, Lignin and NFC contents were significantly influenced by the inclusion levels of macauba palm cake (MPC) (Table 2). There was an increasing linear effect ($p < 0.05$) of MPC levels on DM content of elephant grass silage, and for each 1% of additive, there was an increase of 0.66% in DM contents of silage. This result evidences the effectiveness of MPC as a moisture sequestering additive. The MPC dry matter (85.49%) was higher than elephant grass DM (22.98%).

Table 2. Chemical composition of elephant grass silages supplemented with increasing levels of macauba palm cake (MPC).

Variable	Levels of MPC (% green mass)						Regression equation	R^2	CV (%)
	0	6	12	18	24	30			
DM	23.81	28.53	33.34	38.25	40.50	43.42	$\hat{Y} = 0.6612x + 24.724$	0.98	3.26
CP	7.34	7.30	7.30	7.29	7.27	6.86	$\hat{Y} = -0.0128x + 7.404$	0.68	2.09
EE	1.50	5.17	8.43	11.13	12.62	15.39	$\hat{Y} = 0.4500x + 2.2883$	0.97	9.35
MM	5.86	6.11	7.23	7.47	6.16	5.56	$\bar{Y} = 6.40$	-	-
NDF	68.97	65.31	61.68	57.09	53.92	52.59	$\hat{Y} = -0.5744x + 68.542$	0.98	1.59
NDFap	67.00	62.51	59.10	54.90	51.47	50.06	$\hat{Y} = -0.581x + 66.221$	0.98	1.53
ADF	42.93	39.44	37.28	35.26	32.81	30.86	$\hat{Y} = -0.3919x + 42.311$	0.98	1.45
LIG	6.57	6.84	6.98	7.14	7.27	7.87	$\hat{Y} = 0.0378x + 6.5459$	0.91	1.77
NFC	18.29	18.94	17.93	19.20	21.97	22.13	$\hat{Y} = 0.140x + 17.635$	0.67	5.33

R^2- Coefficient of determination; CV (%) - Coefficient of variation; DM- Dry matter (%); CP- Crude protein (% DM); Ethereal extract (% DM); MM- Mineral matter (% DM); NDF- Neutral detergent fiber (% DM); FDNcp- Neutral detergent fiber corrected for ash and protein (% MS); FDA- acid detergent fiber (% DM); LIG- Lignin (% DM); NFC- Non-fibrous carbohydrates (% DM).

The silage must present between 28 and 40% DM. The silages with DM content below 28% can be considered less stable and poor in lactic acid. The high value for water activity of these silages increases the survival of enterobacteria and clostridia, which are part of the epiphytic microorganisms on the crop at ensiling (Borreani et al., 2018). However, the DM content within the ideal range reduces the activity of deteriorating microorganisms, especially clostridial activity, allowing the lactic acid bacteria to produce enough organic acids to stabilize the silage quickly.

The addition of 15.54% MPC in elephant grass silage would provide 35% DM in the silage, reaching a suitable range for correction (Table 2). The increase in DM content with the use of moisture absorbing additives was also confirmed by other authors. Rezende et al. (2010), studying the addition of MPC in elephant grass and sugarcane silages, found a linear effect for DM content of silages ($p < 0.01$), verifying that for each 1% of inclusion, DM contents of elephant grass silages increased in 0.56 percentage points and 0.61 percentage points for sugarcane silages. Andrade et al. (2010) observed positive effect of the inclusion of dry by-products from agriculture in the dry mass of elephant grass silages. According to Oliveira et al. (2011) the use of African palm cake (similar to MPC) increases the dry mass content of silage made with guinea grass cv. Massai.

There was a linear negative response in crude protein (CP) with the addition of MPC. So, for each percentage unit of cake added to the silage, there was a decrease of 0.013% in CP. This reduction in CP is a consequence of the lower protein content of the cake compared to the elephant grass (Table 1). The values obtained in the silages are above the minimum level (7% PB) recommended for good ruminal functioning (Sampaio et al., 2009), except for the treatment with 30% MPC.

The EE contents of elephant grass silages increased linearly ($p < 0.05$) with the addition of MPC, with 0.45 percentage points for each 1% MPC added. This can be explained by the higher percentage of EE in MPC (23.93%) compared to the elephant grass (1.03%). The pressing process, normally used in the extraction of macauba oil, provides a by-product called cake with high lipids content which contribute positively to the energy and TDN of the diets. Although EE increases the energy, care must be taken to not exceed the limit of 7% in dry matter (Allen, 2000). EE values above the recommendation may be detrimental to ruminants due to interference in ruminal fermentation, causing deleterious effect on fiber digestibility. Seven percent of EE in the silage could be obtained with the estimated dose of 10.47% MPC. Another consequence associated with the high EE content is the increase in silage pH. Large amounts of lipids in the silage may reduce the efficiency of lactic acid bacteria in the colonization and production of organic acids.

The addition of MPC in elephant grass silage did not promote significant changes in MM levels, which presented mean value of 6.40%. On the other hand, NDF, NDFap and ADF contents of elephant grass silages reduced linearly ($p < 0.05$) with increasing levels of MPC (Table 2). This reduction is justified by the low content of these fibrous fractions in the additive (Table 1). As a consequence, elephant grass silage presented a linear increase ($p < 0.05$) in NFC content as the additive dose increased. Reduction in NDF and ADF levels in elephant grass silages was also observed by Cruz et al. (2010) and Cardoso et al. (2016) in studies performed with the addition of dehydrated passion fruit peel (*Passiflora edulis*) and crambe bran (*Crambe abyssinica*), respectively. The reduction in fiber content and the increase in NFC content highlights the potential of MPC as an additive for grass silage due to its ability to provide components of higher digestibility.

There was a linear increase ($p < 0.05$) in lignin content in elephant grass silage as a result of MPC increasing levels (Table 2). Despite the low fiber content, MPC presents a high amount of lignin in the fibrous fraction, which can be explained by the mesocarp fruit processed with macauba palm cake. For each percentage unit of MPC, there is an increase of 0.04% in lignin content. This result corroborates the one described by Viana et al. (2013) who evaluated the nutritive value of elephant grass silage supplemented with increasing levels of cotton cake. According to the authors, the linear increase in lignin can be attributed to its higher content in the cake (9.2%) compared to the elephant grass (6.3%).

There were significant effects of the addition of MPC on pH, ammoniacal nitrogen ($N\text{-}NH_3$), effluent production (EFP) and dry matter losses (DML) (Table 3). The regression analysis revealed a linear negative effect ($p < 0.05$) of MPC levels on $N\text{-}NH_3$ levels. For each percentage unit of cake, there was a reduction of 0.17% in $N\text{-}NH_3$. The ammonium nitrogen is an important parameter in the evaluation of silages, since it indicates the extent of the activity of microorganisms such as clostridia in the degradation of protein and ensiled mass. These results evidenced the potential of the cake in controlling undesirable fermentations in the silage.

The addition of MPC reduced effluent production (EFP) to minimum values, demonstrating its high potential as a moisture absorbing additive (Table 3). The values of EFP in elephant grass silage decreased linearly ($p < 0.05$) with the addition of MPC. The increase of 1% in the concentration of MPC in elephant grass silage caused a decrease of 1.22 g kg^{-1} in EFP fresh mass. Silage effluent carries soluble nitrogenous compounds, sugars, organic acids and mineral salts. The loss of soluble compounds can decrease the silage quality and cause environmental damages as eutrophication and contamination of the groundwater (Gebrehanna et al., 2014). According to Faria et al. (2010), the inclusion of a moisture sequestering as peel of coffee beans can reduce the DM content and EFP of elephant grass silages. So, the inclusion of MPC was an advantageous alternative to prevent or control this type of loss.

Table 3. Fermentation profile, effluent production and dry matter losses of elephant grass silages with increasing levels of macauba palm cake (MPC).

Item	Levels of MPC (% fresh mass)						Equation of Regression	R^2	CV (%)
	0	6	12	18	24	30			
pH	3.62	3.76	3.88	3.95	4.12	4.18	$\hat{Y} = 0.0188x + 3.634$	0.93	1.33
NH_3-N	11.90	9.42	7.89	7.58	6.61	6.42	$\hat{Y} = -0.1722x + 10.886$	0.86	9.12
EFP	36.93	36.59	25.05	9.59	6.80	6.78	$\hat{Y} = -1.2348x + 38.658$	0.88	23.67
DML	7.12	3.31	2.56	1.76	2.19	1.20	$\hat{Y} = 0.0093x^2 - 0.4409x + 6.5585$	0.88	24.47

R^2- Coefficient of determination; CV (%) - Coefficient of variation; NH_3-N - ammoniacal nitrogen (% total nitrogen); EFP- Effluent production (kg ton^{-1} of ensiled fresh mass); DML - dry matter losses (% Dry matter);

Dry matter losses (DML) in elephant grass silage presented a quadratic response ($p < 0.05$) to MPC addition. A minimum value of 1.33% of DML referring to the inclusion level of 23.70% MPC was estimated. With successive increases in MPC levels, the DML moved from 6.56% (no MPC) to 1.33% with 23.70% of MPC. So, the use of MPC reduced the DML in 5.23%. In the study of Andrade et al. (2010), the inclusion of agriculture by-products increases the dry mass recovery and reduces the losses of elephant grass silages in 3%.

Dry mass losses are associated with the silage fermentation profile. So the reduction of these losses is probably due to the change in the dynamics of the microbiota, which has been constituted by microorganisms such as clostridial bacteria, enterobacteria and acid lactic bacteria. According to Dunière et al. (2013), the butyric acid bacteria, as the *Clostridium* and *Bacillus*, are able to convert lactic acid into butyric acid, hydrogen and carbon dioxide at a relatively low pH. The extensive growth of this bacteria can induce a pH increase, growth of less acid-tolerant spoilage microorganisms and result in significative loss of dry matter.

The aerobic stability of elephant grass silage was also influenced by the use of MPC (Table 4). The values of maximum temperature (Tmax) increased linearly ($p < 0.05$) with the addition of MPC in elephant grass silage. The elevation of temperatures in silages may be related to the greater contribution of easily fermentable nutrients which favored the proliferation of deteriorating aerobic microorganisms after the silo opening.

The time to reach the maximum temperature (TTmax) of elephant grass silages responded quadratically ($p < 0.05$) to the addition of MPC. The highest value for TTmax, estimated in 209.5 hours, corresponded to the level of 18.95% of MPC. From this value, a reduction in TTmax was observed, confirming the greater performance and proliferation of deteriorating aerobic microorganisms. The maximum temperature reached (TmaxR) responded quadratically with the inclusion of MPC. The minimum point was estimated at 4.13°C up to room temperature and was estimated to the dose of 6.04% MPC. Even though increases on the TmaxR were observed from this point on, the use of 30% MPC resulted in a difference of 7.55°C. It was the maximum value observed in the experiment.

Table 4. Aerobic stability of elephant grass silages supplemented with increasing levels of macauba palm cake (MPC).

Variable	Doses of MPC (% green mass)						Regression equation	R^2	CV (%)
	0	6	12	18	24	30			
Tmax	28.3	28.8	29.0	29.0	29.9	31.4	$\hat{Y} = 0.0832x + 28.273$	0.74	4.18
TTmax	48	135	183	207	207	150	$\hat{Y} = -0.452x^2 + 17.143x + 47.14$	0.99	3.19
TmaxR	3.9	4.65	4.95	4.23	5.38	7.55	$\hat{Y} = 0.005x^2 - 0.062x + 4.328$	0.66	24.31
ST	13.7	15.1	12.1	6.3	11.0	26.4	$\hat{Y} = 0.05x^2 - 1.284x + 16.86$	0.62	29.72
Ttrend	24	96	144	168	168	120	$\hat{Y} = -0.393x^2 + 15.214x + 21.43$	0.99	3.68
Treach	39	111	159	183	183	135	$\hat{Y} = -0.393x^2 + 15.214x + 36.43$	0.99	3.28

R^2- Coefficient of determination; CV (%) - Coefficient of variation; Tmax: maximum temperature reached (°C); TTmax: time to reach the maximum temperature (hours); TmaxR: maximum silage temperature discounting the room temperature (°C); ST sum of the temperature differences of the silages and room (°C); Ttrend: time for elevation trend (hours); Treach: time required for the silage temperature to reach 2 °C above room temperature (hours);

The sum of the temperature differences of the silages and room (ST), also responded in a quadratic way to the addition of MPC ($p < 0.05$). During the 240 hours, the lowest temperature accumulation (8.62°C) was estimated to 12.84% of MPC inclusion. From this point on, there was an increase in the accumulation of temperature. The ST is an alternative to study the temperature variation in silage, because high ST values are related to shorter time to break the stability.

The time necessary for the elevation of 2°C (Treach) is considered the time to break the silage aerobic stability. So, the Treach and the time of elevation trend (TTrend) in the elephant grass silages responded in a similar way to the addition of MPC (Table 4). The maximum Treach and TTrend converged to the same inclusion level of MPC (approximately 19.00%), showing that this dose promoted the longest aerobic stability. Inclusion levels besides 19% reduced the time of stability due to the higher content of rapidly fermentable carbohydrates, which create a favorable environment to the growth of spoilage microorganisms as fungi and yeasts. According to Muck (2010), after the silo opening, the yeasts start the deterioration of water-soluble carbohydrates and lactic acid in contact with O_2. The consumption of lactic acid increases the pH and opens space to spoilage microorganisms.

On the other hand, the silage with no MPC was also characterized by a rapid break in stability (39h) possibly due to the effect of high moist forage on the growing of spoilage microorganisms. With low DM, the silages are susceptible to deterioration by yeast and bacteria (*Bacillus* and Enterobacteria) since the beginning of the ensiling process. The microbial activity of theses microorganisms is responsible for the quick loss of stability after the opening.

The silage with no MPC was the first to reach the maximum temperature after opening and then the treatments with 6 and 30% of MPC (Figure 1). The treatments with 0, 6, 12 and 30% of MPC shows a peak followed by a reduction in the temperature. This result indicates that the treatments with 18 and 24% of MPC do not reach the maximum temperature and were better preserved.

The same tendency of the temperature data was observed in the pH evaluation of stability (Figure 2). As the evaluations of silage stability test progressed, increases in pH values were observed in all elephant grass silages (Figure 2). At the beginning of the air exposure, at time 0, elephant grass silages without the inclusion of MPC had the lowest pH values. However, at 72 hours of exposure to oxygen, these silages had already demonstrated excessive pH increase, which may have occurred due to the rapid consumption of lactic acid by yeast. In the other silages, the pH value was still constant. The better constancy in pH values was verified in treatments with 18 and 24 % (Figure 2), in which the stability break started around 192 hours of exposure to air.

It was verified the convergence between the methodologies to evaluate the aerobic stability of silages, which indicated close results for the doses of MPC that provide greater stability. However, the values between 18 and 24% are not the ones that provide better bromatological composition of the silage, because the excessive elevation of lipids and lignin in silage. Probably the treatments with 18 and 24% of MPC showed a high production of acetic acid as a result of heterofermentative lactic acid bacteria, which are considered one of the main responsible for greater aerobic stability in silages (Taylor & Kung, 2002). The aerobic stability of corn silages was related to acetic acid, which is produced during the ensiling and which inhibit aerobic yeasts and molds. (Weinberg et al., 2011).

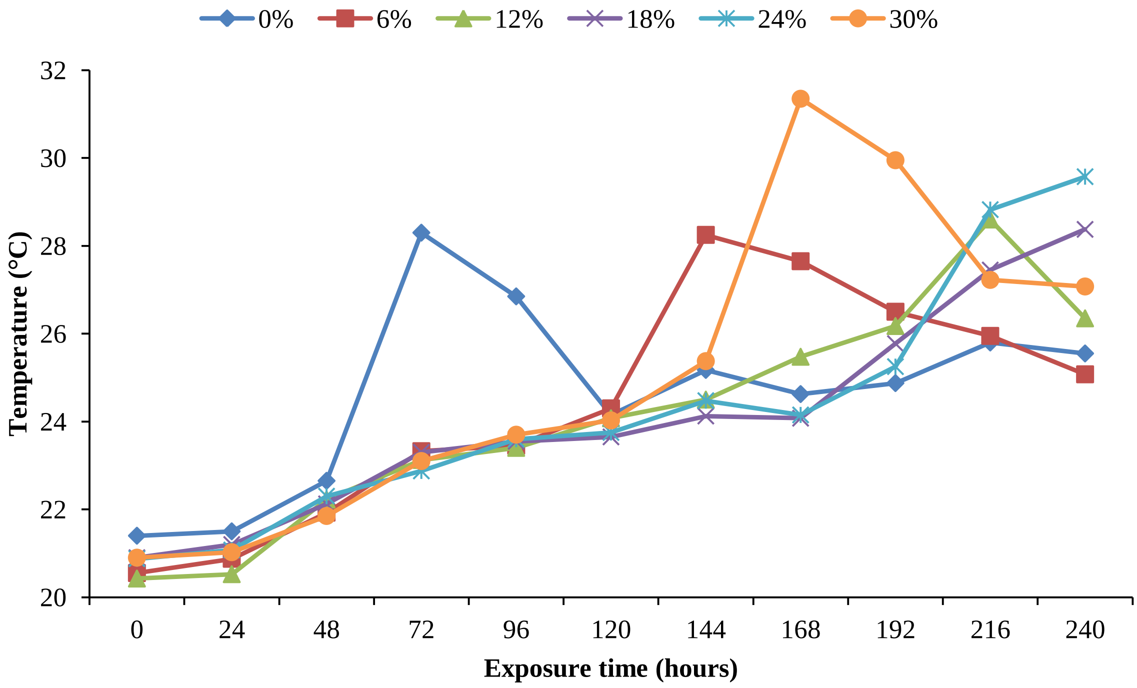

Figure 1. Variation in temperature during aerobic stability test of elephant grass silage according to the levels of macauba palm cake (0, 6, 12, 18, 24 and 30%).

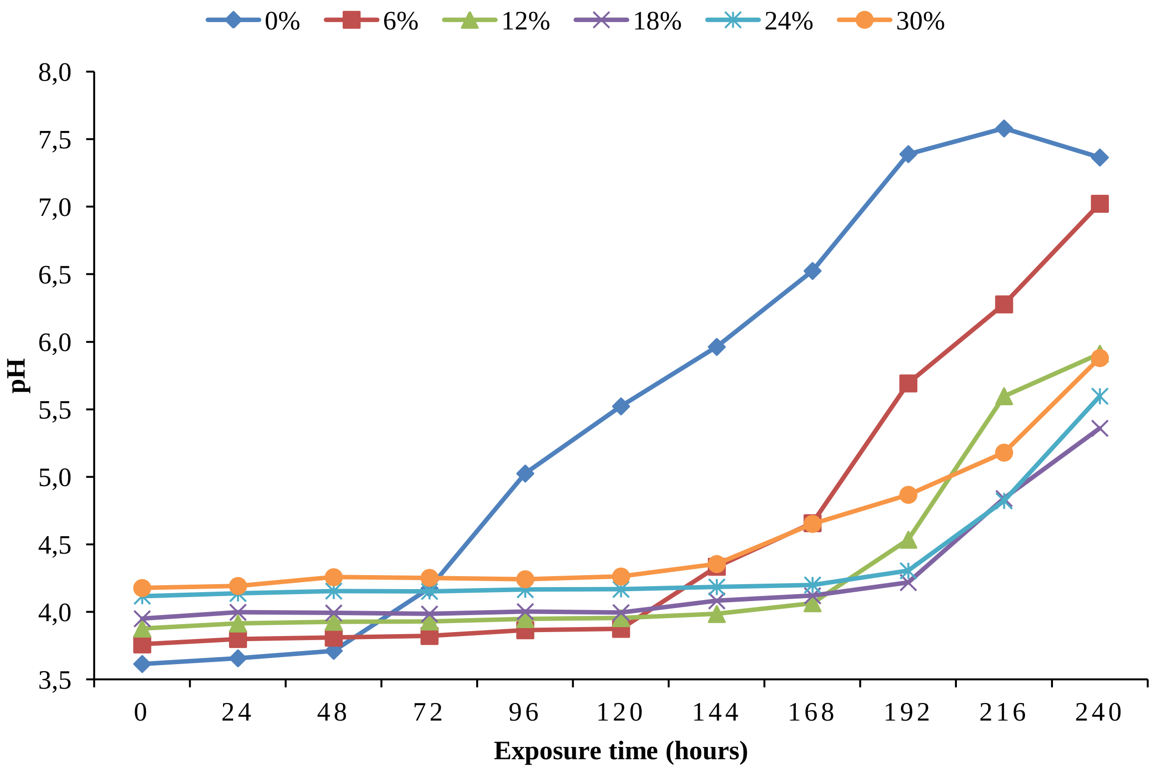

Figure 2. pH variation during aerobic stability test of elephant grass silages according to the levels of macauba palm cake (0, 6, 12, 18, 24 and 30%).

Conclusion

The addition of macauba palm cake affects the chemical composition, dry matter losses and effluent production of elephant grass silage.

The inclusion levels between 10 and 15% of macauba palm cake are sufficient to optimize dry matter and ethereal extract contents of the silages, providing lower dry matter losses and effluent production and increasing their aerobic stability.

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