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Fermentation characteristics and nutritional quality of elephant grass silage added the buriti fruit peel

Características fermentativas e qualidade nutricional de silagem de capim elefante adicionado de casca de fruto de buriti

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Abstract

The objective of this research was to evaluated the inclusion of buriti fruit peel as additive on the fermentation profile, losses, chemical composition and degradability of elephant grass silage. We used a completely randomized design with five levels of buriti fruit peel (0, 50, 100, 200 and 400 g kg^{-1}). The silos were opened after 28 days of storage. *In situ* degradability monitoring was conducted using a split-plot design in which four animals represented the blocks and silage supplemented with five levels of buriti fruit peel represented the treatments. The use of the additive in elephant silage increased dry matter (DM) ($P < 0.001$), ether extract (EE) ($P < 0.001$), ash ($P < 0.001$), neutral detergent fiber (NDF) ($P < 0.001$) and acid detergent fiber (ADF) ($P= 0.0000$). The pH ($P= 0.0000$), N-NH_3 ($P = 0.024$) and there was a decrease in gas losses ($P < 0.001$), effluent losses and dry matter recovery ($P = 0.218$) not were influenced by the addition of buriti fruit peel. The inclusion of buriti fruit peel linearly reduced the ruminal degradability DM of soluble fraction (a) ($P < 0.001$) and potentially degradable insoluble fraction (b) ($P < 0.001$). The DM content increase with the addition of the buriti fruit peel to the elephant grass silage promotes improvements in the fermentation process, reduces losses of nutrients and ruminal disappearance of dry matter and does not significantly change the chemical composition with the inclusion of 166.7 g kg^{-1} of the buriti fruit peel.

Key words: Ammonia nitrogen. By-product. Forage conservation. *In situ* degradation. pH.

Resumo

O objetivo desta pesquisa foi avaliar a inclusão de cascas de frutos de buriti como aditivo no perfil de fermentação, perdas, composição química e degradabilidade da silagem de capim-elefante. Foi utilizado um delineamento inteiramente casualizado, com cinco níveis de cascas de frutos de buriti (0, 50, 100, 200 e 400 g kg^{-1}). Os silos foram abertos após 28 dias de armazenamento. O monitoramento da degradabilidade *in situ* foi conduzido usando um esquema de parcelas subdivididas em que quatro animais representaram os blocos e a silagem suplementada com cinco níveis de cascas de frutos de

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buriti representou os tratamentos. A utilização do aditivo na silagem de capim elefante aumentou a matéria seca (MS) (P < 0,001), extrato etéreo (EE) (P < 0,001), cinzas (P < 0,001), fibra em detergente neutro (FDN) (P < 0,001) e fibra em detergente ácido (FDA) (P < 0,001). O pH (P < 0,001), N-NH3 (P = 0,024) e a redução das perdas por gases (P < 0,0001), perdas por efluentes e a recuperação de matéria seca (P = 0,218) não foram influenciados pela adição de cascas de frutos de buriti. A inclusão de cascas de frutos de buriti reduziu linearmente a degradabilidade ruminal da MS da fração solúvel (a) (P < 0,001) e a fração potencialmente degradável insolúvel (b) (P < 0,001). A correção do teor de matéria seca por meio da adição de cascas de frutos de buriti à silagem de capim-elefante promove melhorias no processo de fermentação, reduz as perdas de nutrientes e desaparecimento ruminal da matéria seca e não altera significativamente a composição química com a inclusão de 166,7 g kg^{-1} de cascas de frutos do buriti.
Palavras-chave: Conservação de forragem. Co-produto. Degradação *in situ*. Nitrogênio amoniacal. pH.

Introduction

Elephant grass (*Pennisetum purpureum* Schum.) is a grass widely used in the production of ruminants in tropical and subtropical regions due to its great potential for dry matter production and great acceptability by animals (YANG et al., 2013). However, although elephant grass presents nutritional value considered ideal for the process of fermentation, it has great moisture content, which can compromise the efficiency of fermentation in silage because great moisture content favours the development of *Clostridium* sp. In addition, the great degrade soluble carbohydrates content results in the production of butyric acid and release of ammonia, adversely affecting the quality of the silage and reducing its nutritional value (OLIVEIRA et al., 2012; SILVA et al., 2014a).

Dry matter (DM) is a major factor in the biochemical processes that affect the quality of silage. McDonald (1981) emphasises the need for dry matter values between 30 and 35% for a plant to be considered ideal for silage. According to Ridwan et al. (2015), the first stage in silage production is competition among epiphytic microorganisms for the use of the soluble carbohydrates; however, undesirable microorganisms, such as Enterobacteriaceae, clostridia and fungi, can develop in the silage and cause nutritional losses. Therefore, some additives that present good water retention capacity, offer good palatability and supplement carbohydrate fermentation can be used to increase the dry matter content of the material to be ensiled (ZANINE et al., 2010; SANTOS et al., 2014).

Thus, the buriti palm (*Mauritiaflexuosa* L.), belonging to the Arecaceae family, byproduct of the extraction of fruit for pulp production (the fruit pulp is marketed as a cosmetic and a sweetener), the buriti fruit peel has no commercial value and is usually discarded. Instead of being discarded in the environment as a residue with a great DM (95%) content and low protein value (6%), it is a potential additive to silage, as it may improve the conservation of its nutritional value. Therefore, the buriti fruit peel can be used as an additive to correct the DM content of elephant, inducing a rapid decrease in the pH and stabilizing the fermentation process quicker, resulting in good-quality silage. The objective of this study was to evaluate the effects of the inclusion of buriti fruit peel in elephant during ensiling on the fermentation profile, gas losses, chemical composition and ruminal degradability of the mixed elephant and buriti fruit peel silage.

Material and Methods

Ethical considerations and local conditions

This study was carried out in strict accordance with the recommendations in the Guide for the National Council for Animal Experiments Control (CONCEA). The col was approved by the Committee on the Ethics of Animal Experiments of the Federal University of Piaui, Piaui State, Brazil (Permit Number: 016-14).

The experiment was carried out from July 2013 to December 2014 in the Research Unit on Small Ruminants at the Technical College of Bom Jesus City, located on the Campus of Teacher Cinobelina Elvas at the Federal University of Piaui. The city is situated at a latitude of 09º04'28" S and longitude 44º 21'31" W and has an elevation of 277 m. The climate is characterized as hot and semi-humid, with a minimum temperature of 18 °C, maximum temperature of 36 °C, and average precipitation of 900 mm.

Treatments and silage preparation

The experiment was a completely randomized design with mixed five levels of buriti fruit peel (0, 50, 100, 200 and 400 g kg^{-1} elephant grass DM) (Table 1).

Table 1. Chemical composition of the buriti fruit peel (*Mauritia flexuosa* L.) and elephant grass.

Nutrients	Ingredients	
	Buriti fruit peel	Elephant grass
Dry matter g kg^{-1} as fed	856.1	232.5
Crude protein g kg^{-1} DM	27.8	74.5
Ether extract g kg^{-1} DM	27.7	17.5
Neutral detergent fiber g kg^{-1} DM	751.6	780.0
Acid detergent fiber g kg^{-1} DM	636.0	622.7
Ash g kg^{-1} DM	100.6	65.1
Total carbohydrates g kg^{-1} DM	843.9	842.9
Non-fiber carbohydrates g kg^{-1} DM	92.3	62.9

The elephant grass was obtained from an experimental field at the Research Unit for Small Ruminants, Agricultural College of Bom Jesus. The grass was harvested at 60 days of age and then chopped into 2-3 cm lengths in a stationary forage harvester machine. The plants were then triturated to 2-3 cm in an electric stationary shredder machine (GT-2000L, Garthen®). The buriti fruit peel was obtained after the extraction of the fruit pulp, and bunches were harvested when the first fruits began to loosen, which is an indicator of adequate maturity. Next, the peels were covered with plastic sheeting for 48 h, after which they were immersed in water for 48 hours until the peel began to loosen; after this process, the peels were dried for addition into the forage.

Chemical analyses procedures

To determine the chemical composition of the elephant, buriti fruit peel and silage were dried at 55°C for 72 hours, ground with a Willey Mill knife (Tecnal, Piracicaba City, São Paulo State, Brasil) with a 1 mm sieve, stored in plastic containers, and sealed until the laboratory analysis of the levels of dry matter (DM) (Method 967.03) (AOAC, 1990), ash (Method 942.05) (AOAC, 1990), ether extract (EE) (Method 920.29) (AOAC, 1990) and crude protein (CP) (Method 981.10) (AOAC, 1990). To determine the NDF and ADF contents, the methodology of Van Soest et al. (1991) was used with the modifications that were proposed in the Ankon device manual (Ankon Technology Corporation, Macedon, New York, US). The total carbohydrate (TC) values were determined using the equation described by Sniffen et al. (1992):

$$TC = 100 - (\% CP + \% EE + \% Ash)$$

The levels of non-fiber carbohydrates (NFC) were determined with the following equation (MERTENS et al., 1997):

$$NFC = 100 – (CP + NDF + ash + EE)$$

To determine the pH and ammonia nitrogen, twenty-five experimental silos (5 treatments and 5 repetitions) were constructed of PVC pipe (10 cm in diameter, 40 cm long), sealed with plastic tape (1 m wide, 2 m long and 150 μm thick), and stored in a shed. To analyze the pH, silage samples were collected after 28 days after silo closure. Next, 100 g of fresh silage was weighed in a beaker, and 60 ml of water was added and allowed to stand for 30 minutes, after which the pH was measured using a potentiometer (SILVA; QUEIROZ, 2002). Sample (100 g) was triturated with 600 ml of distilled water and centrifuged for 20 minutes at 3000 rpm in a centrifuge tube (Kjeldahl). Then, 20 ml of the centrifuged sample was mixed with 20 ml of KOH and 50 ml distilled water, after which distillation was performed using a micro-Kjeldahl apparatus based on the CP technique (without neutralization with NaOH). Finally, titration with 0.02 N H_2SO_4 was performed to determine the concentration of ammonia (NH_3) (MIZUBUTI et al*.,* 2009).

To assess pH, ammonia nitrogen, gas and effluent losses of the silage and the chemical composition, 25 experimental silos (5 treatments and 5 repetitions) were constructed using buckets (approximately 3 L) sealed with plastic tape and a Bunsen-type valve that was adapted to the bucket covers to allow for the escape of gases from fermentation. Sand (1 kg) was placed at the bottom of each bucket, separated from the forage by a layer of cotton cloth, for the measurement of the amount of effluent retained. A quantity of fodder mass corresponding to a density of 500 kg m^{-3} was placed in each silo to obtain good compaction of the silage. The silos were opened 28 days after ensiling, and the top and bottom layers (approximately 10 cm) of the silage were discarded for greater sampling reliability. The core silo material was removed and placed in a plastic bag for homogenization. Then, 500 g samples were collected from each experimental unit.

The equations described by Zanine et al. (2010) were used to obtain the values of silage dry matter loss in the form of gases and effluents and the recovery of dry matter. The dry matter losses in silage in the form of gases were quantified using the weight difference. Using the equations below, the gas losses, effluent losses and the recovery of dry matter were determined:

Gas losses were calculated according to the following equation:

$$G = (WFC – WFO) / (HMC \times DMC) \times 10{,}000,$$

wherein G = gas losses (% DM); WFC = weight of full silo at closing (kg); WFO = weight of full silo at opening (kg); HMC = herbage mass at closing (kg); DMC = concentration of herbage dry matter at closing (%).

Effluent losses were calculated using the following equation, based on the sand weight difference and the mass of green matter (GM) at closing:

$$E = [(WEF – TB) – (WEI – TB)] / HMC \text{ x } 100,$$

wherein E = effluent losses (kg/t HM); WEF = weight of the empty silo + weight of the sand at opening (kg); TB = weight of the empty silo (kg); WEI = weight of the empty silo + weight of the sand at closing (kg); and HMC = herbage mass at closing (kg). The following equation was used to calculate the recovery of dry matter:

$$DMR = (HMO \times DMO) / (HMC \times DMC) \times 100,$$

wherein DMR = dry matter recovery rate (%); HMO = herbage mass at opening (kg); DMO = concentration of dry matter forage storage durations (%); HMC = herbage mass at closing (kg); DMC = herbage concentration at closing (%);

In situ degradability of dry matter

For the determination of *in situ* degradability, four Santa Ines sheep (approximately 14 months of age, 45 kg in weight) were used. The sheep were provided with permanent fistulated rumen cannulas and kept in individual pens. The animals

were submitted to a period of adaptation for 14 days, during which concentrated feed and elephant silage (40:60) was provided twice each morning. Water was available to the animals *ad libitum*. The elephant silage samples with 0, 50, 100, 200 or 400 g kg^{-1} additions of buriti fruit peel were placed in TNT type bags (weight 100 mm, 15 × 8 cm) in a quantity of approximately 24 g of DM bag^{-1} to retain approximately 20 mg of DM cm^{-2} of surface area in the bag (NOCEK, 1988). Incubation periods of 0, 6, 12, 24, 48, 72, 96 and 120h00 were used. The bags were placed in reverse order and quadruplicated while in the animals to ensure a repetition for all animals and to promote uniformity. After each incubation period, the bags were removed from the rumen, washed thoroughly under running distilled water, and dried.

The *in situ* degradability of the DM was determined using the weight difference for each component between the weighing conducted before and after ruminal incubation and was expressed as a percentage. After obtaining the coefficients A, B, and C, they were inserted into the equation proposed by Ørskov and McDonald (1979) to calculate the degradability:

$$Dt = a + b \times (1 - e^{-ct}),$$

wherein Dt = fraction degraded at time t (%); a = soluble fraction (%); b = potentially degradable insoluble fraction (%); c = rate of degradation of fraction b (h^{-1}); and t = time (h). The nonlinear coefficients a, b and c were estimated using Gauss-Newton iterative procedures.

Statistical design

The results were statistically evaluated by regression using PROC REG SAS® (2014) software. The chemical composition, pH, ammoniac nitrogen ($N\text{-}NH_3$) and losses (gases and effluents) was used an experimental design completely randomized, with 5 levels of peel addition (0, 50, 100, 200 and 400 g kg^{-1}) and 5 replications (n = 25). Degradability data were analyzed via analysis of variance for a split-plot design, where the buriti fruit peel levels represented the main plots and incubation times (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, and 120h00) represented the subplots. The degradation curves for the DM silos mixed with buriti fruit peel used for each animal were subjected to adjustment by the respective models, which yielded the estimates of the parameters analyzed.

The in situ degradability coefficients were analyzed by the iterative process of the SAS® PROC NLIN implementation of the Marquardt algorithm. The treatment means were compared by regression test 0.05* and 0.01** and 0.001*** levels of probability.

Results

The DM of elephant grass silage showed a linear increase (P<0.001) with inclusion of buriti fruit peel levels (Table 1). The NFC (P<0.001) and TC (P<0.001) values showed a linear decrease of 66% and 3% respectively when comparing the without added and 400 g kg^{-1} added buriti fruit peel treatments. For the CP variable, there was no effect (P = 0.800) of inclusion levels of this additive on the elephant grass silage. The variables EE (P<0.001), NDF (P<0.001), ADF (P<0.001), and ash (P<0.001) showed a linear increase, with increases of 0.15; 0.28 and 0.03 g $kg^{-1}$of DM, respectively, for each g of buriti fruit peel added to the elephant grass silage (Table 2).

The inclusion of buriti fruit peel in the elephant grass silage provided a linear increase in pH (P<0.001) with the opening time of the silo (Table 3). With the inclusion of buriti fruit peel in the elephant grass silage, a linear increase (P = 0.024) in the production of $N\text{-}NH_3$ was observed, with $N\text{-}NH_3$ mean of 0.23% DM.

Table 2. Chemical composition of the silage of elephant grass mixed with different levels of buriti fruit peel (*Mauritia flexuosa* L.) after 28 days of silo storage.

Nutrients (g kg^{-1} DM)	Buriti fruit peel Levels (g kg^{-1})					Mean	CV%†	*P*-value‡
	0	50	100	200	400			
Dry matter (g kg^{-1} as fed)	266.4	287.5	308.5	350.6	434.7	329.5	14.94	<0.001***
Crud protein	74.1	74.0	74.0	73.8	73.6	73.9	3.93	0.800^{ns}
Ether extract	22.3	29.4	34.3	37.9	38.15	32.4	7.53	<0.001***
Neutral detergent fiber	694.2	704.3	714.4	734.7	775.3	724.6	3.26	<0.001***
Acid detergent fiber	459.9	476.5	493.1	526.4	592.9	509.8	3.31	<0.001***
Ash	71.9	75.1	78.2	84.6	97.2	81.4	6.84	<0.001***
Non-fiber carbohydrates	139.7	115.0	98.7	69.5	34.1	91.4	5.16	<0.001***
Total carbohydrates	833.9	819.3	813.1	804.2	809.4	815.9	4.18	<0.001***

†CV % = coefficients of variation (%).
‡ P-value = Probability by regression model at 0.05*; 0.01**; 0.001*** and ns not significant levels of probability.

Table 3. Ammoniacal nitrogen (N-NH_3), pH values, gas losses, effluent losses and dry matter recovery (DMR) of silage of elephant grass mixed with different levels of buriti fruit peel (*Mauritia flexuosa* L.).

Variables	Buriti fruit peel Levels (g kg^{-1})					Mean	CV%†	*P*-value‡
	0	50	100	200	400			
pH	3.48	3.60	3.65	3.68	4.82	3.84	2.84	<0.001***
N-NH_3 (%DM)	0.26	0.30	0.27	0.28	0.37	0.23	18.30	0.024*
Gas losses (% MS)	0.40	0.31	0.25	0.20	0.41	0.31	55.02	0.033*
Effluent losses (%)	22.74	21.01	19.28	15.82	8.89	17.54	18.77	<0.001***
Dry matter recovery (%)	95.5	91.43	88.24	84.49	87.57	89.45	12.18	0.218^{ns}

†CV % = coefficients of variation (%).
‡ P-value = Probability by regression model at 0.05*; 0.01**; 0.001*** and ns not significant levels of probability.

The result of losses by gases showed that there was a quadratic effect (P = 0.033), wherein the smallest loss by gases occurred with the addition of 166.7 g kg^{-1} ($y = 0{,}043x^2 - 0.270x + 0.646$; $R^2 = 0.812$) of buriti fruit peel in the elephant grass silage. The observed values of effluent losses in the elephant grass silage showed a linear decrease (P<0.001) in response to rising levels of additive in the silage. For the dry matter recovery values, no significant difference (P = 0.218) was observed among the different inclusion levels of buriti fruit peel.

When comparing degradability of the dry matter (DM) of elephant grass silage with added buriti fruit peel due to the incubation period, the treatment that included 50 g kg^{-1} buriti fruit peel predominated at all times (Table 4).

The ruminal disappearance of DM silage differ among treatments, but only in the treatment that included 50 g kg^{-1}of buriti fruit peel in the silage did disappearance reach more than 65% at the end of 120h00.

The inclusion of the buriti fruit peel contributed to a linear reduction in the soluble fraction (a) (P<0.001) and potentially in the degradable insoluble fraction (b) (P<0.001) (Table 4). There was a linear decrease of 18% and 55% respectively on soluble fraction (a) and potentially degradable insoluble fraction (b) when comparing without addition and 400 g kg^{-1} buriti fruit peel addition in elephant silage. No difference (P = 0.3524) was observed in fraction (c), which is the fractional breakdown rate in time.

Table 4. Dry matter degradability (DMD) ruminal, soluble fraction (a), potentially degradable insoluble fraction (b) e fractional breakdown rate (c) in elephant grass silage with buriti fruit peel addition, incubated in the rumen.

	Buriti fruit peel Levels (g kg^{-1})					CV%	*P*-value
	0	50	100	200	400		
DMD (120h00)	67.33	68.21	54.40	51.92	57.54	11.03	<0.001***
Fraction a	25.28	24.46	24.16	23.88	20.54	16.28	<0.001***
Fraction b	66.05	50.66	44.17	30.49	30.36	14.12	<0.001***
Fraction c	0.0123	0.0039	0.1000	0.1800	0.0740	5.65	0.352ns

†CV % = coefficients of variation (%).
‡ P-value = Probability by regression model at 0.05*; 0.01**; 0.001*** and ns not significant levels of probability.
Fraction a = soluble fraction (%);
Fraction b = potentially degradable insoluble fraction (%);
Fraction c = fractional breakdown rate (h^{-1}) (% / h).

Discussion

The increased DM of the elephant grass is related to the great dry matter content (142.9 g kg^{-1}) of the buriti fruit peel reached. The value presented is considered ideal for process efficiency (Table 2). Therefore, the inclusion of up to 200 g kg^{-1} buriti fruit peel satisfies the DM value (300-350 g kg^{-1}) recommended by McDonald (1981) to obtain good quality silage. Therefore, DM levels above or below these values will contribute to undesired fermentation processes, negatively affecting the quality of the final product (ZANINE et al., 2010; FERREIRA et al., 2016). Thus, the production of good quality silages depends on several factors and especially an appropriate DM content in the material to be ensiled which increase the fermentation process of the silage (ÍTAVO et al., 2010).

The low value of CP in the elephant grass silage with the additive can be explained by the use of an additive that is low in this nutrient (27.8 g kg^{-1} of DM) (Table 1). However, Cruz et al. (2010), who examined the addition of passion fruit peel to elephant grass silage, verified an elevation in the CP content, which reflects the protein quality of the additive used. According to Monteiro et al. (2011), a decrease in the CP content may also be related to the dilution effect, due to the DM proportion in the additive.

The main characteristic of the additive used was its ability to increase the DM forage, which remained great even after the silage process. Cruz et al. (2010) found an increase in DM content in elephant grass silage with the addition of increasing levels of dehydrated passion fruit peel (DPP), reporting that this increase is related to the addition of the DPP, which has greater DM content than elephant grass.

The response of the NDF, ADF and ash of the herbage mass to be ensiled, was similar to that for elephant grass silage. These increases, which were in proportion to the buriti fruit peel levels, may be related to the reduction in losses by effluents from the silage, combined with the great content of fibrous carbohydrates and minerals present in the additive (NDF = 751.6; ADF = 636.0 and ash = 100.6 g kg^{-1} of DM) (Table 1). Studying different inclusion of buriti fruit peel in leucaena silage, Ferreira et al. (2016) observed ideal conditions for silage up to a level of 50 g kg^{-1} and the researchers concluded that the buriti fruit peel increases the DM content by 38% and reduces the pH and gas losses in leucaena silage.

The TC decreasing in the elephant grass silage shows the use of this fraction by anaerobic microorganisms developed during the elephant grass silage process, and the use of the TC improved the fermentation process through the production of desirable metabolites, such as lactic acid. Monteiro et al. (2011) tested different additives (rice bran, soybean peels, and corn meal) in elephant grass

silage and found degradation of TC to be significant when the contents of the forage were compared with the silage.

A reduction in the NFC was verified with increasing levels of buriti fruit peel by comparing the amount of NFC in the forage mass to that in the elephant grass silage with added buriti fruit peel. This may be related to low NFC in the buriti fruit peel (Table 1), which was further diluted on addition to the elephant grass; on the other hand, this response may also be caused by the use of these substrates by fermentative bacteria during the fermentation because efficiency in the conservation of the chemical composition of the plant did occur. In elephant grass silage with cassava meal, Oliveira et al. (2012) observed an increase in the NFC of the elephant grass silage and explained this by the fact that the cassava meal is rich in NFC.

The addition of buriti fruit peel efficiently decreased the pH of the elephant grass silage, producing well-fermented silage (Table 3). Good-quality silage can be obtained at 28 days after the closing of the silo due to stabilising pH mean value of 3.84, respectively, which corroborate the values of 3.8-4.0 that are recommended by McCullough (1977) as optimum for good fermentation. According to Arriola et al. (2011), a pH below 4 can be used to preserve food for a long time, which reflects the adequacy of the fermentation to restrict the growth of undesirable microorganisms.

Thus, the pH observed at the time of ensiling, with buriti fruit peel increase maintained qualitative aspects of roughage since the acidity of the silage inhibits the growth of genus *Clostidium*, the same time stimulate the proliferation of lactic acid bacteria (OHSHIMA; McDONALD, 1978). According Woolford (1972), the more rapid the pH reduction or the establishment of an acidic environment in the ensiled mass, the more efficient the preservation because it is quickly established anaerobic environment in the silo and consequently lower the extent of degradation Aerobic of proteins and carbohydrates, as well as the action of bacteria of the genus *Clostidium*.

For the addictive level of 400 g kg^{-1}, stabilisation of the fermentation process could not be achieved even in 28 days (pH = 4.82), a fact that can be attributed to the great dry matter content; this created difficulty in compacting the layers. The resulting greater accumulation of oxygen inside the silo made the environment favourable to the proliferation of aerobic microorganisms of the genus *Clostridium*, which use the soluble carbohydrates from the plant for the production of gases (CO_2) and butyric acid, causing heating inside the silo and depreciation in the nutritional value of the silage (OHSHIMA; McDONALD, 1978; MUCK, 1988). Furthermore, these conditions extend the aerobic phase, which in turn, negatively influences the development and proliferation of bacteria in the genus *Lactobacillus.* The reduction in soluble carbohydrate content, followed by decreased production of lactic acid, increases the time required to reach the stabilisation phase of the fermentation process. Tropical grass silage deterioration is characterised mainly by the presence of aerobic bacteria, which result in conditions of great humidity, stability in fermentation pH above 4.5 and no substrate for the growth of desirable microorganisms (ANDRADE et al., 2012).

The inclusion of buriti fruit peel influenced N-NH_3 in the elephant grass silage, causing an increase in the production of this compound (Table 3). With an increase in the quantity of volatile nitrogen as a percentage of the total nitrogen, the quality of the silage is diminished, indicating the degradation of protein compounds (SILVA et al., 2014a). However, N-NH_3 values are within normal ranges for obtaining good quality silage. N-NH_3 values less than 10% were found by Silva et al. (2014b) in elephant grass silage with added wheat bran, and they reported that such results may be indicative of the efficiency of the fermentation process.

Gas losses are associated with the fermentation profile of the silage, so the lowest losses are caused by homofermentative bacteria that utilise glucose as a substrate for the synthesis of lactate (PACHECO et al., 2015). In this experiment the increase in buriti levels increased gas losses.

The reduction in the losses of effluent demonstrates the effectiveness of the use of additives in elephant grass silage, contributing to correction of the DM content and thereby reducing the leaching of nutrients through effluent production (Table 3). The increase in the DM content of the ensiled material helps to reduce the great moisture content of the elephant grass, making conditionsless favourable for the growth of yeasts and bacteria of the genus *Clostridium* sp. in the silage. The use of forages with great moisture content are more susceptible to compaction, which results in disruption of the cell membrane and leakage of the contents, causing substantial loss of nutrients and hence nutritional value (RABELO et al., 2012). Viana et al. (2013) found a reduction in losses by effluent in elephant grass silage with increased inclusion of cottonseed meal, likely a result of the great DM content of the additive used at the time of ensiling.

The difference in the final degradation (120 hours) may have been influenced by the amount of cell wall present in forage because the fibre and neutral detergent fibre (NDF) increased as buriti fruit peel levels reached 78% (Table 2). This is a negative factor in the inclusion of the peel; as Mertens (1997) noted, ruminal filler is a limiting factor in consumption because the passage rate of food is lowered with greater NDF intake. Therefore, feed consumption is negatively correlated with the NDF; that is, the less degradable the feed, the longer the forage remains in the rumen, and consequently, the intake of more bulk is limited.

Whereas fraction (a) represents the portion of the plant that is readily available to the rumen microorganisms, it is possible that the buriti fruit peel contributed to the decrease of this fraction in the silages as no added peel treatment resulted in a value greater than 25.28 DM (Table 4). Chizzotti et al. (2005), who evaluated the ruminal degradability of elephant grass silage, found a value of 29.3% for fraction (a). The addition of peel also raised the potentially degradable insoluble fraction (b) of DM, similar to the effect observed with the addition of the buriti fruit peel, which is also of low nutritional quality.

Conclusion

The correction of the dry matter content using the buriti fruit peel as an absorbent additive in elephant grass silage promotes improvements in the fermentation process, reduces losses of nutrients and does not significantly change the chemical composition of the silage with the inclusion of 166.7 g kg^{-1} of buriti fruit peel.

However, the addition of buriti fruit peel above 50 g kg^{-1} to elephant grass silage results in silages with lower ruminal degradability rates. Still, the indigestible fraction values increase with the inclusion of levels above 50 g kg^{-1} buriti fruit peel, and these increases in the indigestible fraction must be observed and considered in balancing diets for ruminants.

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