Núcleo de Meio Ambiente
Universidade Federal do Pará
Rua Augusto Corrêa, 01, Guamá
Belém, Pará, Brasil
https://periodicos.ufpa.br/index.php/agroecossistemas

Cristiane Rebouças Barbosa
Universidade Federal do Oeste do Pará
cris_ag10@hotmail.com

Marcia Mourão Ramos Azevedo
Universidade Federal do Oeste do Pará
marciazevedos@yahoo.com.br

Andréa Krystina Vinente Guimarães
Universidade Federal do Oeste do Pará
andreavinente@gmail.com

Jéssica de Carvalho Pantoja
Universidade Federal do Oeste do Pará
jessicka.carvalho17@gmail.com

Maicon Alexandre Silva Farias
Universidade Federal do Oeste do Pará
maicon.alexandresf@gmail.com

Received: 2020-01-20
Evaluated: 2021-01-25
Accepted: 2021-09-29

AEROBIC STABILITY AND QUALITY OF ELEPHANT GRASS SILAGES CONTAINING LEVELS OF RESIDUE OF AÇAÍ

ABSTRACT: The objective of this study is to evaluate the elephant grass silage with different levels of inclusion of açaí residue on the fermentative quality and aerobic stability. For this purpose 20 silos (SE) were made, 04 per treatment. The elephant grass and the residue of açaí berry were mixed at the time of the silage. The experimental design was completely in randomized design in five levels of inclusion, 0; 10; 20; 30 and 40% of industrial residue of açaí. The SE were opened in 30 days and samples were collected for bromatological analysis. The content of dry matter (DM) increased by 10.8% in 0 to 40% of silages of inclusion of the residue. At every 1% of added residue, organic matter content increased 0.063%. At temperatures of the silages there was linear reduction ($P < 0.05$) of 0.028% with the addition of the açaí residue of açaí. Silages with 20 and 30% of residue of açaí remained for a longer period within the ideal range of pH, 3.82 and 3.98 at 60 and 72 hours, respectively. Silages with 10, 20, 30, 40% presented the highest aerobic stability, because they reached 2° C elevation in relation to room temperature, with 12 hours of exposure to oxygen. However, the silage without inclusion of açaí residue remained stable for only 1 hour. All treatments with residue of açaí provided silages with sensory, fermentative features and MS content that tank them as having good quality, especially the treatment with 20% of açaí residue, as it presents the best results of the analyzed variables.

KEYWORDS: By-product, *Euterpe oleracea*, Silage.

ESTABILIDADE AERÓBICA E QUALIDADE DE SILAGENS DE CAPIM-ELEFANTE CONTENDO NÍVEIS DE RESÍDUO DE AÇAÍ

RESUMO: Objetivou-se nesta pesquisa avaliar a silagem de capim-elefante com diferentes níveis de inclusão de resíduo de açaí sobre a qualidade fermentativa e a estabilidade aeróbia. Para isso foram confeccionados 20 silos experimentais (SE), 04 por tratamento. O capim-elefante e o resíduo de açaí foram misturados no momento da ensilagem. O delineamento utilizado foi inteiramente casualizado em cinco níveis de inclusão, 0; 10; 20; 30 e 40% do resíduo agroindustrial do açaí. Os SE foram abertos com 30 dias e colhidas amostras para análise bromatológica. O teor de matéria seca (MS) aumentou em até 10,8% nas silagens de 0 a 40% de inclusão do resíduo. A cada 1% de resíduo adicionado, o teor de matéria orgânica apresentou acréscimo de 0,063%. Nas temperaturas das silagens houve redução (P<0,05) linear de 0,028% com a adição do resíduo de açaí. As silagens com 20 e 30% de resíduo do açaí permaneceram por mais tempos dentro da faixa ideal de pH, 3,82 e 3,98 às 60 e 72 horas, respectivamente. As silagens com 10, 20, 30, 40% apresentaram a maior estabilidade aeróbia, pois atingiram elevação de 2°C em relação à temperatura ambiente, com 12 horas de exposição ao oxigênio. Porém, a silagem sem inclusão do resíduo de açaí manteve-se estável por apenas 1 hora. Todos os tratamentos com resíduo de açaí proporcionaram silagens com características sensoriais, fermentativas e teor de MS que as classificam como de boa qualidade, destacando-se o tratamento com 20% de resíduo de açaí, por apresentar os melhores resultados das variáveis analisadas.

PALAVRAS-CHAVE: Ensilagem, *Euterpe oleracea*, Subproduto.

ESTABILIDAD AERÓBICA Y CALIDAD DE ENSILAJE DE HIERBA DE ELEFANTE QUE CONTIENE NIVELES DE RESIDUOS DE AÇAÍ

RESUMEN: El objetivo de esta investigación fue evaluar el ensilaje de hierba de elefante con diferentes niveles de inclusión de residuos de açaí en la calidad fermentativa y la estabilidad aeróbica. Para esto, se realizaron 20 silos experimentales (SE), 04 por tratamiento. La hierba de elefante y los residuos de açaí se mezclaron en el momento del ensilado. El diseño utilizado fue completamente al azar en cinco niveles de inclusión, 0; 10; 20; 30 y 40% de los residuos agroindustriales de açaí. Los SE se abrieron después de 30 días y se tomaron muestras para análisis bromatológicos. El contenido de materia seca (MS) aumentó hasta un 10,8% en ensilajes del 0 al 40% de inclusión del residuo. Por cada 1% de residuo agregado, el contenido de materia orgánica aumentó en un 0.063%. En las temperaturas de los ensilajes hubo una reducción lineal (*P* <0.05) de 0.028% con la adición del residuo de açaí. Los ensilajes con 20 y 30% de residuo de Açaí permanecieron por más tiempo dentro del rango de pH ideal, 3.82 y 3.98 a las 60 y 72 horas, respectivamente. Los ensilajes con 10, 20, 30, 40% mostraron la mayor estabilidad aeróbica, ya que alcanzaron una elevación de 2 ° C en relación con la temperatura ambiente, con 12 horas de exposición al oxígeno. Sin embargo, el ensilaje sin incluir residuos de Açaí permaneció estable durante solo 1 hora. Todos los tratamientos con residuo de Açaí proporcionaron ensilajes con características sensoriales, fermentativas y contenido de MS que los clasifica como de buena calidad, destacando el tratamiento con 20% de residuo de Açaí, para presentar los mejores resultados de las variables analizadas.

PALABRAS CLAVES: Ensilaje, *Euterpe oleracea*, Subproducto.

INTRODUCTION

Elephant grass (*Pennisetum purpureum*, Schum) stands out from other forages for its production potential, nutritional value and versatility of use. Its production capacity reaches up to 50t of dry matter (DM) per hectare per year, and the conservation of forage under the forms of silage is a way to take advantage of the excess forage produced in the period of abundance and use in the period of scarcity. In addition to increased production capacity, elephant grass can be produced at a lower cost than other species, such as corn and sorgo (EMBRAPA, 2016).

Silage comprises the conservation of moist or partially dried foods in an aerobic environment, standing out as one of the main forage conservation techniques used in Brazil. In this process, a specific group of fermentative bacteria produces lactic acid, which reduces the pH of the ensiled mass and inhibits the growth of undesirable microorganisms. This technique aims to conserve the nutritional value and characteristics of the food (LIMA et al., 2015).

The use of surplus weed production in the form of silage has to be seen in a technical way, because the high moisture content and the low concentration of soluble carbohydrates predispose the growth of undesirable microorganisms, which result in loss of fodder and lower nutritional value (Borges et al., 2018). However, an alternative to improve the fermentation patterns and the nutritive value of silage would be the use of additives.

There is an increasing number of studies with the inclusion of MS-rich additives that absorb and sequester moisture, in addition to increasing nutritional value (MOTA et al., 2012). Some authors have highlighted the potential of the inclusion of Açaí (*Euterpe oleracea*) residue in animal nutrition, and may replace the corn of the lactating búfalas supplement by consuming 3 kg of supplement/animal/day, in the rainy season without causing a decrease in milk production (10kg) and in milk solids production (GOMES et al., 2012; LIMA, 2017).

The fruit of Açaí comes from a tropical palm tree native of the Brazilian Amazon, with great social economic influence in the Northern region of Brazil. According to IBGE (2020), the main producer of Açaí in Brazil continues to be the state of Pará, where 1,478,168 tons were extracted in 2019. However, approximately 90% of this volume is equivalent to the residues generated after fruit processing, which are mostly disposed of incorrectly, resulting in environmental disorders.

Therefore, research of by-products that contribute to the increase of dry matter and stability of elephant grass are fundamental for animal nutrition and for technical recommendations, given mainly to silage producers. In this context, the objective was to evaluate elephant grass silage with different levels of Açaí residue inclusion on fermentative quality and aerobic stability.

MATERIALS AND METHODS

The experiment was conducted at the Bromatology Laboratory of the Federal University of Western Pará (UFOPA), in the municipality of Santarém - Pará, whose geographic coordinates are latitude 02° 26' 35" S and longitude 54° 42' 30" W, altitude of 51 meters and an area of 24422.5 km² (IBGE, 2018). With an average annual temperature between 25°C and 28°C, the average relative humidity of 86%, having hot and humid climate as dominant in the region, typical of tropical regions.

The elephant grass for silage came from the Experimental Farm of UFOPA, Km 37 of the PA-370, in the city of Santarém-Pará. The harvest occurred with approximately 90 to 100 days of regrowth, mechanically, 10 cm from the soil, with the aid of a picadeira would park with an average particle size of 4.0 cm. The agro-industrial residue of Açaí was obtained at Mercadão 2000 in the municipality of Santarém - PA. It was then crushed in stationary pike and passed in sieves of 5.0 mm in diameter in order to separate the most fibrous part of the pits.

The materials (grass and Açaí residue) were transported to the Bromatology Laboratory/UFOPA, where they were pre-dried in the sun for 2 hours to remove part of the moisture. After pre-drying, the agro-industrial residue of the Açaí was manually mixed with elephant grass. Five levels of inclusion of Açaí residue were evaluated in increasing percentages (0%; 10%; 20%; 30% and 40%) in elephant grass silage in a completely randomized design with four replications.

From each sample to be ensiled, 500 g were removed, packed in paper bags and placed in a forced air ventilation oven at a temperature of 55ºC for 5 days, for the determination of the chemical-bromatological composition (Table 1).

Table 1. Chemical-bromatological composition of the fresh ingredients used to make silages.

Constituent [1]	Level of inclusion (%)					Açaí byproduct
	0	10	20	30	40	
DM (%MN)	27,69	30,62	36,95	41,05	45,13	62,10
% in DM						
OM	85,30	85,99	88,59	89,72	91,05	96,29
MM	14,70	14,02	11,41	10,29	8,96	3,72
EE	2,15	2,23	1,75	1,83	2,47	2,06

[1] MN= natural matter; DM=dry matter; OM=organic matter; MM=mineral matter; EE=ether extract. Source: Prepared by the author.

Elephant grass and Açaí residue were mixed and ensiled in 20 experimental PVC silos (SE) with 100 mm diameter and 350 mm in length containing 1,650 kg of silage. The material was manually compacted in the SE using a wooden handle, in order to reach a density of 600 kg/m3. The SE was equipped with a Bunsen valve for the exhaust of gases and sealed with commercial PVC covers in order to prevent air from entering these microenvironments.

After 30 days of fermentation, the SE were opened. The sensory evaluation of the silages was then carried out according to the criteria established by Meyer, Bronsch and Liebetseder (1989), regarding the aspects odor, staining and manipulation (DM content), for which the silages received scores and, from the sum of these, the silages were then classified as good to very good, satisfactory, regular and unsatisfactory.

Soon after the opening of the SE, a sample was taken to determine the pH values of the silages according to the methodology described by Silva and Queiroz (2002). The silage temperature inside the SE was also measured using a digital thermometer inserted in the ensiled mass, in a depth of 10 cm. Samples of 500g of silage were taken, pre-dried, in an air circulation oven at 55°C for 72 hours, ground in a knife mill with a sieve of 2 mm and subsequently determined the DM values.

The determination of total DM losses was calculated by the difference between the gross weight of initial and final DM of the SE, in relation to the amount of ensiled forage. The weight of the experimental silo was deducted in the silage and opening, according to the equation described by Schmidt (2006).

$$PDM = [(DMi - DMf)] \times 100/ DMi$$

Where:
PDM = Total Loss of DM;
DMi = Initial DM amount. Weight of the experimental silo after filling - weight of the empty set (dry tare) x DM content of the forage in silage;
DMf = Amount of final DM. Weight of the full experimental silo before opening – weight of the empty assembly (wet tare) x DM content of the forage in the opening.

For the aerobic stability assay, a composite sample of each treatment (0%; 10%; 20%; 30% and 40%) was made with 2 kg of uncompressed silage packed in polypropylene buckets with a capacity of 15 kg, where they stayed for 7 days in a closed room with room temperature. The temperature of the room was monitored twice a day (7:00 and 19:00 h) for seven days, along with the temperature of the silages, using a thermometer inserted 10 cm from the mass. The ambient temperature was monitored with the same thermometer used in the silage temperature. 16 evaluation times (0, 1, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, 168 hours after the opening of the SE) were evaluated and at the same time the pH values were also measured, according to the methodology described by Silva and Queiroz (2002).

Aerobic stability was calculated as the number of hours observed so that silage, after opening the experimental silo, presented an increase of 2ºC in relation to room temperature (MORAN et al., 1996).

Gas losses and DM recovery were quantified according to the equations proposed by Paziani et al. (2006). The determination of gas losses was calculated by the difference in weight of the forage mass at the time of silage and opening and their respective DM contents (equation 1).

$$G=((Pfe - Pab))/((MFfe \times DMfe)) \times 100$$

In which:

G gas loss (% DM);
Pfe = weight of full experimental silo at closure (kg);
Pab = weight of the full experimental silo in the opening (kg);
FfM = forage mass at closure (kg); DMfe = DM content of forage at closure (% DM).

The dry matter recovery index (RDM) was obtained through the weight obtained by the forage mass at the moments of silage and opening and their respective DM content (equation 2).

$$RDM= ((MFab \times DMab))/((MFfe \times DMfe)) \times 100$$

In which:
RDM = dry matter recovery index (%);
MFab = forage mass at the opening (kg);
DMab = dry matter content of the forage at the opening (%);
FfM = forage mass at closure (kg);
MDfe = dry matter content of forage at closure (%).

The chemical-bromatological composition of *in natura* samples and silage was obtained according to Silva and Queiroz (2002) for DM, mineral matter (MM) and ether extract (EE). The values of OM (organic matter) were estimated by the following formula:

In which: OM = 100 - MM;

The means of the variables obtained were submitted to analysis of variance and regression, when the F was significant, the Tukey test was applied, considering the $P<0.05$ value as the level of statistical significance. When the regression coefficients were significant, the equations were adjusted using the Statistical Package SISVAR 5.6 ® (FERREIRA, 2014).

RESULTS AND DISCUSSION

The sensory evaluation regarding the nutritive aspect of elephant grass silages with the addition of different levels of agro-industrial residue of Açaí were classified as "Good to Very Good" (Table 2) because they did not demonstrate significant changes in the analyzed parameters, presenting pleasant odor, characteristic of silages, with greenish coloration, indicating adequate anaerobic fermentation of silages, these results can be explained by the typical density (600 kg/m3) of silage, compaction of the mass and thus the expulsion of oxygen, sealing and proper storage.

Table 2. Sensory evaluation of elephant grass silages with Açaí residue as to the characteristics associated with nutritive value.

Treatment [1]	Total Score	Classification *	Parameter *
1	24,75	Good to Very Good	21 a 25
2	25	Good to Very Good	21 a 25
3	25	Good to Very Good	21 a 25
4	25	Good to Very Good	21 a 25
5	25	Good to Very Good	21 a 25

[1] Equivalent to treatment 1: No by-product of Açaí; 2: Inclusion of 10% by-product of Açaí; 3: Inclusion of 20% of Açaí by-product; 4: Inclusion of 30% of Açaí berry by-product; 5: Inclusion of 40% by-product of Açaí. Source: Prepared by the author. *According to criteria established by Meyer, Bronsch and Liebetseder (1989).

Regarding the sanitary aspect, the silages were classified as "Good to Very Good" (Table 3), with typical greenish coloration, consistent texture and no molds. However, Lira Júnior et al. (2018) when analyzing elephant grass silages with inclusion of passion fruit bark, classified the sensory characteristics of all treatments as good, since they presented yellowish coloration, slightly acrid odor and visible absence of mold.

Table 3. Sensory evaluation of elephant grass silages with Açaí residue as to the characteristics associated with the sanitary aspect.

Treatment [1]	Total Score	Classification *	Parameter *
1	-4,5	Good to Very Good	0 a -5
2	0	Good to Very Good	0 a -5
3	0	Good to Very Good	0 a -5
4	0	Good to Very Good	0 a -5
5	0	Good to Very Good	0 a -5

[1] Equivalent to treatment 1: No by-product of Açaí; 2: Inclusion of 10% by-product of Açaí; 3: Inclusion of 20% of Açaí by-product; 4: Inclusion of 30% of Açaí berry by-product; 5: Inclusion of 40% by-product of Açaí. Source: Prepared by the author. *According to criteria established by Meyer, Bronsch and Liebetseder (1989).

A reduction in DM content was observed in all analyzed silages when compared to the ensiled material (Table 1 and 4). This reduction in DM of silages with the addition of agro-industrial residue of Açaí, used in the *in natura* form, can be explained by the moisture content of the additive. However, Negrão et al. (2016) evaluated the losses, fermentative profile and chemical composition of *Brachiaria decumbens* grass silages with inclusion of rice bran. And they obtained an increase in dm content to the average that rice bran was added, evidencing that it is efficient in absorbing moisture, since it provided an increase in DM content.

Table 4. Chemical-bromatological composition of silages.

Variable [1]	Level of inclusion (%)					EPM(2)	r^2	Equation (3)
	0	10	20	30	40			
DM (%MN)	27,63	28,86	32,45	35,81	38,43	0,48	98,77	$y=27{,}288+0{,}213x+0.002x^2$*
OM (%DM)	93,14	93,71	94,41	95,13	95,58	0,55	99,47	$y=93{,}132+0{,}063x$*
MM (%DM)	6,86	6,29	5,59	4,87	4,42	9,32	99,47	$y=6{,}867-0{,}063x$*
EE (%)	1,98	2,26	1,52	1,63	2,25	16,43	35,68	$y=2{,}164-0{,}044x+0{,}001x^2$*

[1] MN= natural matter; DM=dry matter; OM=organic matter; MM=mineral matter; EE=ether extract.
* Significant P<0.05 by test t. (2) Standard error of the mean. (3) Regression equation, orthogonal polynomial test, linear, quadratic, cubic or quartic response. Source: Prepared by the author.

The use of Açaí by-product increased up to 10.8 percentage points in the DM content in silage, at its highest level of inclusion. The increase in DM content (Table 4) was estimated at 0.21 percentage units for every 1% of Açaí by-product added in silage. This elevation can be explained by the DM content (62.10%) present in the residue when purchased from elephant grass (Table 1). Differently, Bonfá et al. (2015) working with elephant grass silage added from passion fruit bark, noticed that the inclusion of passion fruit bark levels led to a decrease (0.43%) in the DM content of silages. According to the aforementioned authors, this fact occurred due to the low DM content present in the co-product at the time of silage, evidencing that the higher the level of inclusion of passion fruit bark, the higher the moisture content added to the material.

To obtain a good silage, the DM content is one of the most important requirements, since it directly interferes with the fermentative process of silages, with influence on the types of organic acids formed (MELO et al., 2016). It was observed that the silages of the present study presented mean DM content of 32.67%, this value is at the level recommended by the literature, of 28 to 35% of DM, necessary for the occurrence of lactic fermentation (PACHECO et al. 2014).

The organic matter content of the ensiled masses was influenced ($P<0.05$) by the addition of the additive. With an increase of 2.44 percentage points in the OM content in silage, at its highest level of inclusion. It was found that for every 1% inclusion of Açaí residue, there was an increase of 0.063% in silage OM. Possibly this increase in OM values is related to the high OM content in the Açaí residue (Table 1). As well as the by-product of Açaí, the agro-industrial residue of acerola has a high organic matter content, confirmed by Maia (2015) when evaluating elephant grass silages with levels of acerola residues (*Malpighia emarginata*), and it was observed that there was an increase in organic matter contents (0.16%) with the addition of the residue in elephant grass silage.

Mineral matter was influenced by the different levels of Açaí residue ($P<0.05$), ranging from 4.42 to 6.86% in silages with inclusion of 40% of Açaí residue and silage without additive (control), respectively (Table 4). These results can be explained by the low MM content in the Açaí residue (Table 1). Different effect was obtained by Melo et al. (2016) in fermentative characteristics and chemical composition of tanzania grass silage with additives, in which there was a gradual increase in mineral matter.

A quadratic effect was observed in the ethereal extract (EE) content of silages with the levels of addition of Açaí residue ($P<0.05$), being estimated at 0.044% for each 1% of this agro-industrial residue added to the silage. This reduction in EE content was the result of higher concentration of this nutrient present in elephant grass when compared to Açaí residue, 2.15 and 2.06%, respectively (Table1). Maia et al. (2015), using residue levels of acerola agroindustry in elephant grass silages, observed an increase in EE content in all treatments when purchased at silage control.

There was a reduction in silage temperature with linear Açaí residue addition levels ($P<0.05$), estimating a reduction of 0.028% for every 1% of Açaí residue added to silage (Table 5). These results can be explained by the addition of Açaí residue levels in the effectiveness of controlling the development of microorganisms, reflecting at lower temperatures. Rezende et al. (2011), working with fermentative losses and aerobic stability of sugarcane silages treated with virgin lime and sodium chloride, reported that the doses of 1.0 and 1.5% of lime were effective in controlling the development of microorganisms, reflecting at lower temperatures.

Table 5. Average values of temperature (T (°C)), pH, total dry matter loss (PDM), gas losses (PG), effluent losses (PE) and dry matter recovery (RDM) of elephant grass silages with different levels of Açaí by-product inclusion.

Variable [1]	Level of inclusion (%)					EPM[(2)]	r^2	Equation [(3)]
	0	10	20	30	40			
T (°C)	31,3	30,20	29,75	29,98	29,73	2,10	70,11	$y=30{,}700-0{,}028x$*
Ph	3,57	3,77	3,79	3,95	4,02	2,16	96,05	$y=3{,}588+0{,}014x-0{,}00008x^2$*
PDM (g)	0,80	6,39	21,59	3,80	15,30	6,24	100,00	$y=0{,}800-3{,}965x+0{,}742x^2-0{,}033x^3+0{,}0004x^4$*
PG (%DM)	0,017	0,020	0,017	0,017	0,010	22.82	100,00	$y=0{,}015+0{,}003x-0{,}0003x^2+0{,}00001x^3+0{,}000x^4$*
PE (kg.t-1 MV)	0,123	0,077	0,138	0,124	0,076	100.60	100,0	-
RDM (%)	99,20	93,61	78,41	29,97	29,72	0,66	100,00	$y=99{,}200+3{,}965x-0{,}742x^2+0{,}033x^3-0{,}0004x^4$*

* Significant P<0.05. (1) Standard error of the mean. (2) Regression equation, orthogonal polynomial test, linear, quadratic, cubic or quartic response. Source: Prepared by the author.

The pH values of silages had a quadratic effect (*P*<0.05) with an average of 3.82 (Table 5), within the ideal ph range (3.8 to 4.2) for effective fermentation of good quality silages (McDonald et al., 1981). However, treatments of 0, 10 and 20% presented values below the ideal pH range (Table 5), similar values were found (3.59; 3.83, 3.70 and 4.27) by Barcelos et al. (2018)

who worked with elephant grass silage, cultivar mineiro cut at 70 days after cutting leveling with different proportions of coffee hulls.

Dry matter losses (SMP) decreased due to Açaí residue levels in silages (Table 1) with higher losses for treatment with 20% of additive (P<0.05). Opposite effect was observed by Paziani et al. (2006), with losses of 5.7 to 6.7% of DM in grass silages - Tanzania, with natural moisture or with resources to raise DM.

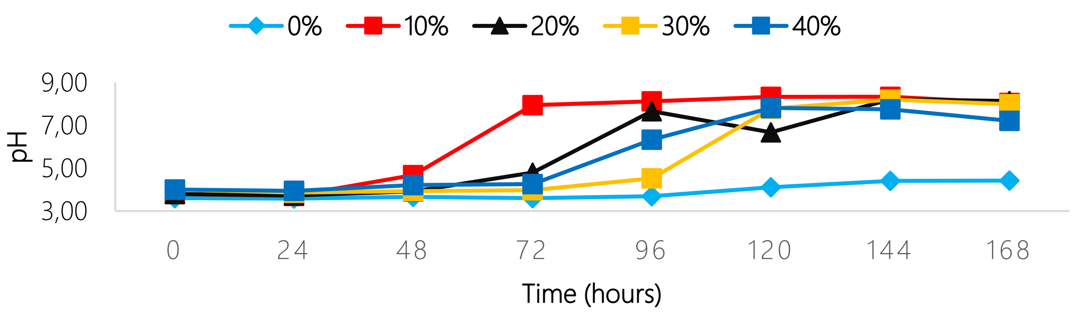
A quantum effect (P<0.05) of Açaí residue levels on gas losses (PG) was observed. The addition of 10% of Açaí residue presented higher PG (0.020%) as compared to the other treatments, but considered of low magnitude. On the other hand, the inclusion of 40% of the additive presented the lowest mean (0.010%) of PG (Table 5). These results are lower than those found by Melo et al. (2016); when evaluating fermentative characteristics and chemical composition of tanzania grass silage with additives, they observed averages of 0.90 to 1.11% of PG. According to the same authors, the higher or lower gas production may be related to PDM during the fermentation process, probably caused by undesirable fermentations from the metabolism of microorganisms, such as chlorhesides, enterobacteria and yeasts that develop at higher pH and are responsible for the production of gases.

Silages did not differ (P>0.05) in terms of effluent loss (PE), with a mean 0.108%. However, it was observed by Rezende et al. (2011) effluent loss (P<0.01) for treatments, observing a linear regression. According to the authors, the decrease in effluent loss from the addition of 14% of potato scrapings can be explained by the DM content, because when this amount of potato scraping was added to silage, a content of 30.03% DM was observed in the silage produced.

The RDM values of the silages decreased in a quartic form (P<0.05) with the addition of Açaí residue. Silages showed a mean recovery of DM of 66.18% (Table 5), but it was verified in the treatment with greater addition (40%) of Açaí residue that it presented lower recovery (29.72). These results were lower than those found by Amaral et al. (2008), working with marandu grass silages, obtaining an average recovery of DM of 92.9%.

Silage without inclusion of Açaí residue maintained its ideal pH value (4.11) up to 120 hours of aerobic exposure (Figure 1). However, T2 presented the shortest time (0 hours) in the ideal ph range (3.8), followed by T5 with 36 hours and pH, 4.00. T3 and T4 showed the highest times (60 and 72 hours) within the ideal pH range, 3.82 and 3.98, respectively.

Figure 1. Temporal behavior of elephant grass silages in aerobiosis in relation to the pH of treatment without by-product of Açaí; with the addition of 10% Açaí by-product; with the addition of 20% Açaí by-product; with the addition of 30% Açaí by-product and 40% addition of Açaí berry by-product.

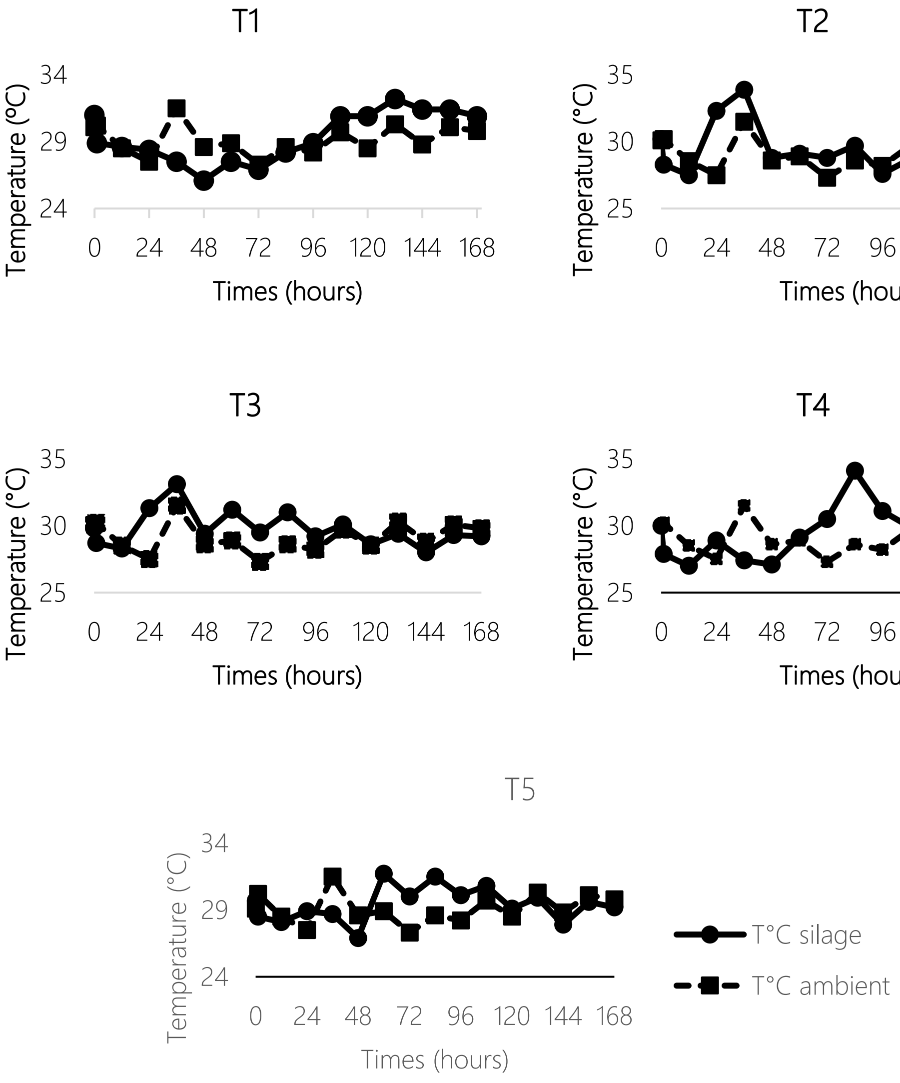


Source: Prepared by the author.

2ºC was added to the room temperature values (Figure 2). Temperature spikes were observed in silages around 28 hours of aerobic exposure, which may be associated with increased ambient temperature.

According to the data (Figure 2), we can observe that the silages of T2, T3, T4 and T5 presented the highest aerobic stability, because they reached an increase of 2°C in relation to the ambient temperature, in up to 12 hours of oxygen exposure. However, silage without inclusion of Açaí residue remained stable for only 1 hour, being the first to reach 2ºC above room temperature. With this, it was also the first to show signs of aerobic deterioration, while the other silages remained stable.

Figure 2. Temporal behavior of the temperature of elephant grass silages with by-product levels of Açaí and ambient temperature during aerobic exposure of treatments without by-product of Açaí; with the addition of 10% Açaí by-product; with the addition of 20% Açaí by-product; with the addition of 30% Açaí by-product and the addition of 40% Açaí by-product.



Source: Prepared by the author.

We can observe (Figure 2) that the maximum temperature was reached by silage with the addition of 30% of Açaí residue, followed by silage with the increase of residue of 10%. Regarding the number of hours spent to reach the maximum temperature, the silages treated with 10% and 30% with the additive, presented maximum temperatures with 36 and 84 hours, respectively. However, silage with the inclusion of 30% of Açaí residue showed greater variation (27 to 34.1 T°C) among silages.

Possibly the silage treated with 30% of Açaí residue expressed higher levels of residual soluble carbohydrates, providing a favorable means for the greater development of deteriorating microorganisms. According to Woolford (1978), the increase in the temperature of silages in oxygen exposure is due to the growth of aerobic microorganisms that use organic acids and other soluble nutrients as an energy source, resulting in nutritional losses.

CONCLUSION

All treatments with Açaí residue provided silages with sensory characteristics, fermentatives and DM content that classify them as good quality, especially the treatment with 20% of Açaí residue, because it presents the best results of the variables analyzed. However, further studies are needed to verify its influences on the animal diet.

REFERENCES

AMARAL, R. C.; BERNARDES, T. F.; SIQUEIRA, G. R.; REIS, R. A. Estabilidade aeróbia de silagens do capim-marandu submetidas a diferentes intensidades de compactação na ensilagem. **Revista Brasileira Zootecnia**, v.37, n.6, p.977-983, 2008.

BARCELOS, A. F.; CARVALHO, J. R. R.; TAVARES, V. B.; GONÇALVES, C. C. M. Valor nutritivo e características fermentativas da silagem de capim-elefante com diferentes proporções de casca de café. **Ciência animal brasileira**, Goiânia, v.19, 1-12, e-27432, 2018.

BONFÁ, C. S.; CASTRO, G. H. F.; VILLELA, S. D. J.; SANTOS, R. A.; EVANGELISTA, A. R.; JAYME, C. G.; GONÇALVES, L. C.; PIRES NETO, O. S.; BARBOSA, J. A. S. Silagem de capim-elefante adicionada de casca de maracujá. **Arquivo Brasileiro Medicina Veterinária Zootecnia**, v.67, n.3, p.801-

808, 2015. http://dx.doi.org/10.1590/1678-4162-7982. Acesso em: 18 nov. 2018.

BORGES, B. R. S.; NEGRÃO, F. M.; ZZANINE, A. M.; MACHADO, A.; CALDEIRA, F. H. B.; LINS, T. O. J. D. Potencial da ensilagem de capim-braquiaria com inclusão de farelo de arroz: Revisão. **PUBVET**. v.12, n.2, a28, p.1-9, Fev., 2018. https://doi.org/10.22256/pubvet.v12n2a28.1-9. Acesso em: 13 jan. 2019.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – EMBRAPA. Pecuária de leite no Brasil. In: Capim-elefante: versatilidades de usos na pecuária de leite. Brasília: Embrapa Pecuária Sudeste, 2016. 195p.

FERREIRA, D. F. Sisvar: a Guide for its Bootstrap procedures in multiple comparisons. **Ciência e Agrotecnologia**, v. 38, n. 2, 2014.

GOMES, D. I.; VÉRAS, R. M. L.; ALVES, K. S.; DETMAN, E.; OLIVEIRA, L. R. S.; MEZZOMO, R.; SANTOS, R. B.; BARCELOS, S. S. Performance and digestibility of growing sheep fed with açai seed meal-based diets. **Tropical Animal Health and Production**, 44(7):1751-7. Oct. 2012.

IBGE. Instituto Brasileiro de Geografia Estatística, 2018. Estimativas Da População Residente Para Os Municípios E Para As Unidades Da Federação Com Data De Referência Em 1º De Julho De 2018. Disponível em: https://cidades.ibge.gov.br/municipio/150680. Acesso em: 24 set. 2021.

IBGE. Instituto Brasileiro de Geografia Estatística, 2020. Disponível em: https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/31672-pam-2020-valor-da-producao-agricola-nacional-cresce-30-4-e-chega-a-r-470-5-bilhoes-recorde-da-serie. Acesso em: 24 set. 2021.

LIMA, E. D. M.; JAYME, D. G.; SILVA, F. C. O.; MICHEL, P. H. F.; CÔRTES, I. H. G.; ANJOS, G. V. S.; SILVA, N. T. A.; OTTONI, D. Deterioração aeróbia de silagens. **Revista Eletrônica Nutritime,** vol. 12, n. 2, p. 3996– 4003, 2015.

LIMA, E. M. **Caroço de açaí (*Euterpe oleracea* Mart.) na alimentação de búfalas lactantes em pastejo**. 2017. Parauapebas – PA: Universidade federal rural da Amazônia – UFRA, 2017. Dissertação (Mestre em Saúde e Produção Animal na Amazônia), Universidade federal rural da Amazônia, 2017.

LIRA JÚNIOR, W.B.; BEZERRA, S.B.L.; PAULA, T.A.; BEELEN, R.N.; AMORIM, P.L.; BEELEN, P.M.G. Características de silagens de capim-elefante (Pennisetum purpureum) e casca de maracujá in natura. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.70, n.3, p.905-912, 2018.

MAIA, I. S. A. S. **Composição químico-bromatológica e avaliação sensorial de silagens de capim elefante (*Pennisetum purpureum*, schum.) com níveis de resíduos da acerola e tamarindo.** 2015. Mossoró-RN: Universidade Federal Rural do Semi-árido. Dissertação (Mestre em

Produção Animal). Universidade Federal Rural do Semi-árido, 2015.

McDONALD, P. **The biochemistry of silage**. Chichester: John Wiley & Sons, 1981. 218p.

MELO, M. J. A. F.; BACKES, A. A.; FAGUNDES, J. L.; MELO, M. T.; SILVA, G. P.; FREIRE, A. P. Características fermentativas e composição química da silagem de capim tanzânia com aditivos. **Boletim de Indústria Animal**, v.73, n.3, p.189-197, 2016. DOI: http://dx.doi.org/10.17523/bia.v73n3p189

MEYER, H.; BRONSCH, K.; LIEBETSEDER, J. Supplemente zu Vorlesungen und bungen inder Tierernhrung. Verlag M. e H. Schaper, Hannover, 1989.

MORAN, J.P.; WEINBERG, G.; ASHBELL, Y.H; Hen, Y.; Owen, T. R. **A comparison of two methods for the evaluation of the aerobic stability of whole crop wheat silage**. In: INTERNATIONAL SILAGE CONFERENCE, 11., 1996, Aberystwyth. Proceedings... Aberystwyth: University of Wales Aberystwyth, p.162-163, 1996.

MOTA, P. E. S.; MOURA, R. L.; CARVALHO, W. F.; SILVA, S. F.; OLIVEIRA, E. M.; SANTANA, A. S.; PORTELA, G. L. F.; OLIVEIRA, M. R. A. Características Fermentativas da Silagem de Capim-Elefante Contendo Diferentes Aditivos. **Revista Cientifica Produção Animal**., v.14, n.2, p.133-137, 2012.

NEGRÃO, F. M.; ZANINE, A. M.; SOUZA, A. L.; CABRAL, L.S.; FERREIRA, D. J.; DANTAS, C. C. O. Perdas, perfil fermentativo e composição química das silagens de capim Brachiaria decumbens com inclusão de farelo de arroz. **Revista Brasileira Saúde Produção Animal**, Salvador, v.17, n.1, p.13-25 jan./mar., 2016.

PACHECO, W. F., DE SOUZA CARNEIRO, M. S., PINTO, A. P., EDVAN, R. L., DE ARRUDA, P. C. L., DO CARMO, A. B. R. Perdas fermentativas de silagens de capim-elefante (*Pennisetum purpureum* Schum.) com níveis crescentes de feno de gliricídia (*Gliricidia sepium*). **Acta Veterinaria Brasilica**, vol. 8, 155-162, 2014.

PAZIANI, S. F.; NUSSIO, L. G.; LOURES, D. R. S.; IGARASI, M. S.; PEDROSO, A. F.; MARI, L. J. Influência do teor de matéria seca e do inoculante bacteriano nas características físicas e químicas da silagem de capim Tanzânia. **Acta Scientiarum. Animal Science**, v. 28, n. 3, p. 265-271, 2006.

REZENDE, A. V.; RABELO, C. H. S.; RABELO, F. H. S.; NOGUEIRA, D. A.; FARIA JUNIOR, D. C. N. A.; BARBOSA, L. A. Perdas fermentativas e estabilidade aeróbia de silagens de cana-de-açúcar tratadas com cal virgem e cloreto de sódio. **Revista Brasileira de Zootecnia**, v.40, n.4, p.739-746, 2011.

SCHMIDT, D. C. Model-driven engineering. **Computer-ieee computer society**, v. 39, n. 2, p. 25, 2006.

SILVA, D.J.; QUEIROZ. A.C. **Análise de alimentos** (Métodos químicos e biológicos). 2.ed., Viçosa, MG: UFV. 2002, 178p.

WOOLFORD, M.K. **The problem of silage effluent**. Herbage Abstracts, v.48, p.397-403, 1978.