FORAGE AND PASTURES

MESQUITE PODS AS A SOURCE OF SOLUBLE CARBOHYDRATES IN ELEPHANT GRASS SILAGES

Francisca Debora da Silva Ferreira,
Universidade Federal do Ceará, Campus Pici - CE, Brazil,
https://orcid.org/0000-0001-9161-1162
Corresponding author: deborahfr08@gmail.com

Bruno Spíndola Garcez,
Instituto Federal do Ceará – Campus Crateús, Crateús - CE, Brazil,
https://orcid.org/0000-0001-8920-6547

Valdênio Mendes Mascena,
Instituto Federal do Ceará – Campus Crateús, Crateús - CE, Brazil,
https://orcid.org/0000-0002-6997-4394

Bárbara Holanda Maia,
Instituto Federal do Ceará – Campus Crateús, Crateús - CE, Brazil,
https://orcid.org/0000-0001-6974-4014

Claudimiro França de Oliveira Pinho Filho,
Instituto Federal do Ceará – Campus Crateús, Crateús - CE, Brazil,
https://orcid.org/0000-0002-8114-5054

João Victor Pereira da Silva,
Instituto Federal do Ceará – Campus Crateús, Crateús - CE, Brazil,
https://orcid.org/0000-0002-7442-0185

Maria Hyenda Alves Lopes,
Instituto Federal do Ceará – Campus Crateús, Crateús - CE, Brazil,
https://orcid.org/0000-0002-5385-1947

Simone Aparecida Alves de Macedo,
Instituto Federal do Ceará – Campus Crateús, Crateús - CE, Brazil,
https://orcid.org/0000-0003-4204-0505

Received: 02/07/2021
Approved: 15/12/2021

Abstract

The objective of this study was to evaluate the fermentation parameters and chemical composition of elephant grass silage with inclusion of crushed mesquite pods, at the levels of 8, 16, 24 and 32% as a source of soluble carbohydrates, in addition to a control treatment (no mesquite pod). Fermentation parameters were evaluated for gas losses (GL), effluent losses (EL), dry matter recovery (DMR), pH, ammonia nitrogen (NH_3-N), and chemical composition related to dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM), cellulose (CEL), lignin (LIG) and total digestible nutrients (TDN). A quadratic behavior ($p<0.05$) was found for GL, with a reduction of 45.58% with 32% inclusion. There was a decrease ($p<0.05$) in EL (59.22%) and NH_3-N (38.21%) and an increase in DMR by 17.57% as the mesquite pod meal was added to the silage. As for the chemical composition, the inclusion of mesquite pod meal promoted increments ($p<0.05$) of 72.28%, 69.58% and 29.80% for the DM, CP and TDN, respectively, and a decrease in NDF (29.92%) and ADF (31.84%) up to the highest level of inclusion of mesquite pod meal (32%). The inclusion of up to 32% mesquite pod meal in elephant grass silage promotes better fermentation stability in the silo, by reducing losses and increasing the DM content of the ensiled mass, which minimizes nutrient leaching. The use of mesquite pod meal as a source of soluble carbohydrates can also improve the silage chemical composition, increasing the content of CP and TDN, and reducing the content of NDF, ADF and Lignin.

Key Words Effluent losses, *Pennisetum purpureum Schum*, *Prosopis juliflora*, Silage.

VAGENS DE ALGAROBA COMO ADITIVO ENERGÉTICO EM SILAGENS DE CAPIM ELEFANTE

Resumo

Objetivou-se nesta pesquisa avaliar os parâmetros fermentativos e a composição química da silagem de Capim Elefante com adição de 8, 16, 24 ou 32% de vagens de algaroba trituradas, como fonte de carboidratos solúveis, junto ao tratamento controle (sem vagens). Foram avaliados os parâmetros fermentativos quanto às perdas por gases (PG), perdas por efluentes (PE), recuperação de matéria seca (RMS), pH, nitrogênio amoniacal (N-NH3), e a composição química referente aos teores de matéria seca (MS), proteína bruta (PB), fibra em detergente neutro (FDN), fibra em detergente ácido (FDA), hemicelulose (HEM), celulose (CEL), lignina (LIG) e nutrientes digestíveis totais (NDT). Observou-se comportamento quadrático ($p<0,05$) para PG, obtendo-se redução de 45,58% nesse parâmetro com 32% de inclusão, em relação ao tratamento controle. Houve decréscimo ($p<0,05$) nos valores de PE (59,22%) e N-NH3 (38,21%) e acréscimo na RMS de 17,57% conforme a adição das vagens na silagem. Quanto à composição química, a inclusão das vagens promoveu incrementos ($p<0,05$) de 72,28%, 69,58% e 29,80% para os teores de MS, PB e NDT, respectivamente, e diminuição nos valores de FDN (29,92%) e FDA (31,84%) até o maior de nível de inclusão das vagens (32%). A inclusão de até 32% de vagens de algaroba trituradas em silagem de capim elefante promove melhor estabilidade fermentativa no silo, por redução nas perdas e aumento no teor de MS da massa ensilada, o que minimiza a lixiviação de nutrientes. O uso das vagens como fonte de carboidratos solúveis, também pode melhorar a composição química da silagem, elevando os teores de PB e de NDT, e reduzindo os teores de FDN, FDA e Lignina.

Palavras-chave Ensilagem, *Pennisetum purpureum* Schum, Perdas por efluentes, *Prosopis juliflora.*

INTRODUCTION

The use of technologies that ensure the productivity of ruminant herds in periods of low forage availability, caused by rainfall deficit, is an increasingly common practice in production systems in the semi-arid Northeast region of Brazil. As well as ensuring resources for feeding animals in periods of nutritional deficit, they also enable the preservation of forage surplus produced in the rainy season in adequate amounts and with good nutritional value (MACÊDO *et al*., 2019).

In this context, the production of tropical grass silage is considered an alternative to increase the supply of roughage in the off-season periods (LIRA JÚNIOR *et al*., 2018). Elephant grass (*Pennisetum purpereum* Schum) stands out among the forages indicated for this process, for having a high forage yield and easy establishment as a grass area.

However, this grass has characteristics inherent to its chemical composition, such as a high moisture content at the time of cutting and a low proportion of soluble carbohydrates (TRINDADE *et al*., 2018), which can lead to undesirable fermentation patterns, with the formation of weak acids that result in slow acidification of the ensiled mass and high effluent production (BARCELOS *et al*., 2018), affecting the quality of the final product.

To minimize these problems and improve the fermentation and nutritional aspects of silage, additives are used upon ensiling, especially those that have absorbent properties and bring an additional contribution of soluble carbohydrates, which will stimulate formation of lactic acid and promote a rapid drop in pH of the ensiled mass, resulting in an improvement in the conservation of nutrients (DANIEL *et al*., 2019).

In semi-arid regions, a strategy for silage production is the use of legume pods as sources of soluble carbohydrates, especially Mesquite (*Prosopis juliflora* (Sw) DC), a perennial species widely disseminated in Brazilian Northeastern region. It has favorable characteristics for development in semi-arid areas, the fruiting period is during the dry season, from September to November, and withstand low levels of annual rainfall (CHATURVEDI; SAHOO, 2013).

The chemical composition of mesquite pods shows a predominance of soluble carbohydrates, with values around 42% sucrose found in their constitution

(NASCIMENTO *et al.,* 2015). In addition, mesquite pods have a CP content above 9% (RÊGO *et al.,* 2011; SANTOS *et al.*, 2012) and high hygroscopicity when ground, which can increase the dry matter content of the ensiled mass by reducing effluent losses and improving fermentation patterns (RÊGO *et al*., 2011). Thus, the objective of this study was to evaluate the fermentation parameters and chemical composition of elephant grass silage with the inclusion of mesquite pod meal.

MATERIAL AND METHODS

The experiment was conducted at the Federal Institute of Education, Science and Technology of Ceará - Campus Crateús, in the municipality of Crateús, located at 5º10'42" South and 40º40'39" West, with an average annual rainfall of 673.3 mm (FUNCEME, 2017). Elephant grass (*Pennisetum purpureum* Schum cv. Cameroon) was grown in an area of approximately 193m², fertilized with nitrogen after cutting and drip irrigated on alternate days. The grass was cut at 10 cm from to the ground, 80 days after regrowth, when it had an average dry matter content of around 25.3%, being later spread for wilting for 12 hours and then ground to particles of approximately 2 cm.

Mesquite pods were harvested at maturity, after natural ripening and falling on the ground, subjected to drying in the sun for 24 hours and then ground in a forage machine with a 1cm sieve. The experimental mini-silos were made with PVC pipes measuring 10 cm in diameter and 50 cm in length, containing tap top seal with a bunsen valve for gas escape and quantification (MOTA *et al*., 2015).

A completely randomized design was adopted for the experiment, with five treatments and four replications, according to the mathematical model $Y_{ij} = \mu + t_i + e_{ij}$, where: Y_{ij} = dependent variable (fermentation or chemical composition parameter); μ = overall mean of the experiment; t_i = effect of inclusion of mesquite pod meal; e_{ij} = experimental error.

The treatments consisted of the inclusion of 8, 16, 24 and 32% mesquite pod meal in relation to the grass fresh weight (2.5 kgMV/mini silo), corresponding to 200, 400, 600 and 800 grams, respectively, in addition to a control treatment (no inclusion). Homogenization and compaction of the mixture (mesquite pod meal + elephant grass) was done manually, with the aid of PVC pipes with a diameter of 7.5 cm, in order to obtain a specific mass of approximately 600 kgMV/m³.

To quantify effluent production (EP), 1 kg sieved sand was added, separated from the forage by a double layer of shading screen, according to the procedure described by Mota *et al.* (2015). First, the silo + tap + sand + screen sets were weighed before ensiling, and then the filled and sealed silos were weighed to determine losses based on weight differences after opening. Samples were taken from each treatment before ensiling to determine the chemical composition (Table 1).

Table 1 – Chemical composition of the ensiled mixture (grass + pods), elephant grass and mesquite pods.

Constituents[1]	Elephant grass	Mesquite pods	Mesquite pod inclusion levels			
			8%	16%	24%	32%
DM	27.13	92.03	27.83	32.92	37.36	38.89
CP	5.42	9.07	7.87	7.58	8.28	9.51
NDF	65.18	20.03	57.1	51.38	48.68	49.93
HEM	23.97	12.75	24.93	22.28	21.99	18.28
ADF	41.21	7.28	32.17	29.10	26.69	31.65
CEL	32.80	5.44	25.85	23.50	21.55	26.13
LIG	8.41	1.84	6.32	5.60	5.14	5.52
TDN[2]	49.58	84.08	55.76	60.13	62.19	61.23

[1]Nutrients in % DM. DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; HEM = Hemicellulose; ADF = Acid detergent fiber; CEL = cellulose; LIG = Lignin; TDN = Total digestible nutrients.
[2]Estimated by the equation: TDN=74.49-0.5635*ADF (R^2=0.84) (Capelle *et al.*, 2001).

The quantification of losses by gases and effluents, and dry matter recovery was performed using the equations proposed by Mota *et al*. (2015). Gas losses were estimated by the equation:

$$GL\ (\%DM) = [(WFSc - WFSo)/(FMe \times DMe)] \times 100$$

, where: GL = gas losses; WFSc= weight of the filled silo at closing (kg); WFSo = weight of the filled silo at opening (kg); FMe = fresh matter of ensiled forage (kg); DMe = dry matter of ensiled forage (%).

Effluent losses were obtained by the equation based on the difference in weight of sand placed at the bottom of the silo at the time of closing and opening the silos:

$$EL\ (kg/t\ FM) = [(ESWo - ST) - (ESWc - ST)]/FMc \times 100$$

, where: EL = effluent losses; ESWo = empty silo weight + sand weight at opening (kg); ST = silo tare; ESWc= empty silo weight + sand weight at closing (kg);

FMc = forage mass at closing (kg).

To quantify the dry matter recovery rate, the equation:

$$DMR (\%) = (FMo \times FDm)/(FMc \times FDc) \times 100$$

was used, where: DMR = dry matter recovery rate (%); FMo = forage mass at opening (kg); FDm = forage dry matter content (%) at opening (%DM); FMc = forage mass at closing (kg); FDc = forage dry matter content at closing (% DM).

Experimental silos were opened 70 days after sealing, where the pH of the silage was determined by a digital pH meter, by immersing the electrode in a solution composed of 9 grams silage and 50 mL distilled water (SILVA; QUEIROZ, 2002). Aliquots of the ensiled mass were also taken from each repetition of the treatments and stored in a freezer (-20 °C) to quantify the ammonia nitrogen content in relation to total nitrogen (NH_3-N/TN) using the treatment with potassium chloride (KCl) and distillation with magnesium oxide (MgO) by the Kjedahl method (AOAC, 2012).

Silage samples, as well as the mixture (pods + grass) collected before silo sealing, were dried in a forced circulation oven at 55°C for 72 hours and then ground to 2 mm particles in a Wiley mill to determine the chemical composition. Based on the methodology of AOAC (2012), the dry matter (DM) content was determined, and with total nitrogen, the crude protein (CP) content was estimated.

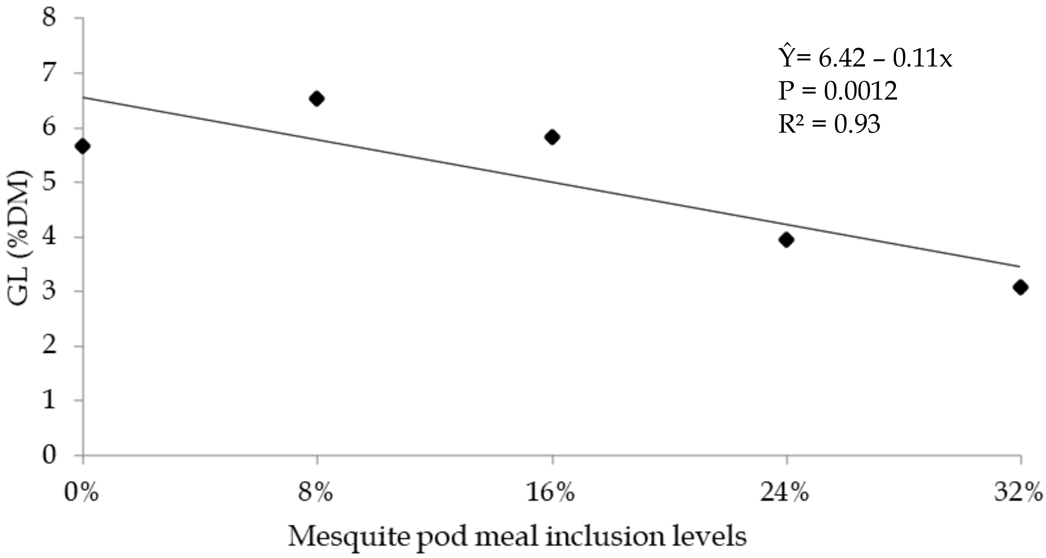
Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (LIG) contents were obtained according to the methodology proposed by Van Soest (1994), adapted for autoclave (105°C/60 min) (BARBOSA *et al*., 2015), using non-woven fabric (TNT) bags with 4x5cm in size and 100µm porosity (VALENTE *et al.*, 2011). The contents of hemicellulose (HEM) and cellulose (CEL) were obtained according to Van Soest (1994), with the formulas: %HEM = %NDF - %ADF and %CEL = %ADF - %LIG, respectively. The estimate of total digestible nutrients (TDN) was obtained by the equation proposed by Cappelle *et al*. (2001): TDN=74.49-0.5635*ADF (R^2=0.84).

Mean values were analyzed for normality using the Shapiro Wilk test and for homogeneity of variances by the Levene test, with the effect of including mesquite pod meal to the ensiled mass evaluated by regression analysis (PROC REG), to construct graphs that defined the effect of treatments, through the statistical software SAS 9.0 (STATISTICAL ANALYSIS SYSTEM, 2010). The model was selected according to the significance of parameters at 5% probability and to the values of the coefficients of determination (R^2).

RESULTS AND DISCUSSION

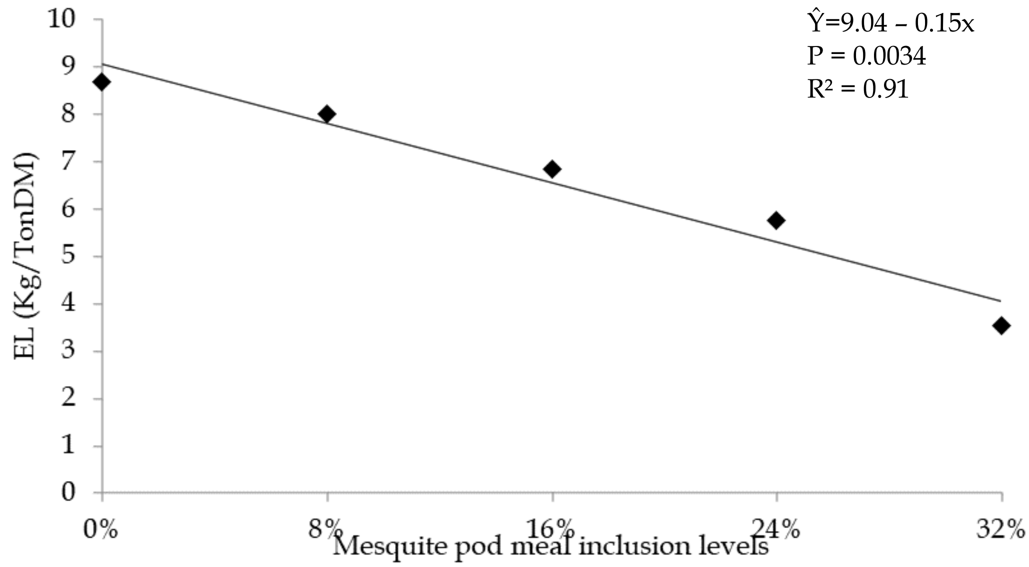
There was a decreasing linear effect ($p<0.05$) for gas losses (GP), with a reduction in this parameter from the inclusion of 8% mesquite pod meal (Figure 1). This effect is associated with the type of fermentation during ensiling, where the lowest values for GP, when the mesquite pod meal was added, indicate that there may have been a reduction in the activity of aerobic microorganisms, such as clostridia and enterobacteria, which promote increased levels of CO_2 and N_2O in the silage, resulting in losses of DM and energy of the ensiled forage (ARAÚJO *et al*., 2020). A similar pattern was observed by Ribeiro *et al*. (2014), when analyzing the effect of castor bean meal on the quality of elephant grass silage, with a reduction from 10.1 to 2% in the production of fermentation gases when 18% additive was included.

Figure 1 – Gas losses (GL) in elephant grass silages with inclusion of different levels of mesquite pod meal.



The inclusion of mesquite pod meal resulted in reductions in the production of effluents (PE) ($p<0.05$) of the silage, with a drop of 52.99% at the level of 32% inclusion compared to the control (Figure 2). As this is a parameter directly linked to the moisture content of the ensiled material, the inclusion of mesquite pod meal brought benefits in relation to PE, due to the expressive DM values in its composition (92.03%) (Table 1) and its high hygroscopicity, which combined with their smaller particle size, reduced the leaching of organic compounds during fermentation, resulting in the efficient maintenance of silage nutrients (BARMAKI *et al*., 2018).

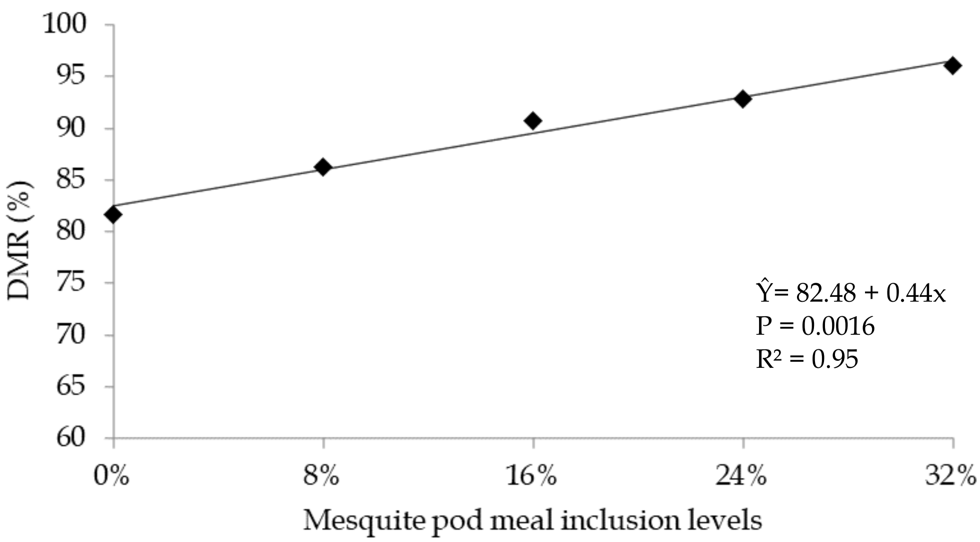
Figure 2 – Effluent losses (EL) in elephant grass silages with inclusion of different levels of mesquite pod meal.



According to Wilkinson and Rinne (2018), ensiled forages with DM contents around 28 - 35% show lower nutrient losses due to effluent leaching in the effluents, as observed in the present study, with the ensiled mass remaining close to recommended even with the inclusion of 32% mesquite pod meal (38.89%), resulting in lower effluent production (3.54 kg/ton DM) in this treatment.

As for the dry matter recovery rate (DMR), a linear increase ($p<0.05$) was observed with the inclusion of mesquite pod meal in the silage, with an increment of 17.56% for the treatment with 32% (Figure 3).

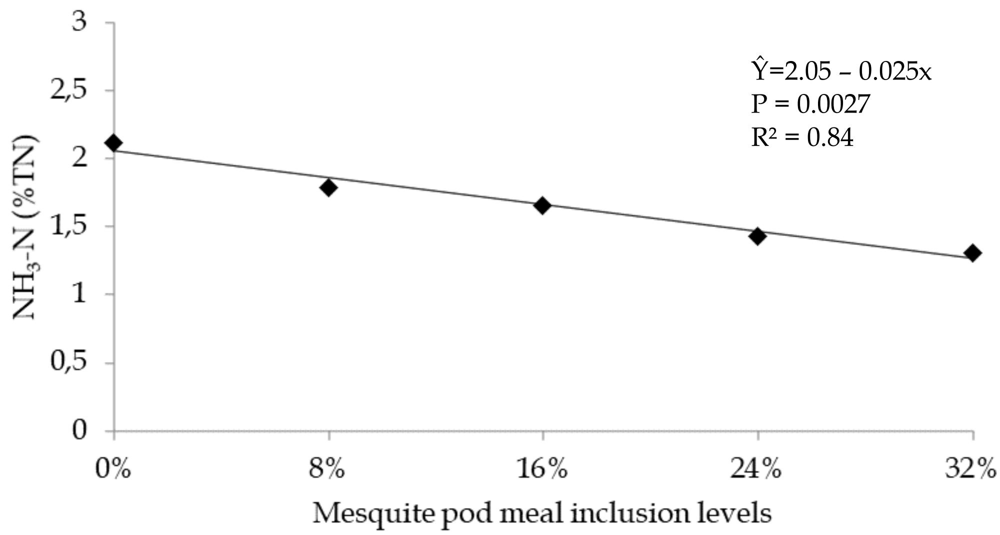
Figure 3 – Dry matter recovery (DMR) rate in elephant grass silages with inclusion of different levels of mesquite pod meal.



The recovery of dry matter of the ensiled mass was inversely correlated with EL and GL, where lower proportions of these are related to a higher percentage of DM in the final product, due to the lower activity of spoilage microorganisms during fermentation, resulting in greater efficiency in the preservation of silage components (FURTADO *et al.*, 2019). A similar effect was reported by Garcez *et al.* (2019), when evaluated the effect of including faveira pod in elephant grass silage, obtaining values of 62.27, 63.56, 68.83, and 70.47% DMR in inclusions of 0, 8, 16 and 24% faveira pods, respectively.

There was a linear decrease ($p<0.05$) in NH_3-N/TN content as mesquite pod meal levels were added to elephant grass silage (Table 2; Figure 4). The evaluation of this parameter is essential as a silage quality parameter, as it indicates the proportion of protein that was degraded during fermentation (PIRES *et al.*, 2013). The reduction in ammonia nitrogen content may be linked to lower clostridian proteolytic activity and, thus, there are decreases in the amino acid deamination process, preserving the protein content of the silage (ZHANG *et al.*, 2019).

Figure 4 – Ammonia nitrogen (NH_3-N) in elephant grass silages with inclusion of different levels of mesquite pod meal.



In all treatments, the content of NH_3-N/TN remained below 10%, indicating a quality characteristic for obtaining good quality silage (CORREA *et al.*, 2016), reflecting the lower activity of proteolytic clostridia, which were inhibited by the rapid drop in pH provided by the additive, generating minimal amounts of protein nitrogen converted into ammonia.

Table 2 - Fermentation parameters and chemical composition of elephant grass silage with inclusion of crushed mesquite pods.

	Mesquite pod meal inclusion levels						
Parameters*	0%	8%	16%	24%	32%	Equation	R^2
GL (%DM)	5.66	6.53	5.82	3.95	3.08	$\hat{Y}= 5.88 + 0.07x - 0.05x^2$	0.73
EL (Kg/tonMS)	8.68	7.99	6.84	5.75	3.54	$\hat{Y}= 9.04 - 0.15x$	0.91
RDM (%)	81.66	86.29	90.71	92.78	96.01	$\hat{Y}= 82,48 + 0,44x$	0.95
pH	3.59	3.57	3.53	3.55	3.54	$\hat{Y}= 3.56$	-
$N\text{-}NH_3$ (%NT)	2.12	1.79	1.65	1.43	1.31	$\hat{Y}= 2.05 - 0.025x$	0.84

*GL= Gases loses in % of DM; EL= Effluent losses; RDM= Recovery of dry matter; NH_3-N)= Ammonia nitrogen in % total nitrogen.

The pH obtained at silo opening remained without variation between treatments and close to the ideal range, which corresponds to a pH around 4.0 (QUIEIROZ *et al.*, 2012), because at these acidity levels, there is restriction in fermentation activity of most unwanted microorganisms (ZHANG *et al.*, 2016). Therefore, a rapid decline in pH during the fermentation, as observed, is crucial for reducing proteolytic activity and halting the growth of harmful microorganisms, such as enterobacteria (BOLSON *et al.*, 2017).

As for the dry matter (DM) content of the silage, increments ($p<0.05$) of 72.28% were obtained with the inclusion of 32% nesquite pod meal compared to the control treatment (Table 3), which is associated with high DM content of this pods (92.03%) and hygroscopic power of the additive, which is beneficial to the final product, as silages with high moisture contents are likely to be colonized with clostridia, which trigger undesirable fermentation, with the use of carbohydrates of DM for the production of butyric acid (WANG *et al.*, 2019).

The evaluation of the DM content should be carried out together with pH values, since it is possible to obtain silages with adequate pH values (3.8 - 4.2), but very wet, and this high water activity is likely to cause heterolactic fermentation, which can reduce the nutritional value of the final product, despite the adequate acidity of the ensiled mass (MACÊDO; SANTOS, 2019). This behavior can be observed in the control treatment, which presented good pH results (Table 2), however with low proportions of DM in the silage (Table 3) and higher effluent production (8.68 kg/ton

Table 3 – Chemical composition of elephant grass silages with inclusion of different levels of mesquite pod meal.

Parameters[1]	Mesquite pod meal inclusion levels					Equation	R^2
	0%	8%	16%	24%	32%		
DM	22.04	25.94	30.54	35.48	37.97	$\hat{Y} = 22.11 + 0.52x$	0.97
CP	5.49	7.83	7.94	8.18	9.31	$\hat{Y} = 6.15 + 0.09x$	0.77
NDF	64.91	59.77	52.82	49.63	45.49	$\hat{Y} = 64.32 - 0.61x$	0.90
ADF	39.60	35.69	31.52	29.14	26.99	$\hat{Y} = 38.94 - 0.38x$	0.91
HEM	25.31	24.08	21.30	20.49	18.50	$\hat{Y} = 25.66 - 0.23x$	0.72
CEL	29.97	28.21	24.81	22.82	21.69	$\hat{Y} = 29.89 - 0.27x$	0.85
LIG	9.63	7.48	6.71	6.32	5.30	$\hat{Y} = 9.05 - 0.12x$	0.80
TDN[2]	49.79	53.72	59.03	61.47	64.63	$\hat{Y} = 54.52 + 0.26x$	0.91

Constituents in % DM. DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; HEM = Hemicellulose; ADF = Acid detergent fiber; CEL = cellulose; LIG = Lignin; TDN = Total digestible nutrients.
[2]Estimated by the equation: TDN=74.49-0.5635*ADF (R^2=0.84) (Capelle *et al.*, 2001).

DM).

CP contents were increased by 42.62, 44.63, 49.0 and 69.58% in treatments of 8, 16, 24 and 32% mesquite pod meal, respectively ($p<0.05$). This increase in protein content is associated with a higher concentration of CP in the pods (9.07%), the low proportions of NH_3-N and the lower effluent loss in silages with inclusion of the additive, as observed in the treatment with 32% (9.31% CP; 1.31% NH_3-N and 3.54 Kg/tonDM) compared to the control (5.40% CP; 2.12% NH_3-N and 8.68 Kg/tonDM). The inclusion of mesquite pod meal promoted acidification of the ensiled mass by inhibiting the growth of proteolytic microorganisms and the formation of ammonia in the silo (SANTOS *et al.*, 2014), in addition to reducing moisture and effluent production in the silo, which minimized leaching of protein compounds.

Low CP values observed in silages of elephant grass alone are associated with a lower proportion of grass soluble carbohydrates, influencing the metabolic activity of its epiphytic proteolytic microbiota, which degrade amino acids from the plant cell structure to generate energy, produce microbial protein and favor its growth and metabolism (SILVA *et al.*, 2011). Thus, the inclusion of mesquite pod meal provided fast fermentation carbohydrates as energy sources for the microorganisms to exercise their metabolic activities during the fermentation in the silo, preserving the amino acid and protein contents of the ensiled forage.

There was a reduction ($p<0.05$) in NDF values as mesquite pod meal levels were included in silages, with values of 45.49% for the 32% treatment, which corresponds to a decrease of 29.92% in compared to the control treatment (64.91%). The reduction in the contents of this constituent is associated with a lower proportion of NDF in mesquite pod meal (20.03%) in relation to elephant grass (65.08%), with a dilution of the total NDF in the treatment with a higher proportion (32%) of mesquite pod meal in the silage. The quantification of the total NDF and the proportion of its constituents (cellulose, hemicellulose and lignin) is essential in tropical grass silages, due to its direct influence on the DM intake by ruminants (VAN SOEST, 1994).

A similar result was verified for ADF values, showing reductions in values ($p<0.05$) with increasing levels of mesquite pod meal in the ensiled material. The lower ADF values observed in silages with inclusion of mesquite pod meal can be considered an important factor from a nutritional point of view, considering that this fraction directly affects the digestibility of DM by ruminants (VAN SOEST, 1994). Treatments of 8, 16 and 24% had respective increases in the ADF of 10.94, 8.32 and 9.18%, after silo opening, when compared to their composition before ensiling (Table 1). The increase in this fraction in ensiled foods may be associated with the intake of soluble carbohydrates during the cellular respiration process at the time of material wilting and during the fermentation process for organic acid production (ANDRADE JÚNIOR *et al.*, 2014).

Regarding the cell wall components, reductions ($p<0.05$) of 26.91, 27.63 and 44.97% were found for hemicellulose, cellulose and lignin, respectively, with the inclusion of 32% mesquite pod meal in the silage, associated both with fermentation in the silo, and the low proportion of these constituents in the mesquite pod meal (12.75, 5.44 and 1.84%, respectively) (Table 1). Hemicellulose hydrolysis by fibrolytic microorganisms present in the ensiled mass can occur, and it is important during fermentation, as it releases soluble compounds that will be used as an energy source for protein synthesis and growth of lactic microbiota inside the silo (COSTA *et al.*, 2016).

The reduction in the cellulose and lignin contents in the ensiled mass is beneficial to the final product, since the lignocellulosic fraction, present in high proportions in the cell wall of ensiled tropical grasses, is responsible for the unavailability of part of the potentially degradable carbohydrates for the ruminal microbiota, due to its insoluble ester bonds, resulting in lower digestibility of silages, which can limit its inclusion in larger proportions in ruminant diets (SILVA *et al*., 2015).

Values of TDN of silages showed increases ($p<0.05$) by 7.89, 18.55, 23.45 and 29.80% at the inclusion levels of 8, 16, 24 and 32% mesquite pod meal, respectively. TDN is an important parameter in ruminant production, because energy and protein are limiting to animal production (OLIVEIRA *et al*., 2015), classifying the forage observed in this study as quality for feeding ruminants in the semi-arid region, mainly with the inclusion of 32% mesquite pod meal (64.63% TDN). The increase in this fraction is associated both with the contribution of soluble carbohydrates in the ensiled mass made available by the mesquite pod meal and by its estimate through the percentage of ADF, which reduced with increasing levels of inclusion of this energy additive.

CONCLUSIONS

The inclusion of up to 32% mesquite pod meal in elephant grass silage promotes better fermentation stability in the silo, by reducing losses and increasing the DM content of the ensiled mass, which minimizes nutrient leaching. The use of mesquite pod meal as a source of soluble carbohydrates can also improve the silage chemical composition, increasing the content of CP and TDN, and reducing the content of NDF, ADF and Lignin.

REFERENCES

ANDRADE JÚNIOR, V. C.; PEREIRA, R. C.; DORNAS, M. F.; RIBEIRO, K. G.; VALADARES, N. R.; SANTOS, A. A.; CASTRO, B. Produção de silagem, composição bromatológica e capacidade fermentativa de ramas de batata-doce emurchecidas. **Horticultura Brasileira**, v. 32, p. 91-97, 2014. DOI: https://doi.org/10.1590/S0102-05362014000100015

ARAÚJO, J. A. S.; ALMEIDA, J. C. C.; REIS, R. A.; CARVALHO, C. A. B.; BARBERO, R. P. Harvest period and baking industry residue inclusion on production efficiency and chemical composition of tropical grass silage. **Journal of Cleaner Production**, v. 266, 2020. https://doi.org/10.1016/j.jclepro.2020.121953

ASSOCIATION OF ANALYTICAL COMMUNITIES – AOAC International. **Official methods of analysis of AOAC international**, 19th.ed. 2610p. 2012.

BARBOSA, M. M.; DETMANN, E.; ROCHA, G. C.; FRANCO, M. D. O. Evaluation of laboratory procedures to quantify the neutral detergent fiber content in forage, concentrate, and ruminant feces. **Journal of AOAC International**, v. 98, n. 4, p. 883-

889, 2015. https://doi.org/10.5740/jaoacint.14-156

BARCELOS, A. F.; J. R. R. D.; TAVARES, V. B.; GONÇALVES, C. C. D. M. Valor nutritivo e características fermentativas da silagem de capim-elefante com diferentes proporções de casca de café. **Ciência Animal Brasileira,** v. 19, 2018. https://doi.org/10.1590/1809-6891v19e-27432

BARMAKI, S.; ALAMOUTI, A. A.; KHADEM, A. A.; AFZALZADEH, A. Effectiveness of chopped lucerne hay as a moisture absorbent for low dry-matter maize silage: Effluent reduction, fermentation quality and intake by sheep. **Grass and Forage Science** v. 73, n.2, p. 406-412, 2018. https://doi.org/10.1111/gfs.12343

BOLSON, D. C.; PEREIRA, D. H.; PINA, D. S.; PEDREIRA, B. C.; MOMBACH, M. A.; XAVIER, I. M. Fermentative and bromatological value of Piatã palisadegrass ensiled with different additives. **Archivos de zootecnia,** v. 66, p515-521, 2017.

CAPPELLE, E. R.; VALADARES FILHO, S. C.; SILVA, J. F. C.; CECON, P. R. Estimativas do valor energético a partir de características químicas e bromatológicas dos alimentos. **Revista Brasileira de Zootecnia**, v.30, p. 1837-1856, 2001. https://doi.org/10.1590/S1516-35982001000700022

CHATURVEDI, O. H; SAHOO, A. Nutrient utilization and rumen metabolism in sheep fed Prosopis juliflora pods and Cenchrus grass. **SpringerPlus**, v. 2, p. 1-7, 2013. https://doi.org/10.1186/2193-1801-2-598

Corrêa, A. A.; Backes, A. A.; Fagundes, J. L.; Barbosa, L. T.; Sousa, B. M. L.; Oliveira, V. S.; Moreira, A. L. Caracterização da silagem da rama da batata doce emurchecida e adicionada de fubá de milho como aditivo. **Boletim de Indústria Animal**, v.73, p.272-280, 2016. https://doi.org/10.17523/bia.v73n4p272

COSTA, C.S.; RODRIGUES, R. C.; ARAÚJO, R. A.; SOUZA, F. B. F.; SANTOS, F. N.S. Composição química e degradabilidade in situ de silagens de capim-Marandu com farelo de babaçu. Revista Brasileira de Saúde e Produção Animal, Salvador, v. 17, p. 572- 583, 2016. https://doi.org/10.1590/s1519-99402016000400002

DANIEL, J. L. P.; BERNARDES, T. F.; JOBIM, C. C.; SCHMIDT, P.; NUSSIO, L. G. Production and utilization of silages in tropical areas with focus on Brazil. **Grass and Forage Science**, v. 74, p. 188-200, 2019. https://doi.org/10.1111/gfs.12417

FUNCEME. **Índices de aridez do Estado do Ceará**. (2017). Disponível em: <http://www.funceme.br/?page_id=5826>. Acesso: 17 de out de 2020.

FURTADO, R. N.; DE SOUZA CARNEIRO, M. S.; COUTINHO, D. N.; CÂNDIDO, M. J. D.; SILVA, E. B. Fermentative losses and chemical composition of elephant grass silage added with castor bean hull. **Revista Ciência Agronômica**, v. 50, p. 140-147, 2019. https://doi.org/10.5935/1806-6690.20190017

GARCEZ, B. S.; MAIA, F. W. R.; FERREIRA, F. D. S.; SILVA, J. V. P.; MAIA, B. H.; PINHO FILHO, C. F. O. Parâmetros fermentativos e composição química de silagem de capim elefante cv. Roxo com adição de vagens de faveira**. Boletim De Indústria Animal,** v. 76, p. 1-7, 2019. https://doi.org/10.17523/bia.2019.v76.e1464

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, p. 905-912, 2018. https://doi.org/10.1590/1678-4162-9410

MACÊDO, A. J. S.; NETO, J. M. C.; SILVA, M. A.; SANTOS, E. M. Potencialidades e limitações de plantas forrageiras para ensilagem: Revisão. **Revista Brasileira de Higiene e Sanidade Animal,** v. 13, p. 320-337, 2019. http://dx.doi.org/10.5935/1981-2965.20190024

MACÊDO, A. J. S.; SANTOS, E. M. Princípios básicos para produção de silagem. **Arquivos de Ciências Veterinárias e Zoologia da UNIPAR**, v. 22, 2019. https://doi.org/10.25110/arqvet.v22i4.6948

MOTA, P. E. S.; MOURA, R. L. M.; PORTELA, G. L. F.; CARVALHO, W. F.; OLIVEIRA, M. R. A. Perdas e características fermentativas da silagem de capim-elefante com diferentes aditivos. **ACSA – Agropecuária Científica no Semiárido**, v. 11, p 126 - 130, 2015. DOI: http://dx.doi.org/10.30969/acsa.v11i1.540

NASCIMENTO, A. P. S.; LIMA, A. K. S.; CAVALCANTI, C. F.; GUSMÃO, R. P. Cinética de secagem de vagens de algaroba, Prosopis juliflora SW. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v. 10, p. 33, 2015. https://doi.org/10.18378/rvads.v10i5.3338

OLIVEIRA, V. S.; MORAIS, J. A. D. S.; FAGUNDES, J. L.; SANTANA, J. C. D. S.; LIMA, I. G. S.; SANTOS, C. B. Produção e Composição Químico-Bromatológica de Gramíneas Tropicais Submetidas a Dois Níveis de Irrigação. **Archives of Veterinary Science**, Curitiba, v. 20, 2015. https://dx.doi.org/10.5380/avs.v20i2.36337

PIRES, D. A. A.; ROCHA JÚNIOR, V. R.; SALES, E. C. J.; REIS, S. T.; JAYME, D. G.; CRUZ, S. S.; LIMA, L. O. B.; TOLENTINO, D. C.; ESTEVES, B. L. C. Características das silagens de cinco genótipos de sorgo cultivados no inverno. **Revista Brasileira de Milho e Sorgo**, v.12, p. 68-77, 2013. https://dx.doi.org/10.18512/1980-6477/rbms.v12n1p68-77

QUEIROZ, O. C. M.; KIM, S. C.; ADESOGAN, A. T. Effect of treatment with a mixture of bacteria and fibrolytic enzymes on the quality and safety of corn silage infested with different levels of rust. **Journal of dairy science**, v. 95, p. 5285-5291, 2012. https://doi.org/10.3168/jds.2012-5431

RÊGO, A. C.; PAIVA, P.C. D. A.; MUNIZ, J. A.; VAN CLEEF, E. H. C. B.; MACHADO NETO, O. R. Ruminal degradation of elephant grass silage with mesquite pods. **Revista Ciência Agronômica**, v. 42, p.199-207, 2011. https://doi.org/10.1590/S1806-66902011000100025

RIBEIRO, L. S. O.; PIRES, A. J. V.; CARVALHO, G. G. P.; PEREIRA, M. L. A.; SANTOS, A. B.; ROCHA, L. C. Características fermentativas, composição química e fracionamento de carboidratos e proteínas de silagem de capim-elefante emurchecido ou com adição de torta de mamona. **Semina: Ciências Agrárias**, v. 35, p. 1447-1462, 2014. https://doi.org/10.5433/1679-0359.2014v35n3p1447

SANTOS, I. A. P.; DOMINGUES, F. N.; RÊGO, A. C. D.; SOUZA, N. S. D. S. D.; BERNARDES, T. F.; BARATA, Z. R. P.; MORAES, C. M. D. Palm kernel meal as additive in the elephant-grass silage. **Revista Brasileira de Saúde e Produção**

Animal, v. 15, p. 592-603, 2014. http://dx.doi.org/10.1590/S1519-99402014000300006

SANTOS, S.; SANTOS-CRUZ, C.L.; ROCHA, J.B.; PIRES, A.J.V.; SANTOS, I.P.A; LIMA, T.R.; JUNQUEIRA, R.S. Degradação ruminal da silagem de capim elefante com diferentes components de algaroba. **Revista Brasileira de Saúde e Produção Animal**, v.13, p.123-136, 2012. http://dx.doi.org/10.1590 S1519-99402012000100011

SAS - STATISTICAL ANALYSIS SYSTEM**. Software, version 9.0**. Cary: SAS Institute, 2000.

SILVA, D. J.; QUEIROZ, A. C. **Análises de alimentos:** métodos químicos e biológicos. (3. Ed). Viçosa, MG: Editora UFV, 2002. 235p.

SILVA, M. D. A.; DE SOUZA CARNEIRO, M. S.; PINTO, A. P.; POMPEU, R. C. F. F.; SILVA, D. S.; COUTINHO, M. J. F.; FONTENELE, R. M. Avaliação da composição químico-bromatológica das silagens de forrageiras lenhosas do semiárido brasileiro. **Semina: Ciências Agrárias**, v. 36, p. 571-578, 2015. DOI: https://www.redalyc.org/articulo.oa?id=445744146047

SILVA, T. C.; DANTAS, P. A. S.; DÓREA, J. R. R.; SANTOS, E. M.; ZANINE, A. M.; PEREIRA, O. G. Populações microbianas, perfil fermentativo e composição de silagens de capim-elefante com jaca. **Archivos de zootecnia**, v. 60, p. 247-255, 2011. http://dx.doi.org/10.4321/S0004-05922011000200009

TRINDADE, P. C.; LANA, R. P.; VELOSO, C. M.; PEREIRA, D. S. Desempenho agronômico e qualidade da silagem do capim elefante com adubação orgânica. **Revista Brasileira de Agropecuária Sustentável**, v. 8, 2018. https://doi.org/10.21206/rbas.v8i2.514

VALENTE, T. V. P.; DETMANN, E.; VALADARES FILHO, S. D. C.; QUEIROZ, A. C. D.; SAMPAIO, C. B.; GOMES, D. I. Avaliação dos teores de fibra em detergente neutro em forragens, concentrados e fezes bovinas moídas em diferentes tamanhos e em sacos de diferentes tecidos. **Revista Brasileira de Zootecnia**, v. 40, p. 1148-1154, 2011. http://dx.doi.org/10.1590/S1516-35982011000500029

VAN SOEST. **Nutrition ecology of the ruminant**. Ithaca, New York: Cornell Univertsity Press, 1994. 476p.

WANG, C.; HE, L.; XING, Y.; ZHOU, W.; YANG, F.; CHEN, X.; ZHANG, Q. Effects of mixing Neolamarckia cadamba leaves on fermentation quality, microbial community of high moisture alfalfa and stylo silage. **Microbial Biotechnology**, v.1, p.1-10**.** 2019. DOI: https://doi.org/10.1111/1751-7915.13429

WILKINSON, J. M.; RINNE, M. Review. Highlights of progress in silage conservation and future perspectives. **Grass and Forage Science,** v. 73 p. 40–52, 2018. https://doi.org/10.1111/gfs.12327

ZHANG, L.; ZHOU, X.; GU, Q.; LIANG, M.; MU, S.; ZHOU, B.; ZOU, C. Analysis of the correlation between bacteria and fungi in sugarcane tops silage prior to and after aerobic exposure. **Bioresource technology**, v. 291, p. 121835, 2019. https://doi.org/10.1016/j.biortech.2019.121835

ZHANG, S.; A, S. C.; DIKY, R.; AMERJAN, O.; GUO, X.; GRANT, R. E.; LONG, C.