



Ruminal degradation of elephant grass silages added with faveira pods

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ABSTRACT. The objective of this study was to evaluate *in situ* ruminal degradability of elephant grass silages with addition of 8, 16 and 24% of faveira pods in experimental silos of 100x50 mm, equipped with bunsen valves. The content of crude protein (cp) and neutral detergent fiber (ndf) were determined on a dry matter basis. To evaluate the *in situ* degradability of dm, cp and ndf, nylon bags containing 4 g sample were incubated in the rumen of three fistulated cattle for 6, 24 and 72h. The dm and cp content of elephant grass silages increased ($p < 0.05$) from 8% inclusion associated with a higher concentration of constituents in faveira pods (77.25 and 9.61% dm). The ndf fraction reduced 10.91% ($p < 0.05$) when adding 24% pods. The potential degradation (pd) of dm and cp increased with inclusion of faveira pods, with 75.97 and 95.21%, respectively, for the level of 24%. There was increased potentially degradable fraction (bp) of ndf by 7.07% with inclusion of 24% faveira pods, as well as a reduced colonization time (lag) from 3.81 to 3.44 hours. The addition of up to 24% faveira pods to elephant grass silages improves rumen microbial degradation, and it is indicated this level of addition to obtain better quality silage.

Keywords: potential degradation; ensiling; *Pennisetum purpureum*.

Degradação ruminal de silagens de capim-elefante com adição de vagens de faveira

RESUMO. Objetivou-se avaliar a degradabilidade *in situ* de silagens de capim-elefante com adição de 8, 16 e 24% de vagens de faveira. A partir da ms, foram determinados os teores de proteína bruta (pb) e fibra em detergente neutro (fdn). Para avaliar a degradabilidade *in situ* da ms, pb e fdn, utilizaram-se sacos de náilon, incubados no rúmen de três bovinos fistulados nos tempos 6, 24 e 72h. Os teores de ms e pb das silagens de capim-elefante aumentaram ($p < 0,05$) a partir de 8% de inclusão associado a maior concentração desses constituintes nas vagens de faveira (77,25 e 9,61% ms). A fração fdn reduziu 10,91% ($p < 0,05$) quando da adição de 24% das vagens. A degradação potencial (dp) da ms e pb aumentou com inclusão das vagens de faveira, com 75,97 e 95,21%, respectivamente, para o nível de 24%. Houve aumento de 7,07% na fração potencialmente degradável (bp) da fdn com inclusão de 24% de vagens de faveira, além de redução no tempo de colonização (lag) de 3,81 para 3,44 horas. A adição de até 24% de vagens de faveira em silagens de capim-elefante melhora a degradação microbiana ruminal, sendo indicado esse nível de adição para obter silagem de melhor qualidade.

Palavras-chave: degradação potencial; ensilagem; *Pennisetum purpureum*.

Introduction

The production of ruminant herds in some sub regions of northeastern Brazil is below the expected animal indices and among the factors responsible is inadequate feeding, based mainly on forages subjected to a seasonality problem caused by low rainfall values. This thus justifies the search for technologies that improve rearing systems as for feeding herds and allow the use of forage resources efficiently.

The use of conserved forage allows the use of the surplus produced in the rainy season, and among the conservation methods, ensiling, which is based on anaerobic fermentation process, is very important

because it allows the preservation of nutrients found in the forage, supplying them with sufficient quality and amount to feed the herds at times of the year with pastures of low nutritive value (Ferreira, Neiva, Rodriguez, Lopes, & Lôbo, 2010). For grasses in tropical regions, such as elephant grass (*Pennisetum purpureum* Schum.), the high moisture contents associated with the low availability of soluble carbohydrates can lead to interference with the fermentation process and, consequently, the quality of the ensiled mass (Ferreira et al., 2017). Thus, the use of soluble carbohydrate additives, such as legume pods, can improve fermentation, since it allows rapid drop of pH with higher

microbial activity by providing energetic substrates for the microorganisms in the silo.

Among these additives, faveira pods (*Parkia platycephala* Benth.) are characterized by high availability during the dry season and high energy content, and can be used as a supplement for herds during periods of food shortage (Alves et al., 2007). Associated with the use of additives, the determination of degradable and non-degradable fractions in the rumen and the microbial efficiency of nutrient utilization from conserved forage are of fundamental importance in the evaluation of their nutritional quality, in which the in situ degradability technique has been indicated by allowing direct contact of the food with the ruminal environment. The goal of this study was to evaluate the in situ ruminal degradability of elephant grass silages with addition of different proportions of faveira pod.

Material and methods

The experiment was conducted in August 2015, at the Department of Animal Science, Center of Agricultural Sciences at Federal University of Piauí, Teresina, Piauí State. The elephant grass for silage came from an area of 6 m x 6 m, delimited in the area of grass for cutting with seven years of implantation, of the goat sector of the Center of Agricultural Sciences (CCA/UFPI). Dry matter (DM) contents were determined fortnightly for production monitoring and cutting point determination, which occurred with a mean of 24.8% (82 days). After cutting, grass was wilted in the sun for 8 hours and ground in a forage machine.

Faveira pods were obtained in an area of natural occurrence in the Piauí State, in the region of Regeneration. Harvesting occurred at the senescence phase, when they are considered physiologically mature and then transported to the goat sector, sun-dried for 24 hours and integrally ground in a forage machine to 1 mm particles.

We determined dry matter (DM) content and, on a dry matter basis, crude protein (CP), and based on total nitrogen (N), acid-neutral detergent insoluble nitrogen (ANDI), according to Association of Official Analytical Chemist (AOAC, 2012), neutral detergent fiber (NDF) and acid detergent (ADF) and lignin content (LIG) by Van Soest, Robertson, and Lewis (1991). The cellulose (CEL) and hemicellulose (HEM) contents were obtained by the difference between the NDF, ADF and LIG fractions, according to the equations proposed by Van Soest et al. (1991).

Table 1. Chemical composition of elephant grass and faveira pods.

	Constituents*							
	DM	CP	NDF	ADF	HEM	LIG	ADIN	NFC
Elephant grass	24.81	4.64	68.14	44.21	23.93	5.58	12.55	12.56
Faveira	77.25	9.21	78.14	40.32	37.82	5.64	3.09	69.26

*DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; HEM = Hemicellulose; CEL = Cellulose; LIG = Lignin; ADIN = Acid detergent insoluble nitrogen; NFC = Bom fibrous carboidrathes.

In the ensiling process, we used PVC experimental silos with a diameter of 100 mm and a length of 50 cm, using a taps seal and a Bunsen valve for the escape and quantification of gases Andrade, Pires, Carvalho, Veloso, and Bonomo (2010). Ground pods were added at levels 0, 8, 16 and 24% on a dry matter basis, with approximately 51, 96 and 145 g faveira pods per silo, respectively, performing manual homogenization. Silos were then filled and compacted with the aid of a wooden stick to obtain a density of 600 kg m⁻³ and opened after 32 days.

Samples collected after opening the silos were dried in a forced circulation oven at 55°C for 72 hours and then ground in a Wiley knife mill to 0.2 mm particles to determine the chemical composition.

To evaluate the in situ degradability of DM, PB and NDF, nylon bags with 12x8 cm dimensions and 50 µm porosity (Ørskov & McDonald, 1979) containing 4 g sample, according to 42 mg cm⁻² ratio adopted by Campos, Borges, Lopes, Pancoti, and Reis (2011) were incubated in the rumen of three fistulated Gyr cattle, with an average weight of 400 kg, for 6, 24 and 72h (Garcez et al., 2014), using five bags per time in each replicate, totaling 225 bags.

After removing the bags from the rumen, samples were placed in a pail with cold water to stop the degradation by the microorganisms; the soluble fraction was estimated by immersion of the nylon bags containing samples equivalent to those incubated in the rumen in a water bath at 39°C for 1 hour, which together with the bags taken from the rumen were washed in a washing machine and pre-dried in a forced air circulation oven at 55°C, for 72 hours, for DM, DP and NDF analyses.

The in situ degradation parameters (a, b and c) and the potential degradability of DM, PB, were estimated by the exponential model of Ørskov and McDonald (1979), expressed by:

$$DP = A - B \cdot e^{-ct} \quad (1)$$

where,

DP = actual percentage of the degraded nutrient after t hours of incubation in the rumen;

A = maximum degradation potential of the material in the nylon bag (asymptote);

B = potentially degradable fraction of the material remaining in the nylon bag after time 0;
 c = degradation rate of the fraction remaining in the nylon bag after time 0;
 t = incubation time.

The effective degradability (ED) of DM and PB in the rumen was estimated considering the rate of passage 2, 5 and 8% h⁻¹, for each treatment using the equation proposed by Ørskov and McDonald (1979):

$$ED = ED = a + [(b c) / (c + k)] \quad (2),$$

where,

DE = effective degradation;
 a = soluble fraction, rapidly degraded;
 b = insoluble fraction, slowly degraded;
 c = fractional rate of degradation of b;
 k = rate of passage.

The model of Mertens and Loften (1980) was used to estimate the parameters of NDF degradation and standardization of the fraction after the adjustments, using equations:

$$R_t = B.e^{-ct} + I \quad (3)$$

where:

R_t = fraction degraded at time t;
 I = undegradable fraction.

$$BP = B / (B + I) \times 100;$$

$$IP = I / (B + I) \times 100 \quad (4)$$

where:

BP = standardized potentially degradable fraction (%);
 IP = standardized undegradable fraction (%).

The experimental design was completely randomized with four treatments (faveira pods inclusion levels) and five replications per treatment (experimental silos) arranged in a split plot, with treatments assigned to plots and incubation times (6, 24 and 72 hours) to the subplots, obtaining the degradation parameters by means nonlinear models (PROC NLIN) of Statistical Analysis System (SAS, 2000). For chemical composition, for DM, CP and NDF contents, a regression analysis was adopted aiming to obtain equations that define the effects of the treatments.

Results and Discussion

The DM content of elephant grass silage increased ($p < 0.05$) from 8% inclusion of faveira pods, associated with the high concentration of this

constituent in the additive (77.2%) (Table 1), in addition to the high hygroscopicity (Table 2), with high water absorption from the grass, to reduce effluent production and nutrient loss through leaching.

Table 2. Content of DM, CP and NDF of elephant grass silages added with faveira pods.

Constituents*	Inclusion level of faveira pods				Equation	R ²
	0%	8%	16%	24%		
DM	24.65	25.74	28.19	34.37	$\hat{Y} = 23.45 + 0.39x$	86.53
CP (%DM)	3.70	4.56	5.64	6.53	$\hat{Y} = 3.67 + 0.11x$	97.35
NDF (%DM)	63.90	61.72	57.16	52.99	$\hat{Y} = 64.54 - 0.46x$	91.14

*DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber.

The maximum inclusion level of faveira pods (24%) resulted in a DM content (34.4%) higher than the 25-28% recommended by Costa et al. (2012) for the predominance of lactic fermentation and inhibition of the undesired fermentation, similar to the results obtained by Santos et al. (2012) for silage with inclusion of mesquite pods, with a mean of 33.3% DM.

The NDF fraction reduced by 10.9% ($p < 0.05$) with inclusion of 24% faveira pods, indicating the effect of the additive on the reduction of components of the fiber fraction of the silage. The increase in soluble carbohydrate content from the faveira pod (69.3%) (Table 1) improves fermentation by providing substrates for the microorganisms that use the most degradable fractions (hemicellulose and pectin) of the grass cell wall as a source of energy, thus reducing NDF levels. A similar effect was found by Mota et al. (2012), when 30% faveira pods were included in elephant grass silages, obtaining a reduction of 12,7% in relation to silage without additive.

For crude protein, there was a positive linear increase ($p < 0.05$) to 6.53% with 24% faveira pod inclusion, close to the 7% minimum required for good ruminal functioning, maintaining the minimum content of 8 mg N-NH₃ dL⁻¹ ruminal fluid (Silveira et al., 2009). This increase was expected, since the additive has a higher protein content than elephant grass. The increase in the content of this constituent is beneficial to silage, especially when using tropical grasses in the process, which have low levels of CP, at higher ages, where part of this fraction becomes unavailable by complexation with the cell wall.

There was an increase in the soluble fraction with the raise of the inclusion levels of the pods, which may be associated with greater solubility of the compounds present in the forage by the fermentation in the silo and consequent passage through the pores of the nylon bag. The potentially

degradable fraction was increased when 24% faveira pods (48.7%) were added, associated to higher dry matter contents (Table 1) and the increase of soluble carbohydrates, which may improve the availability of nutrients for fermentation. However, the degradation rate (c) was close to that obtained for the other treatments, with similar use of nutritional fractions even with higher levels of the additive. The degradation parameters of DM and CP are listed in Table 3.

Table 3. Soluble fraction (a), potentially degradable fraction (b), degradation rate (c), potential and effective degradation of dry matter (DM) of elephant grass silages (EGS) added with faveira pods (FP).

Treatments	Parameters*							R ²
	a	B	c (% h ⁻¹)	PD	ED			
					2%	5%	8%	
EGS	22.19	41.89	3.01	64.08	52.13	43.16	38.32	99.86
EGS + 8% FP	24.08	41.79	3.41	65.87	50.42	41.02	36.57	96.03
EGS + 16% FP	25.80	38.91	3.97	64.71	51.67	43.02	38.70	96.91
EGS + 24% FP	25.27	48.70	3.67	75.97	58.79	47.88	42.59	98.40

*Estimated by the models $DP = A - B \cdot e^{-ct}$ and $DE = a + [(b \cdot c)/(c + k)]$ (Ørskov & McDonald, 1979).

Differences in obtaining fraction a can occur mainly due to the applied washing process, which can result in losses of particles and, consequently, in overestimations of degradability (Campos et al., 2011). The soluble fraction of DM tends to increase in excessively fermented silages, due to the breakdown of organic compounds present in the forage, as well as to disruption of bonds in the fiber fraction and CP solubilization, which makes the forage more susceptible to the action of the microorganisms (Ribeiro et al., 2014). Similar effects were obtained by Rêgo, Cândido, Pereira, Feitosa, and Rêgo (2010) when evaluating elephant grass silages added with the urucum fruit, with an increase in the soluble fraction (5.5%) when the highest level of additive (16%) was added, associating besides the fermentation in the silo, the additive solubility, contributing with a larger fraction a and by Rêgo, Aguiar Paiva, Muniz, Van Cleef, and Neto (2011) in elephant grass silages with addition of mesquite pods (14.6 to 26.5% with inclusion of 16% pods).

The potential degradation of DM was high and above 60% in all treatments, showing an increase of 11.89% when adding 24% faveira pods in comparison to the control. Such increase in this fraction was expected since the faveira pods presented better contents of CP (9.2%) and NFC (69.3%), which provides substrates to ruminal microorganisms. Increase in DP improves the nutrient availability of DM and is usually associated with the degradation rate (c), which improves the use and degradation potential, and the rates obtained herein are higher than those obtained for tropical

grass silages (3% h⁻¹) (Cavalcante, Perin, & Benedetti, 2012).

In elephant grass silages supplemented with cocoa meal or sugarcane, Teixeira et al. (2008) obtained an increase in the potentially degradable fraction, with values close to 82% and addition of 15% additives, associating the effect with the greater availability of NFC from their association, which corroborates the effects obtained in this research. The values of effective degradation were reduced by increasing the rate of passage, due to the reduced time available for ruminal degradation. However, the values obtained were close to elephant grass silages added with the urucum fruit (Rêgo et al., 2010) and mesquite pod (Rêgo et al., 2011), not interfering with the utilization of nutrients by the microorganisms.

Regarding the CP degradation parameters (Table 4), there was no increase in the soluble fraction with the addition of faveira pods.

Table 4. Soluble fraction (a), potentially degradable fraction (b), degradation rate (c), potential and effective degradation of crude protein (CP) of elephant grass silages (EGS) added with faveira pods (FP).

Treatments	Parâmetros*							R ²
	a	B	c (% h ⁻¹)	DP	ED			
					2%	5%	8%	
EGS	26.13	55.26	6.26	81.39	68.01	56.85	50.39	98.78
EGS + 8% FP	25.57	66.09	5.23	90.17	71.89	57.87	50.21	98.85
EGS + 16% FP	25.24	71.20	6.43	94.24	75.72	70.87	65.84	96.18
EGS + 24% FP	25.21	78.46	6.15	95.21	81.44	69.52	59.34	97.45

*Estimated by the models $DP = A - B \cdot e^{-ct}$ (1) and $DE = a + [(b \cdot c)/(c + k)]$ (Ørskov & McDonald, 1979).

The highest CP content of faveira pods (9.21) provided greater availability of nutrients in the silo, which increased the potentially degradable fraction by 23.2% with inclusion of 24% pods, in addition to maintaining potential degradation above 90% at all levels.

The increased in DP of the protein fraction is related to the higher availability of N for the fermentation and associated to the protein degradation rate present in the food, with values above 6% h⁻¹ in the treatments with 16% and 24% faveira. This effect directly influences the ruminal utilization of the other nutritional components, in which a higher degradation rate of CP increases the amount of N available for metabolism and consequent increase in microbial protein synthesis, with growth of the microbiota and improvement in DM degradation (Table 3). The degradation rates obtained for CP in this study are superior to elephant grass silages with addition of 12% (1.2% h⁻¹) and 16% (1.4% h⁻¹) of cashew peduncle (Rêgo et al., 2009) and millet silage (2.14% h⁻¹) and sorghum silage (1.8% h⁻¹) (Cavalcante et al., 2012).

The ruminal degradation of CP of silages may be directly influenced by the use of additives and fermentation in the silo. Higher inclusion of soluble carbohydrate sources may lead to the heating of the ensiled mass, increased fermentation and the use of residual oxygen, promoting the polymerization of protein components with polysaccharides (Maillard reaction), making the N unavailable (Ferreira et al., 2010; Pires et al., 2009), as reported by Teixeira et al. (2008), who used 30% sugarcane in elephant grass silage, and observed a 9.2% reduction in the DP of CP, attributing this to the fast fermentation of sugars of the additive. In this study, in the inclusion of up to 24% there were no problems regarding the reduction of DP, which indicates the possibility of increasing doses in subsequent works.

The potentially degradable fraction corresponded to most of the NDF, indicating a better use of the fiber fraction of elephant grass and the positive effect of adding faveira pods (Table 5).

Table 5. Standardized potentially degradable fraction (Bp), standardized undegradable fraction (Ip), colonization time (lag), degradation rate (k) and coefficient of determination for neutral detergent fiber of elephant grass silages (EGS) added with faveira pods (FP).

Treatments	Parameters*2				R ²
	Ip	Bp	lag	k (% h ⁻¹)	
EGS	43.20	56.80	3.81	3.82	98.16
EGS + 8% FP	45.25	54.75	4.02	5.16	97.33
EGS + 16% FP	34.78	61.22	3.51	4.54	98.11
EGS + 24% FP	35.16	63.84	3.44	5.29	96.89

*Obtained by the model of Mertens and Loften (1980): $R_t = B \cdot e^{-ct} + I$ and standardization of fractions was made by using the equations: $B_p = B/(B + I) \times 100$ and $I_p = I/(B + I) \times 100$

The undegradable fraction was above 30% in all treatments and may be the main determinant for variations in DM degradation, since NDF corresponds to 70% of that fraction for elephant grass. The inclusion of faveira pods improved the ruminal use of the fraction, even though it presented high content of NDF (68%), associated with high hemicellulose (37.2%) and low lignin (5.64%) contents of the additive, which provides a greater amount of carbohydrates for ruminal fermentation.

The lower values obtained for the degradable fraction of NDF, in relation to the other fractions, can be related to the elephant grass cutting age used in the ensiling process (82 days), since tropical grasses reach early phenological maturity with increase of support structures represented by fiber carbohydrates and lignin that reduce the cell wall availability and the percentage of cellular content, interfering with the degradation of DM and NDF (Muniz et al., 2012). The use of lower cutting ages in elephant grass silage may be advantageous for NDF contents. Nevertheless, the content of DM

that can lead to undesired fermentation should be considered low.

There was a reduction in NDF colonization time (lag) (0.37h) as well as an increase in the degradation rate (2.07% h⁻¹) with addition of 24% faveira pods. The colonization time reflects on the adhesion capacity of the ruminal microorganisms and tends to be smaller the higher the nutritional value of the food (Martins-Costa et al., 2008).

The effects obtained herein may be related to the increase of non-structural carbohydrates and protein components from faveira pods, increasing their availability to the microorganisms, associated with high degradation rates of NDF with inclusion of 24% additive (5.29% h⁻¹). In accordance with Mertens and Loften (1980) for forage foods to be considered of good quality, their NDF degradation rates should be between 2 and 6% h⁻¹, being in agreement with the values obtained in this research, which are within this range.

In nutritional terms, it should be considered that all the events of microbial action on the potentially degradable and undegradable fractions of NDF occur in finite time scales. Thus, the form of action on the substrate depends on the time that the enzyme x substrate interaction occurs, that is, on the effectiveness of the degradation process (Detmann et al., 2007). In this sense, the effectiveness of the NDF degradation process in the ruminal environment is directly represented by the estimation of the effectively degraded fraction of the NDF associated with the degradation rate per hour, which depends on the speed of enzymatic action on the substrate and the time available for these systems to perform such actions.

Conclusion

The addition of 24% faveira pods as an additive to elephant grass silages increases the dry matter, crude protein and neutral detergent fiber contents and increases the rumen degradability of nutritional fractions, as it promotes an increase in potential and effective degradation of dry matter and crude protein, and better utilization of the fiber fraction. It is indicated the inclusion of 24% ground faveira pods in silages of elephant grass aged 80-85 days to obtain better quality feed.

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