INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
19–0456/2019/22–6–1393–1398
DOI: 10.17957/IJAB/15.1213
http://www.fspublishers.org

Full Length Article

Feed Alternatives with Cactus Forage Silage for Animal Nutrition

Messias de Sousa Nogueira[1], Gherman Garcia Leal de Araújo[2], Edson Mauro Santos[1], Severino Gonzaga Neto[1], Juliana Silva de Oliveira[1], Alexandre Fernandes Perazzo[1], Anderson de Moura Zanine[3*], Ricardo Martins Araujo Pinho[3], Yohana Rosaly Corrêa[1] and Danillo Marte Pereira[1]

[1]*Department of Animal Science, Federal University of Paraíaba, P.B., Brazil*
[2]*Brazilian Agricultural Research Corporation, Petrolina, P.E., Brazil*
[3]*Department of Animal Science, Federal University of Maranhão, M.A., Brazil*
[*]For Correspondence: anderson.zanine@ibest.com.br

Abstract

Wheat bran is commonly used as an absorbent additive in high moisture silages and urea for its possible actions against undesirable microorganisms. Thus, this study was conducted to evaluate the effects of wheat bran and urea on the fermentation profile, silage losses and chemical composition of *Opuntia* silage. Four levels of wheat bran (0, 50, 100 and 200 g kg^{-1} of dry matter) with urea (10 g kg^{-1} dry matter) or without urea were added in *Opuntia* silage. Wheat bran negatively influenced gas losses (GL) and the levels of organic acids. The addition of urea ($P < 0.05$) reduced GL, but increases the concentrations of lactic acid and propionic acid. Populations of lactic acid bacteria (LAB), moulds and yeasts were reduced by the addition of urea and wheat bran ($P < 0.05$). Regarding the bromatological constituents, an interaction effect between the factors was only observed ($P < 0.05$) for the variables of lignin (LIG) and total soluble carbohydrates (TSC), with increased contents. In conclusion, a dose of 200 g kg^{-1} of wheat bran associated with 10 g kg^{-1} of dry matter in *Opuntia* silage seemed viable option to reduce the silage losses along with sizable improvement in the nutritional value of silage.

Keywords: Lactic acid; Lactic acid bacteria; *Opuntia ficus-indica*; Silage additives; Yeast

Introduction

In semiarid regions, opuntia (*Opuntia ficus-indica* L. Mill) is being widely used and has become one of the main sources of forage for herds in production systems with low and medium technological levels (Tegegne *et al.*, 2007; Costa *et al.*, 2009). However, when its use is intensified, especially in the dry period, the costs related to cutting and supply are increased. Harvesting may also compromise the potential of opuntia to regrow, since its use is unevenly distributed throughout the dry season (Ramos *et al.*, 2015).

Ensiling is the most used technique for forage conservation in semiarid regions, especially to maintain the moisture and nutritional value of the food, besides maintaining the uniformity of plants (Pinho *et al.*, 2013; Silva *et al.*, 2015). According to Gusha *et al.* (2013), forage palm is recognised for its conservation in the form of silage, although it has high moisture contents. This is only possible due to the mucilage (gelatinous substance) that decreases the water activity, controlling the development of clostridia and enterobacteria and reducing effluent losses. However, despite the occurrence of mucilage, the use of an additive in the form of bran could further minimise losses during ensiling. The use of chemical additives and moisture absorbents, such as urea and wheat bran (*Triticum aestivum*), can be effective in wet material silages, ensuring substrate supply throughout the process and the maintenance of the fermentation process, besides minimising undesirable fermentations (Zanine *et al.*, 2006a; Lopes *et al.*, 2007; Zanine *et al.*, 2007; Zambom *et al.*, 2014). Zanine *et al.* (2006b) have reported that wheat bran could be used in silages as an absorbent additive to minimise silage effluent losses, besides adding nutritional value. In addition to its action in the fermentation process, it could also be an additional source of fibre, since *Opuntia* has a reduced amount of neutral detergent fibre (Vieira *et al.*, 2008).

Another property of *Opuntia* is the high amount of sugars, which could imply a predisposition to alcoholic fermentation (Gusha *et al.*, 2013; Macêdo *et al.*, 2018). In this sense, the use of urea in forage cactus silages would be justified for promoting pH control, favouring the production of lactic acid to the detriment of ethanol. Consequently, alcoholic fermentation is inhibited, and the aerobic stability of the silage is increased in the discharge phase, reducing the production costs (Neumann *et al.*, 2010; Dias *et al.*, 2014; Martins *et al.*, 2014). Therefore, this study was conducted to evaluate the effects of wheat bran and urea on

To cite this paper: Nogueira, M.D.S., G.G.L.D. Araújo, E.M. Santos, S.G. Neto, J.S.D. Oliveira, A.F. Perazzo, A.D.M. Zanine, R.M.A. Pinho, Y.R. Corrêa and D.M. Pereira, 2019. Feed alternatives with cactus forage silage for animal nutrition. *Intl. J. Agric. Biol*., 22: 1393–1398

the fermentation profile, silage losses and chemical composition of *Opuntia* silage.

Materials and Methods

Study Area, Silage Material and Treatments

The experiment was performed at the Research Center for the Semi-arid Tropics (CPATSA) of the Brazilian Agricultural Research Agency (EMBRAPA) and the Forage Laboratory of the Federal University of Paraíba (UFPB). The *Opuntia ficus-indica* cv. 'Gigante' used in the present research was harvested after approximately 2 years of regrowth. Soon after the harvest, the material was ensiled in polyvinyl chloride silos (30 cm high and 15 cm in diameter) equipped with a Bunsen valve for the exhaust of gases. At the bottom of the silos, sand was added for draining the effluent, as well as a cotton cloth to avoid contact of the forage with the sand. The material was compacted with wooden sockets; we used approximately 2 kg of fresh forage per silo. The silos were closed, weighed and stored in a covered area at room temperature until being opened. The experiment was performed in a 4 × 2 factorial design (four levels of wheat bran: 0 (control), 50, 100 and 200 g kg^{-1} dry matter; with or without urea in the silage (10 g kg^{-1} dry matter) through a completely randomised design with four replicates. After 45 days of ensiling, each silo was opened and the content was thoroughly homogenised, discarding the upper and lower portions (approximately 5 cm each) of every silo. Samples were taken from the homogenised central portion and taken to the laboratory.

Microbial Populations and Fermentation Profile

Enumeration of the microbial groups was performed on the aqueous extract, obtained by homogenising 10 g of silage sample and 90 mL of phosphate buffer solution in an industrial blender for 1 min, obtaining the dilution of 10^{-1}. Afterwards, the samples were successively diluted to obtain the concentration range from 10^{-1} to 10^{-9}, counting the plaques with values between 30 and 300 colony-forming units (CFU). Plating was performed in duplicate on sterile Petri dishes immediately after preparing the aqueous extract. Microbial populations were quantified using selective culture media for each microbial group, where: MRS (Difco) for enumeration of lactic acid bacteria (LAB) after incubation for 48 h in a BOD oven at 39°C; Violet Red Bile Agar (Difco) for enumeration of enterobacteria (ENT) after incubation for 24 h in a BOD oven at 30°C; and potato dextrose agar plus 1 to 10% tartaric acid after sterilisation for mould and yeast counts (M and Y) after incubation for 3–7 days at room temperature.

To determine the organic acids, an aliquot of approximately 10 mL aqueous extract was acidified with three drops of 50% H_2SO_4 and stored in a freezer (-20°C). In this extract, the organic acids (lactic, acetic, propionic and butyric) were determined according to Siegfried *et al.* (1984) and water-soluble carbohydrates according to Deriaz (1961). The buffer capacity (BC) of the ensiled mass was determined according to a methodology proposed by Playne and Mcdonald (1966). To determine the total water-soluble carbohydrates (WSC), the concentrated sulfuric acid method was used, adapted from Corsato *et al.* (2008).

Dry matter (DM) loss in the form of gas was determined according to the equations described in Zanine *et al.* (2010).

Chemical Analysis

To evaluate the chemical composition, samples of the fresh material (*Opuntia* and wheat bran) were collected, and the silos were opened. These samples were pre-dried for 72 h in a convection oven at 65ºC, ground in a Thomas Wiley mill with a 1-mm sieve and placed in plastic flasks.

The concentrations of dry matter (DM), mineral matter (MM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), ether extract and lignin were determined according to the methodologies described in Detmann *et al.* (2012). The NDF corrections for ashes and protein (NDFap) were performed according to Licitra *et al.* (1996) and Mertens (2002), described in Detmann *et al.* (2012). The total carbohydrate (TC) concentration was estimated by the equation TC = 100 - (dag/kg CP + dag/kg EE + dag/kg MM) and that of non-fibrous carbohydrates (NFC) by the equation NFC = (dag/kg TC - dag/kg NDF), according to Mertens (1997). The chemical compositions of *Opuntia* and wheat bran before ensiling are shown in Table 1.

Statistical Analysis

The obtained data were subjected to analysis of variance and regression. Significant interactions among the factors were detailed. The effect of wheat bran addition was verified *via* regression analysis. The regression equations were chosen based on the coefficient of determination and the significance of the regression coefficients through the t-test, using $\alpha = 0.05$. The urea effect was compared by the F test at 5% probability level. All analyses were performed with the System for Statistical and Genetic Analyses (Saeg, 2007).

Results

Chemical Composition before Ensiling

The concentrations of dry matter (DM), crude protein (CP), neutral detergent fibre (NDF), ether extract (EE), non-fibre carbohydrates (NFC) and water-soluble carbohydrates (WSC) (g kg^{-1} DM) of forage cactus and wheat bran before ensiling are shown in Table 1. The WSC quantity of *Opuntia* (120 g kg^{-1}) was higher than 100 g kg^{-1} DM.

Table 1: Chemical composition (g kg^{-1} DM) of *Opuntia* and wheat bran

Opuntia (g kg^{-1} DM)						
DM	Ash	CP	NDF	EE	NCF	WSC
144.9	128.3	44.8	394.3	9.2	423.4	120
Wheat bran (g kg^{-1} DM)						
DM	Ash	CP	NDF	EE	NCF	WSC
873.7	38.4	175.9	311.8	28.3	313.1	60
Opuntia silage untreated or treated with urea and wheat bran						
DM (g kg^{-1})						
Urea	Wheat bran					
	0	50	100	200		
Without	114.8	187.1	218.9	265.1		
With	108.2	180.1	211.9	255.0		
BC mEq/100g DM						
Urea	Wheat bran					
	0	50	100	200		
Without	22.65	13.89	13.84	6.03		
With	14.42	12.21	16.32	7.69		

DM – Dry matter on a fresh matter basis; CP – Crude protein; NDF – neutral detergent fibre; EE – Ether extract; NFC – non-fibre carbohydrates

The DM content ranged from 108.2 to 265.1 g kg^{-1} (Table 1). The TC, in turn, ranged from 6.03 to 22.65 mEq/100 g DM; based on this, *Opuntia* can be classified as a low-TC material.

Fermentation Quality and Dry Matter Loss of Silages

The addition of wheat bran to the ensilage significantly influenced ($P < 0.05$) gas losses (GL) and the contents of lactic acid (LA), acetic acid (AA), propionic acid (PA) and butyric acid (BA). The addition of wheat bran had a linear decreasing effect ($P < 0.05$) one GL. The addition of urea ($P < 0.05$) influenced the GL variables and the concentrations of LA and PA; the presence of urea in *Opuntia* silage decreased the GL. There was an interaction effect among the factors ($P < 0.05$) for LA, AA, PA and BA (Table 2).

An interaction effect ($P < 0.05$) was observed on all organic acid variables of the *Opuntia* silage (Table 3). The use of wheat bran in the *Opuntia* silage had a quadratic effect ($P < 0.05$) on most variables, except on BA, which showed a linear decreased. An effect of urea ($P < 0.05$) was observed for LA, AA, PA and BA at the levels of 50 and 100 g kg, 0 and 50 g kg, 50, 100 and 200 g kg and 0 g kg of wheat bran, respectively (Table 3).

However, the addition of urea did not alter the populations of LAB, moulds and yeasts in the silage (Table 4). Populations of LAB close to 7 log CFU/g silage were observed after the fermentation process. With respect to ML proliferation, all treatments averaged 5 log CFU/g silage (Table 4). Wheat bran, in turn, decreased the LAB population, probably due to the reduced amount of TSC of the ensiled mass (Table 4).

Chemical Composition of Silages

Regarding the chemical constituents, the use of wheat bran significantly influenced ($P < 0.05$) most of the analysed variables, with the exception of NFC. On the other hand, the addition of urea influenced the variables DM, CP, NFC and TSC. An interaction among the factors was observed ($P < 0.05$) only for the variables LIG and TSC (Table 5).

There was an increasing linear effect ($P < 0.05$) for the variables DM, CP and EE with increasing wheat ban contents in the silages, with variations ranging from 129.26 to 272.31 g kg^{-1}, 58.26 to 137.80 g kg^{-1} and 15.91 to 25.22 g kg^{-1} in the DM of the silage, respectively. A decreasing linear effect ($P < 0.05$) was observed for the contents of ash and NDF, ranging from 118.65 to 68.62 g kg^{-1} and 315.70 to 255.01 g kg^{-1}, respectively. In relation to the NFC contents in the silage mass, a quadratic effect was observed, with averages ranging from 491 to 519 g kg^{-1} (Table 6).

Table 2: Statistical analysis of the fermentative profile of *Opuntia* silage untreated or treated with urea and wheat bran

Item	GL	LA	AA	PA	BA
			P-value		
Wheat bran	0.001	0.000	0.000	0.000	0.000
Urea	0.000	0.000	0.371	0.000	0.198
Wheat bran × Urea	0.202	0.000	0.000	0.000	0.005

GL – Gas losses; LA – lactic acid; AA – acetic acid; PA – propionic acid; BA – butyric acid

Table 3: Concentrations of lactic acid, acetic acid, propionic acid and butyric acid in *Opuntia* silage untreated or treated with urea and wheat bran

Lactic acid (g kg^{-1} DM)					
Urea	Wheat bran levels				
	0	50	100	200	LSD
Without	80.2a	44.3d	47.0d	73.7b	5.9
With	80.8a	57.6c	49.0d	75.0ab	
Acetic acid (g kg^{-1} DM)					
Urea	Wheat bran levels				
	0	50	100	200	LSD
Without	22.5b	12.8cd	10.7d	16.2c	4.7
With	48.6a	15.2cd	11.2d	16.0c	
Propionic acid (g kg^{-1} DM)					
Urea	Wheat bran levels				
	0	50	100	200	LSD
Without	8.1a	5.4b	1.9d	2.1d	1.9
With	8.5a	3.9c	3.0c	5.8b	
Butyric acid (g kg^{-1} DM)					
Urea	Wheat bran levels				
	0	50	100	200	LSD
Without	0.5b	0.4c	0.2e	0.2e	0.8
With	0.7a	0.3d	0.2e	0.2e	

Means followed by different letters differ significantly by the LSD test ($P < 0.05$)

Table 4: Microbial populations (log cfu/g silage) in *Opuntia* silage untreated or treated with urea and wheat bran

Lactic acid bacteria				
Urea	Wheat bran			
	0	50	100	200
Without	7.80	7.02	7.91	7.11
With	7.80	6.97	8.21	6.34
Yeasts and moulds				
Urea	Wheat bran			
	0	50	100	200
Without	5.30	4.54	5.92	4.95
With	5.25	4.48	6.23	4.87

Table 5: Statistical analysis of the chemical composition of *Opuntia* silage untreated or treated with urea and wheat bran

[1]FV	DM	Ash	CP	NDF	EE	LIG	NCF	TSC
Wheat bran	0.0000	0.0000	0.0000	0.0090	0.0001	0.0004	0.0676	0.0000
Urea	0.0075	0.8933	0.0000	0.0966	0.9131	0.9488	0.0130	0.0050
Wheat bran × Urea	1.0000	0.2812	1.0000	0.5140	0.5341	0.0296	0.4416	0.0058
Coefficient of variation (%)	5.73	7.04	5.50	14.02	17.27	8.55	9.36	58.31

DM – Dry matter on a fresh matter basis; CP – Crude protein; NDF – neutral detergent fibre; EE – Ether extract; LIG – lignin; NFC – non-fibre carbohydrates; TSC – Total soluble carbohydrates

Table 6: Chemical composition of *Opuntia* silage with added wheat bran

Item (g kg^{-1})	Wheat bran levels (g kg^{-1})				r^2
	0	50	100	200	
DM	129.26	161.13	203.14	272.31	99.84
Ash	118.65	111.05	85.68	68.62	94.90
CP	58.26	85.28	113.98	137.80	95.19
NDF	315.70	332.46	285.25	255.01	80.02
EE	15.91	18.46	23.27	25.22	90.59
NCF	491.43	452.70	491.80	519.61	67.70

DM – Dry matter on a fresh matter basis; CP – Crude protein; NDF – neutral detergent fibre; EE – Ether extract; NFC – non-fibre carbohydrates

The addition of urea significantly influenced ($P < 0.05$) the nutritive value of the silages, in which the contents of DM, CP and TSC increased with the additive. However, the NFC values were significantly higher ($P < 0.05$) for the silage without urea (Table 7). A quadratic effect ($P < 0.05$) was observed on the LIG contents in the silages with wheat bran without urea; however, when urea was added, the LIG contents decreased linearly ($P < 0.05$). Silage without wheat bran showed a significantly lower lignin content ($P < 0.05$) without the addition of urea. Regarding the TSC contents, a linear decreasing effect ($P < 0.05$) was observed when wheat bran was added to the silage in combination with urea (Table 8).

Discussion

Wheat bran is commonly used as an absorbent additive in high-moisture silages, increasing silage DM and the availability of CP. *Opuntia* showed a low TC content, allowing a lower resistance to pH decrease by the action of organic acids, which may be associated with the high WSC content. The WSC quantity of *Opuntia* (120 g kg^{-1}) was higher than the 100 g kg^{-1} DM recommended by McDonald *et al.* (1991) to obtain well-fermented silages.

In addition to the WSC content being within the range recommended in the literature, *Opuntia* contains a hydrocolloid compound known as mucilage, which, among other characteristics, has a high water retention capacity (Saag *et al.*, 1975). Such capacity is due to the formation of a viscous gel in the presence of Ca^{2+} ions as well as in the presence of water and ions in the medium (Trachtenberg and Mayer, 1982). Mucilage tends to prevent the flow of fluid components present in the cladodes of the plant after cutting. In this study, this gelatinous substance, associated with wheat bran and urea, possibly inhibited the losses (Driehuis and Wikselaar, 2000), which explains the reduction in gas losses (EL) during *Opuntia* ensiling (Table 2).

The concentrations of lactic acid found in the studied silages (Table 3) were higher than the values observed by Çürek and Özen (2004), who obtained *Opuntia* silages with an average lactic acid content of 25.90 g kg^{-1}. A higher lactic acid and acetic acid production (Table 3) occurred in silages treated with urea, indicating a positive effect of urea on silage fermentation, since it provided a favourable environment for the development of homofermentative and heterofermentative lactic bacteria (Table 4). Evaluating *Opuntia* silages, Çürek and Özen (2004) observed an average acetic acid concentration of 1.53 g kg^{-1}. In this study, similar and higher values were found in silages without additives, with values of 2.25 and 4.86 g kg^{-1} in the treatments without and with urea, respectively. The moderate presence of acetic acid in the silage (Table 3) is favourable, since it can decrease aerobic deterioration at the time of feeding. There was a significant effect of urea on the concentrations of butyric acid and propionic acid; despite this, the values were relatively low, making it possible to characterise a suitable fermentation process of *Opuntia* silage in relation to the inhibition of unwanted fermentations (Table 3).

Opuntia presented a high WSC concentration of 120 g kg^{-1} (Table 1), which, in turn, allows a rapid reduction of pH to the silage preservation range (Gusha *et al.*, 2013), creating a favourable environment for the development of lactic acid bacteria. The LAB values shown in Table 4 were derived from the fermentation of WSC (Table 1), which are classified as homofermentative and heterofermentative according to the products of their fermentation (Gollop *et al.*, 2005). However, the addition of wheat bran negatively influenced the availability of WSC in the treatments (Table 1), which may have negatively influenced the LAB proliferation in the silage (Table 4). Due to the low DM content of silages without additives, high concentrations of moulds and yeasts were observed in the material (Table 4).

Table 7: Chemical composition of *Opuntia* silage with added urea

Item (g kg^{-1})	Urea	
	Without	With
DM	182.1^{b}	193.8^{a}
CP	85.8^{b}	106.7^{a}
Ash	97.0^{a}	97.4^{a}
EE	20.4^{a}	20.5^{a}
NDF	284.7^{a}	311.3^{a}
NCF	511.8^{a}	466.6^{b}
TSC	105.3^{b}	213.8^{a}

Means within a row with different superscripts differ significantly ($P < 0.05$)
DM – Dry matter on a fresh matter basis; CP – Crude protein; EE – Ether extract; NDF – Neutral detergent fibre; NFC – non-fibre carbohydrates; TSC - Total soluble carbohydrates

Table 8: Concentrations of lignin and total soluble carbohydrates in *Opuntia* silage untreated or treated with urea and wheat bran

Lignin (g kg^{-1} DM)					
Urea	Wheat bran levels (g kg^{-1} DM)				r^2
	0	50	100	200	
Without	59.12B	65.80	65.10	50.90	97.71
With	69.45A	66.52	59.62	55.33	96.78
Total soluble carbohydrates (g kg^{-1} DM)					
Urea	Wheat bran levels (g kg^{-1}DM)				r^2
	0	50	100	200	
Without	20.04B	8.88	7.41	6.66	-
With	53.24A	19.91	10.01	4.35	73.89

Means within a column with different superscripts differ significantly ($P < 0.05$)

Although it does not represent high losses, fungi under stress conditions can produce mycotoxins, which are harmful to animal and human health (Ivanek *et al.*, 2006).

Yeasts are the main silage-degrading microorganisms, especially after aerobic exposure of the material, promoting marked losses of DM throughout the ensiling process. These microorganisms can grow at a pH below 3.5, since they can use lactic acid as substrate when in anaerobiosis, thus increasing the pH in the silage, which may favour the emergence of undesirable fermentations (Muck, 2010). However, it is noteworthy that LAB populations were higher than those of moulds and yeasts in all silages evaluated (Table 4).

The increase in the DM contents of the silages (Table 6) is associated with the addition of wheat bran, which in turn is an additive that allows forming silage from forages with low DM contents (Souza *et al.*, 2003). Moreover, its addition increases the nutritional value of the silage (Table 6) and results in lower losses during the ensiling process, inhibiting possible undesirable fermentations (Ribeiro *et al.*, 2008).

Mucilage formation may have influenced the reduction in losses during ensiling and the fermentation profile of the silages evaluated, possibly favouring the maintenance of the PC contents of the silages (Table 6) and preserving the nutritive value of the silage. The NFC values presented in Table 6 were lower than those verified by Duru and Turker (2005), who observed changes in the chemical composition of *Opuntia* silages over time. These authors reported NFC values of around 580 g kg^{-1} DM for *O. ficus-indica*, corroborating the values observed in the present study (Table 6).

The positive influence of urea on the chemical composition of *Opuntia* silage was expected due to the protein equivalence of urea. Most likely, urea was dissociated in the ensiled mass and remained in the form of ammonium salts. Regarding the alkaline hydrolysis potential of urea, no action of greater availability of soluble material or reduction of the fibrous portion of the ensiled material was observed (Table 7).

Conclusion

The addition of wheat bran and urea reduced gas losses, moulds and yeasts, increase populations of lactic acid bacteria of the silages. We recommend a dose of 200 g kg of wheat bran associated with 10 g kg of dry matter in *Opuntia* silage seemed viable option to reduce the silage losses along with sizable improvement in the nutritional value of silage.

Acknowledgments

The authors wish to thanks the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and the Fundação de Amparo à Pesquisa do Estado Maranhão (FAPEMA) for their financial support.

References

Corsato, C.E., J.A.S. Filho and E.C.J. Sales, 2008. Teores de carboidratos em órgãos lenhosos do caquizeiro em clima tropical. *Rev. Bras. Fruticult.*, 30: 414–418

Costa, R.C., E.M.B. Filho, A.N. Medeiros, P.E.N. Givisiez, R.C.R.E. Queiroga and A.A.S. Melo, 2009. Effects of increasing levels of cactus pear (*Opuntia ficus-indica* L. Miller) in the diet of dairy goats and its contribution as a source of water. *Small Rumin. Res*., 82: 65–65

Çürek, M. and N. Özen, 2004. Feed value of cactus and cactus silage. *Turk. J. Vet. Anim. Sci*., 28: 633–639

Deriaz, R.E., 1961. Routine analysis of carbohydrate and lignin in herbage. *J. Sci. Food Agric*., 12: 150–160

Detmann, E., M.A. Souza, S.C.V. Filho, A.C. Queiroz, T.T. Berchielli, E.O.S. Saliba, L.S. Cabra, l.D.S. Pina, M.M. Ladeira and J.A.G. Azevedo, 2012. *Métodos para análise de Alimentos*, 1st edition. Suprema, Visconde do Rio Branco, Minas Gerais, Brazil

Dias, A.M., L.C. Ítavo, C.C.B. Ítavo, L.R. Blan, E.N. Gomes, C.M. Soares, E.S. Leal, E. Nogueira and E.M. Coelho, 2014. Ureia e glicerina bruta como aditivos na ensilagem de cana-de-açúcar. *Arq. Bras. Med. Vet. Zool*., 66: 1874–1882

Driehuis, F. and P.G.V. Wikselaar, 2000. The occurrence and prevention of ethanol fermentation in high-dry-matter grass silage. *J. Sci. Food Agric*., 718: 5–7

Duru, B. and N. Turker, 2005. Changes in physical properties and chemical composition of cactus pear (*Opuntia ficus-indica*) during maturation. *J. Prof. Assoc. Cactus Dev*., 7: 22–33

Gollop, N., V. Zakin and Z.G. Weinberg, 2005. Antibacterial activity of lactic acid bacteria included in inoculants for silage and in silages treated with these inoculants. *J. Appl. Microbiol*., 98: 662–666

Gusha, J., S. Katsande, P.I. Zvinorova and S. Ncube, 2013. The nutritional composition and acceptability of cacti (*Opuntia ficus-indica*)-legume mixed silage. *J. Anim. Feed Res.*, 3: 116–120

Ivanek, R., Y.T. Gröhn and M. Wiedmann, 2006. Listeria monocytogenes in multiple habitats and host populations: review of available data for mathematical modelling. *Foodborne Pathog. Dis*., 3: 319–336

Licitra, G., T.M. Hernandez and P.J.V. Soest, 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. *Anim. Feed. Sci. Technol*., 57: 347–358

Lopes, J., A.R. Evangelista and G.P. Rocha, 2007. Valor nutricional da silagem de cana-de-açúcar acrescida de ureia e aditivos absorventes de umidade. *Rev. Bras. Zootec*., 36: 1155–1161

Macêdo, A.J.S., E.M. Santos, G.G.L. Araújo, R.L. Edvan, J.S. Oliveira, A.F. Perazzo, W.C.C.S. Sá and D.M. Pereira, 2018. Silages in the form of diet based on spineless cactus and buffelgrass. *Afr. J. Range For. Sci*., 33: 1–9

Martins, S.C.D.S.G., G.G.P.D. Carvalho, A.J.V. Pires, R.R. Silva, A.C. Lopes, R. Leal, M.S.L. Tosto and D.M.T. Chagas, 2014. Análise econômica da utilização de silagens de cana-de-açúcar tratadas com ureia e óxido de cálcio sobre a produção de leite bovina. *Rev. Bras. Saúde Prod. Anim*., 15: 327–338

McDonald, P., A.R. Henderson and S.J. Heron, 1991. *The Biochemistry of Silage*, 2nd edition. Chalcombe Publications, Marlow, Buckinghamshire, England

Mertens, D.R., 2002. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. *J. AOAC Intl*., 85: 1217–1240

Mertens, D.R., 1997. Creating a system for meeting the fiber requirements of dairy cows. *J. Dairy Sci*., 80: 1463–1481

Muck, R.E., 2010. Silage microbiology and its control through additives. *Rev. Bras. Zootec*., 39: 183–191

Neumann, M., R. Oliboni, M.R. Oliveira, M.V. Faria, R.K. Ueno, L.L. Reinerh and T. Durman, 2010. Aditivos químicos utilizados em silagens. *Pesq. Apl. Agrotecnnol*., 3: 187–196

Pinho, R.M.A., E.M. Santos, J.A.S. Rodrigues, C.H.O. Macedo, F.S. Campos, J.P.F. Ramos, H.F.C. Bezerra and A.F. Perazzo, 2013. Avaliação de genótipos de milheto para silagem no Semiárido. *Rev. Bras. Saúde Prod. Anim*., 14: 426–436

Playne, M.J. and P. McDonald, 1966. The buffering constituents of herbage and silage. *J. Food Sci. Agric*., 17: 264–268

Ramos, J.P.D.F., E.M. Santos, G.R.B. Cruz, R.M.A. Pinho and P.M.D.D. Freitas, 2015. Effects of harvest management and manure levels on cactus pear productivity. *Rev. Caatinga*, 28: 135–142

Ribeiro, R.D.X., R.L. Oliveira, A.R. Bagaldo, E.F.S. Faria, A.F. Garcez Neto, M.S. Borja and B.M. Cardoso Neto, 2008. Capim-tanzânia ensilado com níveis de farelo de trigo. *Rev. Bras. Saúde Prod. Anim.*, 9: 631–640

Saag, L.M.K., G.R. Sanderson, P. Moyna and G. Ramos, 1975. Cactaceae mucilage composition. *J. Sci. Food Agric*., 26: 993–1000

Saeg, S., 2007. *Sistema Para Análises Estatísticas*, Versão 9.1. Fundação Arthur Bernardes - UFV - Viçosa

Siegfried, R., H. Ruckermann and G. Stumpf, 1984. Method for the determination of organic acids in silage by high performance liquid chromatography. *Landwirt. Forsc*., 37: 298–304

Silva, M.D.A., M.S.S.D.S. Carneiro, A.P. Pinto, R.C.F.F. Pompeu, D.S. Silva, M.J.F. Coutinho and R.M. Fontenele, 2015. Avaliação da composição químico-bromatológica das silagens de forrageiras lenhosas do semiárido brasileiro. *Semin. Cienc. Agrar*., 36: 571–578

Souza, A.D., F.S. Bernardino, R. Garcia, O.G. Pereira, F.C. Rocha and A.J.V. Pires, 2003. Valor nutritivo de silagem de capim-elefante (*Pennisetum purpureum* Schum) com diferentes níveis de casca de café. *Rev. Bras. Zootec*., 32: 828–833

Tegegne, F., C. Kijora and K.J. Peters, 2007. Study on the optimal level of cactus pear (*Opuntia ficus-indica*) supplementation to sheep and its contribution as source of water. *Small Rumin. Res*., 72: 157–164

Trachtenberg, S. and A.M. Mayer, 1982. Biophysical properties of *Opuntia ficus-indica* mucilage. *Phytochemistry*, 21: 2835–2843

Vieira, E.L., A.M.V. Batista, A. Guim, F.F. Carvalho, A.C. Nascimento, R.F.S. Araújo and A.F., Mustafa, 2008. Effects of hay inclusion on intake, *in vivo* nutrient utilization and ruminal fermentation of goats fed spineless cactus (*Opuntia ficus-indica* L. Mill) based diets. *Anim. Feed Sci. Technol*., 141: 199–208

Zambom, M., T. Fernandes, M.S.S.P. Soares, D.D. Castagnara, M. Neres, C. Javorski and E.A. Cruz, 2014. Características da silagem de resíduo úmido de fécula de mandioca adicionada de níveis de ureia. *Arch. Zootec*., 63: 677–688

Zanine, A.D.M., E.M. Santos, J.R.R. Dórea, P.A.S. Dantas, T.C. Silva and O.G. Pereira, 2010. Evaluation of elephant Grass silage with the addition of cassava scrapings. *Rev. Bras. Zootec*., 39: 2611–2616

Zanine, A.D.M., E.M. Santos, D.J. Ferreira, L.F.B. Pinto and OG. Pereira, 2007. Características fermentativas e composição químico-bromatológica de silagens de capim-elefante com ou sem Lactobacillus plantarum e farelo de trigo isoladamente ou em combinação. *Cienc. Anim. Bras*., 8: 621–628

Zanine, A.D.M., E.M. Santos, D.D.J. Ferreira, O.G. Pereira and J.C.C.D. Almeida, 2006a. Efeito do farelo de trigo sobre as perdas, recuperação da matéria seca e composição bromatológica da silagem de capim-mombaça. *Braz. J. Vet. Res. Anim. Sci*., 43: 73–81

Zanine, A.D.M., E.M. Santos, D.J. Ferreira, J.S. Oliveira, J.C.C. Almeida and O.G. Pereira, 2006b. Avaliação da silagem de capim-elefante com adição de farelo de trigo. *Arch. Zootec*., 55: 75–84

[Received 19 Mar 2019; Accepted 21 May 2019; Published (online) 22 Dec 2019]