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Nutritional value of pre-dried banana tree pseudostem ammoniated with protected urea

Valor nutricional de pseudocaule de bananeira pré-secado amonizados com ureia protegida

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Highlights:
Ammonization of banana tree pseudostem increased crude protein content by 42.75%.
The soluble fraction of the dry matter of the pseudostem increased with urea ammoniation.
There was linear increase on potential and effective degradability of dry matter of the pseudostem with urea ammoniation.

Abstract

The objective of this study was to evaluate the chemical composition, pH and rumen degradability of banana tree pseudostems pre-dried and ammoniated with different doses of urea (0, 0.5, 1.0, 1.5 and 2.0% in natural matter). The experiment consisted of five treatments (doses of urea) with six replications, following a completely randomized design. There was a linear increase in the pH ($P < 0.01$) of the banana tree pseudostems pre dried with the inclusion of urea. There was no difference ($P > 0.05$) in dry matter, ash, neutral detergent fiber, acid detergent fiber, lignin, non-fibrous carbohydrates and total digestible nutrients; the averages were 31.58, 18.82, 46.43, 9.30, 11.87 and 42.52%, respectively. The inclusion of 2% urea increased the crude protein content ($P < 0.01$) by 42.75%, the soluble fraction "a" by 31.82%, and the potential and effective degradability of dry matter by 15.49% compared to that of the control group (without urea). The potentially degradable fraction, time of colonization and ruminal repletion of the neutral detergent fiber of the pre-dried banana tree pseudostems were not altered with the inclusion of urea ($P > 0.05$). The ammonization of the pre-dried banana tree pseudostems with 2% of urea improved the chemical composition and rumen degradability of the dry matter.
Key words: Chemical composition. Ruminal kinetics. Fiber. Ruminal repletion.

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Resumo

O objetivo deste estudo foi avaliar a composição química, pH e degradabilidade ruminal de pseudocaule de bananeira pré-secado e amonizados com diferentes doses de ureia (0, 0,5, 1,0, 1,5 e 2,0% em matéria natural). O experimento consistiu de cinco tratamentos (doses de ureia) com seis repetições, seguindo um delineamento inteiramente casualizado. Houve aumento linear do pH ($P < 0,01$) do pseudocaule de bananeira pré-secado com a inclusão de ureia. Não houve diferença ($P > 0,05$) na matéria seca, cinzas, fibra em detergente neutro, fibra em detergente ácido, lignina, carboidratos não fibrosos e nutrientes digestíveis totais; as médias foram 31,58; 18,82; 46,43; 9,30; 11,87 e 42,52%, respectivamente. A inclusão de 2% de ureia aumentou o teor de proteína bruta ($P < 0,01$) em 42,75%, a fração solúvel "a" em 31,82% e a degradabilidade potencial e efetiva da matéria seca em 15,49% em relação ao grupo controle (sem ureia). A fração potencialmente degradável, o tempo de colonização e a repleção ruminal da fibra em detergente neutro dos pseudocaules de bananeira pré-secado não foram alterados com a inclusão da ureia ($P > 0,05$). A amonização do pseudocaule de bananeira pré-secado com 2% de ureia melhorou a composição química e a degradabilidade ruminal da matéria seca.

Palavras-chave: Composição química. Cinética ruminal. Fibra. Repleção ruminal.

Introduction

Due to the low cost of production and high accumulation of dry mass, tropical forage has been the basis of ruminant feed in the tropics (Costa et al., 2018). However, forage production is not constant throughout the year, and it is necessary to supplement animals during deficit periods (Rigueira et al., 2018). The use of agroindustrial residues for roughage supplementation in ruminants is a common practice, especially for banana crop wastes (*Musa* spp.) (Carmo et al., 2018; Gerassev et al., 2013; Monção et al., 2016; Wang, Muhammad, Liua, Huang and Cao et al., 2016).

The banana crop is of economic importance worldwide, as it has the highest production of any fruit, 140 million tonnes (Food and Agriculture Organization of the United Nations [FAO], 2019). Brazil is one of the world's three largest producers of fruit, with production exceeding 40.0 million tons per year (FAO, 2019). It is estimated that for each ton of banana bunches harvested, three tons of pseudostem are generated, highlighting the productive potential of this crop residue. Wang et al. (2016) evaluated the nutritional value of the banana pseudostem, *in natura*, and verified that this residue has a potential for rumen degradation of dry matter (DM) of 88%. However, these authors observed low DM (10%) and crude protein (CP; 2.8% of DM) contents in the pseudostem *in natura* that must be addressed for their use in the diet of ruminants. Due to the long (over 15 days) time required for phenation, its use in the form of pre-drying is an option to reduce the drying time and avoid possible losses caused by rainfall. Furthermore, to decrease the fermentation losses and improve the nutritive value primarily of the crude protein content and fiber digestibility, ammonization urea or anhydrous ammonia have been used (Santiago et al., 2013). However, the optimal urea dose to be applied during the ammonization process remains unclear, as do its changes in the nutritional value of the preserved roughage.

Based on the above information, the objective of this work was to evaluate the chemical composition, pH values and rumen degradability of the dry matter and fibrous fraction of the pre-dried banana tree pseudostems ammoniated with different levels of urea.

Material and Methods

Animal care

All animal care and handling procedures were approved by the Animal Care and Use Committee of the Universidade Estadual de Montes Claros, Brazil (protocol CEBEA-Unimontes 155/2016).

Local

The experiment was carried out conducted at the experimental farm of the State University of Montes Claros, Janaúba/Minas Gerais campus. The municipality of Janaúba has geographic coordinates of 15º48 '13''S and 43º19'3''W with an altitude of 510 m. The Koppen climate classification is type aw, the annual average temperature is 27°C and the annual precipitation is 600 mm. The treatments consisted of pre-dried banana tree pseudostems ammoniated with five doses of urea (0, 0.5, 1.0, 1.5 and 2.0% in natural matter) and performed in six replicates.

Pre-drying procedure

The pseudostem was collected from banana (plantation) preinstalled at the experimental farm of Unimontes and processed in a forage model JF-90 (JF Agricultural Machinery, SP, Brazil). After processing, it was dehydrated in the sun on the soil for 120 hours and was manually stirred once per day until the dry matter content was between 30-35%. For ammoniation, protected urea (Produquímica®, São Paulo, Brazil) was utilized. Five mounds of 20 kg of pre-dried pseudostems were created, with urea being added in the respective proportions of each treatment, followed by homogenization. To produce the silage, experimental PVC silos of known weight and 40 cm in length and 10 cm in diameter were used. After the complete homogenization of the forage with the additives, the resultant material was deposited in the silos and compacted with a wooden plunger. For each treatment, the silage density (350 kg of natural material m^{-3}) was quantified, and approximately 3 kg of the chopped material of each fresh forage was quantified, as recommended by Ruppel, Pitt, Chase and Galton (1995). After filling, the silos were closed with PVC caps fitted with Bunsen valves, sealed with adhesive tape and weighed. The silos were stored at room temperature on the premises of the Laboratory of Food Analysis of UNIMONTES and were subsequently opened 60 days after ensiling.

Evaluation

Samples were then collected from the middle of each silo after discarding the silage at the top, where fungi were present, and then pre-dried by forced ventilation at 55°C to a constant weight. Subsequently, some of the pre-dried material was milled in a Willey mill with 1-mm sieves (to analyze chemical composition), and the remainder of the samples were milled with 2-mm sieves (*in situ* degradability assay) and stored in properly identified plastic pots. The pH was determined (Soluble in water) using a digital potentiometer (Digimed model) according to the methodology described by Silva and Queiroz (2002). The pre-dried forage was then analyzed for dry matter (DM; INCT-CA G-003/1), ash (INCT-CA N-001/1), crude protein (CP; INCT-CA M-001/1), ether extract (FT-C-005/1), neutral detergent fiber corrected for ash and protein (NDFap; INCT-CA F-005/1), acid detergent fiber (ADF; INCT-CA F-003/1) nonfibrous carbohydrates (NFC) and nitrogen compound fraction, according to Detmann et al. (2012); and total digestible nutrients (TDN), according to equations proposed by National Research Council – International [NRC] (2001).

To evaluate the ruminal degradation kinetics, four crossbred cannulated steers with a mean weight of 500 ± 65 kg were used. The animals received 3.0 kg of concentrate (25% CP and 70% TDN) in two equal portions in the morning and afternoon as well as diets based on elephant grass (90% of DM) and pseudostem pre-dried (10% of DM). The *in situ* degradability technique was performed using 7.5 × 15-cm non woven fabric bags (TNT, weight 100), according to Casali et al. (2009); the number of samples was determined from the ratio of 20 mg of DM cm^{-2} of bag surface area (Nocek, 1988). The bags were placed in 20 × 30 cm fillet bags along with 100-g lead weights. The fillet bags were tied with a nylon thread, leaving a length of 1 m such that the bags could freely move in the solid and liquid phases of the rumen. The fillet bags were then deposited in the ventral sac region of the rumen

with the end of the nylon thread remaining attached to the cannula for 0, 3, 6, 12, 24, 48, 72, 96 and 144 hours in reverse order, i.e. starting incubation with a duration of 144 hours. Starting incubating in descending order of time to remove all together. The bags related to time zero were not incubated in the rumen but were washed in running water, similar to the incubated bags. Subsequently, the samples were placed in greenhouses at 55°C for 72 hours and then cooled in a desiccator and weighed. The residues remaining in the TNT following collection from the rumen were analyzed for DM and NDF contents. The percent degradation was calculated by the proportion of feed remaining in the bags after ruminal incubation, and the NDF was analyzed according to the methods proposed by Van Soest, Robertson and Lewis (1991) without the use of α-amylase. The obtained data (DM and NDF) were adjusted to a nonlinear regression by using the Gauss-Newton method (Neter, Wasserman, & Kutner, 1985) with SAS software (SAS Institute, Inc., Cary, NC, USA),according to the equation proposed by Ørskov and McDonald (1979): $Y = a + b(1 - e^{-ct})$, where Y = the cumulative degradation of the nutritional component analyzed after time t; a = the degradation curve intercept when t = 0, corresponding to the water-soluble fraction of the analyzed nutrient component; b = the degradation potential of the water-insoluble fraction of the analyzed nutrient component; a+b = the degradation of the analyzed nutritional component when time is not a limiting factor; c = the rate of degradation per fermentative action of b; and t = incubation time in hours. Once calculated, the coefficients a, b and c were applied to the equation proposed by Ørskov and McDonald (1979): ED = a + [(b*c)/(c + k)], where ED = the effective degradability of the nutritional component and k = the feed passage rate. The particle passage rate through the rumen was estimated to be 5%/h, as suggested by Agricultural and Food Research Council [AFRC] (1993). The disappearance value found at time zero ("a") was used to estimate the colonization time (CT) for the DM and NDF, according to Goes et al. (2017), where the parameters "a," "b," and "c" were evaluated by using the Gaus-Newton algorithm: CT = [-ln(a'-a-b)/c].

The NDF degradability was estimated using the model of Mertens and Loften (1980): $Rt = B \times e^{-ct} + I$, where Rt= the fraction degraded in time t; B= the potentially degradable insoluble fraction; and I = the indigestible fraction. After adjusting the NDF degradation equation, the fractions were standardized as proposed by Waldo, Smith and Cox (1972) using the following equations: $Bp = B/(B + I) \times 100$ and $Ip = I/(B + I) \times 100$, where Bp = the standardized potentially degradable fraction (%); Ip= the standardized indigestible fraction (%); B e I= as defined above. The effective NDF degradability was calculated using the model ED = Bp * c/(c + k), where Bp is the standardized potentially degradable fraction (%). The effect of ruminal repletion of potentially degradable (RR1) and nondegradable fractions of NDF (RR2) was estimated by adapting the procedures described by Waldo et al. (1972), according to the following equations: $RR1(h) = Lim \rightarrow \infty \int_0^t B_p \exp^{(-c+k)t} dt$; $RR2(h) = Lim \rightarrow \infty \int_0^t Ip \exp^{kt} dt$; and RR t (h) = RR1+RR2. RRt is total rumen repletion.

Statistical analysis and experimental design

For the variables related to the fermentative characteristic and chemical composition, a completely randomized design with five treatments and six replications was used. The data were submitted to analysis of variance using PROC GLM from SAS (SAS Institute, Inc., Cary, NC, USA). When the "F" test was significant for the treatments, the urea doses were analyzed by means of orthogonal polynomials, and linear and quadratic regression models were tested based on the significance of the parameters. For all tests, $\alpha = 0.05$ was used. For the *in situ* degradability variables, a split plot randomized complete block was used, with five regrowth ages (plots), nine incubation times (subplots) and four

blocks. The different animal weights were the blocking factor. Data were tested via analysis of variance and regression using the MIXED and REG procedure of SAS, version 9.0 (SAS Institute, Cary, NC, USA), respectively, at $\alpha = 0.05$, according to the model: $Yijk = \mu + \tau i + Time\ j + \tau i \times Time\ j + \varepsilon ijk$, where: Yijk is the observation ijk; μ, the overall mean; τ i, the fixed effect of the treatment applied to the plot, with i = 1, 2, 3, 4 and 5; Time, fixed effect of incubation time j to subtract; the random effect of animal k; Ti x Time j, the interaction effect of treatment i and time j; εijk, the random error with mean 0 and variance σ2. Comparisons between the urea doses were performed by breakdown of the sum of squares in orthogonal linear contrasts and quadratic effects, with $\alpha = 0.05$, with subsequent adjustments of the regression equations.

Results

There was a linear increase in the pH ($P < 0.01$) of the pre-dried banana tree pseudostems with the inclusion of urea. There was no change ($P > 0.05$) in the dry matter content, ash, acid detergent fiber (ADF), lignin), non-fibrous carbohydrates (NFC) and total digestible nutrients (TDN); the averages were 31.58, 18.82, 46.43, 9.30, 11.87 and 42.52%, respectively (Table 1).

Table 1
pH value and chemical composition of pre-dried banana tree pseudostem ammoniated with different doses of urea

Item	Urea level (% NM)					SEM	P-value	
	0.0	0.5	1.0	1.5	2.0		L	Q
pH[1]	5.80	6.03	6.07	6.27	6.96	0.15	<0.01	0.07
Dry matter	32.08	33.79	31.02	30.11	30.91	1.95	0.71	0.06
Ash	18.44	18.23	18.58	20.05	18.83	0.64	0.21	0.71
Crude protein[2]	4.70	5.54	5.35	6.67	8.21	0.28	<0.01	0.01
Ether Extract[3]	0.57	1.01	1.61	1.44	2.40	0.26	<0.01	0.08
NDFap[4]	64.23	61.71	61.7	60.29	60.98	1.13	0.04	0.24
Acid detergent fiber	46.48	43.93	48.02	48.98	44.76	1.6	0.75	0.29
Lignin	9.06	8.84	8.53	10.17	9.93	0.46	0.06	0.29
Total carbohydrates[5]	76.27	75.21	74.46	71.83	70.55	0.77	<0.01	0.43
Nonfibrous fiber	12.04	13.5	12.74	11.54	9.57	1.19	0.08	0.11
Total digestible nutrients	40.73	42.66	42.89	42.22	44.14	0.79	0.06	0.74

NM – Natural matter; NDFap – Neutral detergent fiber corrected for ash and protein; SEM – Standard error of the mean; P – probability; L – Linear; Q – Quadratic; Equation; [1]$\hat{Y} = 5.72 + 0.50X$, $R^2 = 0.83$; [2]$\hat{Y} = 4.46 + 1.62X$, $R^2 = 0.87$; [3]$\hat{Y} = 0.59 + 0.81X$, $R^2 = 0.88$; [4] $\hat{Y} = 63.37 - 1.58X$, $R^2 = 0.70$; [5] $\hat{Y} = 76.63 - 2.96X$, $R^2 = 0.96$.

The crude protein content (CP) and ether extract (EE) increased 42.75% and 76.25%, respectively, with the inclusion of 2% urea compared to that of the control group. For each percentage unit of urea inclusion, there was a linear reduction ($P < 0.05$) of 1.58% for the neutral detergent fiber content corrected for ashes and proteins (NDFap)and 2.96% for the total carbohydrate content ($P < 0.01$). The addition of urea for the ammonization of the pre-dried banana tree pseudostems increased and linearly reduced ($P < 0.01$) the soluble fraction (fraction A) and the fraction B1 + B2 of the CP, respectively (Table 2). For the fraction B3 of the CP and the recovery of nitrogen (RN), a quadratic effect was observed ($P = 0.02$), being the maximum and minimum point, respectively, at 1.18% and 1.29% urea.

Table 2
Nitrogen fractionation and nitrogen retention (NR) of pre-dried banana tree pseudostem ammoniated with different doses of urea

Item	Urea level (% NM)					SEM	P-value	
	0	0.5	1	1.5	2		L	Q
A[1]	14.97	26.64	34.39	40.40	60.14	6.24	<0.01	0.54
B1+B2[2]	65.12	49.91	42.61	42.51	35.78	6.12	<0.01	0.84
B3[3]	16.63	19.36	18.88	19.23	18.34	0.70	0.16	0.02
C	3.28	4.09	4.12	4.59	3.54	0.52	0.54	0.11
RN, (%)[4]	-	85.31	71.23	74.78	81.19	2.90	0.50	0.02

A - readily soluble fraction of crude protein; B1+B2 - true protein; C - Indigestible fraction of crude protein; SEM – Standard error of the mean; P – probability; L – Linear; Q – Quadratic; Equation; [1]$\hat{Y}$= 14.48 + 20.82X, R^2= 0.96; [2]$\hat{Y}$= 63.93 + 21.68X, R^2= 0.96; [3]$\hat{Y}$= 16.91 + 4.33X - 1.83X^2, R^2= 0.81; [4]$\hat{Y}$= 105.93 - 52.95X + 20.47X^2, R^2= 0.90.

The readily soluble fraction (Fraction a; P < 0.01), potential degradability (PD; P = 0.01) and effective degradability (ED; P < 0.01) of the DM of the pre-dried banana tree pseudostems linearly increased with the inclusion of urea. The inclusion of 2% urea increased DM of fraction a by 31.42%, PD by 8.8% and ED by 15.49% compared to the control group. The mean values of the rate of degradation per fermentative action of b (c; P < 0.01) and the colonization time (CT; P = 0.01) of the DM were adjusted to the quadratic regression model, with minimum and maximum points of 1.2% and 1.0%, respectively, obtained with the inclusion of urea. Fraction b of DM was not influenced (P > 0.05) by the inclusion of urea, with a mean of 51.60%. For each 1% of urea inclusion, there was a 3.81% reduction in the undegradable DM fraction (UF; Table 3).

Table 3
Ruminal kinetics of dry matter of pre-dried banana tree pseudostem ammoniated with different doses of urea

Item (%)	Urea level (% NM)					SEM	P-value	
	0	0.5	1	1.5	2		L	Q
Fraction a [1]	23.16	26.22	29.09	31.94	33.77	1.64	<0.01	0.66
Fraction b	53.52	52.32	50.98	50.89	50.31	2.05	0.22	0.74
c, %/h[2]	3.40	2.70	3.00	2.50	3.20	<0.01	0.08	<0.01
PD[3]	76.68	78.55	80.07	82.84	84.08	2.22	0.01	0.99
CT, h[4]	5.35	6.47	5.76	6.85	5.15	0.31	0.97	0.01
ED[5]	45.06	45.04	48.26	48.73	53.32	1.82	<0.01	0.32
UF [6]	23.31	21.45	19.92	17.16	15.92	2.22	0.01	0.99

Fraction a - readily soluble fraction; Fraction b - Potentially degradable insoluble fraction; c- Rate of degradation of fraction "b"; PD- potential degradability; CT – Colonization time; ED- effective degradability; k-passage rate (5%/h); UF- Undegradable fraction; SEM – Standard error of the mean; P – probability; L – Linear; Q – Quadratic; Equation; [1]$\hat{Y}$= 23.45 + 5.39X, R^2= 0.99; [2]$\hat{Y}$= 3.2 - 1.2X + 0.5X^2, R^2= 0.89; [3]$\hat{Y}$= 76.62 + 3.82X, R^2= 0.98; [4]$\hat{Y}$= 5.37 + 2.18*X - 1.09X^2, R^2= 0.50; [5]$\hat{Y}$= 55.95 + 3.67X, R^2= 0.84; [6]$\hat{Y}$= 23.37 - 3.81X, R^2= 0.93.

There was no effect (P > 0.05) of the inclusion of urea with the pre-dried banana tree pseudostems on the standardized potential degradable fraction (Bp) of the NDF, with a mean of 80.48% (Table 4). The degradation rate of the Bp fraction (c), CT, ED, undegradable fraction (UF), ruminal repletion of potentially degradable (RR1) and nondegradable fractions of NDF (RR2), and effect of total repletion (RRt) were not modified (P > 0.05) as a consequence of the inclusion of urea.

Table 4
Rumen kinetics of the neutral detergent fiber of pre-dried banana tree pseudostem ammoniated with different doses of urea

Item (%)	Urea level (% NM)					SEM	P-value	
	0	0.5	1	1.5	2		L	Q
Bp[1]	78.45	80.06	80.07	82.14	81.70	1.60	0.11	0.73
c, %/h	2.70	1.80	2.40	2.20	2.50	<0.01	0.95	0.22
CT, h	7.43	9.62	6.95	9.53	7.38	1.05	0.95	0.40
ED, 5%	21.54	16.71	21.35	19.52	22.65	2.08	0.44	0.23
UF [2]	21.55	19.95	19.93	17.86	18.31	1.60	0.11	0.73
RR1	11.96	12.19	10.77	12.17	11.55	0.46	0.58	0.53
RR2	5.57	5.33	8.03	5.29	6.46	0.89	0.55	0.45
RRt	17.54	17.52	18.80	17.45	18.00	0.42	0.53	0.36

Bp – Standardized insoluble but potentially degradable fraction; c- rate of degradation of Bp fraction; CT – Colonization time; ED - effective degradability; UF - standardized undegradable fraction; RR1 - Effect of ruminal repletion of potentially degradable fraction (h); RR2 - Effect of ruminal repletion of undegradable fraction (h); RRt - Effect of total repletion (h); SEM – Standard error of the mean; P – probability; L – Linear; Q – Quadratic; Equation; [1]$\hat{Y}$= 60.93 + 3.83X, R^2= 0.96; [2]$\hat{Y}$= 39.07 - 3.83X, R^2= 0.96.

Discussion

The presence of moisture greater than 50% in the ammoniated substrate favors the hydrolysis of urea with the production of ammonium hydroxide, which in addition to retaining part of the ammonia (NH_3) has an alkalinizing effect, increasing the pH of the ensiled mass (Pires, Carvalho, & Ribeiro, 2010). This increase in pH was verified in the order of 0.5 units for each 1% of urea added during ensiling, reaching a value of 6.96 with the addition of 2% of urea.

In sorghum silage (*Sorghum bicolor* (L.) Moench), Fernandes et al. (2009) found that the addition of urea (0, 2.5, 5 and 7.5% based on the DM) increased 0.07 pH units for each 1% of urea inclusion, reaching 4.3 in the silage with 7.5% inclusion. Oliveira et al. (2014) reported that the ammonia released by urea hydrolysis, in addition to increasing the pH, can inhibit the proliferation of undesirable microorganisms such as fungi and yeasts, promoting conservation of the material. The DM content of the ammoniated banana pseudostems did not vary, with a mean of 31.58%, which is sufficient for the urease (the enzyme present in the ensiled substrate) to be activated and produce ammonia. The CP content of the 2% urea ammoniated pseudostems exceeded the recommended minimum content (70 g kg^{-1} DM) according to Van Soest (1994) as required for growth and reproduction of the ruminal microorganisms. Carvalho et al. (2018) found that the ammonization of millet (*Pennisetum glaucum* [L.] R.Br.) increased the CP content of the diet for confined lambs, but it impaired the DM and CP intake.

According to Fernandes et al. (2009), ammonization of low-quality roughage with urea

increases the CP content and nonprotein nitrogen due to the presence of residual urea, as most of the nitrogen added as urea to silage plants can be recovered either as ammonia or urea. The nitrogen recovery with urea application in the ammonization of the pre-dried banana tree pseudostems was greater than 70%. This recovery is important in ruminant nutrition because soluble nitrogen is essential in the synthesis of microbial proteins, provided there is availability of carbon skeletons (Van Soest, 1994), and is the most expensive nutrient in the diet. According to Schmidt, Wechsler, Vargas and Rossi (2003), nitrogen retention is related to the ureolytic activity responsible for the transformation of urea into ammonia. These authors observed nitrogen retention on the order of 76% in *Brachiaria decumbens* hay ammoniated with 5% of urea in the DM.

Most of the carbon skeletons present in the ruminal environment mainly originate from ruminal degradation of the fibrous fraction of the food. According to Alfaya et al. (2002), among the main objectives of ammonizing low-quality roughage feeds is to promote physico-chemical changes in the constituents of the cell wall solubilizing NDF and hemicellulose with the addition of ammonia sources. In this study, the NDF contents of the ammonia banana tree pseudostems decreased 5.05% with the addition of 2% urea compared to that of the control group (mean of 64.23%), mainly due to hemicellulose solubilization. There are two theories that explain the effect of ammonia on the constituents of the cell walls of plant. The first is termed ammonolysis and is based on the cleavage of ester bonds between the hemicellulose and the lignin with groups or carbohydrate molecules, producing an amide. The second is based on the high affinity between water and ammonia. In this process, alkaline hydrolysis resulting from the reaction of the ammonium hydroxide with the ester bonds between the structural carbohydrates occurs. Alfaya et al. (2002) verified that the effects of roughage ammonization on the levels of ADF and lignin are controversial because they do not always produce a reduction in these fractions. The absence of an alteration in the levels of ADF and lignin in this study may be related to the amount of urea used. The same authors showed that the effects of ammonia on the lignin fraction are only observed at a pH above 8, and values of this order are obtained when using strong alkalis or high ammonia levels. According to the same authors, ammoniated the annoni grass (*Eragrostis plana* Nees) hay with 4% of urea in the DM and did not verify changes in ADF and lignin levels. The interactions of the cell wall components of a plant are complex, consisting of cellulose, hemicellulose and lignin fractions. The steric bonds between lignin and the other two fractions is the factor responsible for the low digestibility of many forages (Van Soest, 1994). During the ammonization process, ammonia reacts with water to form ammonium hydroxide, breaking the linked ester type between the lignin, cellulose and hemicellulose, increasing the access of rumen microorganisms to these fibrous carbohydrates (Carvalho et al., 2018). The improvement in potential and effective DM degradation with urea may result from an increased soluble nitrogen fraction and partial solubilization of cellulose crystalline microfibrils that may limit structural carbohydrate digestion by rumen microorganisms (Leal, Shimada, & Hernández, 1994). The inclusion of 2% of urea in pseudostem ammonization changed the PD from 76.68% (0% urea) to 84.08%. Wang et al. (2016) evaluated the potential degradability of banana tree pseudostems *in natura* and verified values of approximately 88% in the DM. Carmo et al. (2018) highlighted the potential degradation of banana tree pseudostems in diets for lambs and observed values of approximately 79.80%. These values suggest the potential for rumen degradation of pseudostems carbohydrates under different processing forms for ruminant nutrition.

According to Van Soest (1994), carbohydrates are the primary source of carbonic skeletons for microbial protein synthesis when nitrogen is a

limiting factor. At a level greater than 1% of urea inclusion, there was a shorter DM colonization time by ruminal microrganisms, which is important in the synthesis of volatile fatty acids and microbial proteins in the rumen. The banana tree pseudostems, ammoniated with 2% urea in natural matter, have the potential for use in ruminant nutrition, particularly for maintaining animals or composing diets for animals in production. Carmo et al. (2018) evaluated the inclusion of 40% pseudostem hay in the diet for confined lambs and did not observe changes in nutrient intake. However, pseudostem hay increased the concentration of propionic and butyric acid in the rumen.

Regarding the absence of a ruminal repletion effect, this is probably due to the lack of alteration of the standardized indigestible fraction between the treatments, with an average of 19.52%. The reduction in the NDF contents upon urea addition was not sufficient to alter ruminal repletion, as justified by the high proportion of the standardized insoluble potentially degradable NDF fraction (80.48%) and no observation of changes in the passage rates. Wang et al. (2016) observed ruminal degradation of 70% NDF in silage banana pseudostems for 80 days, demonstrating the high availability of the fibrous fraction to ruminal microorganisms.

Conclusion

The ammonization of pre-dried banana tree pseudostems with 2% of urea improves the chemical composition and rumen degradability of the dry matter.

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