# NUTRITIVE VALUE OF ELEPHANT GRASS HAY AMMONIATED BY UREA

## *VALOR NUTRITIVO DO FENO DE CAPIM ELEFANTE AMONIZADO COM UREIA*

**Leonardo Fiusa de MORAIS[1*]; João Carlos de Carvalho ALMEIDA[1]; Delci de Deus NEPOMUCENO[1]; Rafaela Scalise Xavier de FREITAS[1]; Bárbara Maria Gomes de MELO[1]; Joice Fátima Moreira SILVA[1]**
1. Institute of Animal Science, Federal Rural University of Rio de Janeiro, Seropedica, RJ, Brazil. *leonardofiusa @yahoo.com.br

**ABSTRACT:** The aim of this study was to evaluate the effect of ammoniation by urea on the nutritional value of elephant grass hay harvested after flowering. A completely randomized design, in double factorial designs with an additional treatment: 4 urea doses (2, 4, 6 and 8%) x 2 treatment periods (30 and 45 days) + 1 (Control) with four replicates each, was employed. Dry matter, ash, ether extract, neutral detergent fiber, acid detergent fiber, cellulose, lignin, neutral detergent fiber corrected for the ash and the protein, total nitrogen, acid detergent insoluble nitrogen, neutral detergent insoluble nitrogen, non-protein nitrogen, in vitro gas production and carbohydrates fractionation were analyzed. The treatments influenced the contents of DM, EE, NDF, ADF, lignin, cellulose, NDFap, fraction A + B1, fraction B2, fraction C, TN, NPN, ADIN, NDIN, L and $V_{f2}$. There was a positive linear effect of urea dose for NDF, ADIN, NDIN and L, positive linear effect on fraction A + B1, NT and NPN, and positive quadratic effect for $V_{f2}$, with absolute maximum point of 4.5%. Elephant grass hay harvested after flowering has its nutritional value improved, with a minimum dose of 4.5% urea on a dry matter basis.

**KEYWORDS:** Chemical treatment. Fiber. In vitro gas production. Low quality forages. Pennisetum purpureum.

## INTRODUCTION

In Brazil, the elephant grass (Pennisetum purpureum Schum.) is a forage plant of important use in livestock feeding, both for its great dry mass production and for its longevity and nutritive value (DIEHL et al., 2013). However, like most tropical forages, it has low nutritional value when harvested at an advanced stage of maturity, and as forage is the main component of ruminant diets in Brazil, the low-quality forage might result in low animal productivity (DÍAZ et al., 2015).

Elephant grass is mainly grown in the form of spare forage areas, which are designated for cutting and provided chopped in the trough as pasture supplementation over the dry season. However, it is usually harvested at an advanced stage of maturity, when it presents greater forage mass production per area, but low nutritional value (GUEDES et al., 2006). The maturity of the forage plant is an indicator of its fiber content, considering there is an increase of neutral detergent fiber (NDF) and acid detergent fiber (ADF) as the plant gets older (LU; KAWAS; MAHGOUB, 2005), and the NDF has a close relationship with the nutritional value of the forage, acting as a predictor of digestibility (DANIEL et al., 2014).

An alternative to optimize the use of low quality forages for ruminants is through techniques of treatment, which may be chemical, physical and biological, all with the principle of making them more digestible for ruminants, especially by acting on the fiber portion. Among the chemical treatments, the ammoniation with urea has stood out due to the ease of execution and accessibility to the farmer (NGUYEN et al., 2012). The ammoniation promotes higher degradation of cellulose and hemicellulose, due to the expansion of its molecules with rupture of hydrogen bonds and increased fiber hydration (MORAIS et al., 2017), furthermore, this technique leads to an increase in the crude protein content of the roughage, promoted by the addition of non-protein nitrogen derived from the urea hydrolysis (NISA et al., 2007), and increased digestibility (GARCÍA-MARTÍNEZ et al., 2009).

Some factors that affect the efficiency of the treatments by ammoniation are forage quality, urea dose applied, moisture content of the roughage and treatment duration (RAMÍREZ et al., 2007). Thus, studies that aim to determine the optimal dose of urea to be applied on the roughage, as well as the treatment period, promoting better responses in terms of nutritional value, consolidate the use of the ammoniation technique, increasing its efficiency by reducing the cost of treatment. Under the hypothesis that there is an increase in nutritional value of elephant grass hay harvested after flowering and ammoniated with urea during two periods of

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treatment, the aim of this study was to evaluate the application of 2, 4, 6 and 8% of urea on a dry matter basis, for 30 and 45 days of treatment on the nutritional value of hay.

## MATERIAL AND METHODS

The study was conducted in the Instituto of the Zootecnia of the Universidade Federal Rural do Rio de Janeiro, located in Seropédica – RJ (Latitude: 22 º46 ’59 ’’ S. Longitude: 43 º40 ’45 ’’ W and altitude of 33 m). The study was approved by the Research Ethics Committee of UFRRJ, with case number: 23083.010666/2014-11.

The elephant grass (Pennisetum purpureum, Schum.) cv. Cameroon was harvested from an area of 400 $m^2$, originally a spare forage area, located in the Caprine Sector of Instituto of the Zootecnia of the UFRRJ. A soil sample of 0-20 cm deep was collected, which had the following fertility values: pH ($H_2O$) = 6.4; Calcium = 4.40 cmol / $dm^3$; Magnesium = 3.10 cmol / $dm^3$; Aluminum = 0.0 cmol/$dm^3$; Hydrogen + aluminum = 3.80 cmol / $dm^3$; Organic carbon = 9.75 cmol / $dm^3$; Base saturation = 67%; Phosphorus = 133 mg/L; and Potassium = 68 mg/L. On December 16th of 2014, an uniformization cut was executed, when it was applied 100 kg N, 80 kg $P_2O_5$ and 50 kg $K_2O$, and after a month, it was also applied 100 kg N and 50 kg $K_2O$.

The grass was harvested after flowering in May 15th when it was around 5 months old. Its chemical composition is described in Table 1.

**Table 1.** Chemical composition of elephant grass harvested after flowering.

| Components | Mean (95% CI) |
|---|---|
| Dry Matter[a] | 303,4±17,16 |
| Ash[b] | 57,1±2,84 |
| Ether extract[b] | 13,4±0,53 |
| Crude protein[b] | 53,0±0,34 |
| Neutral detergent fiber [b] | 632,1±12,72 |
| Acid detergent fiber[b] | 393,0±4,91 |
| Acid detergent insoluble nitrogen[c] | 113,5±7,16 |
| Neutral detergent insoluble nitrogen[c] | 186,5±11,16 |
| Hemicellulose[b] | 239,1±12,1 |
| Cellulose[b] | 293,2±5,74 |
| Lignin[b] | 82,6±4,15 |

[a]$g.kg^{-1}$ of hay; [b]$g.kg^{-1}$ of DM; [c]$g.kg^{-1}$ of Nitrogen.

The treatments consisted in a combination of urea doses application: 2, 4, 6 and 8%, and treatment periods of 30 and 45 days, and control (hay not ammoniated). A completely randomized design, in double factorial designs with an additional treatment: 4 urea doses (2, 4, 6 and 8%) x 2 treatment periods (30 and 45 days) + 1 control (no ammoniation) with four replicates each, was employed.

The grass was cut, chopped, spread on a plastic tarp, and constantly stirred to promote uniform dehydration until material reached a point of hay (893.7 $g.kg^{-1}$ of dry matter). The ammoniation was performed by storing 500g of hay in 15kg buckets, into which it was added a solution of urea diluted in water. The amount of water used was calculated to reduce the dry matter (DM) content of the hay to 700 $g.kg^{-1}$. After application of the solution, the buckets were hermetically sealed. At the end of each treatment period, the buckets were held open for 48 hours to remove the excess of ammonia. Followed by sampling of the material to be dried up at 55 °C in a forced air circulation drying oven for 72 hours. After that period, the hay was processed in a mill type Willey with a 1 mm sieve screen for the analysis of chemical composition and in vitro gas production.

The chemical composition was determined regarding the dry matter (DM, Method 934,01), ash (Method 924,05), ether extract (EE, Method 960.39), by the Goldfish method of hot extraction with ether and total nitrogen by the Kjeldahl method (TN, Method 984,13) according to AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose and lignin were determined according to the methodology described by Van Soest et al., (1991), and the hemicellulose was calculated through the difference between NDF and ADF. The determination of nonprotein nitrogen (NPN) soluble content was obtained by the difference of the precipitated protein in trichloroacetic acid solution and that which remained soluble in the solution. The content of neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN), were calculated through the nitrogen concentration retained in the solution of ADF and NDF, respectively, according to the methodology described by Licitra, Hernandez and Van Soest (1996).

Carbohydrate fractionation was obtained according to the methodology described by Sniffen et al. (1992), with the fractions A + B1 being represented by the non-fibrous carbohydrates: NFC = 100 - (%CP + %EE + %NDFap + %Ash), and the total carbohydrates: TC = 100 - (%CP + %EE + %Ash). The fraction C was determined by the percentage of lignin multiplied by 2.4, and the fraction B2 obtained by the difference between NDFap and Fraction C, where NDFap corresponds to the neutral detergent fiber corrected for the ash and the protein.

The in vitro incubations for gas production determination were carried out according to Goering and Van Soest (1970). Flasks of 100 mL serum amber bottles, with approximately 0.5 g of sample incubated with 40 mL of reduced medium culture and 10 mL of ruminal inoculum, sealed with rubber covers and aluminum seals. The culture medium was obtained according to the methodology described by Hall and Mertens (2008), with the ruminal inoculum being obtained from three sheep rumen fistulated, fed once a day with corn silage and soybean meal. The time profiles of the cumulative gas production were obtained using a non-automated device, where the gas pressure was obtained by manometric readings and the volume measured by means of a graduated pipette (ABREU et al., 2014). The pressure and volume measurements were performed at the times 0, 2, 4, 6, 8, 10, 12, 16, 20, 30, 36, 48, 72 and 96 hours of incubation.

The models used to estimate the kinetics of gas production were adjusted to the degradation profiles using the NLMIXED procedure of SAS (version 9.4), and the model that best adjusted, according to the Akaike information criteria, was the biphasic model composed of the Monomolecular and GNG1 models (VIEIRA; TEDESCHI; CANNAS, 2008), according to equation:

$$V_t = V_{f1} \times (1 - \exp(-k_1 t)) + V_{f2} \times \left(1 - \left(\delta^N \exp(-k_2 t) + \exp(-\lambda t) \sum_{i=1}^{N-1} \frac{(1-\delta^{N-i})(\lambda t)^i}{i!}\right)\right);$$

in which: $V_t$ cumulative gas production over time (t, h); $V_{f1}$ and $V_{f2}$: Gas productions of fast and slow digestible substrates, respectively (mL/0,1 g DM); $k_1$ and $k_2$: Mean digestion time of fast and slow digestible substrates, respectively (%$h^{-1}$); N: Is a integer positive number that represents the order of time dependency; $\lambda$ is the asymptote of the rate of preparation for digestion (%$h^{-1}$), and $\delta = \lambda/(\lambda - k)$ is a constant.

The means were submitted to an analysis of variance, and in case of significance, a regression analysis was performed for urea doses and the means were compared by Tukey's test for treatment periods using the ExpDes.pt package from the software R (FERREIRA; CAVALCANTI; NOGUEIRA, 2013).

## RESULTS

The control treatment and the combination of factorial treatments for dry matter were significantly different (table 2). For the variables ash and ether extract, there was no effect (p> 0.05) of the dose, treatment period and interaction between dose and treatment period.

**Table 2.** Chemical composition of elephant grass hay ammoniated by urea in two treatment periods (30 and 45 days).

| Urea dose (% DM) | Variable | | | | | |
|---|---|---|---|---|---|---|
| | Dry Matter[a] | | ash[b] | | Ether Extract[b] | |
| | 30 | 45 | 30 | 45 | 30 | 45 |
| Control | 893.7$^A$ | | 83.2$^A$ | | 14.6$^A$ | |
| Mean (Factorial) | 760.5$^B$ | | 84.2$^A$ | | 14.2$^A$ | |
| 2 | 772.8 | 750.3 | 85.1 | 84,5 | 13,6 | 14,4 |
| 4 | 757.7 | 748.6 | 88.2 | 83,3 | 14 | 14,4 |
| 6 | 761.5 | 759.5 | 86.2 | 84,2 | 13,2 | 15,9 |
| 8 | 770.4 | 763.6 | 88.1 | 81,2 | 13,4 | 14,2 |
| Mean (Period) | 765.6 | 755.5 | 86.9 | 83,3 | 13,6 | 14,7 |
| CV (%) | 1.93 | | 6.19 | | 8.75 | |
| | P values | | | | | |
| Polinomial efects | NS | | NS | | NS | |
| Control *vs* Factorial | * | | NS | | NS | |
| Period *vs* Urea. | NS | | NS | | NS | |
| Period | NS | | NS | | NS | |

Means followed by the same capital letter in the same column, do not differ by Tukey's test at 5% of probability; NS: Not significant. *P< 0.01; [a]g.kg$^{-1}$ of hay; [b]g.kg$^{-1}$ of dry matter.

The control and the combination of factorial treatments for NDF, ADF, lignin and cellulose were significantly different, but there was no interaction (p> 0.05) between urea dose and treatment period. No significant effect (p> 0.05) of urea dose was observed for the components of the fibrous fraction, but there was effect (p <0.05) of treatment period, and the lowest NDF values were observed in the hay treated for 45 days (Table 3).

**Table 3.** Components of the fibrous fraction (g.kg$^{-1}$ DM), of elephant grass hay ammoniated by urea in two treatment periods (30 and 45 days).

| Urea dose (% DM) | Variable | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NDF | | ADF | | Lignin | | Cellulose | | Hem | |
| | 30 | 45 | 30 | 45 | 30 | 45 | 30 | 45 | 30 | 45 |
| Control | 758.7$^{A}$ | | 470.6$^{A}$ | | 91.1$^{A}$ | | 347.6$^{A}$ | | 288.5$^{A}$ | |
| Mean (Factorial) | 738.6$^{B}$ | | 442.9$^{B}$ | | 78.4$^{B}$ | | 330.7$^{B}$ | | 295.5$^{A}$ | |
| 2 | 750.5 | 737.5 | 449.3 | 444.3 | 77.6 | 78.3 | 339.5 | 331.1 | 300.1 | 293.2 |
| 4 | 742.3 | 735.2 | 442.2 | 444.6 | 76.9 | 75.1 | 330.6 | 332.4 | 299.4 | 290.4 |
| 6 | 745.4 | 725.5 | 447.7 | 435.5 | 82.8 | 86.2 | 332.3 | 325.5 | 298.6 | 289.3 |
| 8 | 734.2 | 738.1 | 432.3 | 447.4 | 72.1 | 78.7 | 327.3 | 327.3 | 302.1 | 291.3 |
| Mean (period) | 743.1$^{a}$ | 734.1$^{b}$ | 442.8 | 442.9 | 77.4 | 79.6 | 332 | 328.8 | 299.8 | 290.8 |
| CV (%) | 1.7 | | 11.8 | | 10.4 | | 18.3 | | 14.8 | |
| | P values | | | | | | | | | |
| Polinomial efects | NS | | NS | | NS | | NS | | NS | |
| Control *vs* Factorial | ** | | * | | * | | * | | NS | |
| Period *vs* Urea. | NS | | NS | | NS | | NS | | NS | |
| Period | * | | Ns | | Ns | | Ns | | Ns | |

Means followed by the same capital letter in the same column and same small letter in the same line, do not differ by Tukey's test at 5% of probability; NDF: Neutral detergent fiber, ADF: Acid detergent fiber, Hem: Hemicellulose; NS: Not significant. *P< 0.01, **P<0.05.

There was significant difference (p <0.01) between the control and the combination of factorial treatments for NDFap, fraction A + B1, fraction B2 and fraction C. A linear decreasing effect of urea dose was observed for NDFap and linear increasing effect of the dose for Fraction A + B1 (Table 4).

**Table 4.** Carbohydrate Fractionation, of elephant grass hay ammoniated with urea in two treatment periods (30 and 45 days).

| Urea dose (% DM) | Variable | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NDFap[a] | | TC[a] | | A + B1[b] | | C[b] | | B2[b] | |
| | 30 | 45 | 30 | 45 | 30 | 45 | 30 | 45 | 30 | 45 |
| Control | 641.5$^{A}$ | | 821.3$^{A}$ | | 179.9$^{B}$ | | 218.6$^{A}$ | | 422.4$^{A}$ | |
| Mean (Factorial) | 621.6$^{B}$ | | 822.9$^{A}$ | | 201.2$^{A}$ | | 188.4$^{B}$ | | 433.4$^{A}$ | |
| 2 | 630.8 | 633.3 | 823.2 | 824.3 | 192.3 | 190.9 | 186.4 | 188.1 | 444.4 | 445.2 |
| 4 | 617.9 | 611.9 | 819.6 | 821.6 | 201.6 | 209.6 | 185.6 | 180.4 | 433.3 | 431.6 |
| 6 | 623.6 | 625.7 | 822.3 | 826.2 | 198.6 | 200.4 | 199.8 | 207.1 | 424.5 | 418.7 |
| 8 | 613.6 | 616.3 | 819.9 | 826.3 | 206.3 | 210 | 173.1 | 189.9 | 440.5 | 427.4 |
| Mean (period) | 621.5 | 621.8 | 821.3 | 824.6 | 199.7 | 202.7 | 186.2 | 191.4 | 435.7 | 430.7 |
| CV (%) | 1.7 | | 11.8 | | 10.4 | | 18.3 | | 14.8 | |
| | | P values | | | | | | | | |
| Polinomial efects | | *L | | NS | | *L | | NS | | NS |
| Control *vs* Factorial | | ** | | * | | * | | * | | NS |
| Period *vs* Urea. | | NS | | NS | | NS | | NS | | NS |
| Period | | NS | | NS | | NS | | NS | | NS |

Means followed by the same capital letter in the same column do not differ by Tukey's test at 5% of probability; NS: Not significant (P>0,5); **(P < 0,05); *(P < 0,01); L: linear effect; NDFap: Neutral detergent fiber corrected for ash and protein, TC: Total Carbohydrates, A + B1: fraction A + B1, B2: fraction B2, C: fraction C; [a]g.kg$^{-1}$ of dry matter; [b]g.kg$^{-1}$ of Carbohydrates.

The treatments (dose of urea x period) promoted statistic differences for TN, NPN, ADIN and NDIN, in comparison to the control treatment, and there was interaction between treatment period and urea dose for NPN, with higher NPN values observed in treatment for 45 days and applications of 2 and 8% of urea. Positive linear effect (p <0.05) of urea dose for TN and NPN, and negative linear effect (p <0.05) on ADIN and NDIN, and effect (p <0.01) of treatment period for NDIN, where higher

NDIN values were obtained for hay treated for 45 days (Table 5).

**Table 5.** Nitrogen fractionation of elephant grass hay ammoniated by urea in two treatment periods (30 and 45 days).

| Urea dose (% DM) | Variable | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | TN[a] | | NPN[b] | | ADIN[b] | | NDIN[b] | |
| | 30 | 45 | 30 | 45 | 30 | 45 | 30 | 45 |
| Control | $12.4^{B}$ | | $212.3^{B}$ | | $108.0^{A}$ | | 269.8 | |
| Mean (Factorial) | $22.8^{A}$ | | $490.3^{A}$ | | $84.7^{B}$ | | 211.5 | |
| 2 | 17.2 | 17.1 | $344.7_{b}$ | $420.7_{a}$ | $108.7_{a}$ | $99.7_{a}$ | 240.7 | 275.4 |
| 4 | 20.9 | 19.4 | $440.5_{a}$ | $400.4_{a}$ | $87.3_{a}$ | $93.8_{a}$ | 222.2 | 263.6 |
| 6 | 24.2 | 22.8 | $525.6_{a}$ | $516.4_{a}$ | $80.1_{a}$ | $84.0_{a}$ | 200.8 | 207.2 |
| 8 | 29.4 | 31.5 | $619.7_{b}$ | $656.6_{a}$ | $69.4_{a}$ | $54.3_{b}$ | 136.1 | 145.8 |
| Mean (Period) | 22.9 | 22.6 | 482.1 | 498.5 | 86.2 | 83 | $200.0^{b}$ | $223.0^{a}$ |
| CV (%) | 7.45 | | 7.39 | | 9.19 | | 9,73 | |
| P values | | | | | | | | |
| Polinomial efects | *L | | *L | *L | *L | *L | *L | |
| Control *vs* Factorial | * | | * | | * | | NS | |
| Period *vs* Urea. | * | | * | | ** | | NS | |
| Period | NS | | NS | | NS | | ** | |

Means followed by the same capital letter in the same column and same small letter in the same line, do not differ by Tukey's test at 5% of probability; NS: not significant (P>0,5); ** (P < 0,05); * (P < 0,01); L: linear effect; TN: Total nitrogen; NPN: Non protein nitrogen, ADIN: Acid detergent insoluble nitrogen, NDIN: Neutral detergent insoluble nitrogen; [a]$g.kg^{-1}$ of dry matter; [b]$g.kg^{-1}$ of total nitrogen.

The treatments promoted differences for L and $V_{f2}$, in comparison to the control treatment, and higher $V_{f2}$ was observed in those with higher volume for hay treated for 45 days (Table 6). Positive quadratic effect on $V_{f2}$ with absolute maximum point of 4.5% of urea, and negative linear effect for lag time (L) were observed.

**Table 6.** Gas production parameters[a] of elephant grass hay ammoniated by urea in two treatment periods (30 and 45 days).

| Urea dose (% DM) | parameters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $V_{f1}$ | | $k_1$ | | L | | $V_{f2}$ | | $k_2$ | |
| | 30 | 45 | 30 | 45 | 30 | 45 | 30 | 45 | 30 | 45 |
| Control | 7.78 | | 0.159 | | $0.92^{A}$ | | $15.16^{B}$ | | 0.0160 | |
| Mean (Factorial) | 8.14 | | 0.168 | | $0.77^{B}$ | | $16.78^{A}$ | | 0.0166 | |
| 2 | 7.93 | 7.85 | 0.162 | 0.176 | 0.83 | 0.78 | 16.3 | 16.93 | 0.016 | 0.0171 |
| 4 | 8.56 | 8.89 | 0.171 | 0.174 | 0.8 | 0.84 | 16.33 | 17.26 | 0.0169 | 0.0163 |
| 6 | 8.07 | 8.37 | 0.169 | 0.161 | 0.76 | 0.75 | 16.27 | 18.57 | 0.0169 | 0.0183 |
| 8 | 7.61 | 7.75 | 0.175 | 0.163 | 0.75 | 0.77 | 16.29 | 16.37 | 0.0166 | 0.0148 |
| Mean (Period) | 8.04 | 8.24 | 0.169 | 0.168 | 0.77 | 0.78 | $16.30^{b}$ | $17.27^{a}$ | 0.0166 | 0.0166 |
| CV (%) | 1.95 | | 7.68 | | 8.83 | | 5.47 | | 17.72 | |
| P values | | | | | | | | | | |
| Polinomial efects | *Q | | NS | | *L | | NS | | NS | |
| Control *vs* Factorial | NS | | * | | * | | * | | NS | |
| Period *vs* Urea. | NS | | NS | | NS | | NS | | NS | |
| Period | NS | | NS | | NS | | ** | | NS | |

Means followed by the same capital letter in the same column and same small letter in the same line, do not differ by Tukey's test at 5% of probability; NS: not significant (P>0.5); ** (P < 0,05); * (P < 0,01); L: linear effect; Q: quadratic effect; [a]$V_{f1}$ and $V_{f2}$: Gas production of fast and slow digested substrates, respectively (mL/0,1 g DM); $k_1$ and $k_2$: Mean digestion time of fast and slow digested substrates, respectively ($\%h^{-1}$); L: Lag time (h).

## DISCUSSION

The reduction in the dry matter content of ammoniated corn straw with 3% of urea was observed by Moreira Filho et al. (2013), and these authors attributed the reduction in DM content to the addition of water to the roughage during ammonization, which was necessary to reduce the dry matter content to 700 $g.kg^{-1}$. Ferreira and Zanine (2013) ammoniated Tanzania grass hay with 1.5, 2.5

and 3.5% of urea based on DM, and no alteration in ether extract and ash content was observed in comparison to the control treatment. Pádua et al. (2011) treated Paspalum notatum hay with 0. 0.5, 1, 1.5, 2, 2.5% urea for 21, 28 and 35 days of treatment period, and did not observe a significant difference ($p > 0.05$) between the control and the urea doses and treatment periods. According to these authors, dry matter and ash are variables influenced by the moisture content of the forage at the moment of the ammonization, but not during the treatment period.

Sarwar et al. (2006), ammoniated wheat straw with 0, 2 and 4% of urea for 20, 30 and 40 days and observed reduction of the NDF content with the increase of the treatment period, but did not observe difference between the periods 30 and 40 days of treatment. Wanapat et al. (2009) ammoniated rice straw with 5.5% urea, and obtained a reduction from 849 to 720 $g.kg^{-1}$ on NDF, and from 613 to 535 $g.kg^{-1}$ on ADF, in comparison to the control treatment. Dean et al. (2008) ammoniated two tropical grasses and observed a reduction from 485 to 467 $g.kg^{-1}$ on ADF content for Coastal Bermudagrass, but observed no significant effect ($p > 0.05$) for Pensacola Bahiagrass. The reductions in the content of the fiber components occur due to the breakdown of the bonds between lignin and the carbohydrates of the cell wall (cellulose and hemicellulose) (GARCÍA-MARTÍNEZ et al., 2009). Moreover, Abo-Donia et al. (2014), highlights that ammoniation causes changes in the cells of the vascular system, and rupture of internal cuticular surfaces.

Reductions in NDFap levels indicate an increase in fiber solubility, and improvements in nutritional aspect, since this is represented by the fibrous carbohydrates of slow degradation by the ruminal microorganisms. The A + B1 fraction of carbohydrates is represented by soluble sugars with rapid degradation by the ruminal microorganisms (SNIFFEN et al., 1992), and its increase represents an increase of energy source for the development of those microorganisms. Dean et al. (2008), in their study with ammoniation of pensacola bahiagrass and coastal bermudagrass hay, observed an increase in the soluble carbohydrate content attributed to the treatment with urea that promoted the hydrolysis of the fiber, increasing the content of soluble compounds.

An effect of the ammonia action on the forage is the disarrangement of the complex formed by the components of the fiber (cellulose, hemicellulose and lignin), offering to the microorganisms greater area of exposure and, consequently, increasing the solubility of the fiber fractions (ABO-DONIA et al., 2014). This may increase the efficiency of microbial synthesis and animal performance, since A + B1 fraction provides energy faster to the rumen microorganisms (PEREIRA et al., 2010), while fraction C indicates the fraction of carbohydrates unavailable in the digestive compartments of ruminants (FAVORETO et al., 2008).

Gobbi et al. (2005) ammoniated *Urocloa decumbens* hay with 0; 2; 4; 6; 8 and 10% urea, and they obtained a linear increase of total nitrogen, and linear reduction ADIN/TN and NDIN/TN. From these results, the authors affirmed that the increase in the available nitrogen content in function urea levels shows that the addition of nonprotein nitrogen (NPN) promoted dilution of NDIN and ADIN contents in relation to total nitrogen (TN). Abo-Donia et al. (2014) obtained an increase in non-protein nitrogen from 0.04 to 1.65 when ammoniated peanut hulls with 5% of urea compared to non-ammoniated peanut hulls. Those authors, attributed to the addition of nonprotein nitrogen (NPN) by urea, an increased supply of nitrogen to the ruminal microorganisms.

The increase in gas production from the fibrous fraction, is due to the increased solubility of this fraction, and consequently greater accessibility by the ruminal microorganisms when the hay was treated for 45 days. Our results agree with those of Napasirth, Wanapat and Berg (2012), which ammoniated rice straw with urea and obtained an increase from 60.2 to 83.2 ml in the volume of gas from the fibrous fraction, and attributed that increase to the improvement of fiber digestibility, by breaking down the bonds between carbohydrates and lignin present in the fiber.

In addition, the urea treatments increase the nitrogen offered to the microorganisms, through the hydrolysis of urea, serving as a source of non-protein nitrogen for the fermentation of fiber (GARCÍA-MARTÍNEZ et al., 2009). While reductions in the lag time (L), indicate a greater efficiency in the fermentative activity of the microorganisms, since they are affected by the presence of inhibitory substances to ruminal fermentation such as lignin (ABREU et al., 2014).

## CONCLUSIONS

Urea ammoniation provides improvements in the nutritive value of elephant grass hay harvested at an advanced stage of maturity (after flowering) due to fiber reduction, associated with an increase in nitrogen and reduction of the time of colonization of the substrate by the ruminal microorganisms.

The minimum dose that promotes improvements is 4.5% of urea, and a period of 45 days of treatment.

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**RESUMO:** Objetivou-se avaliar o efeito da amonização com ureia sobre o valor nutritivo do feno de capim elefante colheitado após florescimento. O estudo foi delineado, em esquema fatorial duplo com um tratamento adicional: 4 doses de ureia (2, 4, 6 e 8%) x 2 período de tratamento (30 e 45 dias) + 1 tratamento controle, com 4 repetições cada. As variáveis analisadas foram: matéria seca (MS), cinzas, extrato etéreo (EE), fibra em detergente neutro (FDN) e ácido (FDA), FDN corrigida para cinzas e proteínas (FDNcp), celulose, lignina, nitrogênio total (NT), nitrogênio insolúvel em detergente ácido (NIDA) e neutro (NIDN), nitrogênio não proteico (NNP). Produção de gases in vitro proveniente dos carboidratos não fibrosos ($V_{f1}$) e fibrosos ($V_{f2}$), taxa de fermentação dos carboidratos não fibrosos ($k_1$) e fibrosos ($k_2$) e tempo de colonização bacteriana do substrato (L), além do fracionamento de carboidratos. Os tratamentos influenciaram os teores de MS, EE, FDN, FDA, lignina, celulose, FDNcp, fração A + B1, fração B2, fração C dos carboidratos, NT, NNP, NIDA, NIDN, L e $V_{f2}$. Houve efeito linear decrescente de dose de ureia para FDNcp, NIDA, NIDN e L, crescente para fração A+B1, NT e NNP, e, quadrático crescente de dose de ureia para $V_{f2}$, com ponto máximo absoluto de 4,5% de ureia obtido após derivar a equação de regressão aos 45 dias de tratamento do feno. Concluindo que feno de capim elefante colheitado após florescimento tem seu valor nutricional melhorado, com dose mínima de 4,5% de ureia em base da matéria seca.

**PALAVRAS-CHAVE:** Fibra. Forragens de baixa qualidade. Pennisetum purpureum. Produção de gás in vitro. Tratamento químico.

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