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# Eggshell as a source of calcium in the production, nutrition and bromatological composition of 'Piatã' and 'Marandu' grasses

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**Key words:**
pasture fertilization
alternative sources of nutrients
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*Urochloa brizantha*

**A B S T R A C T**
The demand for environmentally sustainable agricultural production systems encouraged this study, which evaluated the productive aspects and nutritional status of 'Piatã' palisadegrass and productive aspects and bromatological composition of 'Marandu' palisadegrass fertilized with eggshell, replacing other sources of calcium. 'Piatã' palisadegrass was grown in the field, in a randomized block design, and 'Marandu' palisadegrass in pots, in a completely randomized design, both with eggshell doses equivalent to 0, 78, 156, 234, 312 and 390 kg ha$^{-1}$ of total calcium, using four replicates. The productive aspects of 'Piatã' and 'Marandu' grasses were not significantly altered by the eggshell doses, as well as the contents and accumulations of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Zn in the 'Piatã' palisadegrass and dry mass, neutral detergent fiber, acid detergent fiber, hemicellulose, crude protein, digestible energy, metabolizable energy and the apparent digestibility of dry mass in the 'Marandu' palisadegrass. As a source of calcium, eggshell did not increase the mass production of the forages and did not promote improvements in the nutritional status of 'Piatã' palisadegrass and bromatological composition of 'Marandu' palisadegrass.

**Palavras-chave:**
adubação de pastagens
fontes alternativas de nutrientes
subprodutos industriais
sustentabilidade ambiental
*Urochloa brizantha*

## Casca de ovo como fonte de cálcio na produção, nutrição e composição bromatológica dos capins Piatã e Marandu

**R E S U M O**
A demanda por sistemas de produção agrícola ambientalmente sustentável estimulou a condução desse estudo no qual foram avaliados os aspectos produtivos e o estado nutricional do capim Piatã além de aspectos produtivos e composição bromatológica do capim Marandu fertilizados com casca de ovo em substituição a outras fontes de cálcio. O crescimento do capim Piatã ocorreu em campo, em delineamento de blocos ao acaso e do capim Marandu em vasos, em delineamento inteiramente ao acaso, ambos com doses de casca de ovo equivalentes a 0, 78, 156, 234, 312 e 390 kg ha$^{-1}$ de cálcio total, fazendo-se uso de quatro repetições. Os aspectos produtivos do capim Piatã e do capim Marandu não foram alterados de forma significativa pelas doses de casca de ovo, tal como as concentrações e os acúmulos de N, P, K, Ca, Mg, S, B, Cu, Fe, Mn e Zn do capim Piatã e os teores de matéria seca, fibra em detergente neutro, fibra em detergente ácido, hemicelulose, proteína bruta, energia digestível, energia metabolizável e a digestibilidade aparente da matéria seca do capim Marandu. Como fonte de cálcio a casca de ovo não aumentou a produção de massa das forrageiras e não promoveu melhorias no estado nutricional do capim Piatã nem na composição bromatológica do capim Marandu.

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## Introduction

Adequate availability of nutrients in pastures of tropical grasses, such as the species *Urochloa brizantha* (Syn. *Brachiaria brizantha*), which occupies large areas in Brazil, is fundamental to maintain high yields and improve forage quality (Primavesi et al., 2006). However, farmers neglect the practice of fertilization or provide only formulations with NPK (N-$P_2O_5$-$K_2O$), which can cause lower sustainability of the pasture ecosystem in the long term (Quadros et al., 2002; Barcellos et al., 2008). It should be pointed out that, in Brazil, extensive areas of pasture are cultivated in soils with low natural fertility, which have low contents of calcium, magnesium, sulfur (Oliveira et al., 2009) and micronutrients. In this context, it is important to evaluate nutritional, bromatological and productive aspects of forages when there is the supply of other nutrients such as calcium, in order to optimize the recommendation of fertilization for pastures (Silveira & Monteiro, 2011).

Calcium performs important physiological functions in plants, as a regulator of cell homeostasis, enzyme activator and participating in the absorption of ions, besides being a structural component of the cell wall (Marschner, 2012). Therefore, adequate availability of this nutrient is essential for plant growth and development (Silveira & Monteiro, 2010; 2011). In pasture areas, calcium is mainly supplied through limestone and gypsum, at planting (Mesquita et al., 2004; Oliveira et al., 2009). Oliveira et al. (2009) evaluated nutritional and productive aspects of *Urochloa brizantha* cv. 'Marandu' cultivated with sources of calcium and reported that there were no differences in shoot calcium contents or in the height of plants supplied with limestone (5.3 t $ha^{-1}$) and gypsum (3.1 t $ha^{-1}$). However, the dry mass production of the forage increased by 25% when there was supply of gypsum, compared with limestone, possibly due to the presence of sulfur in the gypsum composition.

Calcium supply can increase the synthesis of cell wall in grass forages due to its physiological functions, which is undesirable for animal feed and nutrition, because forage consumption rate is negatively correlated with the content of neutral detergent fiber (NDF) (Hoover, 1986; Marschner, 2012). However, Santana et al. (2010) observed that the contents of NDF and acid detergent fiber (ADF) in the shoots of *Urochloa decumbens* were not altered by the doses of calcium supplied through limestone (0 to 3.6 t $ha^{-1}$). Feed composition is influenced, among other factors, by the practice of fertilization and must be taken into consideration for the purpose of animal feed. However, the practice of fertilization is extremely costly and, in intensive ruminant-farming systems, can represent more than 60% of the production cost (Barcellos et al., 2008). Therefore, this fact stimulates the search for sources of nutrients with lower costs and that contribute to environmental sustainability. In this sense, eggshell can be an alternative to supply calcium to plants, since there is about 94% of calcium carbonate in this industrial by-product and the deposition in landfills has been its final destination (Magalhães et al., 2011). Only in the year of 2014, more than 8.5 billion eggs were produced in Brazil, which generates an enormous amount of residues, because 10% of the weight of an egg consists of its shell (Park et al., 2007; IBGE, 2014). The use of eggshell as an alternative source for correcting soil acidity and supplying calcium can reduce the environmental impact favored by the disposal of this by-product and by the use of calcareous rocks, which are not renewable (Park et al., 2007; Magalhães et al., 2011). However, eggshell application to the soil has been little studied, which points to the need for more studies on the use of this by-product in agriculture, especially as source of calcium to forage plants. Therefore, this study aimed to evaluate productive and nutritional aspects of *Urochloa brizantha* cv. 'Piatã' ('Piatã' grass) and productive aspects and bromatological composition of *Urochloa brizantha* cv. 'Marandu' ('Marandu' grass) fertilized with eggshell in a dystrophic Red Yellow Latosol.

## Material and Methods

**Experiment I**

The experiment I was carried out from December 2013 to March 2014, in the municipality of Alfenas-MG (21° 25' 44" S; 45° 56' 49" W; 888 m), located in Southeastern Brazil. The climate in the region is mesothermal tropical, according to Köppen's classification. The climatic conditions along the studied period are shown in Figure 1. The soil in the area was classified as dystrophic Red Yellow Latosol (EMBRAPA, 2013), with the following chemical characterization in the layer of 0-20 cm: pH ($H_2O$) = 5.2; P-Mehlich = 1 mg $dm^{-3}$; $K^+$ = 41 mg $dm^{-3}$; $Ca^{2+}$ = 0.7 $cmol_c$ $dm^{-3}$; $Mg^{2+}$ = 0.4 $cmol_c$ $dm^{-3}$; $Al^{3+}$ = 0.3 $cmol_c$ $dm^{-3}$; H+Al = 5.2 $cmol_c$ $dm^{-3}$; sum of bases (SB) = 1.3 $cmol_c$ $dm^{-3}$; potential CEC = 6.5 $cmol_c$ $dm^{-3}$; base saturation (V%) = 20; aluminum saturation (m%) = 19 and organic matter (OM) = 24 g $kg^{-1}$. The content of calcium available in the soil was classified as low, according to CFSEMG (1999).

Base saturation was not increased in the study, because the use of limestone containing calcium carbonate would compromise the evaluation of eggshell as an alternative source in the supply of calcium to plants. Fertilization at planting was manually performed in all the treatments, using doses equivalent to 40 kg $ha^{-1}$ of nitrogen as ammonium sulfate (21% of N), 120 kg $ha^{-1}$ of $P_2O_5$ as single superphosphate (18% of $P_2O_5$) and 60 kg $ha^{-1}$ of $K_2O$ as potassium chloride (60% of $K_2O$), according to the recommendation of CFSEMG (1999). The sowing of *Urochloa brizantha* cv. 'Piatã' was performed

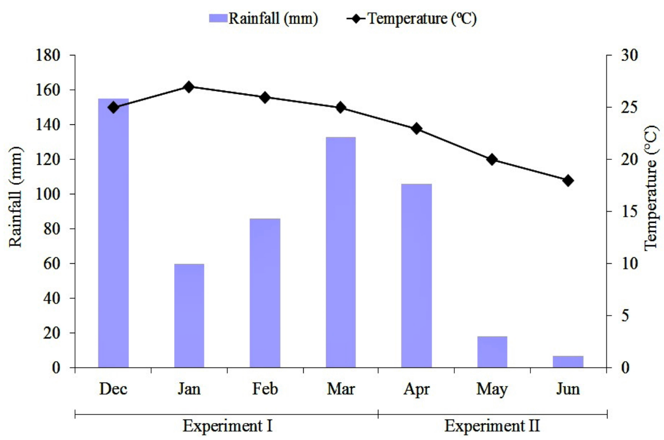


Figure 1. Cumulative rainfalls and mean temperatures recorded during the experiment at the field (December 2013 to March 2014) and in pots (April to June 2014)

broadcast, using 30 g of seeds per plot (4 $m^2$ of area and evaluation area of 1 $m^2$). Simultaneously to forage sowing, there was the application of eggshell, which had been dried at room temperature and ground (78% of total calcium) according to the treatments; then, plots were irrigated every three days until the emergence of the seedlings.

The treatments consisted of the application of eggshell doses equivalent to 0, 100, 200, 300, 400 and 500 kg $ha^{-1}$, which correspond to applications of 0, 78, 156, 234, 312 and 390 kg $ha^{-1}$ of total calcium. The doses were high because of the low solubility of eggshells (between 10 and 15%) and were based on the study of Silveira & Monteiro (2011). The experimental design used in the study was randomized blocks with four replicates. At 30 and 60 days after sowing, two applications of nitrogen were performed as top-dressing, each of which was equivalent to 40 kg $ha^{-1}$, using ammonium sulfate. After the flowering (90 days after sowing) of *Urochloa brizantha* cv. 'Piatã', plants were manually harvested 5 cm above the soil surface and sent to the evaluations.

The evaluations of number of tiller and height of tillers occurred immediately before the cut, while productive and nutritional evaluations were performed in the material from the harvest. The number of tillers was counted in the evaluation area of each plot (1 $m^2$) and the height of seven plants was measured from the base to the tip of the most recently expanded leaf. Tiller emergence rate was obtained by the quotient between the number of tillers and the evaluation interval (represented by the number of days of growth). Green mass production was obtained during the harvest, by weighing on an analytical scale, and dry mass production was obtained after the samples were dried in a forced-air oven at 65 °C for 72 h. After drying, the collected material was ground in a Wiley-type mill for the determination of the contents of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Zn.

For the determination of N content, the material was subjected to sulfuric acid digestion, followed by distillation and titration with sulfuric acid ($H_2SO_4$) at 0.02 mol $L^{-1}$. B was determined through the curcumin colorimetric method, with dry digestion. The other nutrients were analyzed in the extract from the nitric-perchloric digestion, while P contents were determined through colorimetry, K through flame photometry, S through turbidimetry and the other nutrients through atomic absorption spectrophotometry (Malavolta et al., 1989). Nutrient accumulation was obtained by the product of the content of the respective nutrient and the dry mass production.

The data were subjected to analysis of variance ($p < 0.05$) with subsequent regression analysis (only first- and second-order models) to adjust the data distribution, using the statistical program SISVAR® (Ferreira, 2011).

**Experiment II**

The experiment II was carried out from April to June 2014, also in the municipality of Alfenas-MG, and its climatic conditions are shown in Figure 1. This experiment used plastic pots with capacity for 4 kg of soil from the layer of 0-20 cm of a dystrophic Red Yellow Latosol (EMBRAPA, 2013). The soil showed the following chemical characterization: pH ($H_2O$) = 5.3; P-Mehlich = 1 mg $dm^{-3}$; $K^+$ = 30 mg $dm^{-3}$; $Ca^{2+}$ = 0.5 $cmol_c$ $dm^{-3}$; $Mg^{2+}$ = 0.2 $cmol_c$ $dm^{-3}$; $Al^{3+}$ = 0.4 $cmol_c$ $dm^{-3}$; H+Al = 2.2 $cmol_c$ $dm^{-3}$; sum of bases (SB) = 0.8 $cmol_c$ $dm^{-3}$; potential CEC = 3.0 $cmol_c$ $dm^{-3}$; base saturation (V%) = 26; aluminum saturation (m%) = 34 and organic matter (OM) = 7 g $kg^{-1}$. According to CFSEMG (1999), the content of calcium available in the soil was considered as low.

As in the field experiment, base saturation was not increased, but the soil remained incubated for 10 days for stabilization. In this period, soil water content was kept at 100% of field capacity by the addition of distilled water. At the end of the incubation period, phosphate fertilization was performed with dose equivalent to 120 kg $ha^{-1}$ of $P_2O_5$ using single superphosphate. Then, *Urochloa brizantha* cv. 'Marandu' was sown using eight seeds per pot, at the depth of 3 cm. Simultaneously to sowing, eggshell (78% of total calcium) was applied as a source of calcium, according to the treatments. The treatments consisted of the application of doses equivalent to 0, 100, 200, 300, 400 and 500 kg $ha^{-1}$ of eggshell, which correspond to applications of 0, 78, 156, 234, 312 and 390 kg $ha^{-1}$ of total calcium. The pots were distributed in a completely randomized design, with four replicates.

When 70% of the seedlings emerged, nitrogen (40 kg $ha^{-1}$ of N) and potassium (60 kg $ha^{-1}$ of $K_2O$) fertilizations were performed according to the recommendation of CFSEMG (1999), using ammonium sulfate and potassium chloride. The water content in the pots was daily controlled using distilled water, taking into consideration the weight of the pot, in order to maintain the soil at 70% of field capacity. Ten days after sowing, thinning was performed, leaving six plants per pot. Then, two applications of nitrogen as top-dressing were performed (30 and 45 days after seedlings emergence), each of which was equivalent to 40 kg $ha^{-1}$ using ammonium sulfate. Before the flowering *Urochloa brizantha* cv. 'Marandu' (60 days after sowing), plants were manually harvested 5 cm above the soil surface and sent to the evaluations.

The evaluation of number of tillers, height of tillers, tiller emergence rate, green mass production and dry mass production were performed as described in Experiment I, substituting the plots by the experimental units (pots). Bromatological evaluations were performed after drying the material in a forced-air oven at 65 °C for 72 h and grinding in a Wiley-type mill with 1-mm-mesh sieve.

The contents of dry mass (DM) and total nitrogen (TN) were determined following the methods described by the Association of Official Analytical Chemists (AOAC, 1990). The content of crude protein (CP) was obtained by the multiplication of the TN content by the factor 6.25. The determinations of NDF and ADF contents followed the methods described by Goering & Soest (1970) and the contents of hemicellulose were obtained by the difference between the contents of NDF and ADF. The apparent digestibility coefficient of DM (DMD, Eq. 1), the contents of digestible energy (DE, Eq. 2) and metabolizable energy (ME, Eq. 3) were calculated according to the equations proposed by Rodrigues (2009).

$$\mathrm{DMD} = 88.9 - \left(0.779 \times \mathrm{ADF}\right) \quad (1)$$

where:

DMD - apparent digestibility of the dry mass (%); and
ADF - acid detergent fiber (%).

$$DE = \left[87.84 - \left(0.7 \times ADF\right)\right] \times 0.04409 \tag{2}$$

where:
DE - digestible energy (Mcal kg $^{-1}$ DM); and
ADF - acid detergent fiber (%).

$$ME = DE \times 0.82 \tag{3}$$

where:
ME - metabolizable energy (Mcal kg$^{-1}$ DM); and
DE - digestible energy (Mcal kg$^{-1}$ DM).

The data were subjected to statistical analysis, as described in Experiment I.

## Results and Discussion

It should be pointed out that cultivars of the same species have distinct nutritional requirements, including along the phenological cycle; the highest demand for calcium occurs during flowering and seed formation (Marschner, 2012). Because of this, two cultivars of *Urochloa brizantha* ('Marandu' and 'Piatã') were used in the present study, which also evaluated the occurrence of flowering in Experiment I and its absence in Experiment II, in order to assess the nutritional and bromatological composition in different situations.

### Experiment I

Green mass production, dry mass production, number of tillers, tiller emergence rate and height of tillers of *Urochloa brizantha* cv. 'Piatã' were not influenced significantly ($p > 0.05$) by the eggshell doses (Table 1). This can be due to the use of single superphosphate at planting, since this fertilizer has calcium in its composition, associated with the low solubility of the eggshells, which have greater release of calcium in the long term (Magalhães et al., 2011). Thus, the initial demand for calcium by *Urochloa brizantha* cv. 'Piatã' may have been met by the calcium from the single superphosphate, which suggests that eggshells must be evaluated, as a fertilizer, for longer periods.

There are not many studies in the literature on the fertilization of *Urochloa brizantha* cv. 'Piatã', especially with respect to calcium supply. However, the mass production, height and number of tillers of *Urochloa brizantha* cv. 'Piatã' observed in the present study are close to the results obtained by Silva et al. (2013). These authors described dry mass production of 0.4 kg m$^{-2}$, tillers with height of 50 cm and tiller density of 500 per m$^2$ for *Urochloa brizantha* cv. 'Marandu', fertilized with 100 kg ha$^{-1}$ of N.

Table 1. Means of green mass production (GMP), dry mass production (DMP), number of tillers (NT), tiller emergence rate (TER) and height of tillers (HT) after flowering of *Urochloa brizantha* cv. 'Piatã' cultivated with eggshell in a dystrophic Red Yellow Latosol

| Variable | Eggshell doses (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | 400 | 500 |
| GMP (kg m$^{-2}$) | 1.44 | 1.32 | 1.08 | 1.36 | 1.13 | 1.16 |
| DMP (kg m$^{-2}$) | 0.32 | 0.35 | 0.27 | 0.34 | 0.29 | 0.28 |
| NT (m$^{-2}$) | 537.5 | 605.0 | 537.5 | 475.0 | 387.5 | 532.5 |
| TER (tillers d$^{-1}$ m$^{-2}$) | 5.9 | 6.7 | 5.9 | 5.2 | 4.3 | 5.9 |
| HT (cm) | 78.00 | 76.75 | 78.50 | 84.50 | 89.25 | 82.00 |

Structural and productive characteristics of the forage were not altered significantly ($p > 0.05$) by the eggshell doses, but it is important to evaluate the nutritional status of the plants in order to monitor the contents of nutrients for the adequate development, and for the purpose of animal feed (Monteiro et al., 1995; Oliveira et al., 2009). However, the studied doses of eggshell did not alter significantly ($p > 0.05$) the contents or the accumulation of nutrients in the shoots of *Urochloa brizantha* cv. 'Piatã' (Table 2).

The contents of N, P, K, Mg, S, Cu, Mn and Zn in the shoot tissues of *Urochloa brizantha* cv. 'Piatã' remained within the range considered as adequate for normal growth of most plants, but the contents of Ca and B remained below and the contents of Fe were above the range considered as adequate (Marschner, 2012). It is important to point out that these nutrients perform important functions in plants, but the demand for nutrients by forages can be considered as specific (Monteiro et al., 1995; Marschner, 2012). Thus, Ca contents in the shoots of *Urochloa brizantha* cv. 'Marandu' remained close to those reported by Monteiro et al. (1995) and B contents close to those described by Vieira et al. (1991) in the shoots of *Cynodon dactylon* cv. 'Florakirk'. The contents of macro and micronutrients of *Urochloa brizantha* cv. 'Piatã' described in the present study are not limiting to animal feed, but the use of supplementation is recommended to improve animal performance (Casagrande et al., 2013; Detmann et al., 2014).

Table 2. Mean contents and accumulations of macro and micronutrients in the shoots after the flowering of *Urochloa brizantha* cv. 'Piatã' cultivated with eggshell in a dystrophic Red Yellow Latosol

| Nutrients | Eggshell doses (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | 400 | 500 |
| | Contents | | | | | |
| N (g kg$^{-1}$) | 21.00 | 27.00 | 22.00 | 22.00 | 20.00 | 21.00 |
| P (g kg$^{-1}$) | 1.86 | 1.99 | 1.99 | 1.79 | 1.73 | 1.93 |
| K (g kg$^{-1}$) | 16.20 | 13.50 | 17.80 | 15.50 | 16.20 | 13.90 |
| Ca (g kg$^{-1}$) | 4.00 | 4.60 | 4.00 | 4.10 | 4.80 | 4.20 |
| Mg (g kg$^{-1}$) | 3.90 | 4.10 | 3.30 | 3.70 | 4.30 | 3.10 |
| S (g kg$^{-1}$) | 2.10 | 2.20 | 2.40 | 2.20 | 1.90 | 2.10 |
| B (mg kg$^{-1}$) | 11.00 | 6.00 | 7.00 | 9.00 | 10.00 | 11.00 |
| Cu (mg kg$^{-1}$) | 4.00 | 4.00 | 4.00 | 4.00 | 5.00 | 4.00 |
| Fe (mg kg$^{-1}$) | 248.00 | 128.00 | 144.00 | 192.00 | 176.00 | 336.00 |
| Mn (mg kg$^{-1}$) | 127.00 | 137.00 | 118.00 | 110.00 | 148.00 | 136.00 |
| Zn (mg kg$^{-1}$) | 16.00 | 18.80 | 18.80 | 18.40 | 22.00 | 14.80 |
| | Accumulation | | | | | |
| N (g m$^{-2}$) | 6.82 | 9.61 | 6.05 | 7.52 | 5.84 | 5.97 |
| P (g m$^{-2}$) | 0.60 | 0.71 | 0.54 | 0.61 | 0.50 | 0.54 |
| K (g m$^{-2}$) | 5.26 | 4.80 | 4.90 | 5.30 | 4.73 | 3.95 |
| Ca (g m$^{-2}$) | 1.30 | 1.63 | 1.10 | 1.40 | 1.40 | 1.19 |
| Mg (g m$^{-2}$) | 1.26 | 1.45 | 0.90 | 1.26 | 1.25 | 0.88 |
| S (g m$^{-2}$) | 0.68 | 0.78 | 0.66 | 0.75 | 0.55 | 0.59 |
| B (mg m$^{-2}$) | 3.57 | 2.13 | 1.92 | 3.07 | 2.92 | 3.12 |
| Cu (mg m$^{-2}$) | 12.98 | 14.23 | 11.00 | 13.68 | 14.59 | 11.37 |
| Fe (mg m$^{-2}$) | 80.52 | 45.56 | 39.63 | 65.66 | 51.38 | 95.53 |
| Mn (mg m$^{-2}$) | 41.23 | 48.76 | 32.47 | 37.62 | 43.21 | 38.66 |
| Zn (mg m$^{-2}$) | 5.19 | 6.69 | 5.17 | 6.29 | 6.42 | 4.20 |

### Experiment II

Green mass production, dry mass production, number of tillers, tiller emergence rate and height of tillers of *Urochloa* *brizantha* cv. 'Marandu' were not significantly altered (p > 0.05) by eggshell doses (Table 3), as occurred with *Urochloa brizantha* cv. 'Piatã' (Table 1).

Normally, mass production of forage species is positively correlated with the production of tillers, which is more substantially altered by the availability of nitrogen (Difante et al., 2008). Therefore, it is evident that, under adequate conditions of availability of other nutrients, the number of tillers, tiller emergence rate and height of tillers are not altered by the addition of calcium, which leads to similar mass production between treatments.

Forage grasses are little responsive to calcium and have lower demand for this nutrient in comparison to other nutrients for mass production (Monteiro et al., 1995). The content of calcium available in the soil (0.5 $cmol_c$ $dm^{-3}$) and the calcium provided by the single superphosphate probably supplied the amount necessary for the adequate growth of these plants (Sarmento et al., 2006). Monteiro et al. (1995) verified that *Urochloa brizantha* cv. 'Marandu' grown with omission of nutrients, calcium omission was less harmful to the forage, considering its higher mass production and number and height of tillers in this treatment, compared with the omission of the other macronutrients.

Even under conditions of similarity between treatments with respect to structural and productive aspects of the forage, it is interesting to evaluate the composition of the grass when it is intended for animal consumption (Benett et al., 2008). When the amount of forage available is not limiting, forage consumption by ruminant animals is controlled by the composition of the feed (Euclides et al., 2009). However, in the present study, the contents of DM, NDF, ADF, hemicellulose, CP, DE, ME and DMD were not significantly altered (p > 0.05) by the eggshell doses (Table 4).

NDF and ADF contents in the shoots of the forages directly influence the digestibility of the feed and the consumption by ruminants, so that these variables are used as indicative parameters for such purpose. NDF contents between 55 and 60% and ADF contents around 40% result in low forage digestibility and lower consumption by ruminants (Soest, 1994; Benett et al., 2008). The NDF contents of the forage observed in the present study are within the limiting range of consumption and the ADF contents are below it, including in the control treatment, which indicates that these contents are more related to physiological and structural characteristics of *Urochloa brizantha* cv. 'Marandu' than to the supply of calcium.

In all the treatments, CP contents remained above 12.5%, which is extremely desirable for ruminant feed, since CP

Table 3. Means of green mass production (GMP), dry mass production (DMP), number of tillers (NT), tiller emergence rate (TER) and height of tillers (HT) before the flowering of *Urochloa brizantha* cv. 'Marandu' cultivated with eggshell in pots containing dystrophic Red Yellow Latosol

| Variable | Eggshell doses (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | 400 | 500 |
| GMP (g pot$^{-1}$) | 64.52 | 54.93 | 60.25 | 62.56 | 60.47 | 59.08 |
| DMP (g pot$^{-1}$) | 9.97 | 7.11 | 9.94 | 9.34 | 10.41 | 9.53 |
| NT (pot$^{-1}$) | 28.25 | 27.50 | 30.50 | 31.00 | 28.75 | 35.25 |
| TER (tillers d$^{-1}$ pot$^{-1}$) | 0.47 | 0.46 | 0.50 | 0.51 | 0.47 | 0.58 |
| HT (cm) | 48.75 | 42.50 | 45.75 | 46.50 | 45.00 | 47.00 |

Table 4. Mean contents of dry mass (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (Hem), crude protein (CP), apparent digestibility coefficient of the dry mass (DMD), digestible energy (DE) and metabolizable energy (ME) before the flowering of *Urochloa brizantha* cv. 'Marandu' cultivated with eggshell in pots containing dystrophic Red Yellow Latosol

| Variable | Eggshell doses (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | 400 | 500 |
| DM (%) | 15.02 | 13.31 | 15.92 | 14.27 | 16.39 | 15.82 |
| NDF (%) | 58.25 | 58.50 | 58.75 | 55.50 | 57.50 | 57.00 |
| ADF (%) | 28.00 | 27.00 | 28.00 | 26.00 | 28.50 | 27.50 |
| Hem (%) | 30.25 | 31.50 | 30.75 | 29.50 | 29.00 | 29.50 |
| CP (%) | 12.72 | 13.21 | 13.45 | 13.19 | 13.27 | 13.60 |
| DMD (%) | 67.09 | 67.87 | 67.09 | 68.64 | 66.70 | 67.48 |
| DE (Mcal kg$^{-1}$ DM) | 3.01 | 3.04 | 3.01 | 3.07 | 2.99 | 3.02 |
| ME (Mcal kg$^{-1}$ DM) | 2.46 | 2.49 | 2.46 | 2.51 | 2.45 | 2.48 |

contents below 7% lead to lower forage digestion, due to inadequate levels of N, which is limiting to the development of ruminal microorganisms, especially fibrolytic bacteria (Soest, 1994). According to Detmann et al. (2014), the DMD values of *Urochloa brizantha* cv. 'Marandu' are also adequate for ruminant feed. As the protein content, the energetic level of the forage must be considered in the evaluation of feeds, because low contents of DE and ME can limit the ingestion and conversion of forage into animal products (Casagrande et al., 2013; Detmann et al., 2014). However, the values described in the present study are not limiting to the feed of ruminant animals (Soest, 1994).

## Conclusions

1. The forages *Urochloa brizantha* cv. 'Piatã' and *Urochloa brizantha* cv. 'Marandu' were not responsive to the use of eggshell as an alternative source for calcium supply in dystrophic Red Yellow Latosol, in a short period, even when the content of calcium available in the soil was low.

2. The nutritional status of *Urochloa brizantha* cv. 'Piatã' and the bromatological composition of *Urochloa brizantha* cv. 'Marandu' fertilized with eggshell were not limiting to adequate plant development and are not limiting to animal feed.

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