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PHYTOEXTRACTION AND NUTRITIONAL QUALITY OF FORAGES CULTIVATED IN A CONSTRUCTED WETLAND SYSTEM FOR WASTEWATER TREATMENT

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Keywords:
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ABSTRACT

This study aimed to evaluate the effects of different concentrations of sodium on the phytoextraction of nutrients and nutritional quality of forages (*P. purpureum* Schum and *C. dactylon* Pers) grown in wetland system constructed for wastewater generated in cattle slaughterhouses (WGCS) treatment. The experiment was conducted in a randomized complete block design with three replications. The treatments were tested using 2 x 5 factorial scheme, as follows: two species of grass (*P. purpureum* Schum and *C. dactylon* Pers) and five concentrations of sodium in WGCS: 70, 100, 150, 200 and 250 mg L^{-1}. The phytoextraction potential of nutrients and the nutritional quality of forages grown in pots simulating a wetland system constructed for WGCS with sodium concentrations were assessed in terms of the contents of the nutrients nitrogen, phosphorus, potassium, calcium, magnesium and sodium in leaf tissues. The accumulations of these nutrients in the produced forages were also evaluated. Both species presented different behaviors regarding their nutrient phytoextraction potentials. The nutritional quality was changed in the forages due to the cultivation in constructed wetlands. Forage *C. dactylon* Pers presented higher phytoextraction potential of sodium and potassium and *P. purpureum* Schum presented a higher nutritional quality.

Palavras-chave:
Estresse salino
Cynodon dactylon
Penissetum purpureum
Nutrientes
Gramineas forrageiras

FITOEXTRAÇÃO E QUALIDADE NUTRICIONAL DE FORRAGEIRAS EM SISTEMA ALAGADO CONSTRUÍDO PARA TRATAMENTO DE ÁGUA RESIDUÁRIA

RESUMO

Avaliou-se o efeito de diferentes concentrações de sódio na fitoextração de nutrientes e na qualidade nutricional das forrageiras *P. purpureum* Schum e *C. dactylon* Pers cultivadas em sistema alagado construído para o tratamento de água residuária gerada em frigoríficos bovinos (ARFB). O experimento foi conduzido em delineamento experimental de blocos casualizados com três repetições. Os tratamentos foram testados em esquema fatorial 2 x 5, sendo: duas forrageiras (*P. purpureum* Schum e *C. dactylon* Pers) e cinco concentrações de sódio na ARFB: 70, 100, 150, 200 e 250 mg L^{-1}. O potencial de fitoextração de nutrientes e a qualidade nutricional das forrageiras cultivadas em vasos simulando um sistema alagado construido para ARFB com as concentrações de sódio foi avaliada por meio dos teores dos nutrientes nitrogênio, fósforo, potássio, cálcio, magnésio e sódio nos tecidos foliares e da acumulação desses nutrientes na forragem produzida. As forrageiras *P. purpureum* Schum e *C. dactylon* Pers apresentaram respostas diferentes quanto ao potencial de fitoextração de nutrientes e a qualidade nutricional foi alterada nas forrageiras em função do cultivo no ambiente alagado construído. A forrageira *C. dactylon* Pers apresenta maior potencial em fitoextração de sódio e potássio e a forrageira *P. purpureum* Schum apresenta maior qualidade nutricional.

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INTRODUCTION

Although wastewater generated in cattle slaughterhouses (WGCS) is considered a by-product rich in nutrients, its use for the fertigation of agricultural crops can be limited due to its high salinity and the presence of heavy metals, which requires adequate treatment (SHELEF *et al.,* 2012; THEBALDI *et al.,* 2013). The accumulation of salts in the root zone causes the development of osmotic stress and ion influx by the cell membrane, affecting ionic homeostasis and cellular absorption of nutrients such as potassium (K^+), calcium (Ca^{2+}) and nitrogen (NO_3^-) In addition, it causes the absorption and accumulation of toxic ions such as sodium (Na^+) and chlorine (Cl^-). There are also changes in hormonal balance and gene expression, as well as reduction in water absorption and changes in inorganic and organic solute concentrations (GUIMARÃES, 2005; AQUINO *et al.,* 2007; WILLADINO; CAMARA, 2010).

WGCS can be improved by implementing wetland systems (MATOS *et al.,* 2012). These systems, in addition to providing wastewater treatment, allow the recycling of nutrients through the production of plants that act as sinkholes for various elements, improving water quality and leaving nutrients and metals toxic levels at acceptable levels (MATOS *et al.,* 2010; SHELEF *et al.,* 2012; BHATIA; GOYAL, 2013; CAI *et al.,* 2013; HERATH; VITHANAGE, 2015). However, the success of the implementation of this treatment system in the cattle slaughterhouses depends on the choice and tolerance of the plant species to the condition of cultivation in aqueous environment and the presence of high and variable concentrations of Na^+ (MATOS *et al.,* 2010; MATOS *et al.,* 2012; AVELAR *et al.,* 2015).

Constructed wetland systems are artificial ecosystems that use plants grown on substrates such as soil, sand and gravel, where physical, chemical and biochemical processes of treatment of wastewater occur. The mechanisms involved in the treatment are: filtration, microbial degradation of organic matter and phytoextraction of nutrients, among others (MATOS *et al.,* 2010, 2012; CHAVAN; DHULAP, 2012; SHELEF *et al.,* 2012; WU *et al.,* 2014; AVELAR *et al.,* 2015). Plants use nutrients from wastewater for their growth, acting as extractors of most macro and micronutrients of the wastewater under treatment, which accumulate in their biomass (MATOS *et al.,* 2010; CHAVAN; DHULAP, 2012; BHATIA; GOYAL, 2013; HERATH; VITHANAGE, 2015).

Constructed wetland systems have been proposed and used in the treatment of wastewater (e.g., dairy products, coffee agroindustry, and pig farming) after undergoing the process of stabilization in a pond systems (FIA *et al.,* 2008; MATOS *et al.,* 2008, 2010, 2012). Several plant species that are naturally adapted to wetlands have been grown, including grass species, such as the forages *C. dactylon* Pers e *P. purpureum* Schum. These species are adapted to tropical conditions and have been successfully used in the treatment of agro-industrial wastewater (MATOS *et al.,* 2008, 2009, 2010, 2012).

However, research results are not yet found in the literature reporting the effect of sodium (Na^+) concentrations on the nutrient phytoextraction potential and the nutritional quality of *C. dactylon* Pers e *P. purpureum* Schum when grown in a wetland system constructed for WGCS treatment. We hypothesized that forages grown in a wetland system constructed for WGCS, would be able to remove sodium from the residual water and accumulate in the aerial part without affecting its nutritional quality. Therefore, this study aimed to evaluate the effect of different Na concentrations on the phytoextraction of nutrients and nutritional quality of *P. purpureum* Schum e *C. dactylon* Pers grasses when grown in a wetland system constructed for WGCS treatment.

MATERIAL AND METHODS

This study was carried out in partnership between Federal University of Viçosa (UFV), Federal University of Tocantins (UFT) and the Cooperative of Meat and Derivatives Producers of Gurupi (COOPERFRIGU). The implementation of the experiment with the cultivation of the forages in the constructed wetland systems was conducted in the municipality of Gurupi, state of Tocantins, Brazil (geographical coordinates 11°43’45” S and 49°04’07” W, altitude of 280 m). The climate of the region is humid with moderate water deficiency. The average annual temperature is 29.5 °C and the average annual precipitation is 1.804 mm (ALVARES *et al.,* 2013).

The experiment was installed in a randomized block design with three replications. A total of ten treatments were obtained in a factorial arrangement of 2 x 5, in which the first factor consists of two forage species (*P. purpureum* Schum e *C. dactylon* Pers) and the second factor by five concentrations of sodium in WGCS, being 70, 100, 150, 200 e 250 mg L^{-1}. Each concentration was prepared using a cattle wastewater with an initial concentration of 70 mg Na L^{-1}, the other concentrations were obtained with the addition of NaCl for analysis (39.3% of Na), until reaching the desired concentration.

The physical, chemical and biochemical characterization of the cattle wastewater collected in the Australian system composed of four ponds at COOPERFRIGU are: Temperature: 30.1 °C; Turbidity: 68.9 NTU (nephelometric turbidity unit); Electric conductivity: 2057 µS cm^{-1}; pH: 7.99; Dissolved oxygen: 0.0 mg L^{-1} O_2; Chemical oxygen demand (COD): 401.0 mg O_2 L^{-1}; Biochemical oxygen demand (BOD): 233.0 mg O_2 L^{-1}; COD/BOD: 1.72; Oils and greases: 18.2 mg L^{-1}; sedimentable solids: 0.1 mg L^{-1}; suspended solids: 102.0 mg L^{-1}; N: 184.51 mg L^{-1}; Cr: 0.05 mg L^{-1}; P: 11.16 mg L^{-1}; Na: 70.0 mg L^{-1}; K: 26.4 mg L^{-1}; Zn: 0.40 mg L^{-1}; Ca: 43.38 mg L^{-1}; Mg: 16.32 mg L^{-1}; Ni: 0.03 mg L^{-1}; Mn: 5.14 mg L^{-1}; Mo: 0.02 mg L^{-1}; Co: 0.02 mg L^{-1}; Cu: 0.06 mg L^{-1}; and Cd: 0.01 mg L^{-1}. The wastewater used in this study was collected in the fourth pond of the Australian system, after the initial treatments.

Forage *P. purpureum* Schum was obtained at the University Campus of Gurupi, while the seedlings of *C. dactylon* Pers were donated by the Farm Brilhant, also located in the municipality of Gurupi – TO. The seedlings were submitted to standardization in an average size of 25 and 30 cm, and mean nodes of three and two to *P. purpureum* Schum and *C. dactylon* Pers, respectively. The wetland system were constructed with pot polyethylene, with a capacity of 12 dm^3, 30 cm in diameter, 25 cm in height and useful area of cultivation of 0.049 m^2. A vegetative propagule was planted per pot. Thirty days after planting, a uniformity cut was performed at the height of five centimeters for *C. dactylon* Pers and fifteen centimeters for *P. purpureum* Schum.

The macronutrient contents, yield and dry matter of shoot were used for the evaluation of the phytoextraction potential in the two forage species (*P. purpureum* Schum e *C. dactylon* Pers). Thus, the plants were subjected to monthly cuts at 30, 60 and 90 days after cutting uniformity, as suggested by Rodrigues *et al.* (2006). Based on the obtained results, extrapolation of the production area to one hectare of wetland system constructed was carried out (10.000 m^2) in the 12-month period. The green mass of each forage species was weighed and placed in a greenhouse with forced air circulation at 60 °C for 72 hours. After drying, the samples were weighed again to obtain the shoot dry matter, followed by grinding.

To evaluation of the nutrient phytoextraction potential and the nutritional quality of the forages, analyses were carried out to determine the contents of N, P, K, Na, Ca, and Mg in the shoot of each forage species. The fitoextration capacity was based only in the forages uptake. Thus, the contents of elements such as N, P, K, Ca, Mg and Na in the wastewater were not measured after the experiment. The N content was determined by the Kjeldahl method with digestion with concentrated sulfuric acid. The other elements were obtained through digestion with nitric and perchloric acids (MALAVOLTA *et al.,* 1997). Atomic absorption spectrophotometry was used for the contents of Ca and Mg, flame emission spectrometry for K and Na and colorimetry for total P.

The obtained results were submitted to variance and regression analyses using the SISVAR software (FERREIRA, 2011). Regression models were chosen based on the significance of the regression equation coefficients and determination coefficient, using the t-test at 1 and 5% probability levels.

RESULTS AND DISCUSSION

The sodium concentration used in the study significantly affected the phytoextraction capacity of the studied forages. Both forage species *P. purpureum* Schum and *C. dactylon* Pers presented different responses regarding their nutrient phytoextraction potential with different concentration of Na in WGCS (Figure 1), probably due to their different tolerances to sodium and nutrient use efficiency in this condition. Regarding N, it was verified a quadratic response for both forages. *P. purpureum* Schum showed an increase in N phytoextraction up to the concentration of 136.45 mg Na L^{-1} (Figure 1A). At higher Na concentrations, the phytoextraction potential was reduced, becoming equal to that obtained by forage *C. dactylon* Pers at the Na concentration of 250 mg L^{-1} in WGCS. As for *C. dactylon* Pers, despite a reduction in the potential for N phytoextraction due to increased concentration of Na in WGCS, there was an increase in the phytoextraction of N at concentrations of Na higher than 200 mg L^{-1}. However, its higher phytoextraction potential (463 kg ha^{-1} $year^{-1}$) was achieved only at Na concentration of 250 mg L^{-1}, but this value corresponds to just over 50% of the phytoextraction potential observed for *P. purpureum* Schum. On the other hand, the potential for N phytoextraction observed for *C. dactylon* Pers at Na concentration of 250 mg L^{-1} was similar to the phytoextraction of 544 kg ha^{-1} $year^{-1}$ in dairy wastewater observed by Matos *et al.* (2008) and higher than that obtained by Matos *et al.* (2010). However, it is less than the phytoextraction of 963 kg N ha^{-1} $year^{-1}$ in swine wastewater, observed by Matos *et al.* (2009).

According to Vilela (2005), despite having average phytoextraction of 77 kg N ha^{-1} $year^{-1}$, *P. purpureum* Schum presents a genetic potential for phytoextraction higher than 800 kg ha^{-1} $year^{-1}$. In the present study, the greatest genetic potential of *P. purpureum* Schum for N phytoextraction in WGCS occurred when cultivation was carried out with the concentration of 136.45 mg Na L^{-1} that provided a phytoextraction of N in the order of 863 kg ha^{-1} $year^{-1}$ in this Na concentration, reaching its genetic potential described by Vilela (2005).

Regarding the nutrients P, Ca and Mg, a higher potential for phytoextraction was also observed for *P. purpureum* Schum when compared with *C. dactylon* Pers (Figure 1B, E, F). However, at Na concentration of 250 mg L^{-1} the potential for phytoextraction of P, Ca and Mg was the the same for both the forage species. These findings show that high Na concentrations negatively affect the phytoextraction capacity of these nutrients by the studied forages.

In relation to P, both forages used in this study obtained a reduction in the P phytoextraction potential with the increase in Na concentrations, especially for *P. purpureum* Schum. For *C. dactylon* Pers, the greatest effects on reducing the potential for phytoextraction as a function of salinity occurred only when the concentration of Na in WGCS was higher than 200 mg L^{-1} (Figure 1B). The phytoextraction potential of P by *C. dactylon* Pers (approximately 80 kg ha^{-1} $year^{-1}$) when grown in a wetland system constructed for WGCS treatment was higher than 61 kg ha^{-1} $year^{-1}$ found in dairy wastewater by Matos *et al.* (2008) and 38.7 kg ha^{-1} $year^{-1}$ found by Matos *et al.* (2010). However, it is less than the extraction observed by Matos *et al.* (2009) in swine wastewater, which was 127 kg ha^{-1} $year^{-1}$. This shows that the genetic potential for the P phytoextraction by *C. dactylon* may be greater than the results presented in this work under Na concentrations in WGCS. In addition, the P level of the wastewater used is higher than the level of the present study, and the Na levels are lower.

For *C. dactylon* Pers, the phytoextraction of Ca and Mg remained constant in the initial Na concentrations and showed an increase in the potential for phytoextraction for Ca and Mg in a concentration of Na higher than 226.7 and 195.92 mg L^{-1}, respectively. In contrast, despite the greater phytoextraction of Ca and Mg by *P. purpureum* Schum, it is observed that the phytoextraction potential of this forage drastically reduced as the Na concentrations increased, reaching values similar to that obtained for *C. dactylon* Pers at the Na maximum concentration (250 mg L^{-1}). Thus, in the implementation of a wetland system constructed for WGCS treatment with Na high concentrations (> 100 mg Na L^{-1}), it is suggested the cultivation of *C. dactylon* Pers.

Differently from N, P, Ca and Mg, in which the highest phytoextraction was verified in the cultivation of forage *P. purpureum* Schum, K and Na were extracted in higher contents by *C. dactylon* Pers (Figure 1). Forage *C. dactylon* showed increasing Na phytoextraction potential with increasing of Na concentrations in WGCS. The phytoextraction potential of *C. dactylon* Pers for

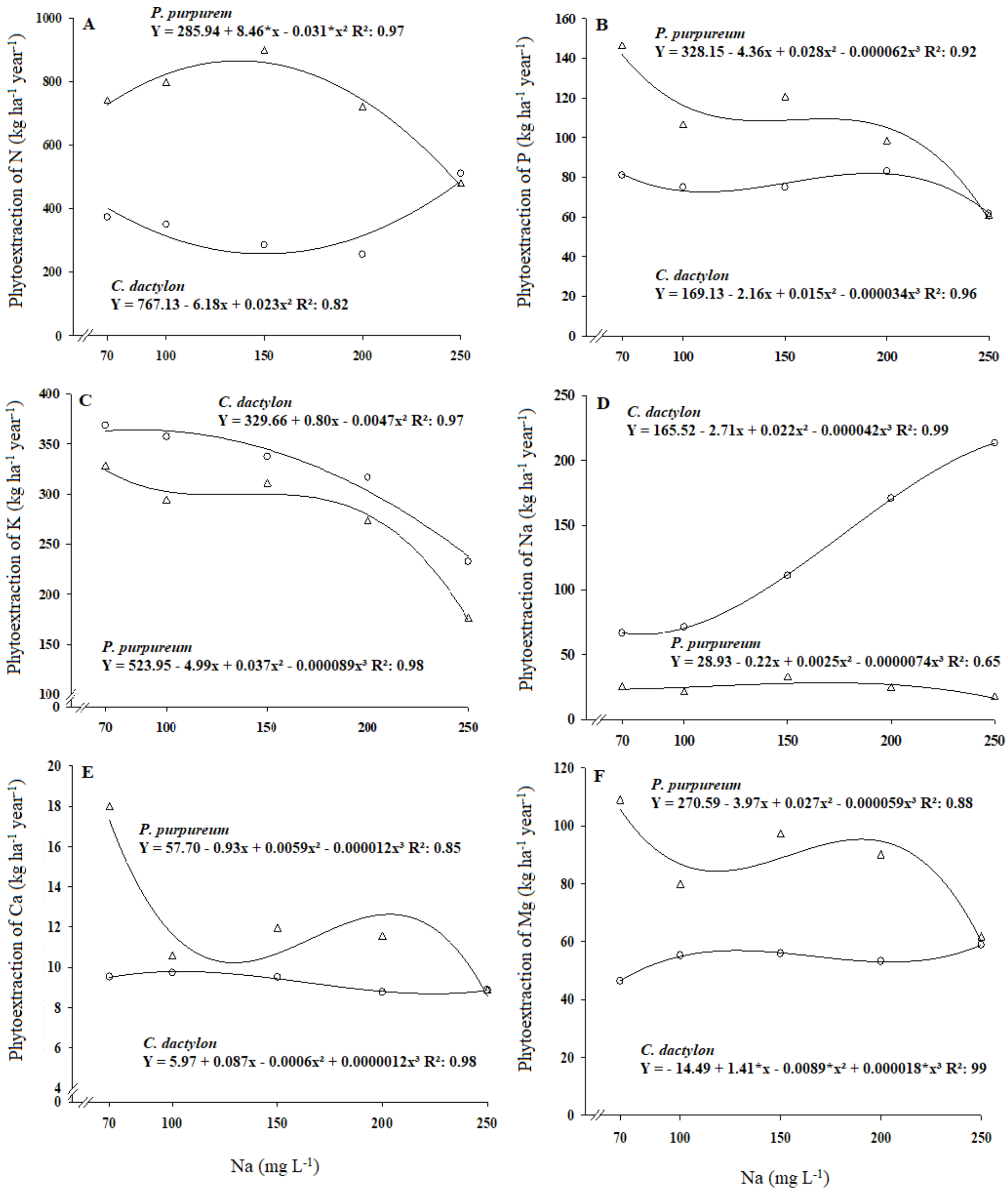

Figure 1. Yearly phytoextraction potential for N, P, K, Ca, Mg and Na by *Cynodon dactylon* Pers and *Pennisetum purpureum* Schum when grown in a wetland system constructed for wastewater generated in cattle slaughterhouses treatment with different concentrations of Na. Y: Ŷ = corresponds to the estimated value of the indicator

Na in the concentration of 250 mg L^{-1} was 14 times higher than that observed for *P. purpureum* Schum. This indicates a greater potential of *C. dactylon* Pers to be used in wetland system constructed for WGCS treatment with high concentrations of Na.

Regarding K, both forages showed a reduction in the phytoextraction potential due to the increase in Na concentrations in WGCS (Figure 1C). The maximum phytoextraction potential of K by *P. purpureum* Schum was only 50% of its genetic potential (594 kg K ha^{-1} $year^{-1}$) considering a soil cultivation with an optimal supply of this nutrient (VILELA, 2005). Matos *et al.* (2009), when evaluating the potential for nutrient extraction by forage *C. dactylon* Pers in a wetland system used for swine wastewater treatment, observed an extraction of 591 kg K ha^{-1}, which is higher than that observed in the present study, even in the lower concentrations of Na in WGCS. However, the extraction potentials of 204 and 129 kg K ha^{-1} verified by Matos *et al.* (2008) and Matos *et al.* (2010), respectively, in dairy wastewater were lower than that extracted in WGCS when the concentration of Na was lower than 200 mg L^{-1} in the present study. This lower K phytoextraction occur because in low concentrations of Na, some grasses can benefit from this element in a beneficial way, which can replace K in some functions without causing damage to plants. Thus, the plant increases the absorption and accumulation of Na in relation to K (CARNEIRO *et al.*, 2017; SILVA *et al.*, 2020).

The nutrient compositions in *P. purpureum* Schum and *C. dactylon* Pers were altered due to cultivation in WGCS with increasing concentrations of Na (Figure 2). However, except for the contents of K in *P. purpureum* Schum, which presented values below 11 g kg^{-1}, and Ca which presented values lower levels than 3 g kg^{-1} in both forages, the other nutrients presented higher contents than those observed by Malavolta *et al.* (1997) and Vilela (2005), considered as suitable for both forages when grown in soil.

The contents of N were higher in *P. purpureum* Schum when compared with *C. dactylon* Pers, with levels higher than 12 g kg^{-1}, which was also higher than that observed by Malavolta *et al.* (1997) and Vilela (2005). This N content represents a minimum necessary guarantee for rumen micro-organisms in adult cattle (SILVA *et al.,* 2008). In both forages, a cubic response was verified in the accumulated N content according to the different concentrations of Na in WGCS (Figure 2A). The content of N increased in *C. dactylon* Pers and *P. purpureum* Schum when they were grown in WGCS with a concentration of up to 114.92 and 124.88 mg Na L^{-1}, respectively. At higher concentrations of Na, the contents of N show a decreasing behavior with the increase in the concentration of Na, until reaching the values of 180.5 and 223.38 mg Na L^{-1}, respectively. When a relationship is made with the phytoextraction of this element, it is observed that *P. purpureum* extracts less N in a higher concentration of Na than *C. dactylon*, however its composition of N is higher (Figure 1A).

The highest levels of N found in *P. purpureum* Schum indicates a change in the nutritional balance imposed by the presence of the saline effect. Usually, higher contents of N are found in *C. dactylon* Pers. Guimarães (2005) pointed out that there are higher N absorption at high concentrations of Na. The increase in the contents of N at high concentrations of Na in WGCS makes it possible to produce forage with high nutritional quality even in periods of absence of rain.

Regarding P, Ca and Mg, higher contents were verified in *P. purpureum* Schum than in *C. dactylon* Pers. For both forages, a cubic effect on the content of accumulated P according to the concentration of Na in WGCS was observed. The contents of P were reduced when forage plants were grown in WGCS containing increasing concentrations of Na (Figure 2B). After a concentration of 200 mg Na L^{-1} the contents of P showed the highest reductions in the levels of leaf P for both forages. This result is probably due to the low phytoextraction capacity and accumulation of P in the Na highest concentration (> 200 mg Na L^{-1}) in both forages tested in this study, as observed in Figure 1B.

Both forages, regardless of the concentration of Na in WGCS, presented P contents that would meet the requirements of P in dry matter (2.8 to 3.7 g kg^{-1}) for a dairy cow with 400 kg of live weight and productivity ranging from 7 the 20 kg milk per day (NRC, 1989). The contents of P were superior to 1.8 g kg^{-1} in fodder of *C. dactylon* Pers fertigated with wastewater generated in the breeding of dairy cattle (ERTHAL *et al.,* 2010). Moreover, they represented increases of three to four times in the content considered appropriate (0.8 g kg^{-1}) (MALAVOLTA *et al.,* 1997; VILELA, 2005). Contents of P higher than 20 g kg^{-1} in forage makes the supplement of this nutrient for beef cattle expendable.

As for Ca and Mg, a cubic effect was also verified on the accumulated contents in *C. dactylon* Pers depending on the concentration of Na in WGCS. The content of Ca increased when the forages was grown in WGCS containing up to 109.48 mg Na L^{-1} (Figure 2E). After this Na concentration, the

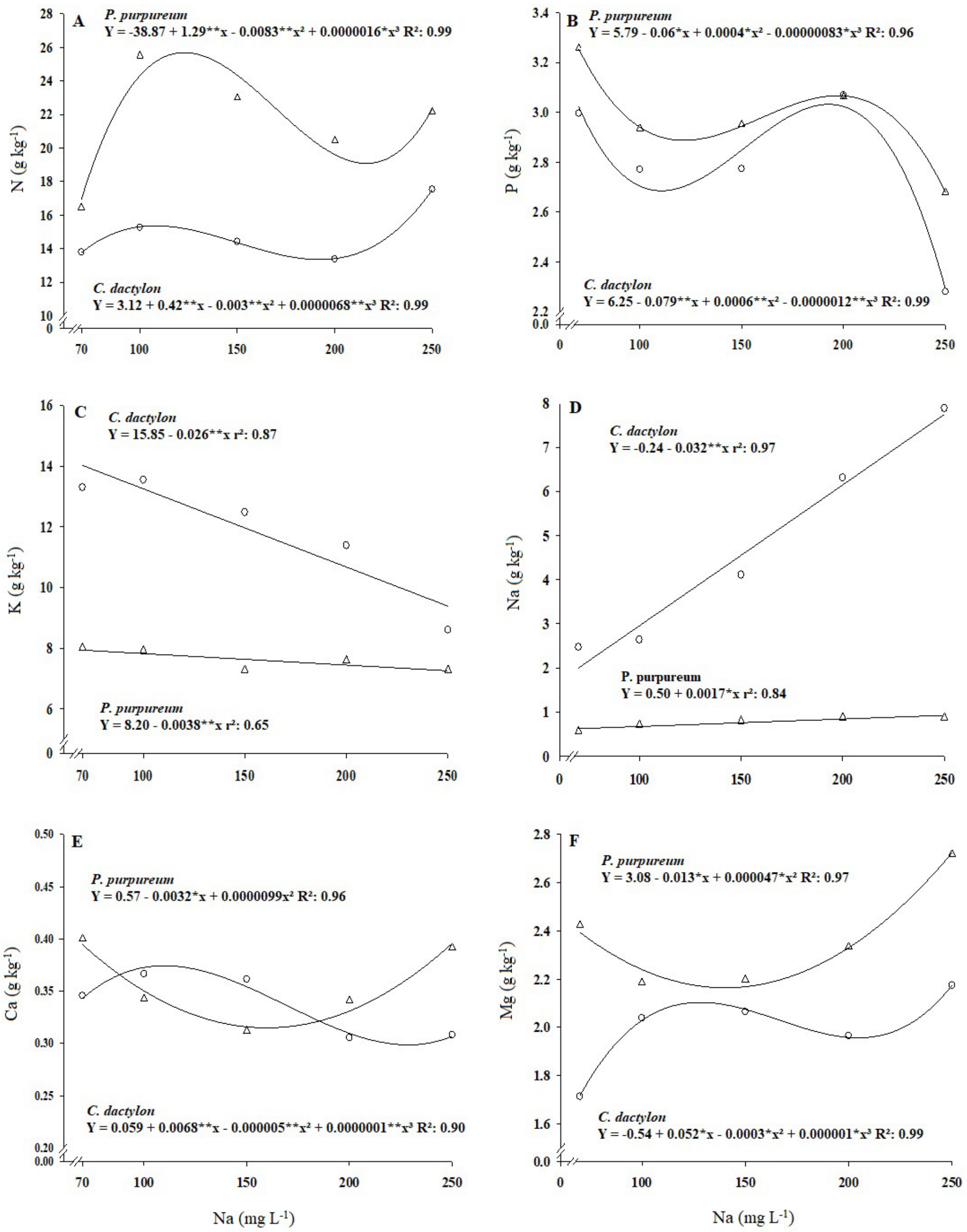

Figure 2. Average of macronutrients levels in *Cynodon dactylon* Pers *and Pennisetum purpureum* Schum when grown in a wetland system constructed for wastewater generated in cattle slaughterhouses treatment with different concentrations of Na for three cycles of 30 days. Y: Ŷ = corresponds to the estimated value of the indicator

contents of Ca have decreased with the increase in the concentration of Na, until 227.52 mg Na L^{-1}. At higher concentrations, there are more accumulation of leaf Ca. As for Mg, a similar response was found. However, the effect of the increase in the concentration of Na accumulation of this nutrient was lower (Figure 2F).

In *P. purpureum* Schum, a quadratic response was found for the accumulated Ca and Mg contents depending on the concentration of Na in WGCS. The contents of Ca decreased when the forages was cultivated with doses up to 161.62 mg Na L^{-1}. After this concentration of Na, the content of Ca presented an increasing behavior due to the increase in the concentration of Na until 250 mg L^{-1}. In relation to the nutrient Mg, the leaf content presented a decreasing behavior only until the concentration of 139.78 mg Na L^{-1}.

It is important to highlight that the results of the elemental composition for Ca and Mg in *C. dactylon* Pers followed a standard behavior similar to that observed in the phytoextraction of this element, regardless of the Na concentration applied (Figure 1E and 1F). On the other hand, it is observed that forage *P. purpureum* extracted less Ca and Mg mainly when subjected to a higher Na concentration (250 mg L^{-1}). Nevertheless, its elemental composition of Ca and Mg remained at increasing levels under these conditions (Figure 2E and 2F).

As for the nutritional quality, both forages presented levels higher than 1.0 g Mg kg^{-1}, which is a value considered suitable for beef grazing (MALAVOLTA *et al.*, 1997; VILELA, 2005), as well as for beef cattle (NRC, 1989). The contents obtained were also higher than 1.3 g Mg kg^{-1}, observed for Erthal *et al.* (2010) in *C. dactylon* Pers grass fertigated with wastewater generated in the breeding of dairy cattle. In this study, both forages present levels of Mg that characterize a nutritional enrichment nearly twice the levels that are considered appropriate.

Contrary to the nutritional enrichment based on the leaf content of Mg, the contents of Ca verified in both forages are considered very low (Figure 2E). The observed contents, regardless of the cultivated forage, were approximately 10 times lower than the contents considered ideal by Vilela (2005) and Silva *et al.* (2008), which might be explained by the presence of high sodium concentration, which might have inhibited the absorption of K, Ca and Mg.

The leaf contents of K reduced with the increase in the concentration of Na (Figure 2C) in both forages. *C. dactylon* Pers showed a greater reduction in the contents of K when compared with *P. purpureum* Schum. This result was directly proportional to the findings for the phytoextraction of this element, in which K phytoextraction also decreased with increasing N concentrations (Figure 1C), mainly for *P. purpureum* Schum. The K contents in the leaves might have been inhibited by the high Na concentrations, through the antagonism that exists between these two ions (Figure 2D). In fact, other authors have observed the existence of multiple absorption systems with different selectivities for Na and K, which may reflect the plant's need to coordinate the influx of these cations (GUIMARÃES, 2005).

However, even though there were great reductions in the contents of K in *C. dactylon* Pers, the observed values are still considered adequate. According to Malavolta *et al.* (1997) and Vilela (2005), K contents superior to 11 g kg^{-1} are considered appropriate for the rearing of beef cattle. Unlike *C. dactylon* Pers, *P. purpureum* Schum showed variations in the contents of K close to 8 g kg^{-1}, which can be considered a value of medium nutritional quality, according to the same authors. Erthal *et al.* (2010), when evaluating the effect of the application of different residue water slides generated in the breeding of dairy cattle on the cultivation of *C. dactylon* Pers, verified an average leaf contents of 1.78 g K kg^{-1} in the first cut. In the assessment of the nutritional quality to meet the requirements of K in dairy cattle feeding (9.0 g kg^{-1}), the contents K were higher (NRC, 1989) only in *C. dactylon* Pers.

As for Na, *P. purpureum* Schum and *C. dactylon* Pers presented a linear response to the accumulation of this element according to the increasing concentrations of Na in WGCS (Figure 2D). However, *C. dactylon* Pers presented a higher accumulation of Na on the leaves than *P. purpureum* Schum. This result is directly linked to the greater phytoextraction capacity of Na that *P. purpureum* Schum has in relation to *C. dactylon* Pers when subjected to Na in increasing concentrations in a wetland system constructed for treatment of WGCS (Figure 1F), corroborating with the results of the Na content in the aerial part obtained for both forage species.

The highest accumulation in *C. dactylon* Pers might be related to increased accumulations in vacuoles as well as greater efficiency in replacing K for Na. Excess Na results in damage mainly to older leaves, providing initial burns along the edges, which might even evolve throughout the leaf, causing necrosis. However, for *C. dactylon* Pers no symptoms of toxicity were verified, even though a cumulative content of Na higher than 6 g kg^{-1} was observed.

CONCLUSIONS

- Forage *C. dactylon* Pers presented greater phytoextraction potentials of Na and K, while *P. purpureum* Schum presented greater phytoextraction potentials of N, P, Ca and Mg.
- Forage *P. purpureum* Schum presented higher nutritional quality when compared with *C. dactylon* Pers, except for calcium, which was higher only in the first and last sodium concentration used in this study.
- The cultivation of both forages, *P. purpureum* Schum and *C. dactylon* Pers, in wetland system constructed for the wastewater generated in cattle slaughterhouses treatment promotes an increase in the nutritional quality of the plants, except for K and Ca, in which there are reductions in the leaf levels due to increasing sodium concentrations.

AUTHORSHIP CONTRIBUTION STATEMENT

SILVA, R.R.: Data curation, Formal Analysis, Investigation, Methodology, Writing – original; FREITAS, G.A.: Data curation, Investigation, Methodology, Writing – original draft; FARIA, A.J.G.: Formal Analysis, Investigation, Validation, Writing – original draft; CARNEIRO, J.S.S.: Formal Analysis, Investigation, Validation, Writing – original draft; OLIVEIRA, I.J.: Data curation, Investigation, Validation, Visualization; MATOS, A.T.: Conceptualization, Methodology, Supervision, Validation, Visualization; ABRAHÃO, A.P.: Conceptualization, Project administration, Supervision, Validation, Writing – review & editing

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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