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Metabolic dynamics of native lambs fed with Tifton 85 hay or Maniçoba hay associated with the spineless cactus

[*Dinâmica metabólica de cordeiros nativos alimentados com feno de capim-tifton 85 ou feno de maniçoba associados à palma forrageira*]

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ABSTRACT

The objective of this study was to evaluate the metabolic response of native lambs fed Tifton 85 hay (*Cynodon dactylon*) or Maniçoba hay (*Manihot pseudoglaziovii*) associated with spineless cactus (*Nopalea cochenillifera* Salm Dyck). Sixteen Morada Nova lambs were used, with a mean initial weight of 19.36±1.48kg, distributed in a randomized block design, with two treatments and eight replications. Dry matter intake was higher for lambs fed Maniçoba hay compared to Tifton hay, while the body weight at slaughter was not influenced by diets. Regarding the blood metabolites, only the serum concentration of urea was influenced, with higher value observed in the lambs that fed the diet containing Tifton hay. When analyzing blood biomarkers, in the different biweekly collections, a linear increase in the blood concentration of urea, glucose, fructosamine, alkaline phosphatase and sodium was observed, as well as a quadratic effect for serum potassium. The other blood metabolites were not influenced in function of the collection days. The replacement of Tifton 85 hay for Maniçoba hay does not cause negative changes in the dynamics of different biomarkers and presents itself as a promising forage resource.

Keywords: blood biomarkers, clinical biochemistry, metabolism, native breeds, nutrition, small ruminants

RESUMO

O objetivo deste trabalho foi avaliar a resposta metabólica de cordeiros nativos alimentados com feno de capim-tifton 85 (Cynodon dactylon) ou feno de maniçoba (Manihot pseudoglaziovii) associados à palma forrageira (Nopalea cochenillifera Salm Dyck). Foram utilizados 16 cordeiros Morada Nova, com peso inicial médio de 19,36±1,48kg, distribuídos em delineamento de blocos ao acaso,, com dois tratamentos e oito repetições. O consumo de matéria seca foi maior nos cordeiros alimentados com feno de maniçoba em comparação ao feno de tifton, enquanto o peso corporal ao abate não foi influenciado pelas dietas. Em relação aos metabólitos sanguíneos, apenas a concentração sérica de ureia foi influenciada, com maior valor observado nos cordeiros que ingeriram a dieta contendo feno de capim-tifton. Quando foi realizada a análise dos biomarcadores sanguíneos nas diferentes coletas quinzenais, foi observado aumento linear nas concentrações sanguíneas de ureia, glicose, frutosamina, fosfatase alcalina e sódio, e efeito quadrático para o potássio sérico. Os demais metabólitos sanguíneos não foram influenciados em função dos dias de coleta. A substituição do feno de tifton 85 por feno de maniçoba influencia positivamente o metabolismo de cordeiros sem causar alterações na dinâmica dos diferentes biomarcadores e se apresenta como um promissor recurso forrageiro.

Palavras-chave: *bioquímica clínica, biomarcadores sanguíneos, nutrição, metabolismo, pequenos ruminantes, raças nativas*

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INTRODUCTION

In the Northeast region of Brazil, more specifically in the semiarid region, there is an abundance of forage during the rainy season; while during the dry season, which can extend from six to nine months, there is a shortage of forage and, consequently, limitations in the availability of food for small ruminants. In order that animal production can be efficient, this situation needs to be combated through the rational use of forage resources adapted (Oliveira *et al*., 2017). In this context, the spineless cactus (*Nopalea cochenillifera* Salm Dyck) is a food resource of extreme importance, used in the feeding of ruminants in semiarid regions of the world, especially during periods of long droughts (Ben Salem *et al*., 2005).

The spineless cactus presents low content of protein and fiber, but is rich in non-fibrous carbohydrates (545g/kg of dry matter (DM)), with high dry matter digestibility (772g/kg) and organic matter digestibility (791g/kg) (Siqueira *et al*., 2017, Cardoso *et al*., 2019). It is known that at certain times of the year the forage cactus is used as a feed and, when supplied almost exclusively, has caused clinical alterations, characterized by alterations in the functioning of the rumen (Batista *et al*., 2003). Recent studies have demonstrated the need to associate the spineless cactus with a physically effective source of fiber, providing nutrients necessary for the proper functioning of the rumen, which is of great importance for the digestibility and absorption of nutrients from the diet (Oliveira *et al*., 2017; Pinho *et al*., 2018). Fiber is of extreme importance and can be found in hay, pasture, and grain or grass silage.

In view of the importance of using a fiber source in spineless cactus-based diets, an alternative is the maniçoba (*Manihot pseudoglaziovii*), a native forage of the Caatinga which stands out as it produces excellent hay, with crude protein contents between (105–160.6g/kg of DM) (França *et al*., 2010, Maciel *et al*., 2015), allowing an increase in the dry matter level and protein of the of diets forage cactus-based diet. In addition, forage conservation methods, such as haying, constitute efficient ways to reduce the concentration of the hydrocyanic acid in fodder plants, thus making them usable in animal feed (França *et al*., 2010).

It is perceived that alternative feeds can cause metabolic disturbances and negatively influence animal performance, and, in this context, it is necessary to quantify the nutrient intake as well as its use by the animal, verified by means of tests of digestibility and analysis of the blood biochemical profile (Van Cleef *et al*., 2009). Understanding of the effects of the use of the spineless cactus and maniçoba on the feeding of ruminants in relation to nitrogen, energy, and the electrolytic metabolism is fundamental to optimize the use of this ingredient in the feed.

Thus, the objective of this study was to evaluate the influence of Tifton 85 hay or Maniçoba hay in a diet based on the spineless cactus (*Nopalea cochenillifera* Salm Dyck) on the intake and dynamics of some energy, protein, and electrolytic profile biomarkers of native Morada Nova lambs.

MATERIAL AND METHODS

The management and care of animals were performed in accordance with the guidelines and recommendations of the Committee of Ethics on Animal Use (CEUA) at the Federal Rural University of Pernambuco (UFRPE), under license number 010705/2008.

The experiment was performed in the Sheep and Goats Department, Animal Science Department, Federal Rural University of Pernambuco, located in Recife, Pernambuco, Brazil. In total, sixteen Morada Nova lambs were used, with a mean initial weight of 19.36±1.48kg and a mean age of eight months. The animals were distributed in a randomized blocks design, using the initial weight as the criterion for the formation of blocks, with two treatments and eight replications. The experimental period lasted 58 days, with 10 days of adaptation to the management system and experimental diet and 48 days of data and biological material collection.

Throughout the period of the experiment, the animals were confined in individual stalls measuring 1.0m × 2.8m provided with a feeder and drinking trough, with water *ad libitum*. The animals were fed with feed that allowed gains of 150g/day, offered in two meals daily (9:00 a.m. and 4:00 p.m.) as a complete mixture, composed of Tifton-85 hay, spineless cactus (*Nopalea* *cochenillifera* Salm Dyck), maniçoba hay (*Manihot pseudoglaziovii*), corn, soybean meal, urea and mineral supplement (Table 1). In this period, the supply of feed and leftovers (20% of the feed offered), were weighed to quantify the intake of feed.

Table 1. Chemical composition and percentage of experimental diets ingredients

Ingredients (g/kg)	Diets	
	Tifton 85 hay	Maniçoba hay
Corn	180.0	200.0
Soybean meal	100.0	45.0
Spineless cactus	300.0	335.0
Tifton 85 hay	400.0	0.00
Tifton 85 hay	400.0	0.00
Maniçoba hay	0.00	400.0
Mineral Supplement	10	10
Urea	10	10
Chemical composition (g/kg of DM)		
Dry matter [a]	260.5	243.1
Organic matter	884.1	874.4
Crude protein	135.0	136.0
Ether extract	20.0	26.0
Neutral detergent fibre$_{ap}$ [b]	396.0	380.0
Non- fibrous carbohydrates	333.1	337.5
Total carbohydrates	729.2	717.5
Metabolizable energy (Mcal/kg of DM)	2.35	2.37

[a] g/kg of fresh matter, [b] *ap* corrected for ash and nitrogenous compounds.

Samples of feed and leftovers were collected for determination of dry matter (DM), organic matter (OM), ether extract (EE) and crude protein (CP) analyses were performed according to the Association of Official Analytical Chemists (Official…, 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest *et al*. (1991) and corrected for ash and protein according to the methodology described by Mertens (2002) and Licitra *et al*. (1996), respectively. For the estimation of total carbohydrates (TC), the following equation was used, proposed by Sniffen *et al*. (1992), TC (%) = 100 – (%CP + %EE + % Ash). Non-fibrous carbohydrates (NFC) were calculated according to Hall (2000): NFC (%) = 100 - [(%CP - %CP derived from urea + %urea) + %NDFap + %EE + %ash].

Blood samples were collected biweekly (0d, 15d, 30d, and 45d), four hours after the morning feeding, through jugular venipuncture, in siliconized tubes with and without anticoagulant to obtain serum and plasma, respectively. The following serum biomarkers were determined: creatinine, urea, total protein, albumin, fructosamine, aspartate aminotransferase, gamma-glutamyl transferase, alkaline phosphatase, and plasma glucose, which were analyzed in a biochemical BIOPLUS 2000 with LABTEST® commercial kits. Sodium and potassium electrolytes were determined by flame photometry (BENFER BFC 300) and chlorine on a BIOPLUS 2000 biochemical analyzer with a commercial DOLES® kit.

A randomized blocks design with two treatments and eight replications was used, considering initial body weight as the criterion for the formation of blocks. The data were submitted to analysis of variance and regression, using the statistical package Statistical Analysis System (Statistical…, 2009), and the means were compared by the least significant difference (l.s.d) of the SNK Test, at a level of significance (p) of 5%.

RESULTS AND DISCUSSION

The dry matter intake (g/kg^{0,75}) was greater in lambs fed on diets based on maniçoba hay diet ($P< 0.05$) than those fed Tifton hay-based diet, while the body weight at slaughter was not influenced by diet ($P> 0.05$, Table 2).

The response from the use of maniçoba hay in relation to Tifton 85 hay as a source of roughage for the intake variable was expected and is probably related to the high nutritional value of the forage, with adequate CP content and high digestibility of non-fibrous carbohydrate (Maciel *et al*., 2019). According to França *et al*. (2010), the maniçoba presents anatomical characteristics similar to those of C3 plants, so that its anatomy favors the intake and, consequently, the digestibility, due to the arrangement of the mesophyll with more intercellular spaces than in C4 plants, as well as more spaces between the vascular bundles, which may have conferred to the maniçoba hay greater ruminal degradation when compared to Tifton 85 hay. Maciel *et al*. (2019) also observed greater DM intake by sheep fed maniçoba hay in relation to Tifton 85 hay, corroborating the results of the present study. Van Soest (1994) reports that the intake of dry matter is regulated by several factors and that although ruminants have homeostatic mechanisms to regulate the intake of concentrated foods, the intake of forage is limited by the rate of disappearance of this material from the rumen. The disappearance is related to particle size, digestion rate, and nutrient digestibility, reflecting the increase in feed intake.

Table 2. Productive parameters and metabolic profile of Morada Nova lambs receiving diets with Tifton 85 Hay or maniçoba hay associated with spineless cactus

Item	Diets		SEM
	Tifton 85 hay	Maniçoba hay	
Productive parameters			
Dry matter intake (g/kg^{0,75})	58.05b	68.96a	2.99
Body weight at slaughter	25.54	24.76	0.81
Biochemical Parameters			
Creatinine (µmol/L)	75.38	80.33	2.71
Urea (mmol/L)	9.23a	8.34b	0.28
Total Protein (g/L)	59.00	57.20	1.96
Albumin (g/L)	30.60	30.30	1.03
Globulin (g/L)	28.80	27.30	2.40
Glucose (mmol/L)	4.81	4.92	0.12
Fructosamine (µmol/L)	194.68	201.10	7.59
AP (IU/L)	881.31	821.83	92.3
AST (IU/L)	79.61	79.83	2.74
GGT (IU/L)	56.23	57.56	1.48
Na (mEq/L)	128.65	127.68	2.23
K (mEq/L)	4.34	4.24	0.12
Cl (mEq/L)	106.89	107.06	1.38

AP alkaline phosphatase, *AST* aspartate aminotransferase, *GGT* gamma-glutamyltransferase.
SEM standard error of the mean. Means followed by different letters in the same line differ from each other by the SNK test at 5% probability.

It can be assumed that the degradation and reduction in the maniçoba hay particles in the rumen, followed by a greater digesta flow to the gastrointestinal tract, allowed greater intake of this diet. It is known that denser particles are more likely to escape from the reticulum-rumen (Seo *et al*., 2009), probably favoring higher DM intake by the animals that received the maniçoba hay. In this study, the replacement of Tifton grass hay as the fiber source with maniçoba hay fiber did not compromise animal performance, which favors the association of these sources of roughage with the spineless cactus, in order to supply the limitations in the fiber content that this cactus presents. Pinho *et al*. (2018), recommend a minimum value of NDF of 109g/kg DM from forage, in diets based on forage cactus in order not to compromise rumen function.

Regarding the blood metabolites, the only serum concentration of urea was influenced, with higher value observed in the lambs that fed the diet containing Tifton hay in relation to maniçoba hay (P< 0.05, Table 2). The higher serum concentration of urea in the animals fed Tifton hay diet could be justified by the presence of soybean meal in the diet, which was the main source of nitrogen, because the diets were similar in composition, with 135 and 136g/kg of DM, respectively. It is probable this response is related to the presence of high ruminal degradability protein, with higher nitrogen intake, and consequently higher urea production in the rumen (González and Scheffer, 2003).

According to Van Soest (1994), diets with a high level of nitrogen lead to a greater flow of this nutrient to the tissues and liver, and, after metabolism, a higher concentration of urea in the blood. The increased concentration of circulating urea in the blood of lambs fed the diet containing Tifton hay could be attributed to the inappropriate synchrony between protein and energy available for microorganisms in the rumen. Maciel *et al*. (2019) reported higher digestibility of non-fibrous carbohydrates by sheep fed maniçoba hay associated with spineless cactus (0.85g/kg) compared to a diet containing Tifton hay (0.76g/kg).

Other aspects that should be taken into account, when the serum concentration of urea is high, is the efficiency with which the microorganisms convert the nitrogen of the food into microbial protein, the rate of release of the ammonia, and its assimilation by the organism. If the form of release is rapid, there may be excess ammonia to be absorbed, carried to the liver and converted to urea (Kaneko *et al*., 2008). Regarding the observed values, in both treatments, the serum urea concentration was within the normal range, so that the microbial protein from the experimental diets was effective, with adequate assimilation.

There was an increasing linear effect (P> 0.05) on serum urea, glucose, fructosamine (Table 3), alkaline phosphatase (AP) and sodium (N) (Table 4) in the different biweekly blood collections.

Table 3. Proteic and energy profile of Morada Nova lambs blood samples, in the function of the collections days, receiving diets with Tifton 85 Hay or maniçoba hay associated with spineless cactus

Item	Biweekly collections				SEM	*P*-value	
	0d	15d	30d	45d		L	Q
Proteic profile							
Creatinine (μmol/L)	81.75	76.48	79.69	73.43	2.96	ns	ns
Urea (mmol/L)	8.28b	8.06b	8.92b	9.93a	0.36	0.001	ns
Total Protein (g/L)	57.40	62.70	56.40	56.40	0.18	ns	ns
Albumin (g/L)	29.00	30.70	31.60	30.70	0.10	ns	ns
Globulin (g/L)	28.60	32.50	25.30	26.10	0.23	ns	ns
Energy profile							
Glucose (mmol/L)	4.71b	4.76b	4.88b	5.11a	0.11	0.013	ns
Fructosamine (μmol/L)	176.85c	189.90c	198.74b	226.07a	5.89	0.001	ns

Means followed by different letters in the same line differ from each other by the SNK test at 5% probability. *SEM* standard error of the mean. ns – non significant (P> 0.05).

When the urea serum concentration profile was evaluated in the biweekly collections after the beginning of the diet, it was verified that the metabolic response was satisfactory for the two experimental groups, in which the nutrients of the diets were well utilized in relation to the blood concentration of urea, as evidenced by the positive linearity as a function of time (Table 3). It should be considered that the presence of spineless cactus in this design presented a mean level of 317g/kg of DM. Vieira *et al*. (2008) report the importance of the inclusion of fibrous foods in diets based on spineless cactus and observed that high intake occurs when the percentage of hay in the feed is around 300g/kg of DM. Araújo *et al*. (2012) also found a linear increase in serum urea concentration in lambs when they evaluated the effect of Tifton hay replacement with castor bean hull in diets based on spineless cactus. The authors considered the use of different biochemical markers in the evaluation of lambs receiving diets with variations in composition and their possible correlation with other parameters of production, such as intake and nutrient absorption, to be of great importance.

When the composition of the experimental diets was verified, there was a differential in soybean meal percentage in the diet with Tifton hay, in which this percentage was 100g/kg of DM, in relation to the diet with maniçoba hay where it was only of 45g/kg of DM, although both were associated with spineless cactus. Better synchronization between protein and energy available for ruminal microorganisms directly influenced the smaller blood urea concentration in the lambs' diet, since there may have been greater nutrient utilization and greater activities of the ruminal microbiota in relation to the availability of energy components and proteins.

The positive blood glucose linearity remained above that referenced by Kaneko *et al*. (2008) and coincides with the data of Santos *et al*. (2009) and Gouveia *et al*. (2015). Hyperglycemia can occur in situations of stress, young animals, pancreatitis, hyperinsulinism, and intravenous glucose infusion (González, 2000); however these situations cannot be related to the present study, since the animals were in hygienic conditions, with an adequate adaptation period to the housing conditions and sanitary and nutritional management.

This is most likely related to the effective intake of dry matter and nutrient utilization by the lambs, as well as the increase in the metabolic rate in the liver of the animals, providing effective gluconeogenesis over time receiving the experimental diets, regardless of the type of roughage used. This fact may also be related to the time of collection of the blood samples, which was performed four hours after the morning feed. According to Gouveia *et al*. (2015), when animals are recently fed and this occurs coincidently with blood collection, glycemia results in ruminants may be higher.

The increase in glycemia as a function of the diet supply time may be associated with the age of the animals (eight months) and with the time of receiving the feed, in addition to the fact that the diet offered contained a source of carbohydrate and starch. Diets containing high amounts of starch increase the availability of free glucose and stimulate the growth of several bacteria, increasing the production of volatile fatty acids in the rumen and hepatic gluconeogenesis (Van Soest, 1994).

Regarding the serum fructosamine, evaluating the mean range, from the beginning to the end of the experiment, values between 176.85 and 226.07µmol/L were obtained. These values are above that referenced by Kaneko *et al*. (2008), 172±2.0µmol/L, and in agreement with the data of Gouveia *et al*. (2015). The condition that justifies this result is probably related to the hyperglycemia observed in the animals during the time of receiving the diets since the total protein and albumin are within the levels of normality for the species (Kaneko *et al*., 2008). The concentration of fructosamine in plasma or serum is controlled by the balance between the synthesis and elimination of protein and glucose compounds.

However, if protein concentrations remain almost constant, the concentration of fructosamine is related to plasma glucose concentration in the previous two weeks (Filipovic´ *et al*., 2011). It can be identified in Table 3 that there was no influence of the time of receiving the diets on serum protein, albumin, or globulin, so the fructosamine profile is more related to increased glycemia. As is known, fructosamines are ketoamines formed by the non-enzymatic reaction between glucose and protein (60 to 70% is glycosylated with serum albumin) associated with the intensity and duration of glucose, directly reflecting the dynamics of the glucose concentration of the previous three weeks (Goldstein *et al*., 2004). The use of this biomarker in experimentation with sheep is scarce in Brazilian literature.

While there was a quadratic effect on serum levels of potassium (K) (P> 0.05) (Table 4). The other blood metabolites were not influenced.

Table 4. Enzymatic activity and electrolytic profile of Morada Nova lambs blood samples, in the function of the collections days, receiving diets with Tifton 85 Hay or maniçoba hay associated with spineless cactus

Item	Biweekly collections				SEM	*P*-value	
	0d	15d	30d	45d		L	Q
Enzymatic activity							
AP (IU/L)	597.80c	880.60b	747.80b	1195.00a	59.7	0.001	ns
AST (IU/L)	78.92	82.69	75.20	81.36	2.69	ns	ns
GGT (IU/L)	55.28	58.18	56.78	57.88	1.47	ns	ns
Electrolytic profile							
Na (mEq/L)	122.68b	126.31b	125.56b	138.67a	1.63	0.001	0.007
K (mEq/L)	4.32b	4.03b	4.19b	4.64a	0.11	0.030	0.001
Cl (mEq/L)	107.84	107.96	108.10	103.96	1.33	ns	ns

AP alkaline phosphatase; *AST* aspartate aminotransferase, *GGT* gamma-glutamyl transferase.
SEM, standard error of the mean; ns - non significant (P> 0.05).

When the mean values of AP are evaluated, it can be seen that they remained well above the limits considered normal for the species (Kaneko *et al*., 2008). It is very important to consider the positive linear effect of AP in lambs fed diets with spineless cactus, as observed in the present study. This enzyme is characterized by its extreme sensitivity, an increase being observed in cases of hepatic alterations (González and Scheffer, 2003). Liver damage was not characterized based on the evaluation of the gamma-glutamyltransferase (GGT) or aspartate aminotransferase (AST) profile during the period when the lambs received the experimental diets and the data remained physiological. In different situations, AP may be increased, such as secondary nutritional hyperparathyroidism, bone diseases, and as a consequence of the increase in bone cell activity and bone resorption (González, 2000). The significant increase in AP activity may be related to the presence of spineless cactus in the diet, since other forage cactus-containing experiments have shown an increase in this enzyme (Dantas *et al*., 2011; Araújo *et al.*, 2012; Gouveia *et al*., 2015).

Dantas *et al*. (2011) studying the biochemical profile of animals receiving a diet with spineless cactus, reported that there was a positive linear effect of AP activity in the different biweekly collections of biological material, strengthening the hypothesis that there is modification in the Ca:P ratio, direct action of oxalate on Ca chelation, and alteration in the enzymatic profile. It is worth mentioning that spineless cactus presents high levels of calcium oxalate and this can facilitate a situation of imbalance in the Ca:P ratio since this molecule does not have high enough bioavailability for organic Ca to meet the requirements, inducing mobilization of bone reserves. According to Araújo *et al*. (2012), forage cactus has a high Ca content and low P content in its bromatological composition, so that the presence of forage cactus in sheep diets can influence the metabolic profile.

In view of this situation, there is still no plausible explanation of the dynamics of AP in sheep receiving diets with different levels of spineless cactus, accompanied by different sources of roughage, as a source of effective fiber, and there is a need to better understand the influence of spineless cactus on the diet of ruminants, with more research on the biochemical dynamics, concentration of minerals, and hormones related to bone metabolism.

A positive linear effect was observed for Na and a quadratic effect for K, where it decreased up to 30 days after receiving forage cactus-containing diets. The values of Cl and K are within normal limits for the species according to Kaneko *et al*. (2008), but the values of Na are below those referenced by Kaneko *et al*. (2008), 139 to 152 mEq/L. In general, the forage cactus has high concentrations of Ca, K, and Mg (Santos *et al*., 2009; Rekik *et al*., 2010; Andrade *et al*., 2016) and low concentrations of P and Na (Rekik *et al*., 2010; João Neto *et al*., 2016).

João Neto *et al*. (2016) observed an increase in the rate of urinary excretion of K in sheep fed on spineless cactus, noting that this effect was expected due to the large amount of K in the forage cactus (Batista *et al*., 2003). K also increases the secretion of aldosterone and, consequently, the higher rate of urinary excretion of K. Although the urinary excretion of electrolytes in lambs was not evaluated, it is assumed that there was greater urinary excretion of K and consequent lower concentrations of this electrolyte in the blood for up to 30 days after beginning to receive the experimental diets.

Neto *et al*. (2016) found a lower rate of urinary excretion of Na, being justified by the lower concentration of this electrolyte in the spineless cactus composition, directly reflecting not only in the blood but also the urinary concentrations. The lower mean Na concentration in the different collection moments, from the beginning to 45 days can be explained by the fact that the forage cactus has a lower concentration of Na in its composition (Batista *et al*., 2003), as well as the fact that the forage cactus contains large volumes of water and Na hemodilution occurred, justifying means lower than the reference values for the species, according to Kaneko *et al*. (2008). The low concentration of Na present in the spineless cactus is a factor that should be highlighted since this mineral element performs several functions in the animal organism (González, 2000).

CONCLUSIONS

The replacement of Tifton 85 hay for Maniçoba hay does not cause negative changes in the dynamics of different biomarkers related to the energy, protein, and electrolyte profile. Maniçoba hay is a forage resource that can be used to feed Morada Nova lambs.

REFERENCES

ANDRADE, S.F.J.; BATISTA, A.M.V.; CARVALHO, F.F.R.; LUCENA, R.R.L. *et al*. Fresh or dehydrated spineless cactus in diets for lambs. *Acta Sci. Anim. Sci*., v.38, p.155-161, 2016.

ARAÚJO, P.B.A.; ANDRADE, R.P.X.; FERREIRA, M.A.; BATISTA, A.M.V. *et al*. Efeito da substituição do feno de capim tifton (*Cynodon* spp.) por casca de mamona (*Ricinus communis*) em dietas a base de palma forrageira *(Nopalea cochenilifera* Salm Dick) sobre o metabolismo energético, proteico e mineral em ovinos. *Rev. Bras. Med. Vet*., v.34, p.327-335, 2012.

BATISTA, A.M.V.; MUSTAFA, A.F.; SANTOS, G.R.A.; CARVALHO, F.F.R. *et al*. Chemical composition and ruminal dry matter and crude protein degradability of spineless cactus. *J. Agron. Crop Sci*., v.189, p.123-126, 2003.

BEN SALEM, H.; ABDOULI, H.; NEFZAOUI, A.; EL-MASTOURIA, A. *et al.* Nutritive value, behaviour, and growth of Barbarine lambs fed on oldman saltbush (*Atriplex* nummularia L.) and supplemented or not with barley grains or spineless cactus (*Opuntia* ficus-indica F. Inermis) pads. *Small Ruminant Res*., v.59, p.229-237, 2005.

CARDOSO, D.B.; CARVALHO, F.F.R.; MEDEIROS, G.R.; GUIM, A. *et al*. Levels of inclusion of spineless cactus (*Nopalea cochenillifera* Salm Dyck) in the diet of lambs. *Anim. Feed Sci. Technol*., v.247, p.23-31, 2019.

DANTAS, A.C.; SOARES, P.C.; BATISTA, A.M.V.; MAIA F.C.L. *et al.* Perfil enzimático (AST, GGT e FA) de ovinos recebendo dieta com palma forrageira (*Nopalea cochenillifera) in natura* ou desidratada. *Vet. Zootec.*, v.18, p.385-388, 2011.

FILIPOVIC´, N.; STOJEVI, Z.; MASEK, T.; MIKULEC, Z. *et al*. Relationship between fructosamine with serum protein, albumin and glucose concentrations in dairy ewes. *Small Ruminant Res*., v.96, p.46-48, 2011.

FRANÇA, A.A.; GUIM, A.; BATISTA, A.M.V.; PIMENTEL, R.M.M. *et al*. Anatomia e cinética de degradação do feno de Manihot glaziovii. *Acta Sci. Anim. Sci*., v.32, p.131-138, 2010.

GOLDSTEIN, D.E.; LITTLE, R.R.; LORENZ, R.A.; MALONE, J.I. *et al*. Tests of glycemia in diabetes. *Diabetes Care*, v.27, p.1761-1773, 2004.

GONZÁLES, F.H.D.; SCHEFFER, J.F.S. Perfil sanguíneo: ferramenta de análise clínica, metabólica e nutricional. In: GONZÁLES, F.H.D., CAMPOS, R. SIMPÓSIO DE PATOLOGIA CLÍNICA VETERINÁRIA DA REGIÃO SUL DO BRASIL, 2003, Porto Alegre. *Anais*... Porto Alegre: UFRGS, 2003. p.73-89.

GONZÀLEZ, F.H.D. Uso do perfil metabólico para determinar o status nutricional em gado de corte. In: GONZÀLEZ, F.H.D. *et al*. *Perfil metabólico em ruminantes*: seu uso em nutrição e doenças nutricionais. Porto Alegre: Universidade Federal do Rio Grande do Sul, 2000. p.63-74.

GOUVEIA, L.N.F.; MACIEL, M.V.; SOARES, P.C. *et al.* Perfil metabólico de ovinos em crescimento alimentados com dietas constituídas de feno ou silagem de maniçoba e palma forrageira. *Pesqui. Vet. Bras.*, v.35, p.5-9, 2015.

HALL, M.B. *Calculation of non-structural carbohydrate content of feeds thatcontain non-protein nitrogen*. Gainesville: University of Florida, 2000.

JOÃO NETO, P.; SOARES, P.C.; BATISTA, A.M.V.; ANDRADE, S.F.J. *et al.* Balanço hídrico e excreção renal de metabólitos em ovinos alimentados com palma forrageira (*Nopalea cochenillifera* Salm Dyck). *Pesqui. Vet. Bras*., v.36, p.322-328, 2016.

KANECO, J.J.; HARVEY, J.W.; BRUSS, M.L. *Clinical biochemistry of domestic animals*. 6.ed. San Diego: Academic Press, 2008. p.916.

LICITRA, G.; HERNANDEZ, T.M.; VAN SOEST, P.J. Standardization of procedures for nitrogen fractionation of ruminant feed. *Anim. Feed Sci. Technol*., v.57, p.347-358, 1996.

MACIEL, M.V.; CARVALHO, F.F.R.; BATISTA, A.M.V.; GUIM, A. *et al*. Carcass and non-carcass characteristics of sheep fed on cassava (*Manihot pseudoglaziovii* Pax & K. Hoffm.). *Chil. J. Agri. Res*., v.75, p.307-312, 2015.

MACIEL, M.V.; CARVALHO, F.F.R.; BATISTA, A.M.V.; SOUZA, E.J.O. *et al*. Maniçoba hay or silage replaces Tifton 85 hay in spineless cactus diets for sheep. *Acta Sci. Anim. Sci*., v.41, p.42553, 2019.

MERTENS, D.R. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beaker or crucibles: collaborative study. *J. AOAC Int*., v.85, p.1217-1240, 2002.

OFFICIAL methods of analysis. 15.ed. Arlington: AOAC, 1990.

OLIVEIRA, J.P.F.; FERREIRA, M.A.; ALVES, A.M.S.V.; MELO, A.C.C. *et al*. Spineless cactus as a replacement for sugarcane in the diets of finishing lambs. *Trop. Anim. Health Prod*., v.49, p.139-144, 2017.

PINHO, R.M.A.; SANTOS, E.M.; OLIVEIRA, J.S.; CARVALHO, G.G.P. *et al*. Does the level of forage neutral detergent fiber affect the ruminal fermentation, digestibility and feeding behavior of goats fed cactus pear? *Anim. Sci. J*., v.89, p.1424-1431, 2018.

REKIK, M.; BEN SALEM, H.; LASSOUED, N.; CHALOUATIA, H. *et al*. Supplementation of barbarine ewes with spineless cactus (*Opuntia ficus-indica* f. inermis) cladodes during late gestation-early suckling: Effects on mammary secretions, blood metabolites, lamb growth and postpartum ovarian activity. *Small Ruminant Res.*, v.90, p.53-57, 2010.

SANTOS, K.L.L.; GUIM, A.; BATISTA. A.M.; SOARES, P.C. *et al*. Balanço de macrominerais em caprinos alimentados com palma forrageira e casca de soja. *Rev. Bras. Saúde Prod. Anim*., v.10, p.546-559, 2009.

SEO, S.; LANZAS, C.; TEDESCHI, L.O.; PELL, A.N.; FOX, D.G. Development of a mechanistic model to represent the dynamics of particle flow out of the rumen and to predict rate of passage of forage particles in dairy cattle. *J. Dairy Sci.*, v.92, p.3981-4000, 2009.

SIQUEIRA, M.C.B.; FERREIRA, M.A.; MONNERAT, J.P.I.S.; SILVA, J.L. *et al*. Optimizing the use of spineless cactus in the diets of cattle: total and partial digestibility, fiber dynamics and ruminal parameters. *Anim. Feed Sci. Technol*., v.226, p.56-64, 2017.

SNIFFEN, C.J.; O'CONNOR, J.D.; VAN SOEST, P.J.; FOX, D.G. *et al*. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. *J. Anim. Sci*., v.70, p.3562-3577, 1992.

STATISTICAL analyses sistem. SAS/STAT Users Guide,Version 9.1. Cary: SAS Institute Inc., 2009.

VAN CLEEF, H.E.; PATINO, P.R.; NEIVA JÚNIOR, P.A.; SERAFIM, S.R. *et al*. Distúrbios metabólicos por manejo alimentar inadequado em ruminantes: novos conceitos. *Rev. Colomb. Cienc. Anim*., v.1, p.319-341, 2009.

VAN SOEST, P.J. *Nutritional ecology of the ruminant*. 2.ed. New York: Cornell University Press, 1994. 476p.

VAN SOEST, P.J.; ROBERTSON, J.B.; LEWIS, B.A. Methods for dietary fibre, neutral detergent fibre, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.*, v.74, p.3583-3597, 1991.

VIEIRA, E.L.; BATISTA, A.M.V.; GUIM, A.; CARVALHO, F.F. Effects of hay inclusion on intake, in vivo nutrient utilization and ruminal fermentation of goats fed spineless cactus (*Opuntia ficus-indica* Mill) based diets. *Anim. Feed Sci. Technol*., v.141, p.199-208, 2008.