Metabolic response of endangered goats fed spineless cactus associated with Tifton-85 hay or Maniçoba hay

Resposta metabólica de caprinos ameaçados de extinção alimentados com palma forrageira associada ao feno de Tifton-85 ou feno de Maniçoba

Respuesta metabólica de caprinos en peligro de extinción alimentados con nopal asociados con heno Tifton-85 o heno Maniçoba

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ABSTRACT
The aim of this study was to evaluate the effects of replacement of Tifton-85 hay by maniçoba hay, in spineless cactus-based diets, on markers of energy, protein, mineral metabolism and serum enzyme activity of Moxotó goats. Sixteen uncastrated male Moxotó breed goats, with 20 months old and initial body weight of 21.7 ± 3.92 kg were used in a randomized blocks design, using the initial weight as the criterion for the formation of blocks, with two treatments and eight replicates per treatment. The experimental treatments consisted of two diets: diets containing Miúda spineless cactus associated with Tifton-85 hay (1) or maniçoba hay (2), with roughage:concentrate ratio of 70:30. Blood samples were collected fortnightly (baseline, 15 days, 30 days and 45 days) during the feedlot period. There was a higher serum concentration of total protein and fructosamine ($P < 0.05$) in goats that received maniçoba hay. However, there was higher serum gamma-glutamyl transferase (GGT) enzyme activity in goats that ingested Tifton-85 hay ($P < 0.05$). Concerning to the profile of blood metabolites in the different fortnightly collections, it was possible to verify a significant effect for urea, fructosamine, GGT enzyme activity, K and Cl levels ($P < 0.05$). In conclusion, Tifton-85 hay and maniçoba hay combined with spineless cactus does not cause metabolic disorders in feedlot native goats.

Keywords: adapted plants, blood parameters, drylands, Euphorbiaceae, Moxotó goat breed.

RESUMO
O objetivo deste estudo foi avaliar os efeitos da substituição do feno de Tifton-85 pelo feno de maniçoba, em dietas à base de palma forrageira, sobre marcadores de metabolismo energético, proteico, mineral e atividade enzimática sérica de caprinos Moxotó. Foram utilizados 16 caprinos machos, não castrados, da raça Moxotó, com 20 meses de idade e peso corporal inicial de 21,7 ± 3,92 kg, em delineamento experimental de blocos casualizados, utilizando-se o peso inicial como critério para formação dos blocos, com dois tratamentos e oito repetições por tratamento. Os tratamentos experimentais consistiram de duas dietas: dietas contendo palma forrageira Miúda associada ao feno de Tifton-85 (1) ou feno de maniçoba (2), com relação volumoso:concentrado de 70:30. Amostras de sangue foram coletadas quinzenalmente (*baseline*, 15, 30 e 45 dias) durante o período de confinamento. Houve maior concentração sérica de proteínas totais e frutosaminas ($P < 0,05$) nos caprinos que receberam feno de maniçoba. Entretanto, observou-se maior atividade sérica da enzima gama-glutamil transferase

(GGT) nos caprinos que ingeriram feno de Tifton-85 (P < 0,05). Quanto ao perfil dos metabólitos sanguíneos nas diferentes coletas quinzenais, foi possível verificar efeito significativo para ureia, frutosamina, atividade da enzima GGT, níveis de K e Cl (P < 0,05). Conclui-se que o feno de Tifton-85 e o feno de maniçoba combinados com palma forrageira não causam distúrbios metabólicos em caprinos nativos confinados.

Palavras-chave: caprinos Moxotó, Euphorbiaceae, parâmetros sanguíneos, plantas adaptadas, terras secas.

RESUMEN
El objetivo de este estudio fue evaluar los efectos de la sustitución del heno Tifton-85 por heno de maniçoba, en dietas a base de nopal, sobre marcadores de energía, proteínas, metabolismo mineral y actividad enzimática sérica de caprinos Moxotó. Se utilizaron dieciséis machos caprinos enteros de raza Moxotó, con 20 meses de edad y peso corporal inicial de 21,7 ± 3,92 kg, en un diseño de bloques al azar, utilizando el peso inicial como criterio para la formación de bloques, con dos tratamientos y ocho repeticiones por tratamiento. Los tratamientos experimentales consistieron en dos dietas: dietas que contenían nopal Miúda asociado con heno Tifton-85 (1) o heno de maniçoba (2), con una relación forraje:concentrado de 70:30. Se recolectaron muestras de sangre quincenalmente (línea de base, 15 días, 30 días y 45 días) durante el período del corral de engorde. Hubo una mayor concentración sérica de proteína total y fructosamina (P < 0,05) en las cabras que recibieron heno de maniçoba. Sin embargo, hubo una mayor actividad de la enzima gamma-glutamil transferasa (GGT) en suero en las cabras que ingirieron heno Tifton-85 (P < 0,05). En cuanto al perfil de metabolitos sanguíneos en las diferentes colectas quincenales, se pudo verificar un efecto significativo para la urea, fructosamina, actividad de la enzima GGT, niveles de K y Cl (P < 0,05). En conclusión, el heno Tifton-85 y el heno de maniçoba combinados con nopal no causan trastornos metabólicos en caprinos nativos confinados.

Palabras clave: Euphorbiaceae, parámetros sanguíneos, plantas adaptadas, raza caprina Moxotó, tierras secas.

1 INTRODUCTION

The Brazilian semiarid region is characterized by high temporal and spatial rainfall variability, in addition to high atmospheric evaporation (Moura *et al*, 2007), and these factors combined significantly affect forage production. Thus, it is essential to cultivate and use native or exotic adapted crop forages in feeding the ruminants. In this context, the spineless cactus (SC) (*Nopalea* and *Opuntia*) is very adapted to edaphoclimatic conditions of dry environments worldwide, demonstrating excellent potential as a dietary ingredient in the production of cattle, goats and sheep (Moraes *et al*, 2019; Albuquerque *et al*, 2020; Mâcedo *et al*, 2020; Silva *et al*, 2021a).

In nutritional terms, SC is a feed resource rich in water, energy and minerals (Rocha Filho *et al*, 2021; Costa *et al*, 2022; Silva *et al*, 2023). Recent studies have shown that the Miúda

SC species (*Nopalea cochenillifera* Salm Dyck) has the following chemical composition, based on dry matter (DM): 96 g/kg DM (natural matter), 146.4 g/kg ash, 50 g/kg crude protein (CP), 196.3 g/kg neutral detergent fiber (NDF), 608 g/kg non-fibrous carbohydrates (NFC), and 137 g/kg total sugars (Edvan *et al*, 2020; Rocha Filho *et al*, 2021). On the other hand, this cactaceae has low levels of fiber (Siqueira *et al*, 2019; Pessoa *et al*, 2020), which encourages its use in combination with other roughages (fresh or conserved) containing physically effective neutral detergent fiber (Pinho *et al*, 2018; Souza *et al*, 2018).

In recent study, Bezerra *et al.* (2023) recommended the inclusion of up to 400 g/kg DM of SC in lamb diets to maximize performance. A successful roughage option commonly used in association with SC in diets for small ruminants is Tifton-85 (*Cynodon* spp.) (Cardoso *et al*, 2019; Lopes *et al*, 2020). Furthermore, maniçoba (*Manihot pseudoglaziovii* Pax & K. Hoffm.), a native species of the Caatinga rangeland (seasonally dry tropical forest), when in the form of hay or silage, and for presenting high nutritional value, has been successfully used as a source of fiber in SC-based diets for lambs (Maciel *et al*, 2015; Maciel *et al*, 2019; Moura *et al*, 2020; Nascimento *et al*, 2023), without negatively affecting the metabolic profile of the animals (Gouveia *et al*, 2015; Soares *et al*, 2020).

The Moxotó breed is considered one of the main local goat breeds in the Northeast region of Brazil and endangered, being of great economic importance (Medeiros *et al*, 2020). According to Lima Júnior *et al.* (2015), the replacement of Tifton-85 hay by maniçoba hay, in the diet of Moxotó goats, does not change the carcass components. Additionally, Santos *et al.* (2021) reported that maniçoba hay can replace up to 30% of Tifton-85 hay, without negatively affect nutrients intake and ruminal parameters of Santa Inês sheep. However, there are few studies of a metabolic nature involving native goats of the Moxotó breed.

The study of blood biochemical markers is essential for understanding the possible effects that certain dietary components associated with SC can cause in one or more organ systems and, consequently, in the animal health and production. According to Soares *et al.* (2020), the replacement of Tifton-85 hay by maniçoba hay does not cause negative changes in the dynamics of different biomarkers of locally adapted lambs. Therefore, the objective of this study was to evaluate the replacement of Tifton-85 hay by maniçoba hay, in SC-based diets, on markers of energy, protein, mineral metabolism and serum enzyme activity of Moxotó breed goats.

2 MATERIALS AND METHODS

The trial was approved by Committee of Ethics in the Use of Animals of the Federal Rural University of Pernambuco (UFRPE), under license number 010705/2008. The experiment was carried out in the Department of Animal Science at the UFRPE, Recife, PE, Brazil. This research has part of the methodology based on a previous study by Lima Júnior *et al.* (2015).

2.1 ANIMALS AND FACILITIES

Sixteen uncastrated male Moxotó breed goats, with 20 months old and initial body weight of 21.7 ± 3.92 kg were used in a randomized blocks design, using the initial weight as the criterion for the formation of blocks, with two treatments and eight replicates per treatment. Previous to the feedlot, all animals were weighed, identified, vaccinated against clostridioides and treated against ecto- and endoparasites. Subsequently, they were randomly distributed in individual pens (1.0 m x 2.8 m) provided with individual feeder and drinker. The study was 58 days, including 10 days of the adaptation period and 48 days of the record taking and sampling period.

2.2 TREATMENTS AND MANAGEMENT

The experimental treatments consisted of two diets formulated for provide an average gain of 150 g/day/animal (NRC, 2007): diets containing SC species Miúda associated with Tifton-85 hay (1) or maniçoba hay (2), with roughage:concentrate ratio of 70:30 (dry matter basis) (Table 1). The Tifton-85 hay and maniçoba hay were crushed in a forage machine and passed through 4 mm sieves.

Table 1. Ingredients proportion and chemical composition of the experimental diets

Ingredients (g/kg)	**Diets**	
	Tifton-85 hay	**Maniçoba hay**
Corn grain	180	200
Soybean meal	100	45
Miúda spineless cactos	300	335
Tifton-85 hay	400	0
Maniçoba hay	0	400
Mineral mix[1]	10	10

Urea	10	10
Diet composition (g/kg dry matter (DM), unless stated)		
DM (g/kg FM[2])	260.5	243.1
Organic matter	884.1	874.4
Metabolizable energy (kcal/kg DM)[3]	2355	2378
Crude protein	135	136
Ether extract	20	26
Total carbohydrates	729.2	717.5
Non-fibrous carbohydrates	333.1	337.5
Neutral detergent fiber$_{ap}$[4]	396	380

[1]Mineral supplement composition (guarantee levels/kg): vit. A = 135,000 IU; vit. D3 = 68,000 IU; vit. E = 450 mg; Ca = 240g; P = 71g; K = 28.2g; S = 20g; Mg = 20g; Co = 30 mg; Cu = 400 mg; Cr = 10 mg; Fe = 2500 mg; I = 40 mg; Mn = 1350 mg; If = 15 mg; Zn = 1700 mg; F (max) = 710 mg; Phosphorus solubility in 2% citric acid (min) = 95%; [2]fresh matter; [3]values estimated from Valadares Filho *et al.* (2002); [4]neutral detergent fiber assayed with a heat stable amylase and corrected for ash and nitrogenous compounds.
Source: Prepared by the authors

The diets were provided *ad libitum* as a total mixed ration twice a day, at 09:00 h and 16:00 h. The amount of feed supplied was adjusted daily, according to the dry matter (DM) intake of the previous day, allowing 20% leftovers. The nutrient intake was determined by the difference between offered feed amounts and leftovers.

2.3 BROMATOLOGICAL ANALYZES

Samples of feed and leftovers were collected for determination of DM, organic matter (OM), ether extract (EE) and crude protein (CP), and analyses were performed according to the Association of Official Analytical Chemists (AOAC, 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].

2.4 BLOOD COLLECTION, PROCESSING AND ANALYSIS

Blood samples were collected three hours after the morning feeding, by jugular venipuncture, in vacuum siliconized tubes (VACUETTE®, Greiner Bio-One Brazil - Americana, SP) with anticoagulant (Sodium Fluoride with EDTA) to obtain plasma and without anticoagulant to obtain serum. Blood samples without anticoagulant were kept at room temperature, while the others with anticoagulant were homogenized, refrigerated and taken to the laboratory for further processing. All tubes were subjected to centrifugation for 15 minutes at 1600 G. Aliquots of serum and plasma were subsequently conditioned in 2-mL polyethylene tubes (type Eppendorf) and stored at a temperature of –20º C. The collections were carried out fortnightly (baseline, 15 days, 30 days and 45 days).

The biochemical indicators analyzed were: creatinine, urea, total protein, albumin, fructosamine, alkaline phosphatase (AP), aspartate aminotransferase (AST), gamma-glutamyl transferase (GGT), sodium (Na), potassium (K) and chlorine (Cl) (serum), and glucose (plasma). Serum globulin was obtained by the difference between total protein and albumin. Commercial kits of LABTEST® brand reagents were used to determine fructosamine and DOLES® brand kits for the other biochemical markers. Blood biochemical determinations were carried out using a BIOPLUS 2000 semi-automatic biochemical analyzer. Sodium and potassium were determined by flame photometry using a Benfer BFC 300 device.

2.5 STATISTICAL ANALYSIS

The data were submitted to ANOVA using the Statistical Analysis System (SAS, 2009) computational program, using the GLM procedure. In cases where there was significance in the F test, the means were compared by the minimum significant difference of the SNK Test.

The analyzes were carried out according to the model below:

$$Y_{ij} = \mu + T_i + M_i + T_i M_i + \epsilon_{ij} \quad (1)$$

Where:

Y_{ij} = observation referring to treatment i in repetition j;
μ = constant associated with all observations;
T_i = effect of treatment i on repetition j;
M_i = effect of collection times on j repetition;
T_iM_i = effect of treatment interaction x collection times;
ϵ_{ij} = error associated with all observations.

In addition, regression analysis was performed, depending on the moments of blood collection from the animals. For all statistical analyzes performed, a significance level of 5%

was adopted.

3 RESULTS

There was a higher serum concentration of total protein and fructosamine ($P < 0.05$) in goats that received maniçoba hay. On the other hand, there was higher serum GGT enzyme activity in goats that ingested Tifton-85 hay ($P < 0.05$). The tested diets did not cause significant variations in the other blood metabolites evaluated ($P > 0.05$) (Table 2).

Table 2. Indicators of protein and energy metabolism, enzymatic activity and electrolyte profile of goats fed Tifton-85 hay or maniçoba hay, in spineless cactus-based diets

Parameters	Diets		CV[1] (%)
	Tifton-85 hay	Maniçoba hay	
Creatinine (µmol/L)	85.0±10.71	84.15±12.15	13.86
Urea (mmol/L)	8.91±1.97	9.37±2.05	19.36
Total protein (g/L)	60.50±10.90b	66.60±10.30a	16.74
Albumin (g/L)	31.10±5.10	32.80±5.10	15.43
Globulin (g/L)	28.70±10	33.50±10.40	32.09
Plasma glucose (mmol/L)	4.43±0.54	4.67±0.45	10.74
Fructosamine (µmol/L)	257.42±96.68b	275.88±21.38a	9.06
Alkaline phosphatase (U/L)	509.54±413.61	469.02±211.52	68.54
Aspartate aminotransferase (U/L)	61.36±11.82	64.66±14.96	21.25
Gamma-glutamyl transferase (U/L)	47.01±6.62a	42.49±8.15b	13.30
Sodium (mEq/L)	128.56±7.29	128.68±8.05	5.81
Potassium (mEq/L)	4.25±0.61	4.30±0.68	14.51
Chlorine (mEq/L)	106.89±12.80	108.60±5.01	8.65

[1]Coefficient of variation. Averages in rows followed by different letters are statistically different by the SNK test at 5% probability.

Source: Prepared by the authors

Concerning to the profile of blood metabolites in the different fortnightly collections, it was possible to verify a significant effect for urea, fructosamine, GGT enzyme activity, K and Cl levels ($P < 0.05$; Table 3). Lower serum urea concentrations were observed at the beginning of the experiment (baseline), compared to the other collections ($P = 0.007$). Higher means of fructosamine were observed after 45 days of feedlot ($P = 0.001$).

As for serum GGT activity and serum K concentration, higher averages were recorded in the initial collection, and these decreased with the other fortnightly collections ($P < 0.05$). Serum GGT activity decreased linearly ($P = 0.001$). Decreasing and increasing linear effect were recorded for serum levels of K ($P = 0.027$) and Cl ($P = 0.041$), respectively (Table 3).

Table 3. Indicators of protein and energy metabolism, enzymatic activity and electrolyte profile of goats fed Tifton-85 hay or maniçoba hay, in spineless cactus-based diets, depending on the time of collection

Parameters	Collection				P-value		CV[1] (%)
	Baseline	15d	30d	45d	Linear	Quadratic	
Creatinine (µmol/L)	80.89±7.20	84.47±10.51	85.55±14.27	87.38±12.42	NS	NS	13.47
Urea (mmol/L)	7.61±1.56b	9.33±1.40a	10.57±2.28a	9.12±1.69a	0.005	0.007	19.22
Total protein (g/L)	66.40±13.01	59.60±8.00	61.60±11.10	66.50±10.50	NS	NS	17.10
Albumin (g/L)	31.00±4.70	32.40±4.50	31.10±6.90	33.30±4.10	NS	NS	16.24
Globulin (g/L)	33.50±11.40	28.20±9.70	30.20±10.30	32.50±10.20	NS	NS	33.66
Energy profile							
Plasma glucose (mmol/L)	4.56±0.39	4.76±0.54	4.33±0.40	4.55±0.61	NS	NS	10.92
Fructosamine (µmol/L)	152.15±19.23c	248.13±20.77b	234.64±25.00b	431.69±53.44a	0.001	0.001	9.11
Enzimatic profile							
AP[2] (U/L)	547.46±333.38	357.75±287.38	524.88± 263.80	527.03±399.39	NS	NS	66.45
AST[3] (U/L)	62.48±14.88	57.96±14.61	66.22±14.47	65.84±8.64	NS	NS	21.30
GGT[4] (U/L)	49.99±5.98a	46.96±5.58ab	43.56±7.31a	38.48±7.17c	0.001	NS	14.64
Electrolyte profile							
Sodium (mEq/L)	127.75±6.19	126.06±6.83	132.75±9.25	127.93±6.84	NS	NS	5.73
Potassium (mEq/L)	4.50±0.56a	4.20±0.54ab	4.48±0.83a	3.90±0.39b	0.027	NS	14.20
Chlorine (mEq/L)	102.78±16.45b	107.71±3.82ab	111.76±6.34a	108.72±4.88ab	0.041	NS	8.67

[1]Coefficient of variation; [2]alkaline phosphatase; [3]aspartate aminotransferase; [4]gamma-glutamyl transferase. NS: not significant (P>0.05). Averages in rows followed by different letters are statistically different by the SNK test at 5% probability
Source: Prepared by the authors

4 DISCUSSION

Total protein serum values, in function of the tested diets and collections, remained within the normal physiological limits for the goat species: 64 to 70 g/L (Kaneko *et al*, 2008). On the other hand, the diet containing maniçoba hay caused an increase in the blood level of total protein (Table 2), which may be related to the higher protein intake provided by maniçoba hay in relation to Tifton-85 hay. Studies involving maniçoba in the semiarid of Brazil have reported values of up to more than 160 g/kg of crude protein (DM basis) in its composition (França *et al*, 2010; Matias *et al*, 2020), which is a value normally higher than that observed in the Tifton-85 hay (Lopes *et al*, 2020; Santos *et al*, 2021). Additionally, as reported in our complementary paper (Lima Júnior *et al*, 2015), there was no effect of diets on DM intake.

Mean urea blood concentrations were 8.91 and 9.37 mmol/L in goats fed Tifton hay and maniçoba hay, respectively (Table 2), values below those reported by Silva *et al.* (2021b), when investigating the blood biochemistry of goats that received different species of spineless cactus associated with Tifton-85 hay. However, the serum urea levels obtained in the present study can be considered within the reference range (Contreras *et al*, 2000): 4.0 to 10.0 mmol/L. The blood urea concentration is directly related to the protein intake of the diets, the energy:protein ratio, as well as being a result of rumen ammonia absorption and protein metabolism in the animal's tissues (González and Scheffer, 2002).

Concerning to the collections, the blood urea concentration showed a quadratic behavior (P = 0.007), with the highest level of circulating urea obtained 30 days after the introduction of the experimental diets (Table 3). Thus, it is inferred that the increase in blood levels of this biomarker of the protein metabolism is related to the greater input of nutrients that the animals received through the intake of balanced diets, in relation to the baseline collection. It is important to emphasize that urea is produced by the liver through the catabolism of proteins and its measurement in serum is usually performed to assess kidney function, liver failure or congenital anomalies of the portal system, and it may also fluctuate depending on the diet. Therefore, possibly the increase in serum urea, not accompanied by the increase in creatinine levels, which always remained normal, are due to the dietary factor, not having pathological significance.

The highest serum concentration of fructosamine was observed in goats that ingested maniçoba hay (275.88 μmol/L), compared to those that ingested Tifton hay (257.42 μmol/L) (Table 2). In the regression analysis as a function of collection time, there was positive linearity of serum fructosamine concentration (P = 0.001). In addition, in conjunct analysis, regardless of the type of hay, the means showed a significant variation in the first fortnight after receiving the experimental diets. The animals in the present experiment were in healthy conditions, being all males and of native breed, which allows considering that such values can be considered as a reference for further studies and necessary to establish reference values in the face of several variation factors, particularly those related to energy and protein metabolism, breeds, sex and species.

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 hyperglycemia, directly reflecting on the dynamics of glucose concentration over the last three weeks (Weerasekera and Peiris, 2000; Gouveia *et al*, 2015). In this study, it was observed that the glycemic levels were above the referenced in the literature (Kaneko *et al*, 2008), in addition to the fact that the protein level varied in relation to the type of hay used, a fact that can justify the referred profile.

According to Filipovic *et al.* (2011), the serum level of fructosamine depends on the average concentration of glucose in the blood during the previous two weeks. In addition, Kaneko *et al.* (2008) reported that the concentration of fructosamine does not directly depend on the concentration of serum proteins, but on the half-life of the proteins. Albumin is the most abundant serum protein and is glycosylated more rapidly than other serum proteins. Thus, glycosylated albumin accounts for about 80% of glycosylated proteins in serum (Mosca *et al*, 1987). In the correlation analysis between fructosamine, total protein and albumin, it was identified that fructosamine was significantly associated with albumin ($r = 0.24$; $P < 0.05$).

Due to the link between serum fructosamine concentration, protein metabolism and mean blood glucose concentration (Filipovic *et al*, 2011), it is suggested that there is a better investigation into the usefulness of fructosamine as an indicator of energy metabolism and protein from small ruminants fed diets containing spineless cactus and different sources of fiber, as is the case of Tifton hay and maniçoba hay. Thus, the importance of the data obtained here is emphasized, since reference values for fructosamine in goats are limited in the literature and there are still few references in relation to sheep.

Although they vary depending on the collections, the serum GGT activities are within the normal limit for goats (Kaneko *et al*, 2008): 20 to 56 U/L, which associated with the observed AST and AP activities, suggest absence of marked liver damage (González and Scheffer, 2003; Lassen, 2007). Gouveia *et al.* (2015), when evaluating the metabolic response of sheep fed hay or maniçoba silage replacing Tifton-85 hay, combined with spineless cactus, also did not observe significant changes in the enzymatic profile of growing sheep. Serum levels of K and Cl can be considered normal (Kaneko *et al*, 2008) and the concentrations of these electrolytes are consistent with the values reported by Soares *et al.* (2020), using these same diets for native lambs.

5 CONCLUSION

Tifton-85 hay and maniçoba hay combined with spineless cactus does not cause metabolic disorders in feedlot native goats. Therefore, the use of maniçoba hay represents a nutritional alternative for grass hay in the Brazilian semi-arid region.

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