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Maniçoba hay or silage replaces Tifton 85 hay in spineless cactus diets for sheep

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ABSTRACT. The aim of this study was to evaluate the replacement of Tifton 85 hay (*Cynodon* spp.) by maniçoba hay or silage (*Manihot glaziovii* Muell. Arg) on sheep intake and performance. Twenty-four male Santa Ines animals were used, with initial body weight of 19.77 ± 1.95 kg and average age of 160 days. The animals were distributed in three treatments (Tifton 85 hay-TH, Maniçoba hay-MH and Maniçoba silage-MS), arranged in a randomized blocks design, with 8 replicates per treatment. The feedlot period lasted for 71 days. The means of the variables were tested by Tukey's test at 5% probability. Sheep fed MH presented higher dry matter intake ($p > 0.05$) than those fed TH (1.17 kg day^{-1} vs 1.06 kg day^{-1}). Neutral detergent fiber intake was higher ($p > 0.05$) for MH-fed sheep (0.394 kg day^{-1}) when compared to MS (0.340 kg day^{-1}). The digestibility of total carbohydrates was higher ($p > 0.05$) for MH diet (0.71 g kg^{-1}) than TH (0.67 g kg^{-1}). The average daily gain and body weight at slaughter did not differ ($p > 0.05$) among treatments. Maniçoba hay or silage can replace Tifton 85 hay in sheep diets.

Keywords: caatinga; *Euphorbiaceae*; native forage; *Nopalea*; sheep performance.

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Introduction

Spineless cactus occupies a prominent position in the composition of ruminant diets and is the most cultivated cactaceous in the semiarid region of Brazil. However, the exclusive supply of spineless cactus to ruminants may cause non-pathological diarrhea and bloat (Gebremariam, Melaku, & Yami, 2006) due to its low content of fiber (Siqueira et al., 2017) and high dry matter degradability (rate of 10% h^{-1}) (Batista et al., 2009). Vieira et al. (2008) support the inclusion of at least 300 g kg^{-1} Tifton 85 hay in the diet of small ruminants fed with spineless cactus to optimize the use of dietary energy and to promote ruminal health. Other sources, such as soybean hulls (Souza et al., 2009), cotton seed (Costa et al., 2012) and sugarcane bagasse (Pessoa et al., 2013) have been suggested to be associated with spineless cactus. However, studies on forages adapted to the semi-arid zone in spineless cactus diets are still scarce.

The *Manihot* (Euphorbiaceae) genus originated in the Mesoamerica (Duputié, Salick, & McKey, 2011) and presents more than 98 species. The cosmopolitan *Manihot esculenta* Crantz is distributed throughout the American continent and is considered the main source of starch in the tropical world (Nassar, Hashimoto, & Fernandes, 2008). Other wild species such as *Manihot glaziovii* (Muell. Arg) also presents potential in animal feed (Backes et al., 2014).

Manihot glaziovii (Muell. Arg) is xerophilous lacticiferous, toxic to animals when ingested *in natura* (Amorim, Medeiros, & Riet-Correa, 2005), but innocuous as hay or silage. Castro, Silva, Medeiros, and Pimenta Filho (2007) recommended the inclusion of up to 800 g kg^{-1} maniçoba hay in sheep diets. Campos et al. (2017) recommended the inclusion of 500 g kg^{-1} natural hybrid of *M. glaziovii* (Muell. Arg) with *M. esculenta* silage in sheep diets.

Considering the scenario of climatic changes and the adaptation of *M. glaziovii* (Muell. Arg) to semi-arid zones, the aim of this study was to evaluate the replacement of Tifton 85 hay (*Cynodon* spp.) by Maniçoba hay or silage (*M. glaziovii* Muell. Arg) on the intake, digestibility and performance of confined sheep.

Material and methods

The experiment was performed in the following geographic coordinates: 8º04'03'S and 34º55'00''W, altitude of 4 meters. According to Koppen (Köppen & Geiger, 1928), the climate of the region is classified as Ams', which is characterized as hot and humid, with an average annual temperature of 25.2°C.

Twenty-four non-castrated male Santa Ines hair sheep were used, with average body weight of 19.77 ± 1.95 kg and average age of 160 days, distributed in 3 treatments [Tifton 85 hay (TH), Maniçoba hay (MH) and Maniçoba silage (MS)], arranged in a randomized blocks design with eight replicates. The animals were housed for 71 days in individual suspended pens with dimensions of 1.2 m x 1.2 m, with feeders and drinkers. The first 15 days were intended for adaptation to the management and 56 days for data collection.

The diets were calculated to meet the gain requirements of 150 g day^{-1} (National Research Council [NRC], 2007) and were composed by spineless cactus (*Nopalea cochenillifera* Salm-Dyck), Tifton 85 grass hay (*Cynodon* spp.), Maniçoba hay or silage (*Manihot glaziovii* Muell. Arg), soybean meal, corn, mineral mixture and urea (Table 1 and 2).

Maniçoba hay and silage were made from plants harvested directly from the Caatinga biome in Brazil, in the fruiting phase and composed of thin leaves and branches. The material was crushed in a forage machine (Trapp, model TRF-90F) and dried in the sun (hay) or compacted (silage) in polyethylene casks of 250 liters. Tifton 85 hay was also crushed in a forage machine with 8 mm sieve.

All the ingredients were mixed and offered as a complete mixture twice a day at 9 am and 4 pm, with refusals of 15% of the offered. Feed and refusals were quantified for the calculation of daily intake, sampled and stored for later analysis.

The apparent digestibility was obtained with the aid of external purified and enriched lignin (LIPE®). The aid LIPE was analyzed in spectrophotometer with light detector in infrared spectrum (FT-IR). Samples of dried and ground feces at 2mm were mixed with KBr and the concentration of LIPE was determined. The assay lasted for 14 days: 9 for adaptation and 5 for total collection. During the collection period, daily samples of feed, refusals and feces were collected to obtain a composed sample per animal. These samples were stored at -15°C and then dried in oven, processed in a mill and subjected to laboratory analysis.

Feed, refusals and feces were analyzed for dry matter (DM), mineral matter (MM), crude protein (CP) and ether extract (EE) according to the Instituto Nacional de Ciência e Tecnologia de Ciência Animal (INCT-CA, 2012). Van Soest, Robertson, and Lewis (1991) methodology was used for neutral detergent fiber (NDF). The equation proposed by Sniffen, O'Connor, Van Soest, Fox, and Russell (1992) was used for the estimation of total carbohydrate (TCH), and for non-fiber carbohydrate (NFC), the equation proposed by Hall, Hoover, Jennings, and Webster (1999) was adopted.

Results and discussion

On average, sheep fed maniçoba hay (MH) consumed 100 g DM more ($p > 0.05$) than the animals fed tifton hay (TH). However, the intake of animals fed maniçoba silage (MS) did not differ from the other treatments (Table 3).

The higher DMI of FM-fed animals in relation to FT can be attributed to the anatomical differences between the plant species. Maniçoba has a similar anatomy to C_3 plants (França et al., 2010). Therefore, it has an easier ingestion and digestibility than the tropical grass *Cynodon* (Akin, 1989).

Crude protein intake (170 g day^{-1}) and digestible protein (120 g day^{-1}) were not influenced ($p > 0.05$) by the diets. Although it is a woody shrub, maniçoba presents a low content of condensed tannin (1.64% DM) (Cruz et al., 2007), which may contribute to the lack of effect on the protein digestibility. However, maniçoba hay and silage presented levels of 105.0 and 125.0 g kg^{-1} DM, respectively, higher than grass hay (75.0 g kg DM^{-1}). Thus, conserved maniçoba can be recommended as a supplement for herds in protein deficit (Harun, Alimon, Jahromi, & Samsudim, 2017).

Table 1. Chemical composition of dry matter (DM), organic matter (OM), mineral matter (MM), crude protein (CP), ether extract (EE), insoluble neutral detergent fiber corrected for ash and protein (NDFap) non-fiber carbohydrates (NFC), total carbohydrates (TC) of the ingredients of the experimental diets (g kg^{-1} DM).

Ingredients (g kg^{-1})	DM	OM	MM	CP	EE	NDFap	NFC	TCHO
Corn ground	904	964	36	83	45	151	684	836
Soybean meal	893	932	68	480	14	155	283	438
Spineless cactus	92	885	115	63	15	217	590	807
Tifton hay	925	907	91	75	22	644	120	812
Maniçoba hay	895	919	82	105	55	538	159	758
Maniçoba silage	347	914	86	125	62	401	254	726

*Values in g kg^{-1} DM.

Table 2. Chemical composition and percentage of the experimental diets (g kg^{-1} DM).

Ingredients (g kg^{-1} DM)	Tifton Hay	Maniçoba Hay	Maniçoba Silage
Ground corn	200	160	175
Soybean meal	115	120	105
Spineless cactus	360	400	400
Tifton hay	300	00	00
Maniçoba hay	00	300	00
Maniçoba silage	00	00	300
Mineral mixture	10	10	10
Urea	15	10	10
DM (g kg^{-1})	619.0	577.0	413.0
CP (g kg^{-1} DM)	159.0	155.0	156.0
EE (g kg^{-1} DM)	21.0	31.0	34.0
NDFap (g kg^{-1} DM)	320.0	291.0	251.0
MM (g kg^{-1} DM)	94.0	94.0	95.0
OM (g kg^{-1} DM)	891.0	896.0	895.0
NFC (g kg^{-1} DM)	449.0	456.0	493.0
TCH (g kg^{-1} DM)	752.0	737.0	733.0
TDN (g kg^{-1} DM)	610.0	647.0	631.0

Table 3. Nutrient intake (g day^{-1}) and digestibilities (g kg^{-1}) (mean ± standard deviation) in sheep fed Maniçoba hay or silage in replacement of Tifton 85 hay.

Variables	Tifton Hay	Maniçoba Hay	Maniçoba Silage	SEM#	P < value
Dry matter (g day^{-1})	1060.1±138.0^{b}	1168.5±95.4^{a}	1066.9±93.2^{ab}	110.79	**
Dry matter (g kg^{-1})	0.63±0.03	0.66±0,04	0.65±0.03	0.04	0,13
Crude protein (g day^{-1})	168.4±15.8	175.7±19.5	167.8±13.0	16.32	0,27
Crude protein (g kg^{-1})	0.72±0.04	0.71±0.04	0.68±0.04	0.04	0,54
Neutral detergent fiber (g day^{-1})	379.1±54.1^{ab}	393.9±31.4^{a}	340.1±29.7^{b}	39.96	**
Neutral detergent fiber (g kg^{-1})	0.59±0.06	0.58±0.04	0.57±0.04	0.04	0,74
Ether extract (g day^{-1})	24.4±3.2^{b}	37.4±3.1^{a}	35.2±3.1^{a}	3.10	**
Ether extract (g kg^{-1})	0.68±0.07	0.71±0.05	0.69±0.06	0.06	0,33
Organic matter (g day^{-1})	958.3±124.8	1058.6±86.4	963.5±84.2	100.18	0,23
Organic matter (g kg^{-1})	0.66±0.04	0.71±0.02	0.67±0.03	0.04	0,17
Non-fibrous carbohydrate (g day^{-1})	477.0±62.1	537.5±43.9	522.8±45.7	51.20	0,89
Non-fibrous carbohydrate (g kg^{-1})	0.76±0.04^{c}	0.85±0.02^{a}	0.80±0.03^{b}	0.03	**
Total carbohydrates (g day^{-1})	805.7±104.9	864.7±70.6	789.5±69.0	83.14	0,35
Total carbohydrates (g kg^{-1})	0.67±0.05^{b}	0.71±0.02^{a}	0.68±0.03^{ab}	0.03	**

Means followed by different letters, in the same line, differ from each other, by the Tukey test at 5% of probability. #SEM standard error of the mean.

The neutral detergent fiber intake (NDFI) did not differ (p > 0.05) between TH diet and maniçoba diets. However, NDFI was lower (p > 0.05) for animals fed SM when compared to MH. It was observed that NDF content of maniçoba silage (401 g kg^{-1}) was lower than the hay of the same forage (538 g kg^{-1}), and this may have resulted in the decrease of total NDF. The NDFI did not differ among treatments, indicating that *Euphorbiaceae* could replace grass in association with spineless cactus without effects on fiber intake.

Santos et al. (2010) studying fiber sources for diets with spineless cactus, did not find effects of the fiber source on NDFI in sheep either.

Data were submitted to analysis of variance at 5% significance (Statistical Analysis System [SAS], 1999). When differences were identified, means were compared by the Tukey's test, at the same level of significance.

Total carbohydrate and NFC intakes were not influenced by the diets (p > 0.05). However, the digestibilities of these analytical fractions were higher (p > 0.05) in the MH diet than in the TH. The TCH and NFC digestibilities were higher in the MH diet than in TH, probably due to the prevalence of A+B1 carbohydrates fraction in maniçoba hay (Santos et al., 2017) when compared to Tifton 85 (Muniz et al., 2011).

The digestibility of the non-fibrous carbohydrates of maniçoba silage was lower (p > 0.05) than in maniçoba hay. The ensiling process consumes some of the soluble carbohydrates of the forage during fermentation (Wilkinson & Davies, 2013). Therefore, it is likely that the residual non-fibrous carbohydrates of silage were more resistant to digestion when compared to those of maniçoba hay.

The final body weight, average daily gain and feed conversion did not differ among treatments and presented means of 28.07 kg, 148.5 g day^{-1} and 7.67, respectively (Table 4).

Table 4. Performance (mean ± standard deviation) of sheep fed Maniçoba hay or silage in replacement to Tifton 85 hay.

Variables	Tifton Hay	Maniçoba Hay	Maniçoba Silage	SEM[#]	Pvalue
Initial body weight (kg)	19.3±2.5	20.1±1.8	19.9±1.7	2.01	0,54
Final body weight (kg)	27.9±2.5	28.8±3.2	27.5±2.8	2.83	0,12
Average daily gain (g day^{-1})	153.3±13.3	156.9±45.9	135.3±32.9	30.70	0,13
Feed conversion	6.9±0.9	7.9±1.9	8.2±1.7	1.50	0,32

Means followed by different letters, in the same line, differ from each other, by the Tukey test at 5% of probability. [#]*SEM* standard error of the mean.

Despite the effects of MH on dry matter intake and carbohydrate digestibility, daily weight gain was within what was predicted by NRC (2007) and did not differ (P > 0.05) among treatments. Lima Júnior et al. (2014) also did not observe effect of Tifton 85 hay replaced by maniçoba hay. The similarity in TDN values among treatments (610.0 g kg^{-1} TH, 647.0 g kg^{-1} MH and 631.0 g kg^{-1} MS) probably explains the proximity in weight gain and body weight at slaughter.

Conclusion

Maniçoba hay or silage can replace Tifton 85 hay in sheep diets associated with spineless cactus. Maniçoba hay or silage are alternative forage resources for feeding sheep in arid and semi-arid areas.

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References

Akin, D. E. (1989). Histological and physical factors affecting digestibility of forages. *Agronomy Journal, 81*(1), 17-25. doi: 10.2134/agronj1989.00021962008100010004x.

Amorim, S. L., Medeiros, R. M. T., & Riet-Correa, F. (2005). Intoxicação experimental por Manihot glaziovii (*Euphorbiaceae*) em caprinos. *Pesquisa Veterinária Brasileira, 25*(3), 179-187. doi: 10.1590/S0100-736X2005000300009.

Backes, A. A., Santos, L. L., Fagundes, J. L., Barbosa, L. T., Mota, M., & Vieira, J. S. (2014). Valor nutritivo da silagem de maniçoba ("*Manihot pseudoglaziovii*") com e sem fubá de milho como aditivo. *Revista Brasileira de Saúde e Produção Animal, 15*(1), 182-191. doi: 10.1590/S1519-99402014000100016.

Batista, Â. M. V., Ribeironeto, A. C., Lucena, R. B., Santos, D. C., Dubeux Junior, J., & Mustafa, A. F. (2009). Chemical composition and ruminal degradability of spineless cactus grown in Northeastern Brazil. *Rangeland Ecology & Management, 62*(3), 297-301. doi: 10.2111/07-099R1.1.

Campos, F. S., Carvalho, G. G. P., Santos, E. M., Araújo, G. G. L., Gois, G. C., Rebouças, R. A., ... Leite, L. C. (2017). Influence of diets with silage from forage plants adapted to the semi-arid conditions on lamb quality and sensory attributes. *Meat Science, 124*, 61-68. doi: 10.1016/j.meatsci.2016.10.011.

Castro, J. M. C., Silva, D. S., Medeiros, A. N., & Pimenta Filho, E. C. (2007). Desempenho de cordeiros Santa Inês alimentados com dietas completas contendo feno de maniçoba. *Revista Brasileira de Zootecnia, 36*(3), 674-680. doi: 10.1590/S1516-35982007000300022.

Costa, S. B. M., Andrade, M. F., Pessoa, R. A. S., Batista, Â. M. V., Ramos, A. O., Conceição, M. G., & Gomes, L. H. S. (2012). Tifton hay, soybean hulls, and whole cottonseed as fiber source in spineless cactus diets for sheep. *Tropical Animal Health and Production, 44*(8), 1993-2000. doi: 10.1007/s11250-012-0169-2.

Cruz, S. E. S. B. S., Beelen, P. M. G., Silva, D. S., Pereira, W. E., Beelen, R., & Beltrão, F. S. (2007). Characterization of condensed tannin of the species maniçoba (*Manihot pseudoglaziovii*), flor-de-seda (*Calotropis procera*), feijão-bravo (*Capparis flexuosa*) and jureminha (*Desmanthus virgatus*). *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 59*(4), 1038-1044. doi: 10.1590/S0102-09352007000400033.

Duputié, A., Salick, J., & McKey, D. (2011). Evolutionary biogeography of Manihot (*Euphorbiaceae*), a rapidly radiating Neotropical genus restricted to dry environments. *Journal of Biogeography, 38*(6), 1033-1043. doi: 10.1111/j.1365-2699.2011.02474.x.

França, A. A., Guim, A., Batista, A. M. V., Pimentel, R. M. M., Ferreira, G. D. G., & Martins, I. D. S. L. (2010). Anatomia e cinética de degradação do feno de *Manihot glaziovii*. *Acta Scientiarum. Animal Sciences, 32*(2), 131-138. doi: 10.4025/actascianimsci.v32i2.8800.

Gebremariam, T., Melaku, S., & Yami, A. (2006). Effect of different levels of cactus (Opuntia ficus-indica) inclusion on feed intake, digestibility and body weight gain in tef (*Eragrostis tef*) straw-based feeding of sheep. *Animal Feed Science and Technology, 131*(1-2), 42-51. doi: 10.1016/j.anifeedsci.2006.02.003.

Hall, M. B., Hoover, W. H., Jennings, J. P., & Webster, T. K. M. (1999). A method for partitioning neutral detergent soluble carbohydrates. *Journal of the Science of Food and Agriculture, 70*(15), 2079-2086. doi: 10.1002/(SICI)1097-0010(199912)79:15<2079::AID-JSFA502>3.0.CO;2-Z.

Harun, N. L. A., Alimon, A. R., Jahromi, M. F., & Samsudim, A. A. (2017). Effects of feeding goats with *Leucaena leucocephala* and *Manihot esculenta* leaves supplemented diets on rumen fermentation profiles, urinary purine derivatives and rumen microbial population. *Journal of Applied Animal Research, 45*(1), 258-274. doi: 10.1080/09712119.2016.1205499.

Instituto Nacional de Ciência e Tecnologia de Ciência Animal [INCT-CA]. (2012). *Métodos para análise de alimentos*. Visconde do Rio Branco, MG: Suprema.

Köppen, W., & Geiger, R. (1928). *Klimate der Erde*. Gotha: Verlag Justus Perthes.

Lima Júnior, D. M., Carvalho, F. F., Ribeiro, M. N., Batista, A. M. V., Ferreira, B. F., & Monteiro, P. B. (2014). Effect of the replacement of Tifton 85 with maniçoba hay on the performance of Morada Nova hair sheep. *Tropical Animal Health and Production, 46*(6), 995-1000. doi: 10.1007/s11250-014-0600-y.

Muniz, E. B., Mizubuti, I. Y., Pereira, E. S., Pimentel, P. G., Azambuja, E. L. R., Junior, J. N. R., ... Brito, V. M. (2011). Cinética de degradação ruminal de carboidratos de volumosos secos e aquosos: técnica de produção de gases. *Semina: Ciências Agrárias, 32*(3), 1191-1200. doi: 10.5433/1679-0359.2011v32n3p1191.

Nassar, N. M. A., Hashimoto, D. Y. C., & Fernandes, S. D. C. (2008). Wild Manihot species: botanical aspects, geographic distribution and economic value. *Genetics and Molecular Research, 7*(1), 16-28.

National Research Council [NRC]. (2007). *Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids* (7th ed.). Washington, DC: National Academy Press.

Pessoa, R. A. S., Ferreira, M. A., Silva, F. M., Bispo, S. V., Wanderley, W. L., & Vasconcelos, P. C. (2013). Diferentes suplementos associados à palma forrageira em dietas para ovinos: consumo, digestibilidade aparente e parâmetros ruminais. *Revista Brasileira de Saúde e Produção Animal, 14*(3), 508-517. doi: 10.1590/S1519-99402013000300012.

Santos, A. O. A., Batista, A. M., Mustafa, A., Amorim, G. L., Guim, A., Moraes, A. C., ... Andrade, R. (2010). Effects of Bermudagrass hay and soybean hulls inclusion on performance of sheep fed cactus-based diets. *Tropical Animal Health and Production, 42*(3), 487-494. doi: 10.1007/s11250-009-9448-y.

Santos, K. C., Magalhães, A. L. R., Silva, D. K. A., Araújo, G. G. L., Fagundes, G. M., Ybarra, N. G., & Abdalla, A. L. (2017). Nutritional potential of forage species found in Brazilian Semiarid region. *Livestock Science, 195*(3), 118-124. doi: 10.1016/j.livsci.2016.12.002.

Statistical Analysis System [SAS]. (1999). *SAS Software, Version 9.1*. Cary, NC: SAS Institute Inc.

Siqueira, M. C. B., Ferreira, M. A., Monnerat, J. P. I. S., Silva, J. L., Costa, C. T. F., Conceição, M. G., ... Melo, T. T. B. (2017). Optimizing the use of spineless cactus in the diets of cattle: Total and partial digestibility, fiber dynamics and ruminal parameters. *Animal Feed Science and Technology, 226*, 56-64. doi: 10.1016/j.anifeedsci.2016.12.006.

Sniffen, C. J., O'Connor, J. D., Van Soest, P. J., Fox, D. G., & Russell, J. B. (1992). A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. *Journal of Animal Science, 70*(11), 3562-3577. doi: 10.2527/1992.70113562x.

Souza, E. J., Guim, A., Batista, A. M. V., Santos, K. L., Silva, J. R., Morais, N. A. P., & Mustafa, A. F. (2009). Effects of soybean hulls inclusion on intake, total tract nutrient utilization and ruminal fermentation of goats fed spineless cactus (*Opuntia ficus-indica* Mill) based diets. *Small Ruminant Research, 85*(1), 63-69. doi: 10.1016/j.smallrumres.2009.07.008.

Van Soest, P. J., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 74*(10), 3583-3597. doi: 10.3168/jds.S0022-0302(91)78551-2.

Vieira, E. L., Batista, A. M. V., Guim, A., Carvalho, F. F. R., Nascimento, A. C., Araújo, R. F. S., & Mustafa, A. F. (2008). Effects of hay inclusion on intake, in vivo nutrient utilization and ruminal fermentation of goats fed spineless cactus (*Opuntia fícus-indica* Mill) based diets. *Animal Feed Science and Technology, 141*(3-4), 199-208. doi: 10.1016/j.anifeedsci.2007.05.031.

Wilkinson, J. M., & Davies, D. R. (2013). The aerobic stability of silage: key findings and recent developments. *Grass and Forage Science, 68*(1), 1-19. doi: 10.1111/j.1365-2494.2012.00891.x