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Intake, digestibility, ingestive behavior and performance of goats fed spineless cactus genotypes resistant to carmine cochineal

[*Consumo, digestibilidade, comportamento ingestivo e desempenho de caprinos alimentados com genótipos de palma forrageira resistentes à cochonilha-do-carmim*]

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ABSTRACT

The objective was to evaluate the intake and digestibility of nutrients, ingestive behavior, and performance of goats fed with spineless cactus genotypes resistant to carmine cochineal (Miúda or Orelha de Elefante Mexicana (OEM). Thirty castrated male goats, without defined breed, aged 12 to 14 months, with an average body weight of 19.0±2.8kg, were distributed in a completely randomized design among three treatments (Control - Tifton hay, Miúda, and OEM) and ten replicates; the initial weight was considered as the covariate. The intake of organic matter (OM), neutral detergent fiber (NDF) was highest in the control treatment, while the intake of NFC was higher in the OEM diet. Treatments containing forage cactus showed the highest digestibility of DM, OM, and NFC. The animals fed the control diet spent more time on rumination and total chewing, but the time spent feeding or feeding efficiency, and performance did not differ. The use of spineless cactus genotypes resistant to carmine cochineal (Miúda and Orelha de Elefante Mexicana) in a diet for goats, in the amount of 450g/kg of DM does not interfere with the performance of the animals and improves the digestibility of OM and NFC.

Keywords: cactus, roughage, sustainability, ingestive behavior, NDF

RESUMO

Objetivou-se com o presente estudo avaliar o consumo e a digestibilidade de nutrientes, o comportamento ingestivo e o desempenho de caprinos alimentados com genótipos de palma forrageira resistentes à cochonilha-carmim (miúda ou orelha-de-elefante-mexicana (OEM). Trinta cabritos machos, castrados, sem raça definida, com idades entre 12 e 14 meses e peso corporal médio de 19,0±2,8kg, foram distribuídos em delineamento inteiramente ao acaso, em três tratamentos (controle - feno de tifton; miúda e OEM) e 10 repetições; o peso inicial foi considerado a covariável. O consumo de matéria orgânica (MO) e de fibra em detergente neutro (FDN) foi maior no tratamento controle; enquanto a ingestão de CNF foi maior na dieta OEM. Tratamentos contendo palma forrageira apresentaram as maiores digestibilidades de MS, MO e CNF. Os animais alimentados com a dieta controle gastaram mais tempo em ruminação e em mastigação total, mas o tempo gasto com alimentação ou a eficiência alimentar e o desempenho não diferiram. A utilização de genótipos de palma forrageira resistentes à cochonilha-carmim (miúda e orelha-de-elefante-mexicana) na dieta de caprinos, na quantidade de 450g/kg de MS, não interfere no desempenho dos animais e melhora a digestibilidade de MO e CNF.

Palavras-chave: cacto, feno, sustentabilidade, comportamento ingestivo, FDN

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INTRODUCTION

The forage cactus studies are now in semiarid regions as main forages cultivated for livestock, due to its characteristic resistance to hydric stress and advanceable nutritive value. However, carmine cochineal (*Dactylopius sp*) has been a limiting factor in the use of this forage, since, like other agricultural crops, pest infestations have led to reduced availability of forage, plant death, and the destruction of planted areas, with a direct influence on animal production (Monteiro *et al*., 2018). In areas where spineless cactus is cultivated for human consumption or cattle feed, farmers regard the species as a pest, and its control is considered a priority (Cruz-Rodriguez *et al*., 2016).

The best strategy for controlling this pest is to cultivate spineless cactus varieties that are resistant to cochineal carmine. This is also an environmentally friendly practice that is of great importance for smallholder farming because it dispenses with costly chemicals that pollute the environment and contributes to the sustainability of the production system (Silva *et al*., 2018). Resistant genotypes of spineless cactus include "Miúda" (*Nopalea cochenillifera* Salm Dyck) and "Orelha de Elefante Mexicana" (*Opuntia strica* Haw). According to Silva *et al*. (2015) the main differences among them are that Opuntia ficus indica presents higher values in levels of moisture, protein, lipids, soluble solids, minerals, and crude fiber in addition to length, width, and fresh weight when compared to *Nopalea cochenillifera*.

The chemical composition of spineless cactus varies: crude protein (41.0–75.4 g/kg of dry matter (DM)), neutral detergent fiber (236–277 g/kg of DM), and non-fiber carbohydrate (460–528 g/kg of DM) (Siqueira *et al*., 2017; Silva *et al*., 2018; Rocha Filho *et al*., 2021). These characteristics give the spineless cactus rapid ruminal degradability and high levels of total digestible nutrients (Batista *et al*., 2003). In addition, maybe an increase in microbial protein synthesis (Cardoso *et al*., 2019). However, it must be consumed in association with physically effective fiber sources (Soares *et al*., 2020).

As the diet adopted can directly or indirectly influence the final body weight, it was hypothesized that the varieties of spineless cactus resistant to carmine cochineal could maximize the intake and the digestibility of nutrients and, consequently, performance. Thus, the objective of this study was to evaluate the intake and nutrient digestibility, ingestive behavior, performance of goats fed with spineless cactus genotypes resistant to carmine cochineal 'Miúda' or 'Orelha de Elefante Mexicana'.

MATERIAL AND METHODS

This research was conducted in the goat sector of the Animal Science Department of the Federal Rural University of Pernambuco (UFRPE) in Recife, Brazil, located in the city of Recife, Pernambuco, Brazil, at the geographic coordinates of 8º04'03 "S and 34º55'00"W. All procedures were carried out with the authorization of the Internal Committee on Ethics in the Use of Animals (CEUA/UFRPE), number license (142/2018).

Thirty castrated male goats, without defined breed, aged between 12 and 14 months, with an average body weight of 19.0±2.8kg, were distributed in a completely randomized design among three treatments and 10 replicates, using the initial weight as the covariate. Before the start of the experimental period, the animals were weighed, vaccinated against clostridiosis, and treated against endoparasites and ectoparasites. During the experimental period, the animals were kept in confinement in individual stalls. The experiment lasted 100 days, with 30 days of adaptation and 70 days of data collection.

The ingredients used in the experimental diets were Tifton 85 hay (*Cynodon dactylon*), "Miúda" (*Nopalea cochenillifera* Salm Dyck) or "Orelha de Elefante Mexicana (OEM)" (*Opuntia strica* Haw) spineless cactus, combined with soybean meal, ground corn, mineral salt and urea (Table 1). The experimental diets were isonitrogenated, aiming at an average daily gain of 150 g/day, according to the nutritional recommendations of the NRC (Nutrient…, 2007). The roughage:concentrate ratio of the diets was 60:40 (Table 2).

Table 1. Chemical composition of ingredients on a dry matter basis (g/kg of DM)

Item	Tifton hay	Miúda spineless cactus	OEM spineless cactus	Soybean meal	Ground corn
Dry matter[a]	895.6	123.6	97.3	882.7	877.1
Crude protein	86.0	40.0	55.0	487.0	85.0
Organic matter	916.1	870.6	851.0	929.6	987.7
Ash	83.9	129.4	149	70.4	12.3
Ether extract	22.7	13.9	17.8	15.0	38.3
NDFap	669.4	252.8	198.1	134.6	146.8
Acid detergent fiber	336.2	137.1	95.3	116.8	24.5
Lignin	66.7	22.8	24.4	11.1	5.2
NFC	138.0	563.9	580.1	293.0	717.6
Total carbohydrates	807.4	816.7	778.1	427.6	864.4

[a] g/kg of fresh matter, OEM, *Orelha de Elefante Mexicana*, NDFap, neutral detergent fiber corrected for ash and protein, NFC, non-fiber carbohydrates.

Table 2. Proportion of ingredients and chemical composition of the experimental diets

Ingredients (g/kg)	(g/kg DM)		
	Control	Miúda	OEM
Tifton hay	600	150	150
Miúda spineless cactus	0	450	0
OEM spineless cactus	0	0	450
Ground corn	270	271	273
Soybean meal	110	100	100
Urea	5	14	12
Mineral mix	15	15	15
Chemical Composition (g/Kg DM)			
Dry matter [a]	890.8	234.8	190.3
Organic matter	924.0	904.2	895.3
Crude protein	142.1	141.8	143.2
Ether extract	25.6	21.5	23.4
NDFap	456.1	267.4	243.1
Acid detergent fiber	221.1	130.4	111.7
Non-fiber carbohydrates	300.2	473.4	485.8
Total carbohydrates	756.3	740.8	728.8
Lignin	42.6	22.8	23.5
Ash	76.0	95.8	104.7
Total digestible nutrients	677.5	734.1	719.3

[a] g/kg of fresh matter, OEM, O*relha de Elefante Mexicana*, NDFap, neutral detergent fiber corrected for ash and protein.

The spineless cactus was crushed daily in a proprietary machine (Laboremus®, FP1001N) for cactus processing. The hay was crushed in a forage machine with an 8 mm sieve, in order to reduce selection by the animals. All ingredients were mixed to provide a complete feed. The diets were given *ad libitum*, twice a day, allowing a surplus of 15%. During this period, feed and leftovers were weighed to determine feed intake. Leftover samples were taken twice a week during the experimental period (10% of leftovers from each animal) and were frozen at -20°C in hermetically sealed plastic bags.

For the digestibility assay samples of feces were collected directly from the animal's rectal ampulla three times a day, at different times, being at 6:00 am, 12:00 pm, and 4:00 pm on the first day; at 8 am, 2 pm, and 8 pm on the second day and at 10 am, 4 pm and 10 pm on the third day. Samples of feed and leftovers were collected at the same time. Immediately after collection, the samples were weighed and pre-dried in an oven with forced ventilation at 55 ºC for 72 hours. Samples composed of leftovers and feces of each animal were ground in a Willey-type Mill (TE-625, TECNAL, SP,

Brazil), with a 1mm and 2mm screen respectively for subsequent chemical analysis and incubation for determination of indigestible neutral detergent fiber (NDFi).

To estimate the apparent digestibility, fecal dry matter production (FDMP) was calculated, using the NDFi as an internal indicator, after an incubation period of 288 hours in the rumen of an adult bovine (Valente *et al*., 2011). During the incubation period, the animal was fed with Tifton 85 hay and concentrate.

The dry matter (DM), organic matter (OM), crude protein (CP), and ether extract (EE) were determined according to the AOAC (Official…, 1990) using method number 967.03 for DM, 942.05 for OM, 981.10 for CP, and 920.29 for EE. Neutral detergent fiber (NDF) and acid detergent fiber (FDA) were determined according to the methodology proposed by Van Soest *et al*. (1991), while corrections for ash and protein were performed according to the methodology described by Mertens (2002) and Licitra *et al*. (1996), respectively.

Total carbohydrates (TC) were estimated using the equation proposed by Sniffen *et al*. (1992), and non-fiber carbohydrates (NFC) were estimated using the equation recommended by Hall (2000). The equation described by Weiss (1999) was used to estimate total digestible nutrients (TDN).

Behavioral parameters were observed using scan sampling, as proposed by Martin & Bateson (1993), at 10-minute intervals for 24 hours (Johnson and Combs, 1991). The behavioral variables observed were Feeding, Ruminating, and Idle times. The feed and rumination efficiencies of DM and NDF were calculated by dividing the intake of each of these nutrients by the total feeding time (feed efficiency) and rumination time (rumination efficiency), respectively.

To evaluate their performance, the animals were weighed at the beginning and end of the experimental period. Total weight gain (TWG) was calculated as the difference between the final body weight (FBW) and initial body weight (IBW): TWG = (FBW - IBW), average daily gain (ADG) = (TWG/days of the trial period). The feed efficiency (FE) was determined as the ratio between TWG and DMI, FE = (ADG/DM intake).

The experimental design was completely randomized, according to the model below:

$$yij = m + ti + \beta (Xij - X) + eij$$

Where: yij = value observed in the experimental unit that received treatment I, replicate j; m = general effect of the mean; ti = effect of treatment I; β (Xij – X) = covariate effect (initial body weight), eij = random error (residual). For statistical analysis, the statistical package SAS version 9.3 (2011) was used, with significance set at 5%, and initial body weight as the covariate. An analysis of variance was performed and when necessary, the means were compared by the Tukey test at the same level of significance.

RESULTS

There was no significant difference (P>0.05) in the dry matter (DM), digestible organic matter (DOM), or crude protein (CP) intake between treatments. However, there was a significant difference (P<0.05) in intake of organic matter (OM), neutral detergent fiber (NDF), NDF% of body weight (BW), and non-fiber carbohydrates (NFC) (Table 3). The mean intake of DM (g/day and % BW), CP, and DOM was 658g/day, 3%, 95.3g/day, and 466.7g/ day, respectively.

The apparent digestibility of nutrients was influenced by diets (P<0.05), except for CP and NDF digestibility (P>0.05), with averages of 758 and 685 g/kg DM, respectively (Table 3). The diets containing spineless cactus showed higher digestibility coefficients for DM, OM, and NFC. There was an effect (P>0.05) of the diets on ingestive behavior, for the variables rumination time and chewing time, with higher values observed in animals fed with the control diet, while the idle time and the efficiency of the rumination rates were higher in animals fed diets containing the Miúda and OEM genotypes. While there was no influence (P>0.05) of the diets on the feeding time, feeding efficiency of DM, or rumination efficiency of DM, with averages of 3.1 h/day, 0.22g DM/h, and 0.15g DM/h, respectively (Table 4).

Table 3. Intake and digestibility of nutrients in of goats fed with spineless cactus genotypes resistant to carmine cochineal

Item	Treatments			SEM	*P*-value
	Control	Miúda	OEM		
Intake (g/day)					
Dry matter	704	603	668	27.422	0.078
Organic matter	651.0a	547.0b	601.0ab	25.275	0.045
Crude protein	104.0	89.0	97.0	3.941	0.071
NDFap	290.0a	167.0b	161.0b	14.216	<.0001
Non-fiber carbohydrates	236.0b	275.0b	326.0a	13.471	0.001
Digestible organic matter	487.0	446.0	467.0	0.020	0.458
Intake (% BW)					
Dry matter	3.1	2.8	3.0	0.064	0.080
NDFap	1.28a	0.77b	0.73b	0.051	<.0001
Total apparent digestibility (g/kg)					
Dry matter	705.8b	752.8ª	724.5ab	7.393	0.036
Organic matter	743.9b	790.9ª	778.9a	6.324	0.003
Crude protein	755.4	766.2	742.9	6.656	0.413
NDFap	691.7	667.3	683.6	7.071	0.308
Non-fibrous carbohydrates	758.6b	870.0a	848.7a	11.614	<.0002

SEM, standard error of the mean, OEM, Orelha de Elefante Mexicana, NDFap, neutral detergent fiber corrected for ash and protein.
Digestible organic matter (DOM) = OM intake*digestibility of OM.
Averages in rows followed by different letters are statistically different by the Tukey test at 5% probability.

Table 4. Ingestive behavior of goats fed with spineless cactus genotypes resistant to carmine cochineal

Item	Treatments			SEM	*P*-value
	Control	Miúda	OEM		
Feeding time (h/day)	3.63	2.78	3.12	0.189	0.195
Rumination time (h/day)	6.22a	4.37b	4.37b	0.325	0.021
Idle time (h/day)	14.15b	16.87a	16.52a	0.386	0.004
Total chewing time (h/day)	9.85a	7.14b	7.48b	0.385	0.004
Feeding efficiency (g DM/h)	0.20	0.25	0.24	0.017	0.514
Rumination efficiency (g DM/h)	0.12	0.17	0.16	0.013	0.246
Rumination efficiency (g NDF/h)	0.41b	1.09a	1.04ª	0.110	0.009

SEM, standard error of the mean, OEM, Orelha de Elefante Mexicana.
Averages in rows followed by different letters are statistically different by the Tukey test at 5% probability.

No effects (*P*>0.05) were observed for the performance of the animals, with a mean of 24.6kg, 4.9kg, 70.7g, and 0.10, for final body weight, total weight gain, average daily gain (ADG) and feed efficiency, respectively (Table 5).

Table 5. Animal performance of goats fed with spineless cactus genotypes resistant to carmine cochineal

Item	Treatments			SEM	*P*-value
	Control	Miúda	OEM		
Initial body weight (kg)	19.6	19.5	19.6	0.516	--
Final body weight (kg)	25.5	23.5	24.8	0.847	0.127
Total weight gain (kg)	5.9	3.6	5.2	0.519	0.127
Average daily gain (g/day)	85	52	75	7.413	0.127
Feed efficiency	0.11	0.08	0.11	0.008	0.236

SEM, standard error of the mean, OEM, Orelha de Elefante Mexicana.
Averages in rows followed by different letters are statistically different by the Tukey test at 5% probability.

DISCUSSION

The spineless cactus genotypes that are resistant to carmine cochineal showed minimal differences in chemical composition (Table 1) and similar levels of acceptance by the animals in the diets. This is consistent with Vieira *et al*. (2008), who found that including spineless cactus with 150g/kg of Tifton hay in a goat diet led to similar DM intake compared to the control treatment. No differences were reported between dry matter intake in diets containing Miúda and OEM n genotypes in Saanen goats (Goés Neto *et al*., 2021) and dairy cows Monteiro *et al*. (2018).

Regardless of genotype, the spineless cactus diets resulted in a lower intake of NDF and NDF% BW, about the control, due to the lower NDF content in these diets (Table 2). Literature has reported an increase in DM intake as a function of a reduction in dietary NDF (Lins *et al*., 2016; Oliveira *et al*., 2017), but this was not observed in the present study. However, the spineless cactus likely provokes ruminal distension, thus limiting intake, due to the low DM content of the diet (Silva *et al*., 2018).

The reduction in the intake of organic matter (OM) in the Miúda treatment can be attributed to the high ash content of the diet (+ 20.6% in comparison to the control) (Table 2), as well as the increase in intake of NFC in the OEM diet, as a result of the greater availability about the other diets.

The digestibility of a food is closely related to the chemical composition, being the fibrous fraction that exerts greater influence (McDonald *et al*., 2011). In general, the lower apparent digestibility values observed in the control diet compared to the spineless cactus-containing diets can be explained by the fact that fiber-rich diets reduce efficiency through an increase in caloric increment, which is probably a function of increasing feeding and rumination time (Van Soest, 1994). However, the high digestibility values of DM and OM observed in treatments with Miúda and OEM spineless cactus can be attributed to the higher levels of NFC and low NDF levels present in these cacti. High levels of NFC may also result in a decrease in pH in the rumen, reducing cellulolytic activity (Porto Filho *et al*., 2020). However, Siqueira *et al*. (2018) reported that the ruminal pH reduction in forage cactus-containing diets may not be sufficient to limit or inhibit NDF digestibility. It is noteworthy that a large portion of the spineless cactus NFC consists of pectin, β-glucans, and fructosanas, and their ruminal fermentation has the advantage of producing a smaller quantity of lactic acid (Batista *et al*., 2003), reducing the risk of the decline in ruminal pH.

In another study, Monteiro *et al*. (2018) when comparing two genotypes of spineless cactus, found that the digestibility of the nutrients DM, OM, CP, and NFC did not differ between diets containing Miúda and OEM genotypes for dairy cows, attributing this to the chemical similarity between the varieties evaluated. Siqueira *et al*. (2017) evaluated the inclusion of the Miúda spineless cactus replacing Tifton hay in the diet of cattle and also observed an increase in the digestibility of DM and OM.

The succulence of spineless cactus diets and their lower percentage of NDF facilitate chewing and swallowing, as well as reducing the stimulation of regurgitation that precedes remastigation. A longer idle time was observed in animals receiving diets containing spineless cactus in relation to the control diet, despite the similarity in feeding time for all treatments, due to the reduction in rumination time caused by the lower NDF content present in the diet (Table 2). Rumination activity is influenced by the nature of the diet, mainly by the NDF levels (Van Soest, 1991). In the present study, the rumination time ranged from 4.37h/day (OEM) to 6.22h/day (Control), illustrating that the higher the physically effective fiber content, the longer the time spent in rumination.

Likely, the similar nutrient flow to the muscle and adipose tissues from DM and DOM intake did not differentiate anabolism and fat deposition in animals with different treatments. The diets were formulated to meet the nutritional requirements of animals for a gain of 150g/day with an intake of 720g of DM, 480g of TDN, and 108g of CP according to NRC (Nutrient…, 2007); where only the control treatment had expected intake. Although there were no differences in animal performance, the weight gain of goats fed with the OEM spineless cactus of 85g was 38% higher when compared to those fed with the Miúda of 52g. However, regardless of diet, the animals did not reach the expected

performance responses, due to the low genetic potential of the animals for weight gain, age, and lack of adaptation of the animals to the confinement environment, due to the extensive breeding system in which animals were raised before the experimental period (Lima Júnior *et al*., 2015).

CONCLUSION

The use of spineless cactus genotypes resistant to carmine cochineal (Miúda and Orelha de Elefante Mexicana) in a diet for goats, in the amount of 450g/kg of DM does not interfere with the performance of the animals and improves the digestibility of OM and NFC. So, these cactus are important forage resources for semi-arid regions.

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