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Original Article - Zootechnics

Lipid sources associated or not with spineless cactus as a management strategy to reduce feeding costs for dairy goats

[*Fontes lipídicas associadas ou não à palma forrageira como gestão estratégica de redução de custos com a alimentação de cabras leiteiras*]

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ABSTRACT

The objective of this study was to evaluate lipid sources, associated with spineless cactus or not, as a strategy for reducing feed costs in goat milk production. Twelve lactating Saanen goats, with an average body weight of 55.0±8.0kg, were distributed in a 4x4 Latin square, with a 2x2 factorial arrangement. The treatments consisted of two lipid sources (coconut peels - CP; and cottonseed - CT), associated or not with "Orelha de Elefante Mexicana" (OEM) spineless cactus. Goats that consumed diets containing cottonseed as the main source of energy showed higher performance indexes ($P<0.05$). The CP+OEM treatment presented the lowest cost for 1 kg of dry matter (R$ 1.78). The PC diet demonstrated lower daily feeding costs (R$ 2.54). Total revenue was higher for the CT+OEM diet (R$ 8.17), as was net income (R$ 4.19). Therefore, the association of cottonseed with OEM spineless cactus in the feeding of lactating goats is recommended, due to the reduction in feeding costs, especially with roughage, in addition to superior performance, contributing to greater profitability of the activity.

Keywords: economic evaluation, fat feeds, milk production, *Opuntia stricta* (Haw.) Haw., small ruminants

RESUMO

O objetivo deste estudo foi avaliar fontes lipídicas, associadas ou não à palma forrageira, como estratégia para redução de custos com alimentação na produção de leite caprino. Doze cabras da raça Saanen em lactação, com peso corporal médio de 55,0±8,0kg, foram distribuídas em quadrado latino 4x4, com arranjo fatorial 2x2. Os tratamentos constituíram de duas fontes lipídicas (película de coco - PC; e caroço de algodão - CA), associadas ou não à palma forrageira Orelha de Elefante Mexicana (OEM). As cabras que consumiram as dietas contendo o caroço de algodão como principal fonte de energia apresentaram índices de desempenho mais elevados ($P<0,05$). O tratamento PC+OEM apresentou menor custo para 1 kg de matéria seca (R$ 1,78). A dieta PC demostrou menor custo diário com alimentação (R$ 2,54). A receita total foi maior para a dieta CA+OEM (R$ 8,17), assim como a renda líquida (R$ 4,19). Dessa forma, recomenda-se a associação de caroço de algodão com palma forrageira OEM na alimentação de cabras lactantes, em virtude da diminuição dos custos com a alimentação, em especial com o volumoso, além de desempenho superior dos animais, contribuindo para a maior rentabilidade da atividade.

Palavras-chave: avaliação econômica, alimentos gordurosos, Opuntia stricta *(Haw.) Haw, pequenos ruminantes, produção de leite*

INTRODUCTION

In recent years, there has been an increase in demand for goat milk and its derivatives, due to its more desirable chemical characteristics compared to cow milk and its derivatives (Magalhães *et al*., 2021; Fernandes *et al*., 2023), showing itself as a segment in the process of consolidation and economically viable, which generates jobs and income, promoting the development of the dairy production chain in the

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Brazilian Northeast (Ramos *et al.*, 2017). Goat farming guarantees food security for families residing in semi-arid areas, as it presents versatility due to the ability to adapt through the depletion of traditional forage resources and climate change, circumstances inherent to the seasonality of resources throughout the year in these regions (Sejian *et al*., 2021).

Despite the typologies of production systems in Brazil being heavily dependent on feed external to the properties, with a focus on concentrates produced from grains, with low stocking rates of ruminant animals and with little technology applied to the specific crop, there is presence of breeds specialized in dairy farms (Oliveira *et al*., 2022). Thus, feedlot constitutes a management tool used to accelerate animal performance, mainly due to seasonality in the supply of forage (Ortega-Pérez *et al*., 2023).

Considering global population growth, projected to reach a total of 9.7 billion people by 2050, concerns about food security become urgent (The need…, 2021). In this scenario, the use of by-products is an alternative for feeding dairy goats, promoting a reduction in the use of cereals that are conventionally used in human and non-ruminant animal nutrition, a reduction in the total cost of production with prospects for improving production and milk composition (Mizael *et al*., 2020).

In the context of adopting nutritional management strategies in dairy production aiming at productive efficiency, lipid supplementation stands out, which has shown promising results in ruminants (Toral *et al*., 2022). Souza *et al*. (2024), when determining the costs of the production cycle of lambs fed diets containing corn grain or full-fat corn germ (FFCG), associated or not with spineless cactus, reported that replacing corn grain with FFCG promoted better productive and economic performance.

On the other hand, lipid sources readily available in the ruminal environment can cause undesirable effects on ruminal microorganisms, reducing fiber digestion and dry matter intake (Ibrahim *et al*., 2021). To mitigate such problems, recent studies have investigated the use of fat sources with low ruminal degradation, such as fat protected by the shell of cottonseed (CT), allowing slow release of lipids into the rumen (Khan *et al*., 2022; Sun *et al*., 2022).

Another alternative for lipid supplementation is coconut peels (CP), a by-product of coconut fruit pulp processing. This peel contains large amounts of saturated fatty acids, such as lauric acid (C12:0) and myristic acid (C14:0), in addition to having a digestibility of 59% (Silva *et al*., 2022). According to Thaiphanit and Anprung (2016), coconut is grown in 92 countries worldwide on, typically, large-scale plantations, with emphasis on Indonesia, the Philippines and India. The global area harvested with coconut is 11.8 million hectares, producing 62.9 million tons. The coconut tree is cultivated in almost all of Brazil, occupying an area of 187.5 thousand hectares in 2020 and producing 1.6 billion fruits. The Northeast region, the main national producer, concentrates 73.5% of its production (Crops…, 2021).

Additionally, in order to overcome the difficulty of adequately supplying water for animal watering, imposed by the water restrictions observed in the semi-arid Northeast, the cultivation of spineless cactus (*Opuntia* spp. and *Nopalea* spp.) has been adopted, due to their high moisture content (average of 89%), in addition to the high energy content (average of 60% of non-fibrous carbohydrates) (Edvan *et al*., 2020; Rocha Filho *et al*., 2021; Silva *et al*., 2023). Spineless cactus “Orelha de Elefante Mexicana” (OEM; *Opuntia stricta* (Haw.) has been reported as a new genotype of cactus that can be used in ruminants feeding raised in drylands zones (Paula *et al*., 2019; Soares *et al*., 2020; Silva *et al*., 2021).

Therefore, the need for zootechnical planning is highlighted to assist the producer in making decisions regarding the adequate supply of resources at the lowest cost, which ensure the productive longevity of Brazilian dairy properties. Thus, the objective of this study was to assess lipid sources, associated or not with spineless cacti, as a strategy for reducing feeding costs in goat milk production.

MATERIAL AND METHODS

This research was approved by the Committee of Ethics in the Use of Animals of the Federal Rural University of Pernambuco (UFRPE), with protocol number 3503110321. The experiment was carried out at the Dairy Goat Sector, Animal Science Department, UFRPE, Recife, Pernambuco, Brazil.

Twelve multiparous Saanen goats were used, with 60 days of lactation, average body weight of 55.0±8.0kg and daily production of 3.5kg of milk. After weighing, identification, treatment against ecto and endoparasites and vaccination against clostridiosis, the animals were distributed in individual pens (1.10m x 1.20m), equipped with feeder and drinker, with slatted floors, under uniform management in a covered and sanitized shed, under a feedlot regime.

The animals were distributed in a Latin square design (4x4), with a 2x2 factorial arrangement (two lipids' sources, associated or not with spineless cactus). The experiment consisted of four periods of 20 days, the first 15 days being for adaptation to diets and management and five days for data and sample collection. The experiment lasted 80 days, between March and June 2022.

The goats were submitted to four experimental diets containing Tifton-85 hay (*Cynodon* spp.), spineless cactus "Orelha de Elefante Mexicana" (OEM; *Opuntia stricta* (Haw.) Haw.), ground corn (*Zea mays*), soybean meal (*Glycine max* L.), cottonseed (CT; *Gossypium hirsutum* L.) or coconut pells (CP; *Cocos nucifera*) and mineral mix.

Four dietary treatments were used: (1) CP = 5% coconut peels; (2) CP + OEM spineless cactus = 5% CP + 25% OEM spineless cactus; (3) CT = 20% of CT; (4) CT + OEM spineless cactus = 20% CT + 25% OEM spineless cactus. The experimental diets were formulated considering the requirements of lactating goats, with an average body weight (BW) of 50 kg, average production of 3.5 kg/day and 3.5% fat content, as recommended by the NRC (Nutrient…, 2007), with roughage:concentrate of 40:60 (Table 1).

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

Ingredients	Diets (g/kg dry matter)			
	CP[a]	CT[b]	CP+OEM[c] spineless cactus	CT+OEM[c] spineless cactus
Tifton-85 hay	400	400	150	150
OEM[c] spineless cactus	0	0	250	250
Coconut peels	50	0	50	0
Cottonseed	0	200	0	200
Ground corn	382	320	365	295
Soybean meal	148	60	165	85
Mineral mix[#]	20	20	20	20
Chemical composition (g/kg dry matter)				
Dry matter	887.3	888.8	279.7	279.9
Ash	82.07	77.86	98.31	94.12
Crude protein	140.89	147.14	140.28	145.55
Ether extract	56.10	57.58	57.46	57.19
Neutral detergent fiber	424.88	437.92	287.72	299.02
Non-fibrous carbohydrates	311.3	298.57	429.92	416.62
Total digestible nutrients	720.05	750.32	753.9	778.67

[a] coconut peels, [b] cottonseed, [c] Orelha de Elefante Mexicana spineless cactus, [#] Guarantee levels (nutrients/kg): calcium = 150g, sulfur = 12g, phosphorus = 65g, magnesium = 6.000mg, sodium = 107g, copper = 100mg, cobalt = 175mg, iron = 1000mg, maximum fluorine = 650mg, iodine = 175mg, manganese = 1440mg, selenium = 27mg, zinc = 6000mg.

The diets were provided twice a day (08:00 am and 03:00 pm), as a total mixed ration, allowing leftovers of up to 10% and water supply *ad libitum*. During the collection period, daily weighing and sampling of feed provided and leftovers from all animals were carried out to estimate voluntary intake. The samples of the ingredients, in addition to the leftovers, were pre-dried in a forced air oven at 55ºC until obtaining a constant mass and processed in a knife mill (Wiley mill, Marconi, MA-580, Piracicaba, Brazil), using 1 mm sieves, for subsequent chemical analysis according to AOAC (Official…, 1990).

The goats were milked manually, twice a day (07:00 am and 02:00 pm), recording milk production from the 15th to the 17th day of each experimental period. Milk production was recorded daily, individually and at each milking, being corrected to 3.5% fat, using the following formula: MPCF (milk production corrected for fat) = (0.432 + 0.1625 x %fat) x kg of milk (Sklan *et al*., 1992). Milk samples were collected in the morning and afternoon milkings, making composite samples for each day according to milk production. Aliquots of 50 mL were removed from each composite sample to evaluate fat content according to the method described by the International Dairy Federation (Whole…, 1996).

The economic analysis was carried out based on food costs, since fixed costs are identical between treatments, variable costs show greater changes between diets, being a relevant economic indicator, calculated based on the prices for purchasing ingredients in the state of Pernambuco, between March and July 2022. Cost and revenue indicators and economic result measures were calculated according to Deleco (2007) and Lima *et al*. (2010). The evaluation of each treatment generated a set of economic information, which was compared with each other.

The variables were calculated according to the recommendations of Pinho *et al*. (2011):

- Total revenue (TR, R$/animal/day) = milk production multiplied by the price per kg of milk;
- Additional revenue (AR, R$/animal/day) = difference between the TR obtained in each treatment and the average TR obtained between treatments;
- Daily feed cost (DFC, R$/animal/day) = total cost of feed in each treatment;
- Additional feed cost (AFC, R$/animal/day) = difference between the total cost of feed obtained in each treatment and the average cost verified in the treatments;
- Additional profit (AP, R$/animal/day) = difference between the value of the increase in AR and the value of the increase in feed expenditure (AFC);
- Leveling point (LP, kg) = relationship between the DFC and the price of milk;
- Cost per kilogram of milk (R$/kg) = relationship between DFC and milk production.

The data were submitted to analysis of variance, using the MIXED procedure of the SAS statistical program, version 9.0 (2009), assuming 5% as the significance level for type I error. The following model was used:

$$Y_{ijklm} = \mu + Q_i + TSL_j + GS_k + P_m + (A/Q)_{il} + TSL \times GS_{jk} + Q \times TSL_{ij} + Q \times GS_{ik} + e_{ijklm}$$

Where, Yijklm = observation in animal l, in period m, submitted to level j of treatment TSLj and level k of treatment GSk, in Latin square I; μ = general mean; Qi = effect of Latin square i, where i = 1, 2 and 3; TSLj = fixed effect of level j of energy source, where j = 1, 2. GSk = fixed effect of level k of spineless cactus , where k = 1, 2; Pm = effect of experimental period m, where m = 1, 2, 3 and 4; (A/Q)il = effect of animal l, within Latin square i, where l = 1, 2, 3 and 4; TSL × GSjk = effect of the interaction between level j of energy source and level k of spineless cactus; Q × TSLij = effect of the interaction between Latin square i and level j of energy source; Q × GSik = effect of the interaction between Latin square i and level k of spineless cactus; eijklm = random error associated with each observation ijklm; eijklm ∼ NID (0, s2).

The economic evaluation was not subjected to statistical analysis, since the economic differences found were based on greater profitability.

RESULTS AND DISCUSSION

The diet composed of Tifton-85 hay and spineless cactus proved to be more efficient (P<0.05) when compared to diets containing hay as exclusive roughage, presenting higher values for DM intake, fat-corrected milk production and milk fat content (Tab. 2). According to Bezerra *et al*. (2023), the inclusion of up to 36% of spineless cactus combined with Tifton-85 hay increases DM intake and sheep performance, due to effective ruminal degradability.

Table 2. Dry matter intake, milk production and fat content in the milk of goats fed different lipid sources associated or not with spineless cactus

Variables	Lipid source		Spineless cactus OEM[a]		SEM[b]	P-value		
	CP[c]	CT[d]	With	Without		LS[c]	OEM[a]	LS*OEM[a]
DMI[e] (g/day)	1492.5b	1715.0a	1975.5a	1232.1b	90.8	0.020	<.001	0.586
MP[f] (g/day)	2101.4a	2362.0a	2537.5a	1926.0b	211.6	0.066	0.002	0.849
MPCF[g] (g/day)	1959.2b	2406.0a	2495.8a	1869.4b	192.5	0.002	<.001	0.442
FC[h] (%)	2.8b	3.2a	2.9a	3.1a	0.11	0.009	0.145	0.419

[a] Orelha de Elefante Mexicana, [b] standard error of the mean, [c] coconut peels, [d] cottonseed, [e] dry matter intake, [f] milk production, [g] milk production corrected for fat, [h] fat content. Means followed by different letters in the line, for the same variable, differ using the Tukey test (5%).

The low DM intake presented by goats that received CP may be related to the high concentration of medium-chain fatty acids in this co-product, and this characteristic may have interacted with the satiety center of the animals (Silva *et al*., 2022). Goats that consumed diets containing CT as the main source of energy showed higher performance indexes (P<0.05), which can be explained by the fact that, in this ingredient, vegetable oils are protected in the seeds, being hydrolyzed when consumed by ruminants, which improves the use of the diet, thus promoting greater DM intake and an increase in milk fat (Silva, 2023). Furthermore, it is noteworthy that the slight superiority in crude protein and TDN levels in the CT and CT+OEM diets may have contributed to greater performance of the goats fed these diets.

The treatment composed of CP+OEM spineless cactus presented the lowest cost value for 1 kg of DM (R$ 1.78; Table 3). This result can be explained by the lower participation of CP in the composition of the diet, even with a higher acquisition value (R$ 3.12 per kg of DM). The association of spineless cactus with Tifton-85 hay reduced the roughage cost by 45%, compared to the exclusive use of Tifton-85 hay, which presented a cost of R$ 2.88 kg of DM, while the cost of OEM spineless cactus was R$ 0.78 kg of DM. This drastic reduction in the cost of roughage highlights the importance of spineless cactus in semi-arid regions of the world, compared to more traditionally used roughage.

The diet containing CT, without the inclusion of spineless cactus, presented a higher cost (R$ 2.46 per kg/DM), resulting from the higher cost roughage due to the exclusive use of hay, and the concentrate with a 13% higher cost, in relation to the concentrate containing CP. It is important to highlight that at the time of the study some concentrate ingredients, such as corn and mineral mix, had prices that could be considered high in the market. Therefore, at another moment when prices are favorable, these results could be better.

Considering the sales value of goat milk practiced in Pernambuco, Northeast of Brazil (R$ 3.0/liter; PREÇOS, 2022), the diet that presented the best result was CT+OEM spineless cactus, evident in the additional revenue of R$ 1.43 (Table 4), which represents the difference between the total income from the diet and the average income from treatments. This result can be explained by the greater milk production of animals fed this diet, justified by greater intake and, probably, better use of the diet.

Table 3. Description of the costs of experimental diets based on dry matter (in R$).

Ingredients	Experimental diets (R$/kg)				
	DM[a]	CP[b]	CT[c]	CP+OEM[d]	CT+OEM[d]
Tifton-85 hay	2.88	1.15	1.15	0.43	0.43
Spineless cactus OEM[d]	0.78	-	-	0.20	0.20
Coconut peels	3.12	0.16	-	0.16	-
Cottonseed	3.09	-	0.62	-	0.62
Ground corn	1.12	0.42	0.35	0.40	0.32
Soybean meal	2.43	0.36	0.15	0.40	0.21
Mineral mix	9.53	0.19	0.19	0.19	0.19
Total	-	2.28	2.46	1.78	1.97

[a] dry matter, [b] coconut peels, [c] cottonseed, [d] Spineless cactus Orelha de Elefante Mexicana.

Table 4. Economic performance indicators of experimental diets

Indicators	Experimental diets			
	CP[a]	CT[b]	CP+OEM[c]	CT+OEM[c]
Milk price (kg/R$)	3.00	3.00	3.00	3.00
Total revenue (R$/animal/day)	5.48	6.16	7.31	8.17
Additional revenue (R$/animal/day)	1.26	0.57	0.57	1.43
Daily feed cost (R$/animal/day)	2.54	3.16	3.30	3.98
Additional cost (R$/animal/day)	0.69	0.07	0.07	0.75
Additional profit (R$/animal/day)	0.57	0.50	0.50	0.68
Leveling point (kg)	0.85	1.05	1.10	1.33
Feeding cost per kilogram of milk (R$/kg)	1.39	1.54	1.36	1.46
Net income (R$/kg)	2.94	3.00	4.01	4.19

[a] coconut peels, [b] cottonseed, [c] Spineless cactus Orelha de Elefante Mexicana.

The diet containing CP without association with OEM spineless cactus presented lower daily feed costs (R$ 2.54/day; Table 4), due to the lower DM intake by animals fed this diet (Table 3). Thus, using the daily feed cost values and the average feed costs of the other treatments, this diet presented the lowest additional cost (R$ -0.69; Tab. 4), followed by the CT treatment (R$ -0.07/day; Table 4). The diets associated with spineless cactus and Tifton-85 hay presented higher daily feed costs due to the animals' higher DM intake and, consequently, a positive additional cost (Table 4).

The additional profit, which represents the difference between the additional revenue and the additional cost, was positive for diets containing spineless cactus, due to the greater milk production (Table 2), and the diet that presented the highest additional profit was CT+OEM spineless cactus (R$ 0.75/day; Table 4), the result of the considerably high additional revenue.

To assess whether the activity is economically viable, the leveling point is an important indicator, determined by the minimum production at which gross income equals production costs and, from that point onwards, the producer starts to make a profit, and at this point net income is zero. Due to the evaluation of only the cost of feed, the leveling point of the present study is equivalent to the "income equal feed costs" (IEFC), which reports the minimum milk production to cover the cost of feed, considering the sales value of the milk (Atzori *et al*., 2021). For this indicator, the treatment with the lowest leveling point was CP, requiring the production of 0.85 kg/day of milk to cover the cost of feed, being directly linked to the lowest daily cost of feed and DM intake.

The production costs per kilogram of milk were very close, being lower for the CP+OEM spineless cactus treatment, which is due to the average production and the ratio of daily feed costs, being an excellent indicator of productivity. One of the most important results is net income, coming from gross income minus costs (feed). Thus, the CT+OEM spineless cactus diet, despite presenting higher daily feed costs, was the one that provided the highest net income (R$ 4.19/day; Table 5).

The production system and diet adopted affect the quality of the milk and its composition, such as an increase in the solid content and fatty acid profile, which can generate differentiated products and, therefore, add value to milk and its derivatives, promoting higher revenue (Fernandes *et al*., 2023). Thus, in situations of bonuses based on the fat content in milk, the diet containing CT appears to be the most appropriate (Table 3) and can contribute to the economic profitability of production.

In general, all treatments showed positive net income, especially those with an association between lipid source, spineless cactus and Tifton-85 hay (CT+OEM spineless cactus and CP+OEM spineless cactus), showing the influence and relevance of the combination between cactus and physically effective fiber source on DM intake and animal performance, in addition to the importance of protected oils from cottonseed in better dietary utilization. In this context, Soares *et al*. (2020), when investigating the milk production and costs of feeding lactating Saanen goats with diets containing spineless cactus genotypes (*Nopalea cochenillifera* Salm Dyck or *Opuntia stricta* (Haw.) Haw.), reported that the use of up to 35% spineless cactus in the diets, compared to the diet with Tifton-85 hay as only roughage, maintains milk production and decreases feeding production costs.

CONCLUSIONS

The association between cottonseed (200 g/kg dry matter) with spineless cactus "Orelha de Elefante Mexicana" (250 g/kg dry matter) and Tifton-85 hay (150 g/kg dry matter) in the diet of lactating goats is recommended, as it reduces feed costs, especially with the roughage, in addition to improving the production of milk, which contributes to greater profitability of the activity.

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