











Dimensionality reduction of variables in animal nutrition studies: an approach using discriminant analysis

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Abstract

This study aimed to evaluate the effect of including spineless cactus (*Opuntia* spp.) at different levels (0, 250, 500, and 750 g/kg of dry matter) in sheep diets on carcass traits, performance, muscle strength, color, and commercial cuts. Multivariate analyses, including discriminant and canonical analyses, were applied to identify the variables with the greatest discriminatory power among the experimental groups. The first canonical function explained 79.63% of the cumulative variance, while the second function increased this value to 95.07%, demonstrating the model's efficiency. Variables such as shoulder, serrate, rib, leg, and muscle strength were key in distinguishing the groups, especially between the extreme levels of inclusion. The Mahalanobis distance confirmed the distinction between treatments, with 100% accuracy in classifying the 0 and 750 g/kg groups. The two-dimensional distribution revealed overlap among intermediate levels, suggesting a gradual response to cactus inclusion. The results indicate that spineless cactus is a viable alternative for semi-arid regions, with the potential to improve carcass yield and cut quality, while also demonstrating the effectiveness of multivariate techniques in the integrated evaluation of productive parameters.

Keywords: carcass quality; dimensionality reduction; food industry impact; lamb's meat.

Practical Application: Understanding how diet influences traits such as tenderness, juiciness, color, and chemical composition of meat. Meeting consumer demands for products with better flavor and nutritional value.

1 INTRODUCTION

The commercial value is strongly related to carcass yield and composition, which includes the proportions of muscle, fat, and bone; these characteristics vary significantly and have a direct impact on commercial value (Ekiz et al., 2020). In animal production systems, the qualitative and quantitative characteristics of carcasses are crucial for the success of the sector, as they directly influence market acceptance of the product. To meet consumer demands, it is essential to obtain well-conformed carcasses with a high proportion of muscle and an adequate amount of intramuscular fat (Alves et al., 2023), which contributes to the juiciness and flavor of the meat.

Since feed represents approximately 70% of total production costs, there is a continuous effort to find viable alternative feed sources that can replace traditional ingredients without compromising the nutritional quality and productive performance of the animals (Alves et al., 2023; Ferreira et al., 2019). Spineless

cactus has stood out as a sustainable feed source for sheep, especially in semi-arid regions, due to its adaptive capability, associated with its productive potential and low demand for water resources (water-use efficiency). In ruminant feeding, in addition to contributing to the water supply for the animals, it provides an excellent source of energy, rich in non-fiber carbohydrates and total digestible nutrients (Fernades et al., 2020), and despite having low levels of crude protein and neutral detergent fiber when compared to other bulky feeds, it has high dry matter digestibility. Many studies have been conducted using cactus in the diet of sheep (Serviço Brasileiro de Apoio às Micro e Pequenas Empresas, [SEBRAE], 2023).

When dealing with a large number of descriptors, many of them may be redundant, making their elimination beneficial, as they are not only uninformative but also increase the workload in evaluations (Jolliffe, 1972, 1973). Thus, variable reduction can be performed through principal component analysis, whose main objective is to summarize the information contained in

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the complex set of original variables, eliminating redundancies that arise due to correlations between them (Khattree & Naik, 2000). Finally, the application of multivariate models allows a more in-depth analysis of the relationships between the various explanatory variables involved in carcass and animal nutrition studies. Discriminant analysis, in particular, is a useful statistical tool for reducing data dimensionality and identifying relevant patterns to optimize production strategies.

A better interpretation of the dataset can be obtained through multivariate analysis techniques, as they are more appropriate for the study of a set of correlated variables that will be analyzed simultaneously. Thus, multivariate analysis techniques prove to be extremely efficient alternatives when the situation requires the combination of multiple pieces of information from an experimental plot (i.e., an observational vector) to associate or predict biological phenomena from a complex of variables essential for the development of the experimental plan (Dillon & Goldstein, 1984).

Canonical discriminant analysis is a multivariate technique for reducing data dimensionality, similar to the principal component technique and canonical correlation analysis. However, this technique is a specialty of discriminant analysis and is used to represent different populations in a reduced subspace (Guedes et al., 2018). This study aimed to evaluate the effect of including spineless cactus (*Opuntia* spp.) at different levels (0, 250, 500, and 750 g/kg of dry matter) in sheep diets on carcass traits, performance, muscle strength, color, and commercial cuts.

1.1 Relevance of the work

Applying canonical discriminant analysis and principal component analysis to carcass and meat quality data demonstrates a modern, data-driven approach to animal nutrition research. Your study contributes to the refinement of experimental designs by identifying the most informative variables, a valuable asset for future research and practical applications.

2 MATERIALS AND METHODS

Twenty uncastrated male Santa Inês sheep, 4 months old, were used in the experiment. The treatments consisted of increasing levels of forage cactus (*Opuntia ficus-indica*) included in the diet at proportions of 0, 250, 500, and 750 g/kg DM.

At the end of the confinement period, the animals were weighed to determine their final live weight and then subjected to a 16-h fasting period. Slaughter was performed in accordance with Brazilian standards (Brasil, 2025), involving stunning with a captive bolt gun to induce cerebral concussion, followed by exsanguination for 4 min via severing of the carotid and jugular arteries. Blood was collected in pre-weighed containers for subsequent quantification.

Color measurements were taken 50 min post-exposure at room temperature (22 °C) using a Chroma Meter CR-400 colorimeter (Konica Minolta, Osaka, Japan) with a 10° observer angle and D65 illuminant, in Specular Component Included (SCI) mode, on the surface of the Longissimus lumborum (LL) muscle. The CIE L, a, and b* values were recorded, with each sample evaluated in triplicate.

Cooking losses were assessed following the methodology of Wheeler et al. (1994). A 2.5 cm-thick steak was cut transversely to the muscle fibers from the LL muscle, wrapped in aluminum foil, and cooked in a convection oven (FISCHER, Star model) at 150 °C until reaching an internal temperature of 71 °C, monitored using K-type thermocouples (Comark, PK23M, Vienna Court, UK) inserted into the geometric center of the sample. Samples were then cooled at room temperature until reaching 24 °C, measured with an insertion thermometer (TESTO, model 106, Melrose, MA, USA).

A 100 g sample from the right LL muscle of each animal was trimmed of connective tissue and external fat, then ground using a domestic blender for chemical composition analysis. Moisture, ash, protein, and lipid contents were determined according to Association of Official Analytical Chemists (AOAC) protocols (AOAC, 2005). Vacuum-packed samples were thawed at 4 °C for 24 h prior to analysis.

The left LL et lumborum muscle was wrapped in aluminum foil and cooked on a single-plate grill at a controlled temperature of 180 °C until reaching an internal temperature of 70 °C. The muscle was then cut into ten 2 cm² portions, individually wrapped in foil, and labeled with random three-digit codes. Samples were kept warm in a heater at 55 °C until sensory evaluation. To minimize presentation order effects, samples were served to panelists in randomized sequences (Macfie et al., 1989).

For this purpose, the Equation 1 was employed.

$$D(x) = L'x = [x_1 - x_2]'S^{-1}.x \quad (1)$$

Where $D(x)$ represents the Fisher's linear discriminant function, L is the estimate of the discriminant vector, x_1 is the sample mean of population p , and x is the highest mean of population p . The selection of variables with the highest discriminatory power was carried out using the stepwise method, which combines the addition of variables with the greatest discriminatory power and eliminates those with lesser contributions, based on the F-statistic or Wilks' lambda value. The primary objective of this procedure is to identify the best set of variables to compose the discriminant function.

Statistical analyses were performed using Statistica 8.0 software.

3 RESULTS

Discriminant analysis was applied to identify the variables with the greatest discriminatory power among the experimental treatments. The results are presented in Table 1, showing the respective values of Wilks' lambda, partial lambda, and statistical significance (p -value).

The variables that showed statistical significance ($p < .05$) and, therefore, contributed most to group discrimination were: slaughter body weight ($p = .0003$), empty body weight ($p = .0002$), serrote cut ($p = .0032$), color component b ($p = .0186$)*, initial live weight ($p = .0266$), and length L ($p = .0430$). These variables had the lowest partial lambda values, indicating a greater ability to separate the experimental groups.

Among them, empty body weight and slaughter body weight stood out as the main discriminators, suggesting that cactus

inclusion in the diet directly influences tissue deposition and carcass yield. The serrate cut, associated with commercial meat cuts, also showed strong discriminatory power, possibly reflecting morphological changes resulting from dietary treatments.

The b^* variable, related to meat color, indicated that diet may affect sensory attributes important for consumer acceptance. Meanwhile, initial live weight and length L reinforce the importance of initial morphometric characteristics in group differentiation.

On the other hand, variables such as loin eye area, hot carcass weight, leg, shoulder, rib, and loin did not show statistical significance ($p > .05$), indicating lower relevance for treatment discrimination.

Table 2 presents the Mahalanobis distances between the experimental groups subjected to different levels of cactus inclusion in the diet, based on the selected discriminant variables. This multivariate metric allows for the assessment of the degree of separation between groups according to their combined characteristics.

The results indicate that the greatest distances were observed between the extremes of cactus inclusion: the 0 and 75 g/kg groups showed a distance of 29.58, followed by the distance between the 0 and 50 g/kg groups (17.33), both statistically significant at the 5% probability level. These values suggest that

increasing the proportion of cactus in the diet led to substantial changes in the evaluated variables, resulting in greater differentiation between groups.

On the other hand, the shortest distances were observed between the 25 and 50 g/kg groups (5.51) and the 50 and 75 g/kg groups (7.70), indicating less variation among these intermediate inclusion levels. The distance between the 25 and 75 g/kg groups was 8.42, which was also not statistically significant.

Discriminant analysis was able to correctly classify the individuals based on the selected variables, and the results are expressed as the percentage of correct classifications per group (Table 3).

The extreme groups 0 and 750 g/kg showed 100% accuracy, with all animals correctly assigned to their respective groups. This indicates that these levels of cactus inclusion promoted marked changes in the evaluated characteristics, allowing for a clear separation between groups.

The 500 g/kg group achieved 80% accuracy, with 8 out of 10 animals correctly classified, while the 250 g/kg group had the lowest accuracy rate, at 60%, reflecting greater overlap of characteristics with the other groups. In this group, two animals were classified as belonging to the 0 g/kg group, one to the 500 g/kg group, and one to the 750 g/kg group.

These coefficients indicate the relative weight of each variable in the classification function for each group, allowing the evaluation of which characteristics most influence the separation between treatments (Table 4).

Variables with the highest positive coefficients, such as shoulder (paleta), rib (costela), serrate, leg (perna), and neck (pescoço), contributed strongly to group differentiation, especially at the lower levels of cactus inclusion. For example, the 0 g/kg group showed the highest values for shoulder (181.093), rib (127.529), and serrate (120.007), indicating greater development of these body regions.

On the other hand, variables such as hot carcass weight, empty body weight, and force exhibited high negative coefficients, suggesting that these attributes decrease with increasing cactus inclusion in the diet. This may be related to body composition and nutrient utilization efficiency.

The constant associated with each function also progressively decreased with higher cactus inclusion, ranging from -279.385 in the 0 g/kg group to -207.791 in the 750 g/kg group, reinforcing the trend of reduced overall discriminant function values as the alternative ingredient increases.

Table 1. Variables selected and excluded by the *stepwise method*.

Variables	Wilks lambda	Partial lambda	p-value
Initial live weight	0.124656	0.651257	.026643
Final live weight	0.101972	0.796134	.179468
Slaughter body weight	0.193494	0.419562	.000325
Hot carcass weight	0.112572	0.721167	.071250
Empty body weight	0.204986	0.396041	.000181
Loin eye area	0.084686	0.958630	.823524
Lightness (L*)	0.118647	0.684242	.043043
Leg	0.097400	0.833500	.271072
Force (N)	0.106773	0.760333	.117330
Redness (a*)	0.106525	0.762102	.119903
Yellowness (b*)	0.129329	0.627726	.018583
Neck	0.091348	0.888724	.469069
Shoulder	0.088457	0.917764	.605432
Rib	0.087157	0.931454	.676330
Upper rib	0.154329	0.526039	.003209
Loin	0.086848	0.934774	.694010

Table 2. Mahalanobis distance between the evaluated groups with different diets.

Spineless cactus (%)	0	25	50	75
0	—	9.261267	17.32979**	29.57939**
25		—	5.51310	8.42100
50			—	7.70079
75				—

**Significant at 5% probability.

Table 3. Matrix for classifying animals fed different diets based on spineless cactus.

Levels spineless cactus (%)	Percent correct	0	25	50	75
0	100.0000	10	0	0	0
25	60.0000	2	6	1	1
50	80.0000	0	1	8	1
75	100.0000	0	0	0	10

These results demonstrate that cactus inclusion in the diet significantly influences carcass composition and morphometric characteristics of sheep, making it possible to distinguish the groups based on the generated discriminant functions.

The first canonical function (CAN 1) explained 79.63% of the cumulative variance, while the second function (CAN 2) increased this value to 95.07%, indicating that together, the two functions adequately represent the variability among the experimental groups (Table 5).

In CAN 1, the main positive contributors were the variables serrote (7.6591), shoulder (paleta) (5.6823), rib (costela) (3.8683), and leg (perna) (2.9340), suggesting that these body regions were key determinants in group separation. Conversely, variables such as empty body weight (-1.6182), hot carcass weight (-1.4813), and forca (-2.5562) showed strong negative coefficients, indicating an inverse association with this function.

In CAN 2, the highest positive coefficients were observed for hot carcass weight (1.2361), slaughter body weight (0.9620), and forca (2.9182), while leg (-2.9376) and rib (-1.7623) presented the most negative coefficients. This suggests that the second function is more related to performance and muscular strength traits, with less influence from commercial cuts.

These results indicate that morphometric and carcass composition variables are key in differentiating the dietary groups, with shoulder, serrote, and rib being the most influential in the first function, while hot carcass weight and forca stand out in the second.

Figure 1 presents the two-dimensional plot of canonical functions 1 and 2, which explain 79.63 and 95.07% of the cumulative variance among the experimental groups, respectively. Each point represents an individual animal, distributed according to the levels of spineless cactus inclusion in the diet (0, 250, 500, and 750 g/kg of dry matter), identified by different symbols and colors.

Table 4. Classification of functions for the diet with spineless cactus.

Variables	Levels spineless cactus (%)			
	0	25	50	75
Initial live weight	4.298	3.110	2.839	2.162
Final live weight	-2.474	-2.000	-2.693	-1.542
Slaughter body weight	23.176	19.220	19.643	15.281
Hot carcass weight	-27.461	-24.525	-20.059	-20.146
Empty body weight	-28.347	-23.831	-23.561	-19.138
Loin eye area	-3.394	-2.997	-2.634	-2.689
Lightness (L*)	8.840	8.306	7.559	7.434
Leg	72.446	70.238	58.133	58.162
Force (N)	-43.505	-39.228	-29.621	-31.324
Redness (a*)	11.456	9.968	8.874	8.669
Yellowness (b*)	-17.665	-14.969	-13.695	-13.022
Neck	47.643	67.248	56.346	53.542
Shoulder	181.093	167.830	160.071	150.395
Rib	127.529	114.129	108.853	107.700
Upper rib	120.007	96.822	89.885	78.755
Loin	42.333	29.425	26.518	19.801
Constant	-279.385	-249.083	-237.829	-207.791

A clear separation is observed between the 0 and 750 g/kg groups, positioned at opposite ends of the graph, reinforcing the results obtained from the discriminant and canonical analyses. The intermediate groups (250 and 500 g/kg) show greater overlap, indicating a gradual transition in the evaluated characteristics.

This distribution pattern highlights that the inclusion of spineless cactus in the diet significantly influences carcass traits, performance, and commercial cuts, making it possible to distinguish the groups based on the generated canonical functions.

Table 5. Standardized canonical coefficients for the canonical functions of carcass, performance, color, strength, and cut variables in sheep fed diets based on spineless cactus.

Variables	CAN 1	CAN 2
Initial live weight	0.3915	0.03583
Final live weight	-0.1271	-0.42348
Slaughter body weight	1.3565	0.96202
Hot carcass weight	-1.4813	1.23614
Empty body weight	-1.6182	-0.78290
Loin eye area	-0.1436	0.12292
Lightness (L*)	0.2778	-0.17386
Leg	2.9340	-2.93761
Force (N)	-2.5562	2.91819
Redness (a*)	0.5470	-0.29331
Yellowness (b*)	-0.8909	0.29111
Neck	-1.0982	-0.57132
Shoulder	5.6823	-0.15287
Rib	3.8683	-1.76228
Upper rib	7.6591	-0.21375
Loin	4.1469	0.23386
Constant	-12.5605	-3.69627
Eigenvalue	4.3025	0.83407
Cumulative proportion	0.7963	0.95066

CAN: canonical functions.

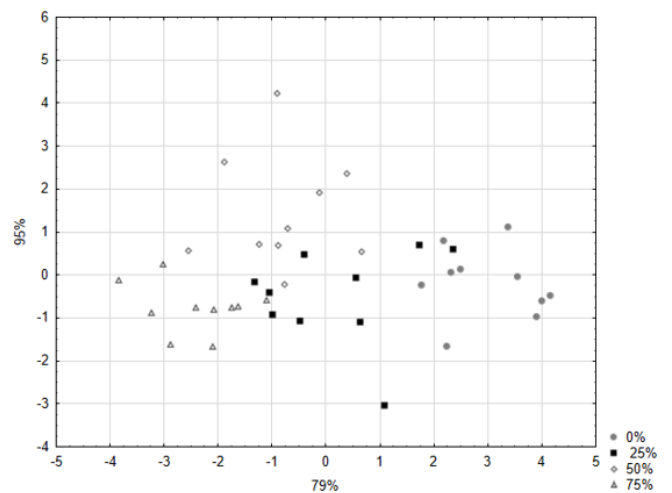


Figure 1. Two-dimensional graph of the distribution of the studied variables.

These findings demonstrate the effectiveness of discriminant analysis as a statistical tool for dimensionality reduction and variable selection in animal nutrition studies. Identifying a reduced set of variables with high discriminatory power allows future experiments to be optimized, reducing costs and increasing evaluation efficiency.

4 DISCUSSION

The discriminant and canonical analyses applied in this study revealed that variables such as shoulder, serrote, rib, leg, and muscle strength were key in distinguishing dietary groups, especially between the extremes of spineless cactus inclusion (0 and 750 g/kg). This separation was confirmed by the Mahalanobis distance, the classification matrix with high accuracy rates (100% in the extreme groups), and the canonical functions, which explained over 95% of the cumulative variance.

These findings are consistent with the results of Sobral et al. (2024), who reported that replacing corn silage with spineless cactus led to significant changes in carcass composition and sensory characteristics of sheep meat, particularly in cuts such as shoulder and rib. The inclusion of cacti in the diet has been considered a viable strategy in semi-arid regions due to their high availability and ability to sustain animal performance.

Furthermore, Lima et al. (2021) demonstrated that using spineless cactus in combination with other fibrous sources, such as cassava hay, directly affects carcass yield and fat deposition, corroborating the negative coefficients observed for empty body weight and hot carcass weight in the present study.

The use of multivariate techniques, such as canonical and discriminant analysis, has been widely recommended in animal nutrition studies. As discussed by Alves et al. (2023), these tools are effective in identifying variables with greater explanatory power and reducing data dimensionality without loss of information. In this study, canonical function 1 was strongly influenced by commercial cuts, while function 2 reflected performance traits and muscle strength, highlighting the complexity of physiological responses to dietary changes.

The two-dimensional distribution of the experimental groups (Figure 1) shows a clear separation between the extreme treatments and overlap among intermediate levels, suggesting that the animals' response to spineless cactus inclusion occurs gradually and is multifactorial. This observation aligns with the findings of Sobral et al. (2024), who also reported progressive morphological transitions in sheep fed varying levels of cactus.

Therefore, the results of this study not only confirm the feasibility of spineless cactus as an alternative ingredient in sheep diets but also demonstrate the effectiveness of multivariate analyses in identifying nutritional effects on carcass traits and animal performance. Identifying key variables allows for the optimization of evaluation protocols and the formulation of more efficient diets tailored to the conditions of the Brazilian semi-arid region.

5 CONCLUSIONS

The inclusion of spineless cactus in sheep diets has proven to be an effective nutritional strategy, capable of promoting significant changes in carcass traits, performance, and commercial cuts. Discriminant and canonical analyses allowed the identification of highly explanatory variables such as shoulder, serrote, rib, leg, and muscle strength, which were key in distinguishing the experimental groups. Furthermore, the two-dimensional distribution of the groups revealed a gradual transition among intermediate levels, suggesting that the effects of spineless cactus occur progressively and are multifactorial. These results indicate that, in addition to being a viable alternative for semi-arid regions, spineless cactus can be strategically used to optimize carcass yield and the quality of commercial cuts.

REFERENCES

- Alves, K. A., Lima, J. A. M., Costa, M. R. G. F., Silva, T. C., Brito, C. L., Gomes, M. L. R., Pereira Filho, J. M., Oliveira, J. P. F., Nascimento, R. R., & Bezerra, L. R. (2023). Effect of replacing corn with cactus pear on the performance and carcass traits and meat quality of feedlot finished lambs. *Ciência Animal Brasileira*, 24, Article e75322E. <https://doi.org/10.1590/1809-6891v24e-75322E>
- Association of Official Agricultural Chemists. (2005). *Official methods of analysis of AOAC International* (18th ed.). AOAC.
- Brazil. (2025, July 14). *Legislação em inspeção de produtos de origem animal*. <https://www.gov.br/agricultura/pt-br/assuntos/inspecao/produtos-animal/legislacao>
- Dillon, W. R., & Goldstein, M. (1984). *Multivariate analysis: Methods and applications*. Wiley.
- Ekiz, B., Baygul, O., Yalcintan, H., & Ozcan, M. (2020). Comparison of the decision tree, artificial neural network and multiple regression methods for prediction of carcass tissues composition of goat kids. *Meat Science*, 161, Article 108011. <https://doi.org/10.1016/j.meatsci.2019.108011>
- Fernandes, R. T. V., Gonçalves, A. A., & Arruda, A. M. V. (2020). Production, egg quality, and intestinal morphometry of laying hens fed marine microalga. *Revista Brasileira de Zootecnia*, 49, Article e20200011. <https://doi.org/10.37496/rbz4920200011>
- Ferreira, T. S., Lana, S. R. V., Lana, G. R. Q., Madalena, J. A., Silva, L. C. L., & Torres, E. C. (2019). Resíduo de acerola em dietas para codornas. *Arquivo Brasileiro Medicina Veterinária e Zootecnia*, 71(1), 259–266. <https://doi.org/10.1590/1678-4162-9965>
- Guedes, D. G. P. G., Ribeiro, M. N., & Carvalho, F. F. R. (2018). Multivariate techniques in the analysis of carcass traits of Morada Nova breed sheep. *Ciência Rural*, 48(9), Article e20170746. <https://doi.org/10.1590/0103-8478cr20170746>
- Jolliffe, I. T. (1972). Discarding variables in a principal component analysis. I. Artificial data. *Journal of the Royal Statistical Society: Series C (Applied Statistics)*, 21(2), 160–173. <https://doi.org/10.2307/2346488>
- Jolliffe, I. T. (1973). Discarding variables in a principal component analysis. II. Real data. *Journal of the Royal Statistical Society: Series C (Applied Statistics)*, 22(1), 21–31. <https://doi.org/10.2307/2346300>
- Khattree, R., & Naik, D. N. (2000). *Multivariate data reduction and discrimination with SAS software*. SAS Institute.
- Lima, A. S., Silva, S. J. F., Souza, M. T. C., Vieira, M. S. B., Praxedes, R. F., Ribeiro, J. S., Cardoso, D. B., Rangel, A. H. N., Carvalho, F. F. R., & Lima Júnior, D. M. (2021). Carcass characteristics and meat quality of lambs fed with cassava foliage hay and spineless cactus. *Animal Science Journal*, 92(1), Article e13519. <https://doi.org/10.1111/asj.13519>

- Macfie, H. J. H., Bratchell, N., Greenhoff, K., & Vallis, L. V. (1989). Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests. *Journal of Sensory Studies*, 4(2), 129–148. <https://doi.org/10.1111/j.1745-459X.1989.tb00463.x>
- Serviço Brasileiro de Apoio às Micro e Pequenas Empresas. (2023). *Cortes especiais de ovinos para agregar valor ao produto: Panorama e desafios da ovinocultura brasileira*. Polo Sebrae Agro. <https://polosebraeagro.sebrae.com.br/wp-content/uploads/2024/04/Cortes-especiais-ovinos-20230920-PM-Pec-SEBRAEGO-PROD.pdf>
- Sobral, G. C., Oliveira, J. S., Santos, E. M., Araújo, G. G. L., Santos, F. N. S., Medeiros, G. R., Souza, E. J. O., Vieira, D. S., Leite, G. M., Coelho, D. F. O., Santana, L. P., Gomes, P. G. B., Torres Júnior, P. C., Santos, M. A. C., & Viana, N. B. (2024). Forage cactus as an additive in corn without the cob silages of feedlot sheep diets. *Tropica Animal Health and Production*, 56(2), Article 72. <https://doi.org/10.1007/s11250-024-03918-y>
- Wheeler, T. L., Cundiff, L. V., & Koch, R. M. (1994). Effect of marbling degree on beef palatability in *Bos taurus* and *Bos indicus* cattle. *Journal of Animal Science*, 72(12), 3145–3151. <https://doi.org/10.2527/1994.72123145x>