Animal Feed Science and Technology 307 (2024) 115824

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

Potential use of vitiviniculture waste in mixed cactus pear silages with elephant grass in lamb diet

Telisson Ribeiro Gonçalves [a], José Renaldo Vilar da Silva Filho [a], Gilmar Amaro Pereira [a], Tarcisio Martins Meira [a], Moema Kelly Nogueira de Sá [b], Glayciane Costa Gois [c,*], Crislane de Souza Silva [a], Fleming Sena Campos [c], Sandra Mari Yamamoto [d], Gherman Garcia Leal de Araújo [e]

[a] *Programa de Pós-Graduação em Ciência Animal, Universidade Federal do Vale do São Francisco, 56304–917 Petrolina, PE, Brazil*
[b] *Programa de Pós-Graduação em Ciência Animal e Pastagens, Universidade Federal do Agreste de Pernambuco, 55292-270 Garanhuns, PE, Brazil*
[c] *Programa de Pós-Graduação em Ciência Animal, Universidade Federal do Maranhão, 65500-000 Chapadinha, MA, Brazil*
[d] *Docente do Centro de Ciências da Natureza, Universidade Federal de São Carlos, 18290-000 São Carlos, SP, Brazil*
[e] *Empresa Brasileira de Pesquisa Agropecuária, 56302-970 Petrolina, PE, Brazil*

ARTICLE INFO

Keywords:
Opuntia stricta
Mixed silages
Vitis vinifera

ABSTRACT

The aim was to evaluate intake, digestibility, water balance, nitrogen balance, ingestive behavior, performance, and carcass traits of lambs on diets containing levels of vitiviniculture waste in mixed cactus pear silages with elephant grass. Twenty-four crossbred male lambs (150 days of age, 20.75 kg ± 1.33 kg body weight) were assigned to a randomized block design, with four treatments (diets) and six animals per treatment. The experimental diets consisted of four elephant grass mixed silages (MS), containing different levels of cactus pear and vitiviniculture waste: MS1 – 255 g/kg cactus pear and 108 g/kg vitiviniculture waste; MS2 – 216 g/kg cactus pear and 144 g/kg vitiviniculture waste; MS3 – 180 g/kg cactus pear and 180 g/kg vitiviniculture waste; MS4 – 144 g/kg cactus pear and 216 g/kg vitiviniculture waste, on a dry matter basis (DM). The experiment lasted 86 days, preceded by 20 days of adaptation. The inclusion of vitiviniculture waste in silages resulted in a quadratic effect for intakes of crude protein, neutral detergent fiber, acid detergent fiber, and total carbohydrates, digestibility of DM and ether extract, metabolizable water, and water balance ($P < 0.05$), with the highest values of intake and digestibility observed in lambs fed on MS2. The MS in diets resulted in a reduction in the carcass conformation of the lambs ($P = 0.034$). Under the experimental conditions, the use of up to 144 g/kg vitiviniculture waste in the composition of mixed cactus pear and elephant grass silages (MS2) in diets for confined lamb as it provides greater nutrient intake and dry matter digestibility.

Abbreviations: ADF, acid detergent fiber; ADC, apparent digestibility coefficient; ADG, average daily gain; CC, carcass conformation; CCI, carcass compactness index; CCW, cold carcass weight; CCY, cold carcass yield; CL, cooling losses; CW, croup width; CP, crude protein; DM, dry matter; DMI, dry matter intake; EE, ether extract; FC, feed conversion; HCW, hot carcass weight; HCY, hot carcass yield; ICL, internal carcass length; LHCW, left half carcass weight; LCI, leg compactness index; LL, leg length; MW, metabolic water; MS, mixed silages; NDF, neutral detergent fiber; NB, nitrogen balance; NFC, non-fiber carbohydrate; SBW, slaughter body weight; TMR, total mixed ration; TC, total carbohydrates; TDN, total digestible nutrients; TWG, total weight gain; TY, true yield; WB, water balance.

* Corresponding author.
E-mail address: glayciane_gois@yahoo.com.br (G.C. Gois).

https://doi.org/10.1016/j.anifeedsci.2023.115824
Received 5 June 2023; Received in revised form 16 September 2023; Accepted 2 November 2023
Available online 4 November 2023
0377-8401/

1. Introduction

Climate change poses serious challenges to small ruminant production systems. Due to long periods of drought, combined with high temperatures, food supply is the main obstacle in regions where droughts are frequent and intense, such as the Brazilian semi-arid region (Pessoa et al., 2020). Thus, the use of bulky foods that are water deficit tolerant, such as cactus pear, is a promising alternative to ensure the sustainability of small ruminant production systems against climate adversities (Moura et al., 2020).

Cactus pear has great potential in semi-arid regions, where it is the main food offered to ruminants, regardless of the time of year (Silva et al., 2022). However, the use of cactus pear in diets for small ruminants has certain peculiarities, given that its high consumption or as the only and exclusive food source can predispose the animals to nutritional disorders, low dry matter intake, and body weight loss (Silva et al., 2021). Therefore, the supply of cactus pear as silage, combined with tropical forages, such as elephant grass, seeks to overcome deficits in dry matter, fiber, and protein, aiming to improve the nutritional contribution of diets and thus avoid gastrointestinal disorders in ruminants (Silva et al., 2022).

Elephant grass (*Pennisetum purpureum* Schum) stands out in semi-arid regions due to its adaptation to different climatic conditions, productivity, regrowth capacity, and good acceptability by animals (Amaral et al., 2020). It is a grass widely used in the ensiling process due to its neutral detergent fiber content (73.1%). However, the high moisture content of elephant grass (83.7%; Garcez Neto et al., 2021) represents an obstacle to its use as silage, as it leads to unsatisfactory fermentation that impairs the quality of the silage and reduces its nutritional value (Zanine et al., 2020). A recommended practice to compensate for this effect is to add ingredients with a high dry matter content to silage to eliminate excess moisture. Thus, agro-industrial waste, such as those from vitiviniculture, can be used as ingredients in animal feed, where they can be supplied fresh or as additives in silage (Figueiredo et al., 2022).

Grape is one of the most produced fruits worldwide. Estimates indicate that approximately 75% world grape production is destined for processing to make wine, generating large amounts of waste that can represent up to 30% of the initial volume of grapes (Silva et al., 2022). Due to the low cost and high concentration of dry matter (32.9 – 49.0%), neutral detergent fiber (56.9 – 62.6%) (Bordiga et al., 2019) and crude protein (29.9 – 39.2%; Hanušovský et al., 2020), vitiviniculture waste can be used as an alternative food ingredient to partially replace forage in the ruminant diet (Santos et al., 2014), or as a complementary ingredient in the composition of silages, such as cactus pear silages combined with elephant grass.

Studying the use of a potentially polluting waste as a complementary additive in the composition of silage of cactus pear with elephant grass, can make vitiviniculture waste a tool for sustainable production. The use of vitiviniculture waste, fresh or as silage, in diets for small ruminants has shown considerable effects on animal performance, as well as on carcass traits and the quality of lamb meat (Flores et al., 2020, 2021; Molosse et al., 2021; Massaro Junior et al., 2021, 2022). To the best of our knowledge, there are no studies that investigated the effect of including levels of vitiviniculture waste in mixed silages of cactus pear with elephant grass in diets for feedlot lambs. Thus, we hypothesized that the inclusion of vitiviniculture waste in mixed silages of cactus pear with elephant grass increases dry matter and crude protein intake by lamb, increasing weight gain and carcass yield.

The aim was to evaluate the intake, digestibility, water balance, nitrogen balance, ingestive behavior, performance, and carcass traits of lambs fed diets containing levels of vitiviniculture waste in mixed silages of cactus pear with elephant grass.

2. Material and methods

2.1. Experimental site

This research was approved by the Animal Research Ethics Committee (CEUA) of the Federal University of Vale do São Francisco - UNIVASF, with protocol number 0018/270219.

The experiment was carried out at the facilities of the goat and lamb sector, at the Federal University of Vale do São Francisco (UNIVASF), Petrolina, Pernambuco, Brazil (9º 19' 28" South latitude, 40º 33' 34" West longitude, 393 m altitude). The climate, according to the Köppen classification (Alvares et al., 2013) is hot semiarid (BSh), characterized by a negative water balance for most of the year and a rainy season between January and May. Average annual rainfall was 376 mm, and maximum and minimum temperatures of 33.83 and 24.56 °C, respectively, with relative humidity between 50.50% and 73.56%.

2.2. Animals, treatments, experimental diets and silage making

Twenty-four crossbred lambs, Dorper x without defined racial pattern, non-castrated males (150 days of age, 20.75 kg ± 1.33 kg body weight), were distributed in individual pens (2.10 m^2) equipped with feeders and drinking fountains. Pens were in a shed covered with ceramic tiles and had concrete floor. The experiment lasted 86 days, preceded by 20 days for adaptation to the experimental diets and facilities. At the beginning of the adaptation period, animals were identified, weighed, treated against endo- and ectoparasites through the application of an oral solution (200 μg/kg body weight; Ivomec, Merial, Campinas, Brazil), and randomly assigned to the pens previously identified according to the treatments. The experimental design was randomized blocks, with four treatments (diets) and six animals per treatment. The initial weight was used to define the blocks.

The experimental diets consisted of four mixed silages (MS) of elephant grass, containing different levels of cactus pear and vitiviniculture waste: MS1 – 255 g/kg cactus pear and 108 g/kg vitiviniculture waste; MS2 – 216 g/kg cactus pear and 144 g/kg vitiviniculture waste; MS3 – 180 g/kg cactus pear and 180 g/kg vitiviniculture waste; MS4 – 144 g/kg cactus pear and 216 g/kg vitiviniculture waste, on a dry matter (DM) basis, plus concentrate based on soybean meal, ground corn, wheat bran, urea and mineral core (Ovinofós, Tortuga, São Paulo, Brazil) (Table 1). The diets were formulated in a forage: concentrate ratio of 60:40 and balanced to allow gains of 200 g/day, as recommended by the NRC (2007).

The vitiviniculture waste, consisting of peel, seed, stems and pressed pulp, was collected directly at the Timbaúba Agrícola Farm, Petrolina, state of Pernambuco, Brazil. The residue came from *Vitis vinifera* grapes of the Magna cultivar. The material was collected wet (50–60% moisture), after processing in the agroindustry, and subjected to natural dehydration, by exposure to air and sun in a cemented area. During dehydration, which lasted 4 days, the material was turned over three times a day.

Cactus pear of the Mexican elephant ear variety, IPA-200016 (*Opuntia stricta* Haw) from a plantation in the Prospecting area for Studies in Biosaline Agriculture in the Caatinga Experimental Field, belonging to Embrapa Semi-Arid, in Petrolina, Pernambuco, Brazil, was harvested 12 months after regrowth so that only the mother cladodes remained on the plant. Elephant grass cv. IRI-381 (*Pennisetum purpureum* Schum) came from a sward that had already been established at the Campus de Ciências Agrárias of UNIVASF, Petrolina, Pernambuco, Brazil, cut at 10 cm from the ground, with approximately 1.90 m in height.

Cactus pear and elephant grass were chopped in a stationary forage machine (Nogueira Pecus 9004, Saltinho, São Paulo, Brazil) to particles with an average size of 2.0 cm. Silages were kept in 200 L plastic silos with a removable lid, sealed with a metallic ring. Samples of material used in the preparation of silages and experimental diets were collected for chemical analysis (Table 2).

2.3. *Intake and digestibility of nutrients*

Diets were supplied as a total mixed ration (TMR) twice a day, at 8:00 h and 15:00 h, and water was provided ad libitum. The amount of food offered was calculated based on the previous day's consumption, not allowing leftovers greater than 20% of the amount offered. Weekly samples of food and leftovers were collected for chemical analysis. Daily dry matter intake (DMI) was obtained by the difference between the total DM of feed consumed and the total DM present in leftovers. Nutrient intake was determined as the difference between the total nutrients present in the feed consumed and the total nutrients present in leftovers, on a total DM basis.

The digestibility trial was carried out after 55 experimental days, with 5 days of collection preceded by 5 days of adaptation. Animals were housed in metabolism cages (1.30 × 0.55 m) equipped with a feeder and drinker in a covered area. Feces were sampled using collection bags attached to animals two days before the sampling period. Bags were weighed and emptied twice a day (08:30 h and 15:30 h) and a subsample of 10% of the total amount of feces was collected to form a composite sample for each animal per treatment at the end of the collection period. Samples were stored in a freezer at − 20 °C.

2.4. *Nitrogen balance*

Urine was collected once a day in plastic buckets containing 100 mL 20% hydrochloric acid (HCl) to prevent nitrogen volatilization and sampled (10% aliquot total urine) for determination of nitrogen content. N ingested (NI), N excreted via urine (NI), excreted via feces (NF), total N excreted (TNE), N absorbed (NA) were determined. Nitrogen balance (NB) was calculated according to the

Table 1
Proportions and chemical composition of experimental diets.

Ingredients (g/kg)	Silages			
	MS1	MS2	MS3	MS4
Elephant grass	240	240	240	240
Cactus pear	255	216	180	144
Vitiviniculture waste	108	144	180	216
Soybean meal	195	187	180	173
Ground corn	162	163	165	167
Wheat bran	20	30	35	40
Urea	5	5	5	5
Mineral mix*	15	15	15	15
	Chemical composition (g/kg dry matter)			
Dry matter* *	440	486	512	526
Ash	55.9	57.9	57.6	57.9
Crude protein	161.7	160.4	160.1	160.1
Ether extract	32.2	34.3	37.8	34.8
Neutral detergent fiber	560.9	561.5	570.7	578.9
Acid detergent fiber	273.8	279.0	283.7	289.1
Total carbohydrates	763.9	761.1	758.2	760.8
Non-fiber carbohydrates	202.9	199.6	169.3	181.9
Lignin	64.8	72.6	77.9	87.6
Total digestible nutrients	598.6	553.7	565.8	495.5

Silages: MS1 – 255 g/kg cactus pear and 108 g/kg vitiviniculture waste; MS2 – 216 g/kg cactus pear and 144 g/kg vitiviniculture waste; MS3 – 180 g/kg cactus pear and 180 g/kg vitiviniculture waste; MS4 – 144 g/kg cactus pear and 216 g/kg vitiviniculture waste, on a dry matter basis (DM); *Guaranteeed levels (per kg active elements): calcium − 120 g (min.); phosphorus − 87 g (min.); sodium − 147 g (min.); sulfur − 18 g (min.); copper − 590 mg (min.); cobalt − 40 mg (min.); chromium − 20 mg (min.); iron – 1800 mg (min.); iodine − 80 mg (min.); manganese – 1300 mg (min.); selenium − 15 mg (min.); zinc – 3800 mg (min.); molybdenum − 10 mg (min.); fluoride − 870 mg (max.); phosphorus (P) solubility in 2% citric acid − 95% (min.); * * in g/kg natural matter.

Table 2
Chemical composition of ingredients used in experimental diets.

Fractions (g/kg DM)	Ingredientes					
	Ground corn	Soybean meal	Wheat bran	Vitiviniculture waste	Cactus pear	Elephant grass
Dry matter*	910.0	910.0	900.0	890.0	129.0	273.5
Ash	41.0	35.5	35.9	28.9	35.1	38.6
Crude protein	72.7	414.2	156.3	127.1	29.2	52.8
Ether extract	30.0	12.3	24.8	527.4	5.4	10.6
Neutral detergent fiber	131.4	141.8	386.8	542.4	339.3	758.3
Acid detergent fiber	100.0	113.4	191.2	349.9	180.5	368.9
Lignin	13.2	17.5	74.8	25.3	52.3	71.7

*in g/kg natural matter; DM – Dry matter.

methodology described by Silva and Leão (1979).

2.5. Water balance

Water intake was assessed daily. Water was weighed before supply in buckets and weighed again 24 h later. Three buckets containing water were distributed in the shed next to the cages to determine daily evaporation. Water via drinking fountain (WIF), water intake via diet (WID), total water intake (TWI), water excretion via urine (WEU), water excretion via feces (WEF), total water excretion (TWE) were determined.

Water balance (WB) was evaluated according to Church (1976). The metabolic water (MW) production was estimated from the chemical analysis of the diets and calculated by multiplying the intake of carbohydrates, proteins and digestible ether extract by the factors 0.60; 0.42 and 1.10, respectively (Church, 1976).

2.6. Ingestive behavior

To evaluate the ingestive behavior, animals were visually observed for 24 h on the 40th experimental day. Observations were made at 10-minute intervals, recording feeding, water intake, ruminating, and idling activities. Artificial lighting was used during nocturnal observation. Data were collected by trained observers using digital stopwatches. The results for behavioral variables were obtained using equations adapted from Bürger et al. (2000).

2.7. Productive performance

Lambs were weighed at the beginning and end of the experimental period, after a 16-hour period of solid food deprivation (with access to water). Average daily gain (ADG), total weight gain (TWG), and feed conversion (FC) were determined.

2.8. Laboratory analysis

Samples of silage ingredients, diets, leftovers, and feces were pre-dried in a forced air oven at 55 °C for 72 h and processed in a knife mill (Wiley mill, Marconi, MA-580, Piracicaba, Brazil), using 1 mm sieves. Chemical analyses were performed using the procedures described by the Association of Analytical Chemists (AOAC, 2016) for dry matter (DM), ash, crude protein (CP), and acid detergent fiber (ADF), using the protocols 967.03; 942.05; 981.10 and 973.18, respectively. The ether extract (EE) was analyzed using a fat extractor (ANKOM TX-10, Macedon – NY, United States) (AOCS, 2017). Neutral detergent fiber (NDF) was determined as described by Van Soest et al. (1991) and lignin was determined by treating the ADF residue with 72% sulfuric acid (Silva and Queiroz 2002).

Total carbohydrates (TC) were estimated by the equation proposed by Sniffen et al. (1992), where:

$$TC = 100 - (\%CP + \%EE + \%ash) \quad (1)$$

Non-fiber carbohydrate (NFC) content in diets containing urea in its composition was calculated as proposed by Hall (2003), where:

$$NFC = 1000 - [(CP - (urea\ CP + urea)) + NDF + EE + ash] \quad (2)$$

The apparent digestibility coefficient of nutrients was calculated as described by Silva and Leão (1979) and Total digestible nutrients (TDN) were estimated based on apparent digestibility data and calculated according to Sniffen et al. (1992).

$$TDN = DCP + (DEE \times 2{\cdot}25) + DTC \quad (3)$$

where CP, EE, and TC are digestible (D).

2.9. Carcass traits

At the end of 86 days of confinement, lambs were slaughtered. Before slaughter, animals were deprived of solid food, in accordance with animal welfare standards. After, animals were weighed to determine their slaughter body weight (SBW). Animals were previously stunned by cerebral concussion and immediately slaughtered by bleeding by cutting the carotid arteries and jugular veins, in accordance with the Regulation on the Sanitary and Industrial Inspection Service for Animal Products (Brasil, 2017).

Carcasses were weighed to obtain hot carcass weight (HCW) and hot carcass yield (HCY). Carcasses were transferred to the cold room (5R-DCP, Gallant, Porto Alegre - Brazil), where they were hung on hooks, maintaining a distance of 17 cm between the tarso-metatarsal joints, and kept under refrigeration at 4 °C for 24 h. After, carcasses were weighed to obtain cold carcass weight (CCW), cold carcass yield (CCY), cooling losses (CL) (Silva Sobrinho et al., 2005) and true yield (TY) (Sañudo and Sierra, 1986).

After refrigeration, the internal carcass length (ICL) was measured (in cm), being the maximum distance between the inner edge of the ischio-pubic symphysis and the inner edge of the first rib at its midpoint; the croup width (CW), maximum width between the femur trochanters, taken with a caliper; and leg length (LL) by the distance between the perineum and the anterior edge of the tarsometatarsal joint surface, following the methodology of Cézar and Souza (2007). These measurements were used to calculate the carcass compactness index (CCI) and the leg compactness index (LCI).

For the subjective evaluations of fat cover and carcass conformation (CC), a five-point scale was adopted, with a value of 1 for an excessively lean carcass without fat cover and 5 for an excessively fat carcass. For conformation assessment, the value 1 was attributed to very poor conformation and 5 to excellent conformation (Cezar and Sousa, 2007).

2.10. Commercial cuts

Carcasses were cut lengthwise and the left half carcass was weighed (LHCW) and sectioned into six commercial cuts: neck, shoulder, rack, rib, loin, and leg. Cuts were weighed separately and then the yields of each cut were calculated in relation to the weight of the left half carcass (Araújo et al., 2021).

2.11. Statistical analysis

The results obtained were analyzed using PROC GLM of the Software Statistical Analysis System (SAS University) and tested by analysis of variance and regression at 5% probability level for type I error, with the breakdown of the sum of squares of treatments into contrasts related to linear and quadratic effects, with the fit of the regression equations. The criteria for choosing the regression models were the significance of the parameters estimated by the models and the values of the coefficients of determination (R^2). Half carcass weight was used as a covariate in the analysis of carcass cuts.

The following statistical model was used:

$$Y = \mu + Bi + Tj + eij \quad (4)$$

Table 3
Intake, nutrient digestibility, and productive performance of lambs fed diets containing levels of vitiviniculture waste in mixed silages of cactus pear with elephant grass.

Variables	Silages				SEM	p-value	
	MS1	MS2	MS3	MS4		L	Q
	Intake (g/day)						
Dry matter	1430	1490	1370	1270	0.05	0.214	0.357
Crude protein[1]	243.18	292.40	274.19	237.66	9.15	0.537	0.003
Ether extract	42.71	58.69	35.96	44.04	6.32	0.748	0.909
Neutral detergent fiber[2]	626.60	754.88	731.31	627.92	24.50	0.905	0.006
Acid detergent fiber[3]	395.60	480.72	461.85	399.37	15.34	0.941	0.005
Total carbohydrates[4]	1102	1324	1283	1100	40.97	0.856	0.002
	Digestibility (g/kg)						
Dry matter[5]	521.0	461.9	444.9	424.9	0.79	< 0.001	< 0.001
Crude protein	672.7	589.5	574.7	566.3	2.15	0.159	0.375
Ether extract[6]	672.7	645.7	605.8	565.2	3.29	0.631	0.038
Neutral detergent fiber	526.2	466.7	442.2	438.8	2.00	0.235	0.495
Acid detergent fiber	131.7	82.7	66.5	48.3	3.47	0.671	0.722
Total carbohydrates	590.3	553.3	515.0	486.8	1.79	0.071	0.155
	Productive performance (kg)						
Initial weight	22.08	21.92	19.83	20.00	0.81	0.257	0.446
Final weight	36.50	39.58	35.50	36.33	1.21	0.669	0.871
Average daily gain (g/day)	220	270	240	250	0.01	0.643	0.751
Total weight gain	14.42	17.67	15.67	16.33	0.71	0642	0.754
Feed conversion	6.52	6.02	6.94	6.19	0.27	0.982	0.983

Silages: MS1 – 255 g/kg cactus pear and 108 g/kg vitiviniculture waste; MS2 – 216 g/kg cactus pear and 144 g/kg vitiviniculture waste; MS3 – 180 g/kg cactus pear and 180 g/kg vitiviniculture waste; MS4 – 144 g/kg cactus pear and 216 g/kg vitiviniculture waste, on a dry matter basis (DM); SEM – Standard error of the mean; p-value – probability value; L- Linear effect; Q – Quadratic effect; Significant at 5% probability. Equations: 1Y= 130.13 + 18.96x–0.21x2. R2 = 0.94; 2Y= 406.41 + 51.93x–0.58x2. R2 = 0.98; 3Y= 263.30 + 33.13x–0.37x2. R2 = 0.96; 4Y= 698.33 + 90.55x–1.01x2; 5Y= 45.63 + 0.37x–0.01x2. R2 = 0.46; 6Y= 46.75 + 5.58x–0.06x2. R2 = 0.40.

where: Y = observed value of the variable; μ = overall mean;Bi = effect of block i; Tj = effect of treatment "j"; eij = residual error.

3. Results

3.1. Intake, digestibility, performance and ingestive behavior of lambs

The inclusion of vitiviniculture waste in silages resulted in a quadratic effect for CP ($P = 0.003$), NDF ($P = 0.006$), ADF ($P = 0.005$), and TC ($P = 0.002$) intake (Table 3). The highest intake of these nutrients was obtained by lambs that received MS2. There was no effect of the levels of inclusion of MS in diets on the intake of DM and EE by the lambs ($P > 0.05$) (Table 3).

Regarding the digestibility coefficients, a quadratic effect was observed for the DM ($P < 0.001$) and EE ($P = 0.038$) digestibility (Table 3), with increasing levels of vitiviniculture waste in silages. There was no effect of MS on the digestibility of CP, NDF, ADF, and TC ($P > 0.05$) (Table 3).

The MS did not affect the productive performance ($P > 0.05$) of the lambs, which showed an ADG of 245 g/day (Table 3). Likewise, the MS did not affect the ingestive behavior of lambs ($P > 0.05$; Table 4).

3.2. Water balance and nitrogen balance

A quadratic effect was found for MW ($P = 0.005$) and WB ($P = 0.024$) with higher average values presented by lambs that received MS2 (Table 5). There was no effect of MS in diets on WIF, WID, and TWI. There was also no effect of the levels of MS in diets offered to lambs on WEU, WEF, and TWE ($P > 0.05$; Table 5).

There was no effect of the inclusion MS in diets on NI, NU, NF, TNE, NA and NB ($P > 0.05$; Table 5).

3.3. Carcass traits and commercial cuts

The MS in diets resulted in a reduction in the carcass conformation of the lambs ($P = 0.034$; Table 6). The mixed silages offered in diets for lambs did not affect hot and cold carcass weights and yields ($P > 0.05$; Table 6). There was also no effect of mixed silages on CL and TY of lambs ($P > 0.05$; Table 6). The CCI and the LCI were not influenced by MS offered to the lambs ($P > 0.05$; Table 6).

As for the LHCW and the weight and yield of the commercial cuts, there was no effect of the MS in diets offered to lambs on these parameters ($P > 0.05$; Table 7).

4. Discussion

The diets showed good acceptability by the lambs, since they showed similarity between DM intake, with an average intake of 1390 g/day of DM per animal. The results obtained are higher than those recommended by the NRC (2007), which suggests an intake of 1100 g/animal/day for animals with 20 kg of body weight. The similarity in DM intake provided by the tested silages allowed the lambs to obtain similar average daily gains between treatments, with an average value of 245 g/day, above the estimated 200 g/day. Thus, we can infer that the experimental diets did not cause consumption limitations and, since animal performance is directly linked to DM intake, this can be considered beneficial to the productive sector by allowing to reduce the feedlot period to less than 86 days.

On the other hand, the inclusion of levels above 14.4% of vitiviniculture waste in silages reduced CP intake. This possibly occurred because of the greater presence of tannins (3–110 mg/g dry weight; Watrelot and Norton, 2020) in MS3 and MS4 silages. During chewing, the presence of tannins in the diet enables the formation of the tannin-protein complex, resulting in a component resistant to microbial hydrolysis and deamination in the rumen, where the pH is neutral, since the compound, in addition to being resistant, promotes the inhibition of the growth and proteolytic activity of the ruminal microbiota (Vieira et al., 2020). According to Yanza et al. (2021) and Silva et al. (2021), the tannin-protein complex reduces fiber digestion and DM intake through the ruminal filling effect combined with the astringent taste. However, differing from the assumptions of the aforementioned authors, in the present study the DM intake was not limited. The ability of tannins to form complexes can be considered beneficial, given that with less degradation of the protein in the ruminal environment, due to the tannin-protein complex, there is a better use of the diet, reflecting positively on weight gain (Min and Solaiman, 2018), which was observed in the present study. The results obtained for CP intake are above the

Table 4
Ingestive behavior of lambs fed diets containing levels of vitiviniculture waste in mixed silages of cactus pear with elephant grass.

Variables	Silages				SEM	p-value	
	MS1	MS2	MS3	MS4		L	Q
Feeding (min/day)	272.50	322.92	316.67	312.50	9.42	0.18	0.14
Drinking water (min/day)	10.00	6.67	2.08	4.58	1.28	0.07	0.10
Ruminating (min/day)	506.67	508.75	483.75	537.08	11.57	0.53	0.46
Idling (min/day)	650.00	601.25	637.50	585.83	13.08	0.19	0.43

Silages: MS1 – 255 g/kg cactus pear and 108 g/kg vitiviniculture waste; MS2 – 216 g/kg cactus pear and 144 g/kg vitiviniculture waste; MS3 – 180 g/kg cactus pear and 180 g/kg vitiviniculture waste; MS4 – 144 g/kg cactus pear and 216 g/kg vitiviniculture waste, on a dry matter basis (DM); SEM – Standard error of the mean; p-value – probability value; L- Linear effect; Q – Quadratic effect; Significant at 5% probability.

Table 5
Water balance and nitrogen balance of lambs fed diets containing levels of vitiviniculture waste in mixed silages of cactus pear with elephant grass.

Variables	Silages				SEM	p-value	
	MS1	MS2	MS3	MS4		L	Q
	Water balance (L/day)						
Water via drinking fountain	2.25	3.12	2.82	2.80	0.17	0.387	0.304
Water intake via diet	0.71	0.76	0.68	0.66	0.03	0.350	0.559
Metabolic water[1]	0.81	0.98	0.92	0.81	0.03	0.736	0.005
Total water intake	3.77	4.87	4.42	4.27	0.21	0.585	0.289
Water excretion via urine	1.41	1.33	1.47	1.35	0.09	0.968	0.994
Water Excretion via feces	1.04	1.13	1.02	1.02	0.08	0.808	0.932
Total water excretion	2.45	2.46	2.49	2.37	0.13	0.869	0.961
Water balance (%)[2]	13.2	24.1	19.3	19.0	0.14	0.226	0.024
	Nitrogen balance (g/day)						
N Ingested	37.63	46.55	41.08	37.65	1.76	0.738	0.206
N urine	3.92	4.17	3.73	3.63	0.19	0.474	0.708
N feces	11.87	16.97	14.32	15.60	1.38	0.501	0.640
Total N excreted	15.82	21.12	18.07	19.25	1.44	0.586	0.682
N Absorbed	21.85	25.45	23.05	18.42	1.37	0.310	0.193
Nitrogen balance (%)	25.77	29.62	26.78	22.07	1.46	0.295	0.196

Silages: MS1 – 255 g/kg cactus pear and 108 g/kg vitiviniculture waste; MS2 – 216 g/kg cactus pear and 144 g/kg vitiviniculture waste; MS3 – 180 g/kg cactus pear and 180 g/kg vitiviniculture waste; MS4 – 144 g/kg cactus pear and 216 g/kg vitiviniculture waste, on a dry matter basis (DM); SEM – Standard error of the mean; p-value – probability value; L- Linear effect; Q – Quadratic effect; Significant at 5% probability. Equations: 1Y= −0.46 + 0.06x–0.001x2; R2 = 0.94; 2Y= −3.98 + 0.26x–0.003x2; R2 = 0.66.

Table 6
Carcass traits of lambs fed diets containing levels of vitiviniculture waste in mixed silages of cactus pear with elephant grass.

Variables	Silages				SEM	p-value	
	MS1	MS2	MS3	MS4		L	Q
Hot carcass weight (kg)	16.18	16.88	15.80	15.86	0.50	0.658	0.865
Cold carcass weight (kg)	15.29	16.13	14.98	15.08	0.48	0.689	0.864
Hot carcass yield (%)	48.56	46.62	48.60	47.32	0.32	0.555	0.741
Cold carcass yield (%)	45.87	44.50	46.07	44.99	0.30	0.698	0.903
Cooling losses (%)	5.54	4.57	5.22	4.93	0.21	0.554	0.620
True Yield (%)	56.19	55.29	56.15	54.70	0.34	0.251	0.488
Carcass Conformation[1]	3.75	3.83	3.50	3.33	0.08	0.034	0.082
Fat cover	3.25	3.75	3.08	3.42	0.13	0.889	0.944
CCI (kg/cm)	0.31	0.33	0.30	0.30	0.01	0.618	0.816
LCI (kg/cm)	0.71	0.65	0.67	0.67	0.01	0.360	0.421

Silages: MS1 – 255 g/kg cactus pear and 108 g/kg vitiviniculture waste; MS2 – 216 g/kg cactus pear and 144 g/kg vitiviniculture waste; MS3 – 180 g/kg cactus pear and 180 g/kg vitiviniculture waste; MS4 – 144 g/kg cactus pear and 216 g/kg vitiviniculture waste, on a dry matter basis (DM); CCI = carcass compactness index; LCI = leg compactness index; SEM – Standard error of the mean; p-value – probability value; L- Significant for Linear effect; Q – Significant for Quadratic effect; Significant at 5% probability. Equation: Y = −4.32 to 0.02x; R2: 0.79

values recommended by the NRC (2007), for lambs with 20 kg body weight, with daily gains of 200 g (117 g/animal/day).

Similar to CP intake, MS3 and MS4 reduced the intake of NDF, ADF and TC by lambs. This is associated with diet composition, in which with greater participation of vitiviniculture waste, which contains a higher concentration of NDF and ADF, there is a reduction in the proportion of cactus pear, whose composition contains a higher content of total carbohydrates and lower fiber content. In addition, the increasing levels of vitiviniculture waste resulted in an increase in the lignin content in the diets, which limits the intake of NDF by the animal, as the digesta is retained longer in the rumen (Daza et al., 2021). Despite the effect observed for fiber intake, the ingestive behavior of lambs was similar in all MS tested.

The reduction in DM digestibility observed can be attributed to the higher content of lignin and EE the residue has in its composition (Table 2), together with the concentration of proanthocyanidins (15%; Castellanos-Gallo et al., 2022) that grape contains. According to Tayengwa et al. (2021), proanthocyanidins reduce DM and cell wall digestibility by binding to bacterial enzymes and/or forming indigestible complexes with cell wall carbohydrates. The authors also mention that multiple phenolic hydroxyl groups of proanthocyanidins result in the formation of complexes with polysaccharides, limiting their availability to ruminants.

The vitiviniculture waste has an EE content higher than the other ingredients used in diets (Table 2). This increase is due to the energy density of grape seeds, whose lipid content varies between 14% and 17%, with a predominant presence of polyunsaturated fatty acids (García-Lomillo and González-SanJosé, 2016). Thus, possibly the seeds present in the waste passed intact through the gastrointestinal tract, not being completely digested, which resulted in a decrease in the EE digestibility. Another aspect in which the EE may have become less digestible is probably due to the binding of polyphenolic compounds to bile salts and cholesterol, which can reduce the absorption and increase the fecal excretion of this nutrient (Santos et al., 2014).

Table 7
Left half carcass weight (LHCW) and commercial cuts of lambs fed diets containing levels of vitiviniculture waste in mixed silages of cactus pear with elephant grass.

Variables	Silages				SEM	p-value	
	MS1	MS2	MS3	MS4		L	Q
	Weight (kg)						
LHCW	7.47	7.91	7.23	7.47	0.24	0.763	0.938
Shoulder	1.37	1.41	1.32	1.33	0.04	0.595	0.852
Neck	0.81	0.85	0.83	0.77	0.03	0.642	0.574
Rack	1.15	1.29	1.13	1.28	0.04	0.612	0.881
Rib	0.79	0.85	0.77	0.82	0.03	0.903	0.990
Loin	0.95	1.08	0.89	0.97	0.04	0.734	0.909
Leg	2.31	2.40	2.28	2.28	0.08	0.750	0.914
	Yield (%)						
Shoulder	18.33	17.90	18.28	17.72	0.19	0.419	0.717
Neck	10.83	10.85	11.60	10.35	0.25	0.762	0.449
Rack	15.44	16.27	15.61	17.11	0.25	0.050	0.155
Rib	10.56	10.65	10.63	11.09	0.27	0.530	0.781
Loin	12.57	13.51	12.34	12.87	0.26	0.907	0.921
Leg	30.96	30.35	31.45	30.34	0.27	0.762	0.873

Silages: MS1 – 255 g/kg cactus pear and 108 g/kg vitiviniculture waste; MS2 – 216 g/kg cactus pear and 144 g/kg vitiviniculture waste; MS3 – 180 g/kg cactus pear and 180 g/kg vitiviniculture waste; MS4 – 144 g/kg cactus pear and 216 g/kg vitiviniculture waste, on a dry matter basis (DM); SEM – Standard error of the mean; p-value – probability value; L- Significant for Linear effect; Q – Significant for Quadratic effect; Significant at 5% probability.

Metabolic water is highly correlated with food intake, being produced by cells during the oxidation of hydrogen contained in protein, carbohydrates, and fats. Thus, 1 g of these nutrients produces 42%, 60% ($C_6H_{12}O_6 + 6\ O_2\ 6\ CO_2 + 6\ H_2O +$ heat), and 100% water, respectively (Souza et al., 2022). Considering that the CP intake of lambs was influenced by the levels of vitiviniculture waste, and that, although no statistical effect was detected on the intake of EE and TC, MS2 diet provided numerically higher intakes of EE and TC. Therefore, metabolic water production accompanied these results, with a decrease in metabolic water production at inclusion vitiviniculture waste levels above 144 g/kg in silages, as observed for MS3 and MS4.

Following the result obtained for metabolic water, the water balance of lambs fed MS2 were above the other MS tested. Nevertheless, all MS resulted in positive water balances. Importantly, the water balance evaluated in this study does not consider the losses inherent to transpiration which, according to Souza et al. (2022), represents about 70% total losses.

Since the diets provided similar dry matter intake and daily gains, and knowing that the weights and yields of carcasses and commercial cuts are directly affected by slaughter body weight (Costa et al., 2019), the diets had no effect on carcass weights and yields and commercial cuts. This demonstrates that even using agro-industrial waste, it is possible to balance diets in order to overcome nutritional differences between them, obtaining a good yield carcass and commercial cuts. The lack of effects of diets on weight and performance reinforces the law of anatomical harmony mentioned by Nascimento Júnior et al. (2022), stating that, in carcasses of similar weight and amount of fat, almost all body regions are found in similar proportions, regardless of the conformation and genotype tested.

Although carcass yields did not vary between the MS tested, according to Campos et al. (2017), in lamb confined in a semi-arid region, hot carcass yield percentages usually vary between 40% and 50%, which involves the development and profile of muscle mass and the amount and distribution of subcutaneous fat. Therefore, we can infer that the lamb carcasses in this study presented yield percentages within the recommended range.

According to Mora et al. (2015), adipose tissue is the latest tissue to be deposited by ruminants and its deposition speed may be related to genetic factors, sexual condition and nutritional factors. Possibly because the diets are similar in terms of energy values, fat coverage was similar between the MS tested. Thus, as fat is a natural thermal insulator for carcasses, which protects against excessive water loss during cooling, there was also no effect of MS on cooling losses. The values observed in this study are above those recommended by Belan et al. (2019), which would be up to 4% losses during cooling, a fact that could possibly have been minimized if the animals had spent more time in confinement and thus deposited more amount of subcutaneous fat.

Lamb carcass conformation ranged from 3.33 to 3.83, and was classified between good and very good, according to Cézar and Souza (2007). Carcass conformation is closely associated with the animal's body condition. The greater the slaughter body weight, the greater the carcass conformation. Although the effect of the inclusion of vitiviniculture waste on slaughter body weight was not observed, there was a reduction in carcass conformation with MS3 and MS4.

According to Burin (2016), the deposition of adipose tissue is not uniform, with internal fat being deposited first, followed by intermuscular fat, subsequently subcutaneous fat and finally intramuscular fat. Therefore, it is possible that the lambs in this study, despite having similar weight gain and being slaughtered on the same day, as animals adapted to semi-arid conditions would have a greater deposition of internal fat in relation to subcutaneous fat. However, this study did not evaluate the deposition of internal fat in carcasses.

Despite the excellent nutritional value and water supply that the MS tested provided to the lambs, future studies evaluating the use of vitiviniculture waste in mixed cactus pear silages with elephant grass on non-carcass components and the quality of meat from lambs in confinement, in addition the use of a greater number of animals in the experimental design is necessary and pertinent to elucidate the contributions of the mixed silages tested on the final product.

5. Conclusion

The inclusion of vitiviniculture waste in mixed silages of cactus pear with elephant grass proved to be a viable alternative for feeding feedlot lambs as its inclusion did not interfere with dry matter intake, performance, carcass traits, and commercial cuts. Due to the effect on the digestibility of dry matter and ether extract, on the water balance and carcass conformation, the inclusion of up to 144 g/kg vitiviniculture waste is recommended for the making mixed silages of cactus pear with elephant grass, which will compose the diet of feedlot lambs.

CRediT authorship contribution statement

Telisson Ribeiro Gonçalves, José Renaldo Vilar da Silva Filho, Gilmar Amaro Pereira, Tarcisio Martins Meira, Moema Kelly Nogueira de Sá, Crislane de Souza Silva: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Validation. **Gheman Garcia Leal de Araújo, Sandra Mari Yamamoto, Fleming Sena Campos**: Conceptualization, Project administration, Supervision. **Glayciane Costa Gois**: Investigation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no competing interests.

References

Alvares, C.A., Stape, J.L., Sentelhas, P.C., Gonçalves, J.L.M., Sparovek, G., 2013. Köppen's climate classification map for Brazil. Met. Z. 22, 711–728. https://doi.org/10.1127/0941-2948/2013/0507.

Amaral, R.C., Carvalho, B.F., Costa, D.M., Morenz, M.J.F., Schwan, R.F., Ávila, C.L.S., 2020. Novel lactic acid bacteria strains enhance the conservation of elephant grass silage cv. BRS Capiaçu. Anim. Feed Sci. Technol. 264, e114472 https://doi.org/10.1016/j.anifeedsci.2020.114472.

AOAC, 2016. Official Methods of Analysis, 20th ed.,. Association of Official Analytical Chemists,, Washington, DC., p. 3100

AOCS, 2017. Official Methods and Recommended Practices of the American Oil, 7th ed..,. American Oil Chemists Society,, Urbana, IL.

Araújo, C.A., Magalhães, A.L.R., Araújo, G.G.L., Campos, F.S., Gois, G.C., Matos, M.H.T., Queiroz, M.A.A., Menezes, V.G., Costa, C.J.P., Santos, K.C., Leite, A.C.S.P., 2021. Effect of reduced of water supply on carcass characteristics, non-carcass components and the volume of digestive compartments of Santa Inês ewes. Liv. Sci. 245, e104402 https://doi.org/10.1016/j.livsci.2021.104402.

Belan, L., Rego, F.C.A., Castro, F.A.B., Serafim, C.C., Gasparini, M.J., Zundt, M., Ludovico, A., Castilho, C., Cunha Filho, L.F.C., Eleodoro, J.I., 2019. Replacing oat hay with coffee husk in the feed of finishing lambs. Semin.: Ci. Agr. 40, 1653–1662. https://doi.org/10.5433/1679-0359.2019v40n4p1653.

Bordiga, M., Travaglia, F., Locatelli, M., 2019. Valorisation of grape pomace: an approach that is increasingly reaching its maturity – a review. Int. J. Food Sci. Techn. 54, 933–942. https://doi.org/10.1111/ijfs.14118.

Brasil, 2017, Ministry of agriculture livestock and supply. Regulation of the industrial and sanitary inspection of products of animal origin. Decree No. 9013 of March 29, 2017 - Regulates Law No. 1,283 of December 18, 1950, and Law No. 7,889 of November 23, 1989, which provide for the industrial and sanitary inspection of products of animal origin.

Bürger, P.J., Pereira, J.C., Queiroz, A.C., Silva, J.F.C., Valadares Filho, S.C., Cecon, P.R., Casali, A.D.P., 2000. Ingestive behavior in Holstein calves fed diets with different concentrate levels. Rev. Bras. Zootec. 29, 236–242. https://doi.org/10.1590/S1516-35982000000100031.

Burin, P.C., 2016. Qualidade da gordura ovina: características e fatores de influência. Rev. Elect. Vet. 17, 1–28.

Campos, F.S., Carvalho, G.G.P., Santos, E.M., Araújo, G.G.L., Gois, G.C., Rebouças, R.A., Leão, A.G., Santos, S.A., Oliveira, J.S., Leite, L.C., Araújo, M.L.G.M.L., Cirne, L.G.A., Silva, R.R., Carvalho, B.M.A., 2017. Influence of diets with silage from forage plants adapted to the semi-arid conditions on lamb quality and sensory attributes. Meat Sci. 124, 61–68. https://doi.org/10.1016/j.meatsci.2016.10.011.

Castellanos-Gallo, L., Ballinas-Casarrubias, L., Espinoza-Hicks, J.C., Hernández-Ochoa, L.R., Muñoz-Castellanos, L.N., Zermeño-Ortega, M.R., Borrego-Loya, A., Salas, E., 2022. Grape pomace valorization by extraction of phenolic polymeric pigments: a review. Processes 10, e469. https://doi.org/10.3390/pr10030469.

Cezar, M.F., Sousa, W.H., 2007. Carcaças Ovinas e Caprinas: obtenção, avaliação e classificação, 1st ed.,. Agropecuária Tropical, Uberaba, MG.,, p. 147.

Church, D.C., 1976. Digestive Physiology and Nutrition of Ruminants: Digestive Physiology, 2nd ed.,. O & B Books Publishing,, Corvallis, p. 349.

Costa, C.A., Carvalho, F.F.R., Guim, A., Andrade, G.P., Cardoso, D.B., Maciel, M.V., Silva, G.G., Nascimento, A.G.O., 2019. Carcass characteristics of lambs fed diets with increasing levels of crude glycerin. Asian-Austral J. Anim. Sci. 32, 1882–1888. https://doi.org/10.5713/ajas.18.0825.

Daza, A., Souza, J.G., Monnerat, J.P.I.S., Ribeiro, C.D.V.M., 2021. Performance of growing lambs supplemented with ground licuri (*Syagrus coronata*). Anim. Biosci. 34, 1014–1021. https://doi.org/10.5713/ajas.20.0199.

Figueiredo, M.R.P., Teixeira, A.C.B., Bittencourt, L.L., Moreira, G.R., Ribeiro, A.J., Silva, F.S.G., Santos, A.L.P., Costa, M.L.L., 2022. Elephant grass silage with addition of regional by-products Acta Scient. Anim. Sci. 44, e56616 https://doi.org/10.4025/actascianimsci.v44i1.56616.

Flores, D.R.M., Fonseca, P.A.F., Schmitt, J., Tonetto, C.J., Rosado Junior, A.G., Hammerschmitt, R.K., Facco, D.B., Brunetto, G., Nörnberg, J.L., 2020. Lambs fed with increasing levels of grape pomace silage: Effects on productive performance, carcass characteristics, and blood parameters. Liv. Sci. 240, e104169 https://doi.org/10.1016/j.livsci.2020.104169.

Flores, D.R.M., Fonseca, P.A.F., Schmitt, J., Tonetto, C.J., Rosado Junior, A.G., Hammerschmitt, R.K., Facco, D.B., Brunetto, G., Nörnberg, J.L., 2021. Lambs fed with increasing levels of grape pomace silage: Effects on meat quality. Small Rum. Res. 195, e106234 https://doi.org/10.1016/j.smallrumres.2020.106234.

Garcez Neto, A.F., Santos, T.M., Silva, J., Fernandes, S.R., 2021. Effect of whey permeate and *Lactobacillus buchneri* on biomass conservation, chemical characteristics and aerobic stability of elephant grass silage. Waste Bio. Val. 12, 879–893. https://doi.org/10.1007/s12649-020-01035-z.

García-Lomillo, J., González-SanJosé, M.L., 2016. Applications of wine pomace in the food industry: approaches and functions. Comp. Rev. Food Sci. Food Saf. 16, 3–22. https://doi.org/10.1111/1541-4337.12238.

Hall, M.B., 2003. Challenges with non fiber carbohydrate methods. J. Anim. Sci. 81, 3226–3232. https://doi.org/10.2527/2003.81123226x.

Hanušovský, O., Gálik, B., Bíro, D., Šimko, M., Juráček, M., Rolinec, M., Zábranský, L., Philipp, C., Puntigam, R., Slama, J.A., Gierus, M., 2020. The nutritional potential of grape by-products from the area of Slovakia and Austria. Emir. J. Food Agric. 32, 1–10. https://doi.org/10.9755/ejfa.2020.v32.i1.2051.

Massaro Junior, F.L., Bumbieris Junior, V.H., Zanin, E., Pereira, E.S., Neumann, M., Galbeiro, S., Calixto, O.P.P., Mizubuti, I.Y., 2021. Grape pomace silage (*Vitis labrusca* L. cv. Isabel) on the intake and digestibility of nutrients, nitrogen balance and ingestive behavior of lambs. Rev. Mex. Ci. Pec 12, 1061–1082. https://doi.org/10.22319/rmcp.v12i4.5820.

Massaro Junior, F.L., Bumbieris Junior, V.H., Pereira, E.S., Zanin, E., Horst, H.E., Calixto, O.P.P., Peixoto, E.L.T., Galbeiro, S., Mizubuti, I.Y., 2022. Grape pomace silage on growth performance, carcass, and meat quality attributes of lambs. Sci. Agric. 79, e20200343 https://doi.org/10.1590/1678-992X-2020-0343.

Min, B.R., Solaiman, S., 2018. Comparative aspects of plant tannins on digestive physiology, nutrition and microbial community changes in sheep and goats: A review. J. Anim. Physiol. Anim. Nutr. 102, 1181–1193. https://doi.org/10.1111/jpn.12938.

Molosse, V.L., Deolindo, G.L., Cécere, B.G., Marcon, H., Rosa, G., Vedovatto, M., Zotti, C.A., Silva, A.D., Fracasso, M., Morsch, V.M., Carvalho, R.A., Pereira, W.A.B., Silva, A.S., 2021. Effect of dietary supplementation with grape residue flour on weight gain, metabolic profile, leukogram, proteinogram and antioxidant response in suckling lambs. Res. Vet. Sci. 139, 112–120. https://doi.org/10.1016/j.rvsc.2021.07.004.

Mora, N.H.A.P., Macedo, F.A.F., Mexia, A.A., Dias-Senegalhe, F.B., Oliveira, E.Q., Radis, A.C., 2015. Características de carcaça de cordeiras Pantaneiras abatidas com diferentes espessuras de gordura subcutânea. Arq. Bras. Med. Vet. Zootec. 67, 290–298. https://doi.org/10.1590/1678-7319.

Moura, M.S.C., Guim, A., Batista, A.M.V., Maciel, M.V., Cardoso, D.B., Lima Júnior, D.M., Carvalho, F.F.R., 2020. The inclusion of spineless cactus in the diet of lambs increases fattening of the carcass. Meat Sci. 160, e107975 https://doi.org/10.1016/j.meatsci.2019.107975.

Nascimento Júnior, J.R.S., Magalhães, A.L.R., Sousa, D.R., Bezerra, J.D.C., Melo, A.A.S., Gois, G.C., Campos, F.S., Santos, K.C., Pereira, K.D., Azevedo, P.S., Santos, L. M., 2022. Bean meal and cactus pear in Santa Inês lamb rations for meat production: Intake, digestibility, performance, carcass yield, and meat quality. Span. J. Agr. Res. 20, e0602 https://doi.org/10.5424/sjar/2022202-18535.

NRC, 2007. National Research Council - Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids, 7th ed.,. The National Academy Press,, Washington, DC, p. 384.

Pessoa, D.V., Andrade, A.P., Magalhães, A.L.R., Teodoro, A.L., Santos, D.C., Araújo, G.G.L., Medeiros, A.N., Nascimento, D.B., Valença, R.L., Cardoso, D.B., 2020. Forage cactus of the genus *Opuntia* in different with the phenological phase: Nutritional value. J. Arid Env 181, e104243. https://doi.org/10.1016/j.jaridenv.2020.104243.

Santos, N.W., Santos, G.T., Silva-Kazama, D.C., Grande, P.A., Pintro, P.M., Marchi, F.E., Jobim, C.C., Petit, H.V., 2014. Production, composition and antioxidants in milk of dairy cows fed diets containing soybean oil and grape residue silage. Liv. Sci. 159, 37–45. https://doi.org/10.1016/j.livsci.2013.11.015.

Sañudo, C., Sierra, I., 1986. Calidad de la canal en la especie ovina. Ovino 1, 127–153.

Silva, A.P.R., Sant'ana, A.S., Nascimento, S.P.O., Barbosa, S.N., Miranda, A.L.A., Luna, F.S., Gois, G.C., Moraes, S.A., Rodrigues, R.T.S., Menezes, D.R., 2021. Tannins in the diet for lactating goats from different genetic groups in the Brazilian semiarid: Nitrogen, energy and water balance. Anim. Feed Sci. Technol. 279, e115023 https://doi.org/10.1016/j.anifeedsci.2021.115023.

Silva, J.F.C., Leão, M.I., 1979. Fundamentos de nutrição de ruminantes. Livroceres. Piracicaba 380.

Silva, J.K.B., Araújo, G.G.L., Santos, E.M., Oliveira, J.S., Campos, F.S., Gois, G.C., Silva, T.S., Matias, A.G.S., Ribeiro, O.L., Perazzo, A.F., Zanine, A.M., 2022. Performance of lambs fed total feed silage based on cactus pear. Rev. Mex. Ci. Pec 13, 19–31. https://doi.org/10.22319/rmcp.v13i1.58.

Silva, M.E.S., Grisi, C.V.B., Silva, S.P., Madruga, M.S., Silva, F.A.P., 2022. The technological potential of agro-industrial residue from grape pulping (*Vitis* spp.) for application in meat products: A review. Food Biosci. 49, e101877 https://doi.org/10.1016/j.fbio.2022.101877.

Silva, T.S., Araujo, G.G.L., Santos, E.M., Oliveira, J.S., Campos, F.S., Godoi, P.F.A., Gois, G.C., Perazzo, A.F., Ribeiro, O.L., Turco, S.H.N., 2021. Water intake and ingestive behavior of sheep fed diets based on silages of cactus pear and tropical forages. Trop. Anim. Health Prod. 53, e244 https://doi.org/10.1007/s11250-021-02686-3.

Silva Sobrinho, A.G., Purchas, R.W., Kadim, I.T., Yamamoto, M., 2005. Características de qualidade da carne de ovinos de diferentes genótipos e idades ao abate. Rev. Bras. Zootec. 34, 1070–1078. https://doi.org/10.1590/S1516-35982005000300040.

Sniffen, C.J., O'Connor, J.D., Van Soest, P.J., 1992. A net carboydrate and protein system for evaluating cattle diets: II. Carboydrate and protein availability. J. Anim. Sci. 70, 3562–3577. ⟨https://www.ncbi.nlm.nih.gov/pubmed/1459919⟩.

Souza, L.L., Araújo, G.G.L., Turco, S.H.N., Moraes, S.A., Voltolini, T.V., Gois, G.C., Campos, F.S., Santos, M.C.R., Santos, F.M., 2022. Water restriction periods affect growth performance and nutritional status of Santa Inês sheep in the Brazilian Semi-arid. Semin.: Ci. Agr. 43, 1037–1050. https://doi.org/10.5433/1679-0359.2022v43n3p1037.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2.

Vieira, L.V., Schmidt, A.P., Barbosa, A.A., Feijó, J.O., Brauner, C.C., Rabassa, V.R., Corrêa, M.N., Schmitt, E., Del Pino, F.A.B., 2020. Use of tannins as a nutritional additive for ruminants. Arq. Ci. Vet. Zool. UNIPAR 23, e2306. https://doi.org/10.25110/arqvet.v23i1cont.2020.8040.

Watrelot, A.A., Norton, E.L., 2020. Chemistry and reactivity of tannins in *Vitis* spp.: areview. Mol 25, e2110. https://doi.org/10.3390/molecules25092110.

Yanza, Y.R., Fitri, A., Suwignyo, B., Hidayatik, N.E., Kumalasari, N.R., Irawan, A., Jayanegara, A., 2021. The utilisation of tannin extract as a dietary additive in ruminant nutrition: a meta-analysis. Anim 11, e3317. https://doi.org/10.3390/ani11113317.

Zanine, A.M., Sene, O.A., Ferreira, D.J., Parente, H.N., Parente, M.O.M., Pinho, R.M.A., Santos, E.M., Nascimento, T.V.C., Lima, A.G.V.O., Perazzo, A.F., Portela, Y.N., Bandeira, D.M., 2020. Fermentative profile, losses and chemical composition of silage soybean genotypes amended with sugarcane levels. Sci. Rep. 10, e21064 https://doi.org/10.1038/s41598-020-78217-1.