https://doi.org/10.22319/rmcp.v13i1.5849

Article

Performance of lambs fed total feed silage based on cactus pear

Juscelino Kubitschek Bevenuto da Silva [a]

Gherman Garcia Leal de Araújo [b]

Edson Mauro Santos [a]

Juliana Silva de Oliveira [a]

Fleming Sena Campos [b]

Glayciane Costa Gois [c*]

Tiago Santos Silva [d]

Alex Gomes da Silva Matias [c]

Ossival Lolato Ribeiro [e]

Alexandre Fernandes Perazzo [f]

Anderson de Moura Zanine [f]

[a] Universidade Federal da Paraiba (UFPB), Centro de Ciências Agrárias, Paraiba, Brazil.

[b] Empresa Brasileira de Pesquisa Agropecuária (Embrapa Semiárido), Rodovia BR-428, Km 152, s/n – Zona Rural, 56302-970, Pernambuco, Brazil.

[c] Universidade Federal do Vale do São Francisco (UNIVASF), Campus de Ciências Agrárias, Pernambuco, Brazil.

[d] Instituto Federal de Educação, Ciência e Tecnologia do Sertão Pernambucano (IF Sertão), Pernambuco, Brazil.

[e] Universidade Federal do Recôncavo Bahiano (UFRB), Ciências Agrárias, Ambientais e Biológicas, Bahia, Brazil.

[f] Universidade Federal do Maranhão (UFMA), Centro de Ciências Agrárias e Ambientais, Maranhão, Brazil.

*Corresponding author: glayciane_gois@yahoo.com.br

Abstract:

This study aimed was to evaluate the intake, apparent digestibility, water balance, nitrogen balance, and productive performance in lamb fed cactus pear silage associated with tropical forages. Forty male intact crossbred lambs, with an initial body weight of 18.85 ± 1.2 kg, were used in the experiment. The experimental design was completely randomized, with 5 treatments and 8 replications. The treatments consisted of diets with different proportions of buffelgrass and wheat bran as sources of neutral detergent fiber (NDF), in total feed silage (TFS) based on cactus pear: TFS1 - 279 g/kg of buffelgrass; TFS2 - 240 g/kg of buffelgrass and 17 g/kg of wheat bran; TFS3 - 198 g/kg of buffelgrass and 34 g/kg of wheat bran; TFS4 - 108 g/kg of buffelgrass and 74 g/kg of wheat bran; TFS5 – 118 g/kg of wheat bran. The lowest NDF intake was found in lambs that consumed TFS5 (402 g/d). The non-fibrous carbohydrates apparent digestibility was higher for TFS5, while the NDF apparent digestibility of TFS5 and TFS4 was higher than TFS1. Diets promoted an average daily weight gain of 180.8 g/d. Under experimental conditions, the use of forage cactus pear and concentrate in the form of total mixed rations silage leads to greater intake of crude protein, non-fibrous carbohydrates, ether extract and greater digestibility of non-fibrous carbohydrates and neutral detergent fiber, however, all diets were viable in the feed of confined sheep, providing gains of up to 198 g/d according with the formulation of the diet.

Key words: Intake, Food conservation, Water balance, Weight gain.

Received: 13/11/2020

Accepted: 13/04/2021

Introduction

Cactus pear (*Opuntia fícus-indica* Mill.) is a crop with great potential for the arid and semi-arid regions, since it is a crop that has a special physiological aspect regarding the absorption, use and loss of water, being well adapted to the soil and climatic conditions of the semi-arid, supporting long periods of drought, cactus pear is characterized as being the main food supplied to the herds, regardless of the time of year[1].

Cactus pear is a forage species with a high potential for dry matter production (10-20 t/ha) per year in dry conditions. It has excellent palatability, high energy value (66–74 % total digestible nutrients), high digestibility (69–78 %), and is rich in water (80 % natural matter)[2], contributing to the supply of quality water for the animal. The use of cactus pear silages in small ruminant diets is already being studied in Tunisia, Mexico, Zimbabwe and Brazil[3]. Miranda-Romero *et al*[4] observed that finishing lamb fed with cactus pear silage had higher dry matter intake (1.1 kg/d compared to lamb fed corn silage (0.7 kg/d). Moura *et al*[5] when evaluating the inclusion of cactus pear in the diet of lambs observed that cactus pear increase in the composition of the diets promoted greater daily gain in relation to the control diet (without cactus pear). Silva *et al*[6] when evaluating the water intake of lamb fed diets based on cactus pear silages found that lambs that ingested cactus pear silage had higher dry matter intake (1,480 kg/d) and higher water intake via food (2,724 kg/d) in relation to animals that received corn silage.

Nevertheless, cactus pear use in small ruminants' diet must be associated with complementation of other high-fiber in roughage and by addition of a protein source, maintaining normal conditions in the rumen and allowing an adequate synchronization between the supply of energy and nitrogen for ruminal microorganisms, considering the high content of soluble carbohydrates in cactus pear[7]. Buffelgrass (*Cenchrus ciliares*) might be used as a source of fiber for forage-based diets (368 g/kg NDF), as it is a grass also adapted to arid and semiarid regions[8]. Another option to compose diets based on cactus pear for the production of total feed silage is the use of co-products with a high amount of neutral detergent fiber, as is the case of wheat bran, which has value average of 394 g/kg NDF[9]. In situations where the fodder supply is limited, due to the common water deficit in arid and semiarid regions, the use of this co-product could economically make it possible to confine lambs fed on cactus pear feed because of its low cost. Therefore, it can be used as a fiber source in forage grasses substitution.

As far as known, studies on the association of cactus pear silage with wheat bran and buffel grass hay in the diet of confined lambs are scarce and should be better explored. Thus, the present study aimed was to evaluate the intake, apparent digestibility, water balance, nitrogen balance, and productive performance in lamb fed cactus pear silage associated with tropical forages.

Material and methods

Description of the study site

The experiment was carried out on the Experimental Caatinga Field, at the Animal Metabolism Unit, belonging to the Brazilian Agricultural Research Corporation, Embrapa Semiarid, located in the municipality of Petrolina - PE, Brazil. Annual rainfall average is 433 mm, relative humidity of 36.73 %, and mean annual temperatures, maximum and minimum, are around 32 to 26.95 ºC.

This research was evaluated and approved by the Ethics Committee on Animal Use (CEUA) of the Embrapa Semiarid, with protocol number 0004/2016.

Animals, treatments and experimental diets

Forty (40) male intact crossbred lambs, with an initial body weight of 18.85 ± 1.2 kg, were used in the experiment. The animals were previously identified, weighed, treated against endo- and ectoparasites and distributed in individual pens (1.00 × 1.20 m), equipped with feeding and drinking troughs for the diets and water supply, where they remained for 66 d, preceded by 10 d for adaptation. The experimental design was completely randomized, with five treatments and eight replications.

The diets were formulated in the form of total feed silage, composed of cactus pear (*Opuntia fícus-indica* Mill.) variety Redonda, buffelgrass (*Cenchrus ciliares*), wheat bran, soybean meal, ground corn and urea (Table 1). The treatments consisted of diets with different proportions of buffelgrass and wheat bran as sources of neutral detergent fiber (NDF), in total feed silage (TFS) based on cactus pear: TFS1 - 279 g/kg of buffelgrass; TFS2 - 240 g/kg of buffelgrass and 17 g/kg of wheat bran; TFS3 - 198 g/kg of buffelgrass and 34 g/kg of wheat bran; TFS4 - 108 g/kg of buffelgrass and 74 g/kg of wheat bran; TFS5 – 118 g/kg of wheat bran on a dry matter (DM) basis. The diets were balanced as to allow an average weight gain of 200 g/day, according to the recommendations of the NRC(10) (Table 2).

Table 1: Chemical composition of the ingredients used in experimental diets

	Ingredients					
Fraction (g/kg DM)	**Cactus pear**	**Buffel grass**	**Wheat bran**	**Soybean meal**	**Ground corn**	**Urea**
Dry matter*	144	623	886	896	892	980
Mineral matter	112	101	52.3	66.5	19.2	1.7
Crude protein	51.2	60.2	169	472	90.3	2822
Ether extract	19.0	17.4	32.1	21.1	51.2	0
Neutral detergent fiber[a]	269	683	433	133	133	0
Acid detergent fiber	193	479	153	92.3	44.5	0
Lignin	63.7	201	60.8	12.8	11.1	0
Cellulose	337	327	111	80.9	37.6	0
Hemicellulose	192	123	339	55.5	97.8	0
Total carbohydrates	837	834	717	442	845	0
Non-fiber carbohydrates	552	86.9	302	282	715	0

DM= Dry matter; *in g/kg Natural matter; [a]= corrected for ash and protein.

Table 2: Chemical composition of the experimental diets

Ingredients (g/kg)	Experimental diets				
	TFS1	**TFS2**	**TFS3**	**TFS4**	**TFS5**
Cactus pear	553	571	590	633	681
Buffelgrass	279	240	198	108	0
Wheat bran	0	17	34	74	118
Soybean meal	48	50	51	51	53
Ground corn	116	119	124	132	147
Urea	4	3	3	2	1
Chemical composition (g/kg DM):					
Dry matter*	383	399	411	431	449
Mineral matter	70.5	88.1	82.8	79.4	71.1
Crude protein	134	136	142	141	139
Ether extract	11.6	18.6	20.4	22.7	25.7
NDFap	511	435	433	439	338
Acid detergent fiber	392	268	255	215	141
Lignin	63.9	43.1	40.7	40.2	29.3
Cellulose	328	225	214	175	111
Hemicellulose	136	215	209	232	280
Total carbohydrates	784	757	755	757	764
Non-fiber carbohydrates	318	356	356	340	438
Metabolizable energy, Kcal/d	23.1	24.1	24.5	24.3	25.5

TFS1= 279 g/kg of buffelgrass; TFS2= 240 g/kg of buffelgrass and 17 g/kg of wheat bran; TFS3= 198 g/kg of buffelgrass and 34 g/kg of wheat bran; TFS4= 108 g/kg of buffelgrass and 74 g/kg of wheat bran; TFS5= 118 g/kg of wheat bran; NM= Natural matter; DM= Dry matter; NDFap= Neutral detergent fiber corrected for ash and protein

*in g/kg natural matter.

Buffelgrass used came from an established pasture, harvested at 65 d old, with 75 cm in high, cut at a height of 15 cm above the ground level. The harvest was performed manually. The cactus pear harvested at 12 mo' age after the uniform cut. The materials were processed in a stationary forage (PP-35, Pinheiro máquinas, Itapira, São Paulo, Brazil) chopper to an average particle size of approximately 2.0 cm. The materials were homogenized, according to the treatments, and were ensiled in 200 L plastic-drum silos (89 x 59 x 59 cm) with a removable lid sealed with a metal ring.

Diets were supplied twice a day at 0830 h and 1530 h and water was provided *ad libitum*. The leftovers were collected and weighed to determine intake and adjust the dry matter intake in order to allow 10% leftovers of the total offered. Samples of the food supplied and leftovers were collected weekly for further laboratory analysis.

Intake and digestibility of nutrients

The dry matter intake (DMI) was obtained by the difference between the total DM of the diet consumed and the total DM present in the leftovers of each animal. The nutrient intake was determined as the difference between the total nutrients present in the diet consumed and the total nutrients present in the leftovers, on a total DM basis.

The digestibility test was performed in the final third of the performance productive period, with a duration of 5 d of collection preceded by 5 d of adaptation. The animals were distributed in metabolism cages provided with feeders and drinking fountains. Feces were sampled using collection bags fixed to the animals, which were attached to the animals before the sampling period. The bags were weighed and emptied twice daily (0800 h and 1500 h) and a sub-sample of 10 % of the total amount was collected for further analysis, which was stored at -20 °C.

Nitrogen balance

Urine was collected and weighed once daily in plastic buckets containing 100 mL 20% sulfuric acid (H_2SO_4) to avoid nitrogen volatilization and sampled (10% total excreted) to determine the nitrogen content. The nitrogen balance (NB) was calculated according to Silva and Leão[(11)].

Water balance

Water intake was evaluated daily. Water was weighed before being supplied in buckets and weighed again 24-h later. Three buckets containing water were distributed in the shed near the animal cages to determine daily evaporation. Water balance was evaluated according to Church[(12)]. The production of metabolic water was estimated from the chemical analysis of the diets and calculated by multiplying the consumption of carbohydrates, protein and digestible ether extract by the factors 0.60; 0.42 and 1.10, respectively[(12)].

Growth performance

The lambs were weighed at the beginning, every 15 d, and the end of the experimental period, after a solid-feed deprivation period of 12-h (with access to water) to obtain the initial weight (IW), final weight (FW), total weight gain (TWG; TWG= final weight - initial weight), and daily weight gain (DWG; DWG= TWG/days in confinement). At the end of the experimental period, feed conversion (FC) was calculated by the following equation: FC = average DMI/ average DWG.

Laboratory analysis

Samples of diets, leftovers, and feces were pre-dried in a forced ventilation oven at 55 °C for 72-h and ground to 1 mm particles (Wiley Mill, Marconi, MA-580, Piracicaba, Brazil). All chemical analyses were performed using the procedures described by the AOAC[13] method for dry matter (DM, method 967.03), mineral matter (MM, method 942.05), crude protein (CP, method 981.10), ether extract (EE; method 920.29) and acid detergent fiber (ADF; Method 973.18). The neutral detergent fiber content corrected for ash and protein (using thermostable alpha-amylase) (NDFap)[14]. Lignin (LIG) was determined by treating the acid detergent fiber residue with 72 % sulfuric acid[15]. Hemicellulose (HEM) was calculated by the following equation: HEM = NDF - ADF.

Total carbohydrates (TC), we used the equation[16]: TC= 100 - (%CP +%EE +%Ash). The non-fiber carbohydrate (NFC) content were calculated as proposed by Hall[17] for diets containing urea, due to its presence in the diet supplied: NFC= 100 - [(CP- (%urea CP + %urea)) + % NDFap + %EE + %ash].

The apparent digestibility coefficient (ADC) of nutrients was calculated as described by Silva and Leão[11]. Total digestible nutrients (TDN) were estimated based on the data of apparent digestibility and calculated according to Weiss *et al*[18]. TDN of diets were converted into digestible (DE) and metabolizable energy (ME) using the equations described by the National Research Council[19].

Statistical analysis

Statistical analyses were run using the Statistical Analysis System version (SAS University) software, using the GLM, with a significance level of 5%, according to Tukey’s test.

Results

The diets resulted in differences for intakes of CP (*P*=0.012), with lower mean values for TFS1, with lower percentage of cactus pear silage in its composition, not differing from TFS2, TFS3 and TFS4 diets (Table 3). The lowest NFC intake was shown by the animals that received the TFS1 diet, not differing from the TFS2 diet (*P*=0.006). The TFS1 diet also provided the animals lower EE intake compared to other diets tested (*P*=0.023). Higher intakes of OM, EE and ME were observed for TFS5; this same diet promoted a lower intake of NDF (*P*<0.05).

Table 3: Intake, digestibility of dry matter and nutrients and productive performance of lambs fed total feed silage containing cactus pear

Variables	Experimental diets					SEM	*P* value
	TFS1	TFS2	TFS3	TFS4	TFS5		
Intake (g/d):							
Dry matter	958	950	1071	1047	1189	0.06	0.067
Dry matter, %BW	30.2	30.2	33.0	33. 2	33.4	0.06	0.089
Organic matter	867^{b}	891^{b}	982^{b}	984^{b}	1005^{a}	37.3	0.016
Crude protein	128^{b}	129^{ab}	150^{ab}	147^{ab}	165^{a}	4.37	0.012
Non-fiber carbohydrates	305^{c}	339^{bc}	382^{b}	357^{b}	521^{a}	17.8	0.006
Ether extract	11.1d	17.6^{c}	21.8^{bc}	23.8^{b}	30.6^{a}	0.15	0.023
Neutral detergent fiber	490^{a}	463^{a}	449^{ab}	414^{bc}	402^{c}	25.8	0.019
Metabolizable energy, Kcal/ d	2.22^{b}	2.29^{b}	2.55^{ab}	2.62^{ab}	3.04^{a}	71.9	0.028
Digestibility (g/kg):							
Dry matter	692	643	690	642	697	13.6	0.414
Crude protein	818	832	833	817	788	13.8	0.170
Non-fiber carbohydrates	758^{c}	780^{c}	796^{bc}	830^{ab}	853^{a}	37.5	0.001
Organic matter	869	846	853	866	846	27.4	0.131
Ether extract	771	842	849	860	874	27.9	0.072
Neutral detergent fiber	522^{ab}	542^{ab}	535^{ab}	578^{a}	580^{a}	35.3	0.001
Productive performance (kg):							
Initial weight	20.8	21.5	21.9	19.9	22.1	0.27	0.295
Final weight	31.8	31.6	31.7	31.1	34.0	0.36	0.551
Total weight gain	11.0	10.1	10.9	11.2	11.9	0.19	0.598
Daily weight gain, g/d	183	168	169	186	198	0.02	0.596
Feed conversion	5.23	5.97	6.63	6.43	6.16	0.36	0.613

SEM= Standard error of the mean;

[abc] Means followed by different letters differ statistically by the Tukey test at the level of 5% probability.

The ADC of NFC (*P*=0.001) was lower in TFS1, increasing gradually with increasing level of cactus pear silage in the diets (Table 3). TFS4 and TFS5 diets had higher ADC of NDF compared to TFS1 (*P*=0.001). The ADC of DM, CP, OM and EE showed no differences between the TFS performance (*P*>0.05). No differences were detected for the variables of productive performance (*P*>0.05).

TFS did not have a significant effect on consumption, excretion and water balance (*P*>0.05; Table 4). TFS1 presented lower mean values for contents of nitrogen intake (*P*=0.027), nitrogen excreted via feces (*P*=0.001) and nitrogen excreted via urine (*P*=0.003). There was no effect of the diets for absorbed nitrogen, retained nitrogen and nitrogen balance (*P*>0.05).

Table 4: Water balance and nitrogen balance of lambs fed total feed silage containing cactus pear

Variables	Experimental diets					SEM	*P* Value
	TFS1	TFS2	TFS3	TFS4	TFS5		
Water balance (L/d):							
Water intake via drinking fountain	2.37	2.05	2.12	2.03	2.32	0.38	0.058
Water intake via feed	1.52	1.42	1.53	1.38	1.19	0.06	0.055
Metabolic water	0.50	0.53	0.53	0.61	0.61	0.04	0.115
Total water intake	4.0	3.48	3.44	3.41	3.51	0.12	0.149
Water excreted via feces	0.55	0.51	0.62	0.61	0.45	0.03	0.447
Water excreted via urine	1.03	0.88	0.93	0.89	1.07	0.08	0.348
Total water excretion	1.58	1.29	1.36	1.50	1.63	0.42	0.358
Retained water	2.09	1.82	1.89	2.12	2.24	0.33	0.219
Water balance, %	39.1	37.2	39.0	43.6	46.8	3.19	0.224
Nitrogen balance (g/d):							
Nitrogen intake	20.5[b]	20.7[ab]	24.0[ab]	23.6[ab]	26.4[a]	2.78	0.027
Nitrogen feces	2.50[c]	2.68[bc]	2.66[bc]	2.92[b]	3.38[a]	0.30	0.001
Nitrogen urine	2.48[b]	3.20[a]	3.19a	3.16[a]	3.22[a]	0.36	0.003
Absorbed nitrogen	18.0	18.0	21.4	20.6	23.0	1.60	0.068
Retained nitrogen	15.5	14.8	18.1	17.2	18.7	1.85	0.214
Nitrogen balance, %	75.3	71.1	74.1	72.9	74.0	3.69	0.549

SEM= Standard error of the mean.

[ab] Means followed by different letters differ statistically by the Tukey test at the level of 5% probability.

Discussion

Dry matter intake of total feed silages showed higher values than those recommended by the NRC[(10)], which suggests the intake of 820g/animal/d. Thus, it is evident that there were no limitations on the DMI (Table 3), which indicates that the silages in study presented desirable fermentation and high acceptability by animals, therefore, neither the filling effect nor a limiting effect on energy demand was noticed. Following the same trend, it was verified that the values in %BW are suitable for sheep, which must present DMI of 3 to 5 % according to the NRC(10). Dry matter intake is an important factor in the performance of feedlot sheep, being considered the determining point of the supply of nutrients necessary to meet the requirements of maintenance and weight gain of the animals(20). Although the diets had similar DMI, the animals did not achieve the expected daily gain of 200 g, obtaining a ADG of 180.8 g/d.

Crude protein intake by lambs fed with total feed silages were above that recommended by the NRC(10). In relation to ME, lambs fed with TFS3, TFS4 and TFS5 presented consumption above 2390 kcal/d recommended by the NRC(10), for animals in this category (Table 3).

The increase in EE and NFC intakes can be explained by the increase in the contents of such nutrients in the diets, associated with a similar DMI among lamb. According to the NRC(10), adequate levels of energy intake for young sheep are necessary to develop for the animals and fulfill their potential, and the maintenance requirement of these lambs is achieved with lower intake when compared to lambs with greater weight and when seeking greater gains, for this it is essential to balance the feed and not only to meet the quality but also the quantity of the nutrients offered to the animals(20). Thus, all diets allowed the maximization of consumption by animals, which were not affected by physical limitation due to excess fiber or high concentration of energy.

Furthermore, the higher MEI observed for animals that consumed TFS5 should be elucidated by the increase in NFC levels, reduction in NDF and ADF levels that occurred proportionally to the increase in the addition of cactus pear and wheat bran in the production of total feed silage. All silages presented NDF concentration above 25 % and NFC below 44 % in dry matter, as recommended by NRC(19). However, TFS4 and TFS5 showed lower NDF values from buffelgrass, as well as TFS5, which had a lower ADF value (Table 2).

The higher digestibility coefficient of non-fibrous carbohydrates and NDF observed for TFS5 and TFS4, is probably due to the higher proportion of cactus pear and wheat bran in diets. Cactus pear and wheat bran have a lower concentration of lignin than buffelgrass (Table 1), favoring the digestibility of these diets. According to Raffrenato *et al*(21), lignin has less digestibility on the cell-wall of grasses than on grains because lignin is an important barrier for ruminal bacteria to move into the plant cell, reducing the cell-wall digestion of grasses. This effect may explain the fact that TFS1 is less digestible, since the NDF of this silage had higher proportions of buffelgrass, while the NDF of TFS5 had higher proportions of wheat bran (Table 3).

The animals obtained an average consumption of 2.178 liters of water/d, higher than that recommended by the NRC(10), which suggests 0.800 L of water/d for lamb. About 37.7 % of the total water intake came from the diets supplied, demonstrating the importance of forage preservation as silage form, aiming at an increase in water supply for animals raised in regions with high water deficits.

As TFS4 and TFS5 showed higher amounts of wheat bran (Table 1), they also showed higher levels of non-degradable protein in the rumen that provided greater losses of N fecal than TFS1 (Table 4). The positive nitrogen balance indicates that the animals did not need to displace body protein reserves to meet their nutritional requirements and that the diet was sufficient to increase nitrogen intake.

Conclusions and implications

Under experimental conditions, the use of forage cactus pear and concentrate in the form of total mixed rations silage leads to greater intake of crude protein, non-fibrous carbohydrates, ether extract and greater digestibility of non-fibrous carbohydrates and neutral detergent fiber, however, all diets were viable in the feed of confined sheep, providing gains of up to 198 g/day according with the formulation of the diet.

Acknowledgements

We thank to the external funding from the National Council for Scientific and Technological Development (CNPq), with process Number 435819/2018-6.

Conflict of interest

The authors declare that they have no competing interests.

Literature cited:

1. Paula TA, Véras ASC, Guido SI, Chagas JCC, Conceição MG, Gomes RN, *et al*. Concentrate levels associated with a new genotype of cactus (*Opuntia stricta* [Haw]. Haw.) cladodes in the diet of lactating dairy cows in a semi-arid region. J Agric Sci 2019;156(10):1251-1258. https://doi.org/10.1017/S002185961900011X 2019 v.1.

2. Oliveira JPF, Ferreira MAF, Alves AMSV, Melo ACC, Andrade IB, Urbano SA, *et al*. Carcass characteristics of lambs fed spineless cactus as a replacement for sugarcane. Asian-Austral J Anim Sci 2018;31(4):529-536. https://doi.org/10.5713/ajas.17.0375.

3. Pereira GA, Santos EM, Oliveira JS, Araújo GGL, Paulino RS, Perazzo AF, *et al*. Intake, nutrient digestibility, nitrogen balance, and microbial protein synthesis in sheep fed spineless-cactus silage and fresh spineless cactus. Small Ruminant Res 2021;194(e106293):1-8. https://doi.org/10.1016/j.smallrumres.2020.106293.

4. Miranda-Romero LA, Vazquez-Mendoza P, Burgueño-Ferreira JA, Aranda-Osorio G. Nutritive value of cactus pear silages for finishing lambs. J Prof Assoc Cactus Dev 2018;20(1):196-215. http://www.jpacd.org/jpacd/article/view/37.

5. Moura MSC, Guim A, Batista AMV, Maciel MV, Cardoso DB, Lima Júnior DM, *et al.* The inclusion of spineless cactus in the diet of lambs increases fattening of the carcass. Meat Sci 2020;160(e107975):1–8. https://doi.org/10.1016/j.meatsci.2019.107975.

6. Silva TS, Araújo GGL, Santos EM, Oliveira JS, Campos FS, Godoi PFA, *et al.* Water intake and ingestive behavior of sheep fed diets based on silages of cactus pear and tropical forages. Trop Anim Health Prod 2021;53(e224):1-7. https://doi.org/10.1007/s11250-021-02686-3.

7. Matias AGS, Araújo GGL, Campos FS, Moraes SA, Gois GC, Silva TS, *et al*. Fermentation profile and nutritional quality of silages composed of cactus pear and maniçoba for goat feeding. J Agric Sci 2020;158(4):304–312. https://doi.org/10.1017/S0021859620000581.

8. Carvalho GGP, Rebouças RA, Campos FS, Santos EM, Araújo GGL, Gois GC, *et al*. Intake, digestibility, performance, and feeding behavior of lambs fed diets containing silages of different tropical forage species. Anim Feed Sci Techn 2017;228(1):140-148. https://doi.org/10.1016/j.anifeedsci.2017.04.006.

9. Silva KB, Oliveira JS, Santos EM, Cartaxo FQ, Guerra RR, Souza AFN, *et al*. Ruminal and histological characteristics and nitrogen balance in lamb fed diets containing cactus as the only roughage. Trop Anim Health Prod 2020;52(2):637-645. https://doi.org/10.1007/s11250-019-02051-5.

10. NRC. Nutrient requirements of small ruminants: Sheep, goats, cervids, and new world camelids. National Research Council. The National Academy Press, Washington, DC; 2007.

11. Silva JFC, Leão MI. Fundamentos de nutrição de ruminantes. Livroceres: Piracicaba;1979.

12. Church DC. Digestive physiology and nutrition of ruminants: Digestive physiology. 2nd ed. O & B Books Publishing, Corvallis;1976.

13. Aoac - Association of Official Analytical Chemists. Official methods of analysis of AOAC International. Ed., Latimer Jr., G.W. 20th ed. Washington, DC; 2016.

14. Mertens DR. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beaker or crucibles: collaborative study. J AOAC Int 2000;285(6):1217-1240. https://pubmed.ncbi.nlm.nih.gov/12477183/.

15. Silva DJ, Queiroz AC. Análise de alimentos: métodos químicos e biológicos. Editora UFV, Viçosa; 2002.

16. Sniffen CJ, O'Connor JD, Van Soest PJ. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. J Anim Sci 1992;70(11):3562–3577. https://www.ncbi.nlm.nih.gov/pubmed/1459919.

17. Hall MB. Challenges with non-fiber carbohydrate methods. J Anim Sci 2003;81(12):3226–3232. https://doi.org/10.2527/2003.81123226x.

18. Weiss WP. Energy prediction equations for ruminant feeds. In: Cornell Nutrition Conference Feed Manufactures, 61, Ithaca. Proc Ithaca: Cornell University, 1993:176-185.

19. NRC. Nutrient requirements of dairy cattle. National Research Council. 7th ed. Washington, DC: The National Academy Press; 2001.

20. McGrath J, Duval SM, Tamassia LFM, Kindermann M, Stemmler RT, Gouvea VN, *et al*. Nutritional strategies in ruminants: A lifetime approach. Res Vet Sci 2018;116(1):28-39. https://doi.org/10.1016/j.rvsc.2017.09.011.

21. Raffrenato E, Fievisohn R, Cotanch KW, Grant RJ, Chase LE, Van Amburgh ME. Effect of lignin linkages with other plant cell wall components on *in vitro* and in vivo neutral detergent fiber digestibility and rate of digestion of grass forages. J Dairy Sci 2017;100(10):8119-8131. https://doi.org/10.3168/jds.2016-12364.