Tropical Animal Health and Production (2021) 53: 244
https://doi.org/10.1007/s11250-021-02686-3

REGULAR ARTICLES

Water intake and ingestive behavior of sheep fed diets based on silages of cactus pear and tropical forages

Tiago Santos Silva[1] · Gherman Garcia Leal de Araujo[2] · Edson Mauro Santos[3] · Juliana Silva de Oliveira[3] · Fleming Sena Campos[4] · Paulo Fernando Andrade Godoi[4] · Glayciane Costa Gois[5] · Alexandre Fernandes Perazzo[6] · Ossival Lolato Ribeiro[7] · Silvia Helena Nogueira Turco[5]

Received: 16 June 2020 / Accepted: 29 March 2021 / Published online: 4 April 2021

Abstract

The objective was to evaluate the water intake and ingestive behavior of sheep fed diets containing silages of cactus pear combined with tropical forages. Forty sheep without defined breed, intact, with initial average weight of 22.65 ± 1.01 kg were distributed in a completely randomized design with 5 treatments and 8 replications. The experimental diets consisted of cactus pear silage (CPS), cactus pear + buffel grass silage (CPBS), cactus pear + gliricidia silage (CPGS), cactus pear + pornunça silage (CPPS), and corn silage (CS). CPGS provided higher water intake via food, total water intake, metabolic water, and excretion via feces and urine ($P < 0.05$). Animals that received diets containing CS showed higher water intake via drinking fountain, less efficient feeding and rumination of dry matter, less efficient rumination of neutral detergent fiber, grams of dry matter per cud, grams of neutral detergent fiber per cud, and the shortest average time spent in chewing per cud ($P < 0.05$). CPGS, CPPS, and CS provided longer times for rumination and numbers of cuds per day ($P < 0.05$). CPS showed animals spending more time in idleness, lower quantity of cuds per minute, higher concentration of crystals in urine, with a higher frequency of ammonia-magnesium phosphate and calcium oxalate. Silages based on cactus pear are an alternative to the supply of water via food for sheep in semi-arid.

Keywords *Opuntia stricta* Haw · Semi-arid region · Water via food

Introduction

Water from food can be an excellent alternative for animal watering, especially from succulent forages. The use of cactus pear (*Opuntia stricta* Haw) as an alternative way to provide water via food is feasible, the feeding of sheep exclusively on cactus pear is associated with negative consequences for the health and performance of the animal. Thus, the use of cactus pear combined with tropical forages in the preparation of silages seeks to improve the dietary nutrient supply and thus avoid gastrointestinal disorders in ruminants (Silva et al. 2019).

Among the possible combinations of cactus pear with forage adapted to the semiarid that have productive potential, there is buffel grass (*Cenchrus ciliares* L.), which is a grass extremely adapted to arid regions and widespread in the Brazilian semi-arid with the potential to improve silage fiber content meeting the minimum demand of ruminants (Shahin and Salem 2018), gliricidia (*Gliricidia sepium*) which, in addition to having a high protein nitrogen content (above 2.5%),

✉ Glayciane Costa Gois
glayciane_gois@yahoo.com.br

1 Instituto Federal de Educação, Ciência e Tecnologia do Sertão Pernambucano, Ouricuri, PE 56200-000, Brazil

2 Empresa Brasileira de Pesquisa Agropecuária – Embrapa Semiárido, Petrolina, PE 56302-970, Brazil

3 Universidade Federal da Paraíba, Areia, PB 58397-000, Brazil

4 Universidade Federal do Agreste de Pernambuco, Garanhuns, PE 55292-270, Brazil

5 Universidade Federal do Vale do São Francisco, Petrolina, PE 56304-917, Brazil

6 Universidade Federal do Maranhão, 65500-000, Chapadinha, MA, Brazil

7 Universidade Federal do Recôncavo Bahiano, Cruz das Almas, BA 44380-000, Brazil

helps in increasing the fiber content of the diet, associated with the ability to go through long periods of drought (Dharmawan et al. 2019), as well as pornunça (*Manihot* sp), which has high content of crude protein (16.7%) and neutral detergent fiber (55.2%), with high tolerance to drought and grows in poor soils in addition to high productive potential (Carvalho et al. 2017).

The evaluation of the potential use of cactus pear silages combined with tropical forages in diets for small ruminants is necessary to validate their productive capacity, becoming a viable food alternative for animal performance and water demand. Thus, the assessment of ingestive behavior with diets containing cactus pear in its composition is an important tool to explain problems such as those related to the reduction in voluntary intake, and the acceptance of diets by animals, since the fiber content of the diet is directly correlated with feeding, ruminating and idle (Schultz et al. 2019).

The objective of this study was to evaluate water intake and ingestive behavior in sheep fed diets containing silages of cactus pear combined 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 32–26.95 °C.

Animals, treatments, and experimental diets

Forty male crossbreed lambs, uncastrated, with an initial body weight of 22.65 ± 1.01 kg an average age of seven months, were used in the experiment. The animals were previously identified, weighed, treated against endo- and ectoparasites, and distributed in individual pens (1.00 × 2.00 m), equipped with feeders, drinkers, and salt blocks, where they remained for 66 days, preceded by 16 days for adaptation. The animals were weighed at the beginning and at the end of the experimental period, to monitor their weight development.

The experimental design was completely randomized, with five treatments and eight replications. The experimental diets consisted of 5 silages (treatments): cactus pear silage (CPS), cactus pear + buffel grass silage (CPBS), cactus pear + gliricidia silage (CPGS), cactus pear + pornunça silage (CPPS), and corn silage (CS; Control diet), plus concentrate based on soybean meal, corn meal, wheat bran, and mineral supplements (Table 1). Silage was made with cactus pear, harvested at 24 months after regrowth. Regarding gliricidia and pornunça, plants with an average height of 1.5 m were selected, and the aerial part of the plants with young leaves and more tender stems was harvested. Buffel grass used came from an established pasture, harvested at 65 days old, with 75 cm in high, cut at a height of 15 cm above the ground level. The harvest was performed manually. 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 × 59 × 59 cm) with a removable lid sealed with a metal ring.

Diets were formulated to be isoproteic for weight gains of 200 g/day following the recommendations of the NRC (2007). In order to increase the fiber content of the cactus pear silage, based on information from McDonald et al. (1991), who recommends a minimum of 200 g/kg fiber, we used a 38:62 forage/concentrate ratio, with wheat bran as a fiber source. In the treatments with silage of cactus pear combined with a

Table 1 Chemical composition of the experimental diets

Ingredients (g/kg DM)	Experimental diets				
	CPS	CPBS	CPGS	CPPS	CS
Silage	378.4	595.2	596.1	596.8	596.4
Soybean meal	58.9	106.9	59.6	65.8	59.6
Corn meal	96.2	263.8	317.5	310.6	315.3
Wheat bran	435.0	0.0	0.0	0.0	0.0
Urea	4.6	6.7	0.0	0.0	1.8
Mineral core[a]	14.4	14.6	14.6	14.6	14.6
Ammonium chloride	12.0	12.1	12.2	12.2	12.2
Ammonium sulfate	0.5	0.7	0.0	0.0	0.2
	Chemical composition (g/kg DM)				
Dry matter[b]	328.27	508.72	289.86	300.22	421.83
Mineral matter	95.67	85.20	89.00	118.90	70.96
Crude protein	156.54	152.54	162.06	161.24	160.80
Ether extract	30.01	28.17	39.86	39.53	40.67
Neutral detergent fiber	304.18	447.23	349.31	398.09	435.28
Acid detergent fiber	230.62	355.73	213.54	320.54	262.18
Lignin	51.10	64.85	53.85	73.24	29.56
Non-fibrous carbohydrates	413.94	287.26	360.03	282.11	293.21

CPS cactus pear silage, *CPBS* cactus pear + buffel grass silage, *CPGS* cactus pear + gliricidia silage, *CPPS* cactus pear + pornunça silage, and *CS* corn silage; [a] Guaranteed levels provided by the manufacturer: (per kg in 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.); fluorine, 870 mg (max.); phosphorus (P) solubility in 2% citric acid, 95% (min.)

[b] in g/kg natural matter

tropical forage, a 70:30 ratio was adopted (CPBS: 416.64 g/kg DM cactus pear + 178.56 g/kg DM buffel grass; CPGS: 417.27 g/kg DM cactus pear + 178.83 g/kg DM gliricidia, CPPS: 417.76 g/kg DM cactus pear + 179.04 g/kg DM pornunça) with a 60:40 forage/concentrate ratio. Ammonium chloride was added to all experimental diets seeking to acidify urine to prevent the appearance of urinary stones in animals.

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 20% leftovers of the total offered. Samples of the food supplied and leftovers were collected weekly for further laboratory analysis.

Nutrient intake and digestibility

The daily 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 days of collection preceded by 5 days 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 (08-h and 15-h), and a sub-sample of 10% of the total amount was collected for further analysis, which was stored at −20 °C.

Urine collection

For urine collection, the animals were housed in metabolic cages provided with a feeder and drinking fountain in a roofed area. The urine was collected and weighed once a day in plastic buckets containing 100-mL 20% hydrochloric acid, to prevent nitrogen losses through volatilization. An aliquot of 10% of the total urine was collected to obtain a composite sample (per animal), packed in identified plastic pots, and stored in a freezer at −10 °C, for later laboratory analysis. To evaluate the crystals in the urine, sedimentoscopy was performed, according to Garcia-Navarro (1996).

Water balance and water efficiency

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 (1976). 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.

Ingestive behavior

To assess ingestive behavior, animals were subjected to visual observation for a period of 24-h from the 23rd to the 24th experimental day, and the observations were carried out in an interval of 5 min, for the evaluation of feeding, rumination, and idle times. Artificial illumination was used during the nocturnal observation. Data were collected by trained observers using digital timers. The results for the behavioral variables of feeding (feeding, rumination and idle) were obtained using equations adapted from Bürger et al. (2000). On the same day, three observations of each animal were made, which were divided into three periods: morning, afternoon, and night. In these periods, the number of chews per cud (n/cud) and the time spent ruminating each cud (sec/cud) were recorded. To obtain the number of cuds per day, the total rumination time was divided by the average time spent to ruminate each cud.

Feed efficiency (FE) for dry matter (DM) and neutral detergent fiber (NDF) were obtained by the following formulas: FEDM = DMI/TSF and FENFM = NDFI/TF. The rumination efficiency (RE) for DM and NDF were obtained using the formulas: REDM = DMI/TRU and RENDF = NDFI/TRU, in which DMI, daily dry matter intake (g); NDFI, neutral detergent fiber intake; TF, time spent in feeding (h/day); TRU, time spent in rumination (h/day); FEDM (g DM consumed/h); FENDF (g NDF consumed/h); REDM (g DM ruminated/h); and RENDF (g ruminated NDF/h).

Laboratory analysis

Samples were pre-dried in a forced-air oven at 55 °C for 72 h. Then, the samples were ground in a knife mill (Wiley Mill, Marconi, MA-580, Piracicaba, Brazil) using a 1 mm sieve. The analyses were performed using the methods described by AOAC (2016) to determine the contents of dry matter (DM; method 967.03), mineral matter (MM; method 942.05), crude protein (CP; method 981.10), and ether extract (EE; method 920.29). The neutral detergent fiber content corrected for ash and protein (using thermostable alpha-amylase) (NDFap) was determined as Licitra et al. (1996) and Mertens (2002), neutral detergent fiber (NDF) and acid detergent fiber (ADF) was determined as described by Van Soest et al. (1991), and the lignin was determined by treating the residue of acid detergent fiber with 72% sulfuric acid (Silva and Queiroz 2002). Total carbohydrates (TC) were estimate according to Sniffen et al. (1992). The content of non-fiber carbohydrates (NFC) in diets containing urea in their composition were calculated as proposed by Hall (2003); in urea-free diets, NFC were obtained according to Weiss (1993). The apparent digestibility (AD) of DM was calculated as described by Silva and Leão (1979).

Statistical analysis

The analyzed variables were tested by analysis of variance (ANOVA). Data were analyzed by the GLM procedure of SAS 9.2, considering as significant probability values those below 5% according to the Tukey's test. The frequency analysis of the crystals was performed using the FREQ procedure.

Results

The animals fed diets containing CPGS showed higher intakes of DM ($P < 0.05$). CPBS and CPGS provided higher intake of NDF ($P < 0.05$). CPPS showed lower digestibility coefficient of DM *($P = 0.001$)*. CPS and CPGS provided greater in ADG ($P = 0.001$). CS provided a greater water intake via drinking fountain ($P = 0.002$) in relation to the other silages. CPGS showed higher water intake via food ($P = 0.001$), total water intake ($P = 0.001$), metabolic water ($P = 0.001$), water excreted via urine ($P= 0.001$), and total water excretion ($P = 0.001$) (Table 2).

The diet containing CPS showed a higher concentration of crystals ($P= 0.010$), with a higher frequency of ammonia-magnesium phosphate (6/8) and calcium oxalate (3/8). Leucine crystals were found in all treatments, with higher frequencies in animals fed diets containing CPBS (7/8) followed by the diet containing CPGS (6/8). Only animals fed diets containing CPPS presented bilirubin (2/8) (Table 3). Diets containing CS showed lower FEDM ($P= 0.025$), lower REDM ($P= 0.001$), lower REDNF ($P= 0.008$), lower DM grams per cud ($P= 0.001$), and lower grams of NDF per cud ($P= 0.001$). CPGS, CPPS, and CS provided longer times for rumination ($P= 0.015$) and number of cuds per day ($P= 0.001$). Shorter rumination times were found in animals fed CPS ($P<0.05$), and in contrast this silage provided the longest time of the animals in idle ($P= 0.044$), fewer cuds ($P= 0.016$), and fewer cuds per minute ($P= 0.015$). The CS had the shortest average time spent in chewing per cud ($P= 0.048$) (Table 4).

Discussion

Values of dry matter intake in the present study were considered higher than those recommended by the NRC (2007), which suggests intake of 1100 g/animal/day for animals with 20 kg BW. DM intake directly affects the intake of other nutrients and the productive performance of the animals, since 60–90% variation in animal performance is due to the DM intake and only 10–40% is related to the digestibility of the diet (Karimizadeh et al. 2017).

The higher intake of water via food and total intake of water in diets containing CPGS are related to the low levels of DM in the diet, confirming the importance of the supply of water via food in arid regions, where drinking water is scarce. Silage of cactus pear combined with legume, in addition to providing a water reserve, improves the contents of effective fiber and CP, providing a water reserve of high potential. The

Table 2 Feed intake, growth performance, and water balance in sheep fed diets based on silages of cactus pear and tropical forages

Items	Diets					MSE	*P* value
	CPS	CPBS	CPGS	CPPS	CS		
Dry matter intake (g kg/d)	1480ab	1400ab	1640a	1460ab	1200b	0.04	0.018
Neutral detergent fiber (g kg/d)	410b	550a	530a	510ab	480ab	0.03	0.015
Dry matter digestibility (%)	77.74a	78.01a	80.99a	66.70b	74.75ab	12.61	0.001
Average daily gain (g/d)	293a	232b	303a	279ab	234b	0.01	0.001
Water intake via drinking fountain (g kg/d)	2720ab	2793ab	2655ab	2277b	3189a	0.08	0.002
Water intake via food (g kg/d)	2724b	1319c	4027a	3405ab	1647c	0.19	0.001
Total water intake (g kg/d)	5459ab	4113c	6683a	5683ab	4836bc	0.03	0.001
Metabolic water (g kg/d)	563b	593ab	739a	517b	515b	0.02	0.001
Water excreted via feces (g kg/d)	590	505	768	660	621	0.03	0.263
Water excreted via urine (g kg/d)	1289ab	902b	1900a	1060b	1087b	0.09	0.001
Total water excretion (g kg/d)	1879b	1408b	2669a	1720b	1709b	0.11	0.001
Water balance (g kg/d)	652.4	659.9	602.5	697.6	652.8	1.03	0.218

CPS cactus pear silage, *CPBS* cactus pear + buffel grass silage, *CPGS* cactus pear + gliricidia silage, *CPPS* cactus pear + pornunça silage, and *CS* corn silage; *MSE* mean standard error; Means followed by distinct letters differ statistically by the Tukey test at the 5% probability level

Table 3 Concentration of crystals and frequency of the types of crystals present in the urine summary in sheep fed diets based on silages of cactus pear and tropical forages

Items	Diets					MSE	*P* value
	CPS	CPBS	CPGS	CPPS	CS		
Crystals	4 a	2.5ab	3 ab	3 ab	2 b	0.19	0.010
	Frequency of crystals						
Ammonia-magnesium phosphate	(6/8)	(3/8)	(1/8)	(3/8)	-		
Leucine crystals	(1/8)	(7/8)	(6/8)	(4/8)	(4/8)		
Calcium oxalate	(3/8)	(1/8)	-	(1/8)	-		
Bilirubin	-	-	-	(2/8)	-		

CPS cactus pear silage, *CPBS* cactus pear + buffel grass silage, *CPGS* cactus pear + gliricidia silage, *CPPS* cactus pear + pornunça silage, and *CS* corn silage; *MSE* mean standard error; Means followed by distinct letters differ statistically by the Tukey test at the 5% probability level

other treatments containing cactus pear in their composition did not differ from corn silage possibly due to the forage: concentrate ratio of the diets, stimulating intake.

The higher proportion of metabolic water in diets containing CPGS is related to the higher total carbohydrate value. Although fat has a higher metabolic weight (9 kcal/g) compared with proteins and carbohydrates, both with an energy value of 4 kcal/g, carbohydrates have a higher production of metabolic water per kcal metabolizable energy produced, 15 mL per 100 g kcal, while proteins and carbohydrates produce 10.5 and 11.1 mL for every 100 g kcal (Moyes and Schulte 2010).

The excretion of water is directly related to its intake. Diets containing very succulent foods, rich in water, can reduce water intake and excrete a considerable volume of urine, as observed by Cordova-Torres et al. (2017), with the increase in urinary excretion for diets containing cactus pear. The greater excretion of water via urine by animals fed diets with CPGS is due to the greater water intake that these animals presented. This occurs due to the regulation of osmolarity of body fluids, which is controlled by the renin angiotensin aldosterone mechanism that acts harmoniously by adjusting the intake and

Table 4 Ingestive behavior of sheep fed diets based on silages of cactus pear and tropical forages

Items	Diets					MSE	*P* value
	CPS	CPBS	CPGS	CPPS	CS		
Feed efficiency for dry matter (g/h)	328.7a	256.3ab	351.27a	303.48a	192.42b	17.7	0.025
Feed efficiency for neutral detergent fiber (g/h)	116.03	113.00	118.37	112.89	74.28	6.1	0.116
Rumination efficiency for dry matter (g/h)	246.62a	208.56ab	224.15ab	171.71bc	118.34c	11.4	0.001
Rumination efficiency for neutral detergent fiber (g/h)	87.06a	91.94a	75.54ab	63.88bc	45.68c	3.6	0.008
Dry matter grams per cud (g DM/cud)	2.69a	2.40ab	2.29ab	1.81b	1.13c	0.27	0.001
Neutral detergent fiber per cud (gNDF/cud)	0.95ab	1.06a	0.77bc	0.67c	0.44d	0.10	0.001
Time spent in feeding (min/dia)	274.29	342.0	298.0	300.0	316.67	10.9	0.429
Time spent in rumination (min/dia)	374.28b	418.0ab	468.0a	510.0a	485.0a	16.0	0.015
Time spent in idle (min/dia)	791.43a	680.0ab	674.0ab	630.0b	638.33b	20.6	0.044
Cud/d	567.86b	605.20b	760.0a	795.0a	843.0a	28.5	0.001
Number of cuds	52c	62ab	53bc	65a	54bc	1.36	0.016
Cud/chewing	39ab	42a	37ab	38ab	34b	0.78	0.048
Cud/minute	79c	90abc	87bc	101a	95ab	2.43	0.015

CPS cactus pear silage, *CPBS* cactus pear + buffel grass silage, *CPGS* cactus pear + gliricidia silage, *CPPS* cactus pear + pornunça silage, and *CS* corn silage; *MSE* mean standard error; Means followed by distinct letters differ statistically by the Tukey test at the 5% probability level excretion of free water, in which the kidney is the main organ responsible for maintaining homeostasis (Reece 2017).

The higher concentration of crystals in the urine of animals fed CPS may be associated with the V/C ratio (38:62) of this diet, since the source of fiber for this diet was wheat bran, thereby increasing the concentration of protein mucus that acts as a cementing agent, aggregating precipitated salts to form uroliths (Constable et al. 2017), associated with reduced saliva production. This would increase renal phosphorus excretion, enabling the formation of crystals and uroliths.

The supply of oxalate-rich foods, such as cactus pear, associated with low water intake may be one of the main causes of urolithiasis in sheep. The high concentration of minerals in cactus pear reflects the increased elimination of these via urine, and when associated with water retention in the intestinal lumen resulting from the higher concentration of magnesium, there is a concentration of salts, leading to precipitation and formation of ammonia-magnesium phosphorus and calcium oxalate crystals in both alkaline and acid pH (Constable et al. 2017).

Leucine crystals are usually associated with liver disease (Mundt and Shanahan 2016). Despite the higher frequency in treatments with CS, CPBS, and CPGS, no clinical changes were found in the animals, probably due to the short period related to feedlot. In agreement with Ettinger et al. (2017), the presence of crystals is not an indication for therapy, however, some types of crystals or large aggregates may have diagnostic, prognostic, and/or therapeutic importance.

The high presence of crystals in the analysis of urine sediments draws attention because it indicates the possibility of animals having urolithiasis, which is a disease of economic importance for feedlot sheep and goats, which is normally associated with the Ca/P imbalance that leads the formation of Ca and Mg crystals, in addition to genetic factors and the amount of fiber in the diet (Freeman et al. 2010). Another factor is the probable increase in the excretion of salts and toxic substances such as oxalates, since cactus pear has a high concentration of oxalate and minerals (Nefzaoui and Ben Salem 2001). In view of the higher concentration of minerals, an adequate supply of water is of great importance for the excretion of toxic substances such as oxalates, ammonia, and mineral salts.

The time spent in feeding is in agreement with Van Soest (1994), considering that confined animals can spend up to 06 h a day in feeding. This result may be associated with the similar amount of fiber present in the experimental diets. Animals fed CPS spent less time ruminating (374.29 minutes/day), probably due to the high concentration of NFC in the diet, as well as the difference in particle size and fiber effectiveness in relation to the other diets, in which for the CPS treatment, the source of fiber offered was wheat bran, which had the least effect on rumination activities, as well as resulting in the longest idle time.

The number of ruminated cuds is dependent on the rumination time and the time spent to ruminate each cud. For CPBS, a higher value was expected, which did not occur due to the selection of the diet by the animal after supply, preferring instead the concentrate food, which probably resulted in the lowest number of ruminated cuds. The greater number of chews for the treatment that contained CPPS is probably linked to the higher content of lignin present in the diet. CPS had a lower number of chews, and this result may be linked to the low content of DM and NDF, which provides a higher rate of passage (Pinho et al. 2018) and thus a lower number of ruminated cuds. The chewing activity is essential to reduce particle size, increasing fiber degradation by ruminal microorganisms, as well as causing cracks in the cell wall and thus allowing access for microbiota (Bürger et al. 2000).

Conclusion

Under the experimental conditions, the diet of CPGS in the proportions 70% cactus pear/30% gliricidia (417.27 g/kg DM cactus pear + 178.83 g/kg DM gliricidia) and a forage/concentrate ratio of 60:40 stood out for meeting part of the animals' water requirement and with higher efficiency and thus demanding less energy expenditure to obtain their nutritional demands.

Authors' contributions Conceptualization: Araújo GGL; Santos EM; Oliveira JS; Perazzo AF; Ribeiro OL; Turco SHN; Data acquisition: Silva TS; Campos FS; Godoi PFA; Data analysis: Silva TS; Campos FS; Gois GC; Design of Methodology: Silva TS; Campos FS; Writing and editing: Gois GC.

Funding We thank to the external funding from the Ministério da Ciência, Tecnologia, Inovações e Comunicações/Conselho Nacional de Desenvolvimento Científico e Tecnológico (MCTIC/CNPq) n° 28/2018.

Data availability (data transparency) Further information on the data and methodologies will be made available by the author for correspondence, as requested.

Code availability (software application or custom code) Not applicable

Declarations

Ethics approval This research was evaluated and approved by the Ethics Committee on the Use of Animals (CEUA) of the Brazilian Agricultural Research Corporation - Embrapa Semiárido, under protocol number 0004/2016.

Consent to participate Not applicable

Consent for publication All authors declare to agree to the publication of the manuscript.

Conflict of interest The authors declare no competing interests.

References

AOAC, 2016. Official methods of analysis. 20th ed. (Association of Official Analytical Chemists, Washington, D.C.).

Bürger, P.J., Pereira, J.C., Queiroz, A.C., Silva, J.F.C., Valadares Filho, S.C., Cecon, P.R. and Casali, A.D.P., 2000. Ingestive behavior in Holstein calves fed diets with different concentrate levels. Revista Brasileira de Zootecnia 29, 236–242.

Carvalho, G.G.P., Rebouças, R.A., Campos, F.S., Santos, E.M., Araújo, G.G.L., Gois, G.C., Oliveira, J.S., Oliveira, R.L., Rufino, L.M.A., Azevedo, J.A.G. and Cirne, L.G.A., 2017. Intake, digestibility, performance, and feeding behavior of lambs fed diets containing silages of different tropical forage species. Animal Feed Science and Technology, 228, 140-148.

Church, D.C., 1976. Digestive physiology and nutrition of ruminants: digestive physiology. 2nd ed. (Corvallis, O & B Books Publishing)

Constable, P.D., Hinchcliff, K.W., Done, S.H. and Gruenberg, W., 2017. Veterinary medicine, a text book of the disease of cattle, sheep, goats, pigs and horses. 11th ed. (London, Elsevier Health Sciences)

Cordova-Torres, A.V., Costa, R.G., Medeiros, A.N., Araújo Filho, J.T., Ramos, A.O. and Alves, N.L., 2017. Performance of sheep fed forage cactus with total water restriction. Revista Brasileira de Saúde e Produção Animal, 18, 369-377.

Dharmawan, R., Surjowardojo, P. and Susilorini, T.E., 2019. Effect of steaming up by *Gliricidia sepium* to dairy goats in late gestation on milk yield and composition during the early lactation. International Research Journal of Advanced Engineering and Science, 4, 290-293.

Ettinger, S.J., Feldman, E.C. and Cote, E., 2017. Textbook of veterinary internal medicine-eBook 2. 8th ed. (London, Elsevier Health Sciences)

Freeman, S.R., Poorea, M.H., Young, G.A. and Anderson, K.L., 2010. Influence of calcium (0.6 or 1.2%) and phosphorus (0.3 or 0.6%) content and ratio on the formation of urolithogenic compounds in the urine of Boer-cross goats fed high concentrate diets. Small Ruminant Research, 93, 94–102.

Garcia-Navarro, C.E.K., 1996. Manual de urinálise veterinária. (São Paulo: Livraria Varela)

Hall, M.B., 2003. Challenges with non-fiber carbohydrate methods. Journal of Animal Science, 81, 3226-3232.

Karimizadeh, E., Chaji, M. and Mohammadabad, T., 2017. Effects of physical form of diet on nutrient digestibility, rumen fermentation, rumination, growth performance and protozoa population of finishing lambs. Animal Nutrition, 3, 139-144.

Licitra, G., Hernandez, T.M. and Van Soest, P.J., 1996. Standardization of procedures for nitrogen fracionation of ruminant feed. Animal Feed Science and Technology, 57, 347-358.

McDonald, P., Henderson, A.R. and Heron, S.J.E., 1991. The biochemistry of silage. 2nd ed. (Marlow, Chalcomb Publishing).

Mertens, D.R., 2002 Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beaker or crucibles: collaborative study. Journal AOAC International, 85, 1217-1240.

Moyes, C.D. and Schulte, P.M., 2010. Princípios de Fisiologia Animal. 2nd ed. (Porto Alegre, Artimed).

Mundt, L. and Shanahan, K., 2016. Graff 's textbook of routine urinalysis and body fluids. 3th ed. (Philadelphia, Lippin-cott Williams & Wilkins).

Nefzaoui, A. and Ben Salem, H., 2001. Opuntia: a strategic fodder and eficient tool to combat desertification in the wana region. http://www.fao.org/2001. Accessed 13 Dec 2019.

NRC, 2007. National Research Council, Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids. (National Academic Press, Washington, DC).

Pinho, R.M.A., Santos, E.M., Oliveira, J.S., Carvalho, G.G.P., Silva, T.C., Macêdo, A.J.S., Corrêa, Y.R. and Zanine, A.M., 2018. Does the level of forage neutral detergent fiber affect the ruminal fermentation, digestibility and feeding behavior of goats fed cactus pear? Animal Science Journal, 89, 1 – 8.

Reece, W.O., 2017. Dukes fisiologia dos animais domésticos. 13th ed. (Rio de Janeiro, Guanabara Koogan).

Schultz, E.B., Amaral, R.M., Glória, L.S., Silva, F.F., Rodrigues, M.T. and Vieira, R.A.M., 2019. Ingestive behavior of dairy goats fed diets containing increasing levels of neutral detergent fiber and particle size using multivariate analysis. Acta Scientiarum. Animal Sciences, 41, e45870.

Shahin, S. and Salem, M., 2018 Grasses in Arid and Semi-Arid lands: The multi-benefits of the indigenous grasses. In: Tadele, Z. (Ed.). Grasses as food and feed. (London, IntechOpen Science Limited).

Silva, J.F., Leão, M.I., 1979. Fundamentos de nutrição de ruminantes. (Piracicaba, Livroceres)

Silva, K.B., Oliveira, J.S., Santos, E.M., Cartaxo, F.Q., Guerra, R.R., Souza, A.F.N., Muniz, A.C.S. and Cruz, G.F.L., 2019. Ruminal and histological characteristics and nitrogen balance in lamb fed diets containing cactus as the only roughage. Tropical Animal Health and Production, 51, 1-9.

Silva, D.J., Queiroz, A.C., 2002. Análise de alimentos: métodos químicos e biológicos. (Viçosa, Editora UFV).

Sniffen, C.J., O'Connor, J.D. and Van Soest, P.J., 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. Journal of Animal Science, 70, 3562-3577.

Van Soest, P.J., 1994. Nutritional ecology of the ruminant. 2nd ed. (Ithaca, Cornell University Press).

Van Soest, P.J., Robertson, J.B. and Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polyssacharides in relation to animal nutrition. Journal of Dairy Science, 74, 3583–3597.

Weiss, W.P., 1993. Energy prediction equations for ruminant feeds. In: Cornell Nutrition Conference Feed Manufactures, 61, Ithaca. Proceedings… Ithaca: Cornell University, p.176-185.