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Forage sources in diets for dairy goats

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ABSTRACT. The objective of this study was to evaluate the use of sorghum silage, Buffel grass hay and forage palm fodder in the diet of dairy goats by means of performance tests and economic viability of different roughage sources. Eight Anglo-Nubian goats, multiparous, weighing around 40.13 ± 2.76 kg of live weight were used. The experiment lasted 84 days, consisting of four periods of 21 days, distributed in two Latin squares (4x4). The treatments represented by diets with different volumetric sources: SSCF: (sorghum silage+ forage palm+ concentrate); BHCF: (Buffel grass hay + cactus forage+ concentrate); SS: (sorghum silage+ concentrate) and BH: (Buffel grass hay + concentrate). Nutritional intake, digestibility, feed behavior, milk production and chemical composition and economic analysis were evaluated. Animals fed the BHCF diet had higher nutrient intakes and consequently were more productive in fat, protein, lactose, fat free solids and total solids. The BHCF diet led to a higher gross income in Brazilian currency. The safety margin of the SSCF diet presented the highest percentage, with 43.06%, and the BHCF diet, the lowest percentage, of 14.89. The association of forage palm with sorghum silage and Buffel grass hay can be used as a bulky source in lactating goat diets.

Keywords: fibrous carbohydrates; intake; forage conservation; milk production; semiarid.

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Introduction

Livestock farming of small ruminants represents one of the most important options for the primary sector of the Brazilian semi-arid region, being one of the main factors for guaranteeing the food supply of rural families and generating employment and income in the region (Aquino et al., 2016; Silva Sobrinho, 2001). However, the development of this activity is strongly influenced by local climatic conditions.

Since intra and inter annual climatic variations define an oscillation in the supply of forage, which causes a deficit in the productive indexes of the herds due to the food shortage. In addition to the amount of fodder, the quality also oscillates over time, which makes it difficult to define food programs. A strategy used in the dry season for dairy goat is the intensification in the production model with the collection of animals to management centers or small areas for the most suitable feeding, allowing even rest in the pasture areas, and sustainable management of the caatinga ecosystem (Araújo, Medeiros, Carvalho, Silva, & Chagas, 2009).

In this context, sorghum (*Sorghum bicolor* L) for silage, Buffel grass (*Cenchrus ciliaris*) for hay and cactus forage (*Nopalea cochenillifera*) are potential alternatives because they are tolerant to low rainfall, with considerable productive potential, easy to cultivate and nutritional value, being easy to grow (Cardoso et al., 2019; Tolentino et al., 2016).

The production of fodder in the rainy season and its conservation as hay and/or silage for the rainfall shortage period has been used as food strategy, standing out as a technique capable of exploiting the high productivity of forages. Thus, it can be a strategic condition for the strengthening of the livestock production system in semiarid regions. However, it is necessary to evaluate the intake, digestibility and efficiency of the use of nutrients from these forages to ensure adequate milk production and good cost-benefit ratio (Branco et al., 2011). Therefore, it is up to the producer to evaluate the best strategy of using different Forages for better sustainability of the goat milk production system.

The objective of this study was to evaluate the performance and economic feasibility of the use of sorghum silage, Buffel grass hay and cactus forage in diets of dairy goats.

Material and methods

The experiment was approved by the Committee of Ethics in the use of Animals - CEUA - CBiotec of the Federal University of Paraíba (UFPB), with protocol: CEUA Nº 01/2016.

The experiment was carried at the Experiment Station Pendência, of State Agricultural Research Corporation, located in the Meso-region of the Agreste region of Paraiba, Microregion of the Western Curimataú, municipality of Soledade (7º 8 '18 "S and 36º 27' 2" W), with an altitude of 534 m. The climatic type of the region is Bsh, hot semiarid, with rains from January to April (Köppen & Geiger, 1928). During the experimental period, it presented medium temperatures (minimum 28.1 and maximum of 30.3ºC) and 62% relative humidity.

Eight Anglo Nubiana goats, multiparous, with 36 months of age, weighing around 40.13 ± 2.76 kg of body weight on average with 30 days of lactation were used.

The experiment lasted 84 days and was composed of 4 periods of 21 days, distributed in two latin squares (4 x 4), according to the milk production, of which the first 14 days of each period were used to adapt the animals to the experimental diets and the next 7 days for data collection.

The animals were treated for endoparasites and vaccinated against clostridiosis, and then they were housed in individual stalls of 3 m^2, with cement floors, provided with a feeder, drinking fountain, to supply the diet and water *ad libitum*.

The experimental diets were isoproteic formulated according to National Research Council (NRC, 2007) to meet the requirements of lactating goats with production of 2 kg day^{-1} and 3.5% milk fat, and composed of grass hay Buffel, cactus forage (*Nopalea cochenilifera* (L.) Salm-Dyck), sorghum silage and concentrate.

The treatments represented by the diets with the different sources of: SSCF (sorghum silage + cactus forage + concentrate); BHCF: (Buffel grass hay + cactus forage + concentrate); SS: (sorghum silage + concentrate) BH: (Buffel grass hay + concentrate).

The concentrate was composed of corn bran, soybean meal, urea, mineral nucleus. The forage: concentrate ratios based on the drought were 65:35; 58:42; 66:34 and 51: 49% for SSCF, BHCF, SS and BH diets, respectively.

Animals were fed immediately after milking at 07:30 and 16:30, with the feed supplied individually, allowing 10% of leftovers, in the form of a complete mix so that the food supply level was correctly adjusted. Leftovers were weighed daily in the morning and afternoon. The chemical composition of the ingredients, the participation of the ingredients and the chemical composition of the experimental rations are found in Tables 1 and 2.

When collected, leftovers samples were packed in plastic bags with appropriate identification of the animals, treatments and harvesting period and frozen at -15°C. At the end of each period, they were thawed, homogenized and a composite sample of approximately 250 g was obtained for each animal. The aliquots were pre-dried in a forced ventilation oven (55 to 60°C) for 72 hours and grounded in a Wiley mill with mesh sieves of one millimeter.

Samples of food (by period) and leftovers (per animal and period) were collected on the last five days of each experimental period. The chemical analyzes were carried out at the Animal Nutrition Laboratory of the Department of Animal Science of the UFPB, following the methodology described by AOAC (2005) for dry matter (DM), Ash, ether extract (EE) and crude energy; The crude protein (CP) was done by the method of Kjeldahl (Nº.2049, AOAC (2005)). To determine the neutral detergent fiber (NDF) content, the methodology recommended by Van Soest, Robertson, and Lewis (1991), in the manufacturer of the ANKOM®.

Table 1. Chemical composition of the experimental diet ingredients based on dry matter.

	Ingredients				
Items	Cactus forage	Buffel grass hay	Sorghum silage	Corn Bran	Soybean bran
DM[1] (%)	16.12	83.43	34.03	85.77	85.72
OM (%DM)	88.83	91.68	90.5	98.17	93.93
MM (%DM)	11.17	8.32	9.5	1.83	6.07
CP (%DM)	5.81	3.10	5.91	8.55	51.00
EE (%DM)	1.65	2.84	1.36	5.18	2.26
NDF (%DM)	23.77	78.33	67.34	10.92	18.55
TC (%DM)	81.37	85.74	83.23	84.44	40.67
NFC (%DM)	57.60	7.41	15.89	73.52	22.12

[1]Dry matter (DM), organic matter (OM), crude protein (CP), ethereal extract (EE), mineral matter (MM), neutral detergent fiber (NDF), Total carbohydrate (TC), nonfibrous carbohydrates (NFC).

Table 2. Ingredients content and chemical composition of the experimental rations.

Items	Diets[1]			
	SSCF	BHCF	SS	BH
	Proportions of ingredients (g kg^{-1} DM)			
Buffel grass hay	0.00	588.81	0.00	1396.53
Cactus forage	509.94	498.75	0.00	0.00
Sorghum silage	720.63	0.00	1396.53	0.00
Corn bran	388.98	486.22	398.70	398.70
Soybean bran	240.03	288.04	278.44	278.44
Urea	7.50	6.00	4.80	4.80
Mineral supplement[3]	17.10	17.1	17.10	17.10
	Chemical composition (g kg^{-1} DM)			
DM (g kg^{-1})[2]	312.00	395.90	426.30	825.40
OM	906.70	915.00	914.50	933.70
CP	121.70	122.80	127.20	128.80
EE	22.20	28.40	21.50	34.50
MM	82.50	74.90	75.80	59.10
NDF	346.80	359.80	502.50	477.50
CT	772.00	771.10	772.00	777.70
NFC	413.70	414.10	273.10	300.10
TDN	620.40	635.50	553.50	593.50

[1]SSCF = sorghum silage and cactus forage; BHCF = Buffel grass hay and cactus forage; SS = sorghum silage; BH = Buffel grass hay. [2]DM: dry matter; OM: organic matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; TC: total carbohydrates; NFC: non-fibrous carbohydrates; TDN: total digestible nutrients. [3]Mineral supplement (nutriente kg^{-1} supplement): vitamin A 135,000.00 U.I.; Vitamin D3 68,000.00 U.I.; vitamin E 450.00 U.I.; calcium 240 g; phosphorus 71 g; potassium 28.2 g; sulfur 20 g; magnesium 20 g; copper 400 mg; cobalt 30 mg; chromium 10 mg; iron 2500 mg; iodine 40 mg; manganese 1350 mg; selenium 15 mg; zinc 1700 mg; maximum fluoride 710 mg. [4]DM is based in natural matter.

For the estimation of total carbohydrates (TC) and non-fibrous carbohydrates (NFC), the following equations were proposed by Sniffen, O'Connor, Van Soest, Fox, and Russell (1992):

$$\text{TC} = 100 - (\text{CP} + \text{EE} + \text{Ash}); \text{NFC} = 100 - (\text{CP} + \text{NDF} + \text{EE} + \text{Ash}).$$

Weiss, Pietrzik, Biesalski, Grunert, and Kleinsorge (1999) estimated the total digestible nutrients (TDN) in kg and the total content of digestible nutrients (TDN), by the following equations:

$$\text{TDNC(kg)} = (\text{ingested CP} - \text{fecal CP}) = 2.25\ (\text{ingested EE} - \text{fecal EE}) + (\text{ingested NFC} - \text{fecal NFC}) + (\text{ingested NDF} - \text{fecal NDF})$$

$$\text{NDT}(\%) = (\text{TDN Consumption}/\text{MS Consumption}) * 100.$$

The water intake was determined during five days, twice a day, close to the feeding times (at 8 and at 15h). The consumption was calculated by means of the weight difference before and after consumption. Two pairs of water buckets were weighed to measure the loss of water by evaporation.

To determine the digestibility coefficients of the nutrients, samples were collected from the faeces of the animals, directly in the final portion of the rectum, being collected in each period at the same time as the 1st, 2nd, 3rd, 4th and 5th day at 6:00 p.m. 9:00 am; 12:00 pm; 3:00 p.m. and 6:00 p.m., respectively. The faeces samples were stored at -15°C until analyzes were performed when thawed and ground in a 2 mm sieve.

Estimates of fecal dry matter (FDMP) production were obtained using the indigestible neutral detergent fiber (NDFi) as an internal indicator. The samples of feces, food and leftovers were conditioned in TNT bags and incubated in the rumen of fistulated cattle for 240 hours. The amount of the incubated sample was 0.8 g for leftovers and feces and 1.0 g for food. The remaining material from the incubation was subjected to neutral detergent extraction and the residue considered being NDFi. To estimate feces production, the equation was used:

$$\text{Faces (g day}^{-1}) = \text{ingested NDF}/\text{concentration of NDFi in faces.}$$

The apparent digestibility coefficient (ADC) was calculated where:

$$ADC = \frac{\{[\text{Nutrient intake (kg)}] - \text{Nutrient excreted in feces (kg)}]}{\text{nutrient}} \text{intake (kg)}\} * 100$$

Milk control was performed daily through individual milk weighing, during the last five days of each period, manual milking was performed twice daily (07:00 AM and 03:00 PM). The milking and handling procedures followed the recommendations of the Technical Regulation on the Production, Identity and Quality of Goat Milk.

On the 11th, 13th and 15th day of the experimental period, the milk was harvested for physico-chemical analysis. After weighing the milk in the morning, it was conditioned in a refrigerated environment and then mixed with the milking milk, which was previously weighed, forming a composite sample/goat/day, respecting the proportion of milk produced per morning shift: afternoon, 60% and 40%, and a total of 200 ml (120 ml and 80 ml, morning and afternoon, respectively) were collected. Subsequently, the chemical composition was analyzed using a MASTER MINIR® electronic milk analyzer in which the percentages of fat, non-fatty solids, protein, lactose, water content, temperature, freezing point and solids were measured.

For conversion of milk production with 4% fat was carried out according to NRC (2001) using the following formula:

$$\text{MPCF } 4\%(\text{kg day}^{-1}) = 0.4 * \text{milk}\left(\text{kg} - \frac{\text{kg}}{\text{day}}\right) * 15 = \text{fat}(\frac{\text{kg}}{\text{day}})$$

Correction of milk to total solids was performed according to Tyrrell and Reid (1965) using the equation:

$$\text{CPCTS} = (12.3 \text{ g fat}) + (6.56 \text{ g non} - \text{fatty solids}) - (0.0752 \text{ x kg of milk}).$$

The feed efficiency was obtained by dividing the milk production corrected to 4% fat (kg day^{-1}) by the dry matter intake observed during the harvest period.

The economic analysis consisted of the determination of the cost for labor, medicines and cost of feeding for the diets: (SS = R$ 0.74 kg^{-1}; BH = R$ 1.11; SSCF = R$ 0.82; BHCF = R$ 0.92) in which Buffel grass, sorghum silage and cactus forage were accounted for with the costs of implantation and cultural treatments, simulating a production unit with these foods and the corn, soybean, urea and minerals were considered the prices practiced in local commerce in the period of November 2014.

It was considered the selling price of milk of R$ liter^{-1} 1.70, considering R$ 1.00 = U$$ 2.862. The costs of feeding were obtained by multiplying the unit value of each input by the quantity consumed in each treatment, and the accumulated average values of 20 days (five harvest days x four periods) were presented.

The cost of labor was accounted for by the temporary hiring of an employee for the 86 days of confinement, based on the current minimum wage (R$ 788.00), being the amount of R$ 4.48/hour considering an average working day of 1.5 hours/man/day for milking, feeding and cleaning of the facilities, as recommended in the region for the management of 8 goats/man/day.

The economic analysis of the treatments was based on the calculation of the gross margin (GM), where gross revenue (GR) was generated from the sale of milk produced (corrected to 4% fat), whereas, the effective operating cost (EOC) included those referring to food, labor and anthelmintic treatment.

In order to evaluate the economic analysis, the gross margin (GM), rate of return (RR), leveling point (LP) and safety margin (SM), adapted from Hoffmann, Engler, Serrano, Thame, and Neves (1987), considering EOC and GR as total cost and total revenue, in which:

$$\text{GM} = \text{GR} - \text{EOC};\ \text{RR} = \text{GM}/\text{EOC};\ \text{LP} = \text{EOC}/\text{milk price};\ \text{SM} = (\text{GR} - \text{EOC})/\text{GR} * 100.$$

The experimental design used consisted of two simultaneous Latin squares (4x4) with four periods and four diets. Data were submitted to analysis of variance (PROC GLM) using the following statistical model:

$$\hat{Y}\text{ijkl} = \mu + \text{Ql} + (\text{L/Q})\text{j} + (\text{C/Q})\text{k} + \text{TiQi} + \text{TxQ} + \text{eijkl}$$

where: Ŷijkl = estimated value; μ = mean; Ql = effect of the Latin square l; (L/Q)j = effect of line j within the Latin frame; (C/Q)k = effect of column k within the Latin square; Ti = treatment effect i; Ti x Ql = interaction between treatment i and Latin square l e; eijkl = residue of the observation.The means of the treatments were compared by the Tukey test at the 5% level of significance. The analyses were performed in the Statistical Analysis System (SAS), version 9.2.

Results and discussion

Nutrient intake differed ($p < 0.05$) among diets (Table 3). It was observed that dry matter intake, organic matter and gross protein were greater in the BHCF and minor diet on the SSCF diet. The dry matter intake was influenced ($p < 0.05$) by the diet being higher for the FBPF, FB and SS diets in (1.855, 1.655 and 1.512 kg day^{-1}) respectively and did not differ among them, being lower value observed for the diet SSFP 1.253 kg day^{-1} (Table 3).

In relation to the intake of NDF, there was a significant effect ($p < 0.05$) of the diets (Table 3). The NDF intake of the SSCF diet was lower than the other treatments (43%).

Table 3. Mean values for nutrient intake by dairy goats fed diets containing different sources of Forage.

Variables	Diets[1]				SEM[3]	CV (%)[2]
	SSCF	BHCF	SS	BH		
DMC (kg day^{-1})	1.253^{b}	1.855^{a}	1.412^{ab}	1.651^{ab}	0.339	21.97
OMC (g day^{-1})	1129.7^{b}	1695.9^{a}	1280.8^{ab}	1543.8^{ab}	0.312	22.09
CPC (g day^{-1})	205.12^{b}	289.63^{a}	242.21^{ab}	274.70^{ab}	46.91	18.22
EEC (g day^{-1})	30.48^{b}	57.64^{a}	31.33^{b}	62.40^{a}	8.85	19.06
NDFC (g day^{-1})	369.21^{b}	588.68^{a}	652.69^{a}	718.30^{a}	181.1	31.08
NFCC (g day^{-1})	573.73^{b}	830.71^{a}	412.80^{b}	542.04^{b}	110.2	18.75
TDNC(kg day$^{-1)}$	0.787^{b}	1243^{a}	0.801^{b}	1037^{a}	0.146	15.10

Means with different letters in the same row differ statistically (p <0.05) by Tukey's test. [1]Forage source: SSCP = sorghum silage and cactus forage; BHCF = Buffel hay and cactus forage; SS = sorghum silage; BG = Buffel grass hay. Dry matter consumption (DMC), organic matter consumption (OMC), crude protein consumption (CPC), ethereal extract consumption (EEC), mineral matter consumption (MMC) neutral detergent fibers consumption (NDFC), non-fibrous carbohydrates consumption (NFCC), total digestible nutrients consumption (TDNC). [2]CV = coefficient of variation; [3]SEM = standard error of the mean.

The higher NFCC among the diets by the animals was verified in the BHCF diet (38.66%) in relation to the other diets. The energy intake in TDN form was higher and similar among BH and BHCF diets, differing from the other diets. The balance between diets had the objective of avoiding variations among the main nutrients of the diets, in order to meet the requirement of lactating goats, but for that, it was necessary to vary the relation forage: concentrate.

With the use of different fodder sources, there was a change in the composition of the diets, mainly in NDF and NFC (Table 2), which influenced the consumption of DM. However, with the change in DM intake, the consumption of the nutrients contained in them was also changed.

According to the requirements of the NRC (2007), the average consumption for a goat with a live weight of 40 kg, producing 2 kg of milk day^{-1} with a fat content of 3,5% is 1,800 kg DM day^{-1}. In the present study, only the BHCF diet with mean values expressed in kilograms (1,855 kg day^{-1}) met the recommended requirements for DM intake for lactating goats, while SSCF diets limited MS intake probably due to the presence of tannin in the sorghum silage.

The present study corroborates data from Osmari, Cecato, Macedo, and Souza (2011) evaluating multivariate sources in CMD by goats were tested diets with mulberry hay and corn silage, the authors concluded that there was a higher consumption of DM by animals in the diet that presented hay at the expense of silage.

The higher consumption behavior of goats in hay diets with silage can be justified by allowing greater selectivity by the animals, which rejected more lignified fractions of the stem, due to their high physical density in relation to the macerated leaves (Osmari et al., 2009). This behavior is reinforced by the Van Soest (1994) hypothesis in which the goats are classified as intermediate selectors, presenting a great alimentary flexibility, that is, considered selective animals, which allows the ingestion of several types of food, besides of being able to select the most nutritious parts of these.

The intake of CP and OM varied among the diets supplied, despite the diets being isoproteic, following the results obtained for dry matter consumption. The diets SS, BH and BHCF were compared among each other for CP and OM consumption, since the latter diet had high DM intake (Table 3). The behaviors of these results are correlated with the variations that occurred in the DMC.

The NDF is a function of the low digestion rate, being considered the first dietary constituent associated to the decrease in DMC by the filling factor (NRC, 2001). According to NRC (2001), the consumption of NDF greater than 1.2% of BW day^{-1} can cause the physical effect of filling that could compromise the intake of DM. In the present study, there seems to have been a limitation to MS consumption. NDF intake was, on average, 1.6% of BW day^{-1} for SS, BH and BHFP diets that did not differ from each other (Table 3). The lower NDF intake of the SSFP diet may be related to the low DM intake for the animals in this treatment, and the discrepancies in the NDF values in the diets, as well as the low NDF content in the cactus forage (23.8%; Table 1).

The results indicate that the mechanism of control of voluntary consumption would be acting preferentially for the diets with hay in its composition would be the ruminal filling, noting that the intake of NDF for both diets containing hay (BH and BHCF) was similar (Table 3). For the diet with sorghum silage in its composition, other mechanisms would be acting together to the ruminal filling, as, for example, the quality of the silage in relation to the presence of molds, other undesirable factors and composition in volatile fatty acids resulting in lower consumption of DM and cell wall constituents. However, the SSCF diet, because it contained forage palm and low NDF, resulted in lower intake of this nutrient.

According to Van Soest (1994), the consumption of silages often tends to be lower than expected in relation to that of a hay with similar NDF content and digestibility. This fact, according to the author, can be caused by the imbalance of nutrients due to the qualitative changes that occurred during the fermentation process.

The higher intake of NFC by the animals fed with the BHFP diet may be related to the high contents of these components in the cactus forage and the high DM consumption of the animals in this treatment (Table 3). Cactus forage is an excellent source of NFC, important source of energy for ruminants (Ferreira, Silva, Bispo, & Azevedo, 2009). The results of the present behavioral research corroborate with Bispo et al. (2010), who reported an increase in DM intake by sheep when associated with cactus fiber sources, especially hay.

It was verified greater intake ($p < 0.05$) 36.9% of voluntary water by the animals of the BH diet. In addition, it was observed that the water intake in the SSCF and BHCF diets were similar to each other and higher ($p < 0.05$) to the SS and BH diets (33.47 and 86.98%), respectively (Table 4). Likewise, it was observed higher water consumption per kg of DM ingested of BH when compared to BHCF.

The lower voluntary intake of water (VWI) by SS, SSCF and BHCF fed in relation to those fed with BH is due to the amount of water contained in forage palm and sorghum silage, leading to a decrease in water consumption in drinking fountains. Thus, the water consumption was lower via the drinker for SSCF and BHCF (48.56% and 51.87%, respectively).

Thus, water intake was lower through the drinking fountain for SSCF and BHCF (48.56% and 51.87%, respectively). This behavior confirms the report by Neto et al. (2016) and Sousa et al. (2018) that water is a limited supply in the semiarid and may be an obstacle to livestock production, however, when consuming succulent foods, water intake may be very low or zero.

Succulent foods, characterized by high water concentrations and low dry matter content, for example, forages and preserves, such as silage, can be important sources of water for goats raised in the semiarid region (Gedir et al., 2016).

The higher intake of water by animals fed with BH can be explained by the sensory properties of ingested food that appear to be important in stimulating water and food intake. The sensation of dryness during food intake has long been considered as a stimulus to water intake to facilitate the chewing and swallowing of dry foods. Araújo, Voltolini, Chizzotti, Turco, and Carvalho (2010) reported an increase in water intake with the increase in the proportion of maniçoba hay in rations for lactating goats, without the observation of increases in DM intake. According to these authors, this happened because the increase in the proportion of fiber stimulated the activities of chewing and rumination, stimulating a greater consumption of water. Costa, Queiroga, and Pereira (2009) reported that there was lower consumption of water by lactating goats that received rations with higher levels of fresh cactus-fodder instead of maize corn, without losses to milk production.

Table 4. Means for voluntary water intake (VWI), water intake contained in the food (WICF), total water intake (TWI) by lactating goats fed diets containing different sources of forage.

Variables	Diets[1]				Mean	SEM[3]	CV (%)[2]
	SSCF	BHCF	SS	BH			
VWI (kg day^{-1})	3.015^{b}	3.336^{b}	3.028^{b}	4.955^{a}	3.583	0.990	27.60
WICF (kg day^{-1})	3.193^{a}	3.093^{a}	2.091^{b}	0.409^{c}	2.182	0.560	25.65
TWI (kg day^{-1})	6.209	6.432	5.138	5.286	5.766	1.152	19.90
VWI: kg DM	2.556^{ab}	1.803^{b}	2.353^{ab}	3.052^{a}	2.441	0.677	27.75

Means with different letters in the same row differ statistically ($p < 0.05$) by Tukey's test. [1]Forage source: SSCF = sorghum silage and cactus forage; FHCF = Buffel hay and cactus forage; SS = sorghum silage; BH = Buffel grass hay. [2]CV = coefficient of variation; [3]SEM = standard error of the mean.

The estimated water intake according to the NRC (2007) is 2.87 kg day^{-1} required to meet the requirements of lactating goats, as the average found in this work was 5.766 kg day^{-1}, resulting in higher values than those estimated (38; 19, 91 and 39%), for the diets SS, BH, SSFP and BHFP respectively. Probably, this difference is due to the characteristics present in the sources of bulk and the higher temperature due to the semiarid climate of the worked environment.

It is pertinent to highlight that only water intake via food of those animals receiving SS, SSFP and BHFP would be sufficient to meet the requirements of this nutrient (Table 4). Thus, in the understanding that water is one of the scarce nutrients in semi-arid regions, the method of conservation of forage that promotes its preservation appears to be the most appropriate.

The EED of the SS diet presented lower values than the others ($p < 0.05$), however, for DMD, OMD, CPD, NDFD and NFCD, the treatments did not differ ($p > 0.05$) (Table 5).

In this study the values of the digestibility coefficients for nutrients, in general (Table 5), were similar to those found by Silva, Pires, Carvalho, Veloso, and Silva (2008) who also used the NDFi as an indicator to estimate the fecal production of dairy goats.

In this experiment, the use of forage palm in the diets did not alter the digestibility coefficients, although the results of the literature confirm the efficiency of the forage palm in the digestibility. Analyzing the factors that interfere with the digestibility, it is inferred that, with the addition of forage palm, there was a change in the composition of the diets (Table 2), where the NFC content increased since the palm had lower NDF and higher NFC than the other forages tested.

NFC levels in diets increased as they rapidly degraded the rumen, disappearing rapidly, increasing energy supply and favoring microbial growth and, consequently, digestion (Bispo et al., 2010).

The lower digestibility of EE for the SS diet (402.5 g day^{-1}) (Table 5) can be explained by the lower intake of DM by the animals of this diet, as well as by the lower food availability (2.15%). These data agree with the results of Silva et al. (2008) who found low EE digestibility (67.95%) when they supplemented goats with elephant grass silage in relation to the other diets.

The evaluated diets changed ($p < 0.05$) milk production in kg day^{-1} and milk production corrected to 4% fat. Regardless of milk production, it was observed that the BH, SSCF and BHCF diets did not differ in milk production and provided better results, being higher (13.88, 11.40 and 18.95%) to the SS diet, respectively (Table 6). As well as, the diets SS, BH and SSCF did not differ for milk production to 4% fat.

Feed efficiency (FE), represented by MP/DMC (kg kg^{-1}), and corrected milk production for total solids were not affected by diets ($p > 0.05$), (Table 6).

Table 5. Apparent digestibility of nutrients in lactating Anglo-Nubian goats fed diets containing different sources of roughage.

Variables	Diets[1]				Mean	SEM[3]	CV(%)[2]
	SSCF	BHCF	SS	BH			
DMD (g kg^{-1})	658.6	638.7	589.0	577.9	616.1	77.3	12.55
OMD (g kg^{-1})	633.1	661.5	561.5	609.8	616.5	90.0	14.68
CPD (g kg^{-1})	686.8	705.3	694.7	698.3	693.6	72.7	10.45
EED (g kg^{-1})	704.7^{a}	618.2^{a}	402.5^{b}	705.8^{a}	607.8	133.0	21.99
NDFD (g kg^{-1})	559.7	416.8	523.9	451.7	463.0	73.1	15.78
NFCD (g kg^{1})	820.7	856.1	730.3	800.9	802.0	116.4	14.52

Means with different letters in the same row differ statistically (P <0.05) by Tukey's test. [1]Forage source: SSCF = sorghum silage and cactus forage; FHCF = Buffel hay and cactus forage; SS = sorghum silage; BH = Buffel grass hay. Dry matter digestibility (DMD), organic matter digestibility (OMD), crude protein digestibility (CPD), ethereal extract digestibility (EED), neutral detergent fiber digestibility (NDFD), non-fibrous carbohydrates digestibility (NFCD), total digestible nutrients digestibility (TDND). [2]CV = coefficient of variation; [3]SEM = standard error of the mean.

Table 6. Milk production and feed efficiency of lactating Anglo-Nubian goats fed diets containing different sources of roughage

Variables	Diets[1]				Mean	SEM[3]	CV(%)[2]
	SSCF	BHCF	SS	BH			
MP (kg day^{-1})	1.526^{ab}	1.718^{a}	1.363^{b}	1.578^{ab}	1.546	0.206	13.32
[4]MPCF$^{4\%}$(kg day^{-1})	1.771^{ab}	1.936^{a}	1.569^{b}	1.822^{ab}	1.785	0.230	12.88
[5]MPCTS (kg day^{-1})	1.170	1.138	1.178	1.153	1.160	0.039	3.40
[6]FE(kg kg^{-1})	1.473	1.064	1.201	1.238	1.244	0.271	21.77

Means with different letters in the same row differ statistically ($p < 0.05$) by Tukey's test. [1]Forage source: SSCF = sorghum silage and cactus forage; BHCF = Buffel hay and cactus forage; SS = sorghum silage; BH = Buffel grass hay. [4]MPCF 4% = milk production corrected to 4% of fat; [5]MPCTS = milk production corrected for total solids; [6]FE = Food efficiency; [2]CV = coefficient of variation; [3]SEM = standard error of the mean.

Animals receiving BH, SSCF and BHCF diets produced higher ($p < 0.05$) and similar amounts of fat, protein, lactose, non-greasy solids and total solids (Table 7). It is observed that the BHCF diet was more productive in fat, protein, lactose, non-fat solids and total solids (21.87, 26.30, 25.29 and 20.85%) relative to the SS diet, respectively.

Table 7. Content and daily production of milk constituents by lactating Anglo-Nubian goats fed diets containing different sources of forage.

Variables	Diets[1]				Mean	SEM[3]	CV(%)[2]
	SSCF	BHCF	SS	BH			
Fat (%)	5.13	5.00	5.08	5.02	5.063	0.255	5.05
[4]NFS (%)	9.97	9.94	9.98	9.96	9.964	0.087	0.87
[5]TS (%)	15.10	14.48	15.07	14.98	15.02	0.335	2.23
Protein (%)	3.78	3.74	3.76	3.76	3.76	0.047	1.25
Lactose (%)	5.41	5.50	5.40	5.37	5.40	0.089	1.65
Minerals (%)	0.78	0.78	0.78	0.78	0.78	0.005	0.71
Production of milk constituents							
Fat (g day^{-1})	76.69^{ab}	86.74^{a}	68.25^{b}	79.39^{ab}	77.77	10.11	13.01
Protein (g day^{-1})	57.25^{ab}	64.54^{a}	51.07^{b}	59.50^{ab}	58.09	7.52	12.95
Lactose (g day^{-1})	82.36^{ab}	92.92^{a}	73.57^{b}	84.79^{ab}	83.81	11.46	13.74
NFS (g day^{-1})	151.80^{ab}	170.09^{a}	135.75^{b}	157.34^{ab}	153.97	20.48	13.30
TS (g day^{-1})	228.50^{ab}	257.74^{a}	204.00^{b}	236.74^{ab}	231.74	30.20	13.03

Means with different letters in the same row differ statistically ($p < 0.05$) by Tukey's test. [1]Forage source: SSCF = sorghum silage and cactus forage; BHCF = Buffel hay and cactus forage; SS = sorghum silage; BH = Buffel grass hay. [4]NFS = non-fat solids; [5]TS = total solids. [2]CV = coefficient of variation; [3]SEM = standard error of the mean.

Milk production and its chemical composition may suffer interference from the diet offered to the animal, as it is responsible for supplying most of the precursors for milk synthesis and its constituents (Dias et al., 2017; Talpur, Bhanger, & Memon, 2009). The behavior of these data for higher milk production followed the DMI and CPI (kg day^{-1}) for the diets, so that the highest production was observed for the BHCP diet when compared to the SS (Table 6). Higher food intake results in increased intake of nutrients for the animal, resulting in better milk production. In addition, dietary protein is degraded and made available in the bloodstream in the form of amino acids and peptides and can be used in the synthesis of milk proteins or even in the synthesis of glucose (neoglygenesis), thus increasing production (Dias et al., 2017; Talpur et al., 2009).

SSCP and BHCP diets, may be associated to the high capacity of the goat species to adapt to the quantitative and qualitative variations of the diets or fodder without causing alteration or reduced performance. Another important factor is the presence of the palm forage that has high NFC content, which favors the increase of the NFC consumption by the animals. The NFC are rapidly fermented in the rumen, improving the energy supply to the animal, since even the animals of the SSPF diet presented low DM intake were similar for milk production in relation to the animals with higher DM intake (Goularte et al., 2011). Thus, the low milk production of goats fed with the SS diet (1,363 kg day^{-1}) may be directly related to DM intake (kg day^{-1}) and mainly to the low CP consumption (kg day^{-1}) being below 0.278 kg day^{-1} recommended by the NRC (2007), which possibly influenced production negatively (Table 7).

The average milk production of 1,546 kg day^{-1} of the present study can be considered satisfactory for a semiarid system of goat milk production, although the diet was formulated in order to obtain production of 2 kg day^{-1}, since nutritional manuals are based on animals subjected to conditions different from those practiced in the semiarid. The breed used in the present study was Anglo Nubiana, which is considered of double suitability and adapted to the semi-arid environment and produces a milk with a high fat content (4 to 6%), especially to produce fine cheeses. The absence of significance in relation to the chemical composition of the milk of the present study (Table 8), can be explained by the correct balancing of the structural and non-fibrous carbohydrates, as well as by the adequate CP levels (Table 2), since these are the main factors responsible for the nutritional factors that modify milk protein and fat content (Carneiro, Ramos, Pimenta Filho, & Moura, 2015).

The mean fat content of 5.06% of the present study is similar (5.40%) to that found by Rufino et al. (2012) for the same breed under study. The high fat content of the present study resulted in higher total solids production in milk, which may improve performance in the production of dairy products, such as cheese, UHT milk, powder, among others. Higher fat content and total milk solids are desirable characteristics in the dairy industry, as they promote increased product yield.

Lactose is one of the most stable nutrients in milk chemical composition and is directly related to the regulation of osmotic pressure, so that higher lactose production leads to higher milk production (Rosa, Trentin, Pessoa, Silva, & Rubin, 2012). This fact was observed in this study, where the highest levels of lactose (g day^{-1}) associated with the highest milk production were found in the RBC diet (5.50%), probably influenced by the different concentrate ratio: forage diets, where diets containing BH provided higher lactose contents when compared to SS diets (Table 7).

Considering the existence of direct correlation between milk production and its constituents (fat, protein, lactose, NFS and TS g day^{-1}), higher values of these variables were observed in goats fed with BH diets, since milk production was higher when compared to the milk production of goats fed the SS diet. Thus, it can be assumed that this diet will result in greater industrial benefits, since the quantities produced from these constituents were higher (Table 7).

The values of the fat, NFS, protein and lactose contents (Table 7) obtained in this study are above the minimum values (2.9, 8.2, 2.8 and 4.3%) recommended by the legislation in force in Brazil for goat's milk. In addition to milk production, the milk fat content depends mainly on the dietary fiber content. NRC (2001) proposed that the minimum dietary neutral detergent fiber content should be 25% based on total dry matter and that 19% would be derived from forage. In addition, the concentration of non-fibrous carbohydrates in the diet should not exceed 44%. In the present work, it can be verified that this relation was respected, since the concentrations of NDF and NFC of the diets varied from 34.68 to 50.25% and 27.31 to 41.37%, respectively (Table 2). Still the metabolism of NFC from the palm provides greater production of acetate, which is linked to the increase of milk fat content (source).

The value of the effective operational cost (EOC), which shows how much resource is being diverted to cover expenses, presented higher value for the BH diet, proving the importance of the participation of the cost of food (74.49%) in the total costs, being the diet that presented the highest cost of production of kg of milk day (R$ 1.25).

According to the GR values in Table 8, the BHCF diet generated a higher value in monetary currency, which represents a differential of 20.69; 8.21 and 11.21% relative to SS, BH and SSCF diets, respectively. Also in Table 8, the GM, variable that allows to know if the establishment survives in the short term, that is, it is covered as direct expenses, presented positive EOC for all diets tested. However, the SSCF diet presented higher value (26.33, 64.25 and 31.54%) in relation to SS, BH and BHCF diets, respectively. These GM results also reflected the rate of return (RR), in which in the diet with SSCF, for each real (R$ 1.00) applied was obtained 0.76 cents of real return, while the SS diet presented lower return 0.17 cents of real (R$).

Table 8. Economic indicators considering milk production of goats fed on diets with different sources of Forage.

Item	Diets[1]			
	SSCF	BHCF	SS	BH
	Revenue			
Milk Production (kg)	61.05	68.77	54.54	63.12
Gross Revenue (R$)	103.80	116.91	92.72	107.30
	Costs			
Cost of Food (%)	69.55	79.14	69.90	80.29
Labor Cost (%)	25.38	17.39	25.08	16.42
Cost of Drugs (%)	5.08	3.48	5.02	3.28
Cost of activity per kg (R$)	0.83	1.11	0.95	1.25
	Economic indicators			
Effective Operational Cost (R$)	59.10	86.27	59.80	91.33
Gross Revenue (R$)	103.80	116.91	92.72	107.30
Gross Margin (R$)	44.70	30.64	32.93	15.98
Rate of Return (R$)	0.76	0.36	0.55	0.17
Break-even point (%)	34.77	50.75	35.17	53.72
Safety margin (%)	43.06	26.21	35.51	14.89
Cost benefit (R$ day^{-1})	1.76	1.36	1.55	1.17

[1]Forage source: SSCF = sorghum silage and cactus forage; BHCF = Buffel hay and cactus forage; SS = sorghum silage; BH = Buffel grass hay; R$ 1.00 = U$$ 2.862.

The LP, which demonstrates the minimum productivity per animal to avoid injury, is observed in (Table 8) when using the diet with BF the animals have to present a higher productivity in order to become profitable.

Regarding the safety margin (SM), the SSCF diet had the highest percentage with 43.06% and the BH diet had the lowest percentage (14.9%).

All diets presented a positive cost-benefit ratio, the best result found in the SSCF diet (1.76 R$ day^{-1}), and the BH diet had lower results accentuated by the other diets (1.17 R$ day^{-1}), (Table 8). The results showed that the milk production cost of goats fed the BH diet was higher (25.11%) than the other diets. Then, in descending order, comes the diet with BHCF, SS and SSCF, the latter being the lowest cost diet (Table 8).

That not always providing cheaper diets results in higher economic returns. This is because, the economically viable diet is the one that provides greater consumption of nutrients and, possibly, greater milk production. In this way, it is more interesting to evaluate the cost of the kg of milk and the income from the sale of the product.

One of the main obstacles to caprine dairy farming, as in any other livestock activity, is related to production costs (Alao, Falowo, Chulayo, & Muchenje, 2017), especially food related to the use of traditional ingredients that generally have high commercial value, such as soybean meal, which in the present study, whose food costs represented on average 74.71% of total productive expenses for the four diets. It is observed that the highest value with R$ 116.91 of GR was for animals fed the BHCF diet, which represents a difference of up to 13.91% of the other diets without forage palm, a fact justified by the higher milk production, on average 68.77 kg (Table 8). In the present research, the diets containing forage palm in their composition showed a higher GR of 9.37% in relation to the others (Table 8). All diets allowed a positive profit margin, which means that production is remunerated and survives, at least in the short term (Table 8). The results show that all the treatments made a profit, at least in the short term, considering the several other factors related to the production system that were not considered in this research, but as a function of the financial indicators the use of the SSCF diet it is still the most viable alternative.

Considering the results observed and the difficulty of forage production in quantity and quality in semi-arid regions, the importance of forage palm in the production systems of these regions stands out. Cactus is a fully adapted fodder that can be supplied in dairy goats as it maintains or increases the milk fat content due to the fermentation product generated. In addition, it reduces the need for potable water, a scarce resource in these regions, and is an excellent source of NFC, which may contribute to increased energy consumption without the need for a large proportion concentrates in feed.

Conclusion

The association of cactus forage with sorghum silages and Buffel grass hay can be used as a forage source in diets of lactating goats. However, the cactus forage diet associated with sorghum silages presented the best financial indicators, and it was inferred that the use of these foods as forage sources in the diet of goats is a viable alternative for semi-arid regions.

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