Botanical composition and nutritional value of natural pasture of the Caatinga selected by sheep receiving different amounts of an energy-protein supplement

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Abstract

This study aimed to evaluate the composition and nutritional value of the diet selected by sheep on Caatinga pasture receiving different amounts of concentrate supplementation. Thirty-two sheep were divided into four groups (0g; 200g; 350g and 500g of supplementation per day), on native Caatinga pasture, during the rainy, transition and dry seasons, from 2015 to 2017. An inventory was carried out and samples of the species present in the pasture were collected to prepare microscopic slides. To identify the selected diet, samples of feces were collected and the slides were prepared and examined. Based on the frequency of species observed in the slide readings and the nutritional value determined in the bromatological analysis, it was possible to determine the key species and the quality of the selected diet. There was no effect of interaction between the level of supplementation offered and the season ($P > 0.05$). Sheep supplemented with 500g concentrate^{-1} day^{-1} had higher preference for herbs and other dicotyledons and less selection for grasses. Of the 63 species catalogued in the caatinga pasture evaluated, the fecal micro-histological technique allowed the identification of 26 species in the botanical composition of the diet, 20 of which were highly preferred and 7 were considered key species: *Stylosanthes humilis* and *Cynodon dactylon*in the rainy season, *Aristida longiseta*, *Mimosa caesalpinifolia*, *Herissanta tiubae* and *Commelina diffusa* in the transition, and *Aristida adscensionis* and *Mimosa caesalpinifolia* in the dry season. Sheep managed on native Caatinga pasture change their selection strategy according to the supplementation they are offered.

1. Introduction

Sheep production in semi-arid environments challenges animals to find the best strategy for grasping feed and farmers to establish an adequate nutritional balance for the herds. In the semi-arid region of Brazil, the Caatinga is the predominant biome, which is characterized by a shrubby-arboreal vegetation favoring goat farming, and the occurrence of a herbaceous stratum composed of grasses and herbaceous dicotyledons that provide potential for sheep grazing (LEITE *et al.*,1995). Thus, in sheep grazing systems in the semi-arid northeast of Brazil, rangelands of the Caatinga biome are the basis of the diet (GONZAGA NETO et al., 2001).

Although the Caatinga biome has botanical diversity and forage potential for sheep grazing, the use of the portion potentially consumable by the animals is limited by the access to forage (e.g., trees and shrubs with foliage over 1.6m) and the disappearance of the herbaceous layer due to the seasonal dry season. The predominance of plant strata in Caatinga areas is dependent on climate, soil and anthropogenic action, which is the main contributor to the degradation and desertification processes observed in those areas.

Overall, the greatest herbage allowance occurs in the rainy season, with a predominance of grasses and herbaceous dicotyledons of ephemeral cycle. With the end of the rains, the plant strata senesce, resulting in a decline in the quantity and quality of the caatinga forage throughout the dry season. During this period, the diet is basically made up of leaf litter, which is the material formed by the deposition of leaves from shrub and tree species on the ground (PEREIRA FILHO and BAKKE, 2010). From a qualitative point of view, the increase in lignification caused by the natural maturation of the forage, with a consequent reduction in protein content and digestibility, are responsible for the change in the nutritional value of the pasture during the dry season, thus requiring the improvement of the available pasture or concentrated supplementation for the animals (BEN SALEM, 2010).

In line with these challenges, there is a need to control animal stocking in pastures in order to prevent further degradation, usually caused by overgrazing. In this scenario, preferentially consumed species, also known as key species, are more vulnerable to disappearance. Thus, botanical knowledge of caatinga pasture areas, as well as managing the use of these areas by animals, is crucial for the conservation of species with forage potential. According to Giulietti et al. (2004), excessive animal loads alter the plant composition of the pasture due to the intense pressure that animals exert on the most palatable species, which tend to decrease.

Assessments to determine the feeding habits of sheep on pasture can be carried out in different ways, from subjective methods such as simulated grazing (MARCHI et al., 2021), to more precise but invasive methods, such as the use of rumen- or esophagus-fistulatedanimals (BOOYSE et al., 2009; MUZZI et al., 2009). Prohmann et al. (2012) commented that accurately determining the diet of grazing animals is a challenge, as they are highly selective, prefer more palatable species and consume different plant structures. Among the available methodologies, the fecal micro-histological technique for botanical identification is based on the use of previously established cytological or histological descriptors to identify the diet selected by the animals (ROSITO E MARCHEZAN, 2003).

The micro-histological technique makes it possible to assess the diet selected by the animal in a non-invasive way, since it is carried out using feces, thus eliminating the need to use fistulated animals. Considering that the starting point for structuring a production system isknowing the quantity and quality of the forage available throughout the different seasons of the year, the adoption of this technique to determine the botanical composition of the forage selected by small ruminants in native pasture conditions is justified due to its high efficiency and the possibility of proposing managements to conserve the Caatinga and maintain animal performance.

Therefore, strategies are needed to contribute to rational grazing in order to accommodate sheep in caatinga pastures without degrading the areas,avoiding overgrazing and guaranteeing the nutritional intake of the flock. Among the applicable strategies, in addition to botanical identification to find out the key species, as well as the nutritional value of the material consumed by the animals throughout the year, the use of energy-protein supplementation to meet the nutritional deficits of the herds is an alternative. Supplementation, in this case, should be made up of energy and protein-rich feeds that are potentially available and capable of meeting the animals' nutritional requirements when the nutritional value of the pasture is insufficient.

Thus, the purpose of this study was to determine, the botanical composition of the caatingausing fecal micro-histologyand the nutritional value of the forage selected by sheep subjected to different levels of concentrate supplementation.

2. Material and Methods

2.1. Caracterization of the experimental area and experimental treatments

The experiment was conducted at the LagoaSeca farm, which is located in the town ofCariré, Ceará, from 2015 to 2017, where small ruminant production is based on the exploitation of native Caatinga pastures. The farm is located at 3°57’02” South Latitude, 40°28’24” West Longitude and has an area of approximately 240 ha.

Thirty-two crossbred multiparous ewes weighing on average 38.8 kg were distributed in four treatments represented by supplementation with concentrated feed (0; 200; 350 and 500g animal^{-1} day^{-1}), with eight replications (ewes) per treatment. The animals grazed freely in the Caatinga areas with native grass for eight hours a day. The animal load in the area was adjusted during the three seasons to ensure that up to 60% of the available forage was used, in order to preserve and guarantee the sustainability of the production system (ARAÚJO FILHO, 2013).

According to the classification defined by Giulietti et al. (2004), the area of LagoaSecafarm is part of the native Caatinga of the shrub type, characterized by its low size, twisted stems and the density that varies between denser and more open plant types. Jurema-preta (*Mimosa tenuiflora*), catingueira (*Cenostigmapyramidale*), sabiá(*Mimosa caesalpiniifolia*) and mandacaru (*Cereus jamacaru*) are some of the dominant species in this type of shrubby Caatinga (ARAÚJO, 1998). The climate is classified as BShw’according to the Köppen classificationwith rainy season from January to June and average rainfall of 700 mm/year. Figure 1 shows the rainfall history for the last 43 years and during the experimental period (2015, 2016 and 2017).

The areas for data collection at Lagoa Seca farm were previously explored in their entirety in order to identify the ecological sites. Visual and descriptive assessments of the areas were used to identify the boundaries, establishing a map according to the existing ecological sites. There was a variation between areas with a higher density of shrub and tree species, which were completely enclosed; areas with a lower density of shrub and tree species, with a greater presence of herbaceous species; and completely open areas, with no shrub or tree species present. The areas were selected beforehand according to the availability of pasture and the management of the property.

Collections and observations of botanical species frequency, cover and phytomass production were carried out using sampling points obtained from macro-plots with arbitrarily defined dimensions or sized according to natural and easily observable differences within the grazing area (closed, thinned and open areas). These variables were collected through micro-plots established in the macro-plots, using an iron frame measuring 1.00 x 0.25 m, as suggested by ARAÚJO FILHO (2013). For uniform distribution of the sampling points, an average distance of approximately 100 m was adopted between the spots. Evaluations in the areas were carried out over 15 days during the seasons (rainy, transition and dry) which correspond to March, June and July respectively of each year.

The quadrant method was used to characterize the shrub and tree strata, by marking random spots within the grazing area, determining four directions and, in each direction, the distance of each shrub or tree species was measured using a tape measure. These measurements always considered the species closest to each quadrant (Fig. 2).

The total density was determined by dividing the area of a hectare by the area per plant. The specific density was obtained by dividing the number of plants of each species by the total number of plants, then multiplying by the total density (Table 1).

Table 1
Specific density (SD), total density (TD), relative density (RD) and total cover (TC) of the tree stratum in the area during the experimental period (average from 2015 to 2017)

Rainy season		
Species	**SD (Plants ha-1)**	**RD (%)**
CATINGUEIRA *(Caesalpinea pyramidalis)*	141.67	7.33
PEÃO BRAVO (*Jatro phamollissima*)	57.14	2.96
JUCÁ (*Libidibia ferrea*)	133.33	6.90
JUREMA PRETA *(Mimosa tenuiflora)*	200.00	10.35
JUREMA BRANCA (*Piptadenia stipulacea*)	147.62	7.64
MARMELEIRO (*Croton sonderianus*)	347.62	17.99
MOFUMBO *(Combretum lepreosum)*	323.81	16.76
MORORÓ (*Bauhinia cheilantha*)	57.14	2.96
PAU BRANCO *(Auxemma oncocalix)*	142.86	7.39
PAU D'ARCO (*Handroanthus impetiginosus*)	23.81	1.23
PAU MOCÓ *(Luetzelburgia auriculata)*	38.10	1.97
SABIÁ *(Mimosa caesalpinifolia)*	290.48	15.03
TINGUÍ *(Amorimia sp.)*	28.57	1.48
Total Density (Plants ha-1)	2427.53	-
Total Cover (% of area)	68.54	-
Transition season		
CATINGUEIRA *(Caesalpinea pyramidalis)*	95.24	7.97
SABIÁ *(Mimosa caesalpinifolia)*	342.86	28.69
MARMELEIRO (*Croton sonderianus*)	319.05	26.69
MOFUMBO *(Combretum lepreosum)*	219.05	18.33
MORORÓ (*Bauhinia cheilantha*)	38.10	3.19
PAU BRANCO *(Auxemma oncocalix)*	180.95	15.14
Total Density (Plants ha-1)	1369.15	-
Total Cover (% of area)	43.27	-
Dry season		
MARMELEIRO *(Croton sonderianus)*	161.90	27.64

Rainy season		
Species	**SD (Plants ha-1)**	**RD (%)**
MOFUMBO *(Combretum lepreosum)*	123.81	21.14
SABIÁ *(Mimosa caesalpinifolia)*	138.10	23.58
PAU BRANCO *(Auxemma oncocalix)*	109.52	18.70
TINGUÍ *(Amorimia Sp.)*	14.29	2.44
AMBURANA (*Amburana cearensis*)	38.10	6.50
Total Density (Plants ha-1)	1833.79	-
Total Cover (% of area)	27.45	-

To estimate production, material from the herbaceous stratum and components of the shrub and tree strata up to 150cm high were collected and weighed. The herbaceous stratum was divided into grasses, legumes, other dicotyledons and litter (Table 2).

Table 2

Yield (kg DM ha^{-1}) of the plant strata in the area during the experimental period

Stratum	Season*		
	Rainy	Transition	Dry
Grasses	292.57	170.12	88.45
Herbaceous legumes	189.64	154.34	142.31
Other dicotyledons	268.32	274.23	278.18
Litter	210.14	334.02	532.60
Total	960.67	932.71	1041.54

*Rainy = referring to the month of March; Transition = referring to the month of June; Dry = referring to the month of July. Average data for the years 2015, 2016 and 2017.

2.2. Identification of forage botanical composition

The method described by Sparks and Malecheck (1968) was used to identify the composition of the plant material ingested by the animals and, consequently, the quality of the selected diet. Samples of the forage available in the grazing area were collected over 15 days in each season (rainy, transition and dry) in the three years (2015, 2016 and 2017). The collection procedure consisted of observing and monitoring the feeding habits of the animals in order to represent a forage canopy using micro-histological slides of each species, which were used to identify the structural indicators of the plants and were used as a reference for analyzing the fecal samples.

The plant samples collected in the field were packed, identified and preserved in 70% alcohol. The process of making the micro-histological slides followed the method described by Rogério et al. (2017). An aliquot of each plant sample was ground in a blender for 1 to 2 minutes, and when the sample was grass, this time was increased by another minute due to the greater resistance of the cell wall. The samples were then sieved through an ABNT 140 sieve with a mesh size of 1.105 mm.

The slides were made from the residue on the sieve, from which a sub-sample was removed and placed on a microscope slide together with the cleaning and mounting solutions. The slides were labeled with the name of the species, the date of collection and the date they were made. Three replicate slides were made for each forage species.

In order to identify the selected diet, feces were also collected (directly from the animals' rectal ampulla) on two days per season (rainy, transition and dry) in each year (2015, 2016 and 2017) during pasture collection (15 days per season). Fecal samples were processed according to the methodology adopted for plant samples (Rogério et al., 2017), and two slides were made per animal.

After preparation and drying, the slides of the forage species were analyzed in an exploratory way using a binocular microscope with an attached digital camera for photographic recording and characterization of the epidermal descriptors observed (e.g., stomata, trichomes, silica bodies, plant wallcells), thus forming an image bank for each species identified. To analyze the fecal slides, 20 points were systematically distributed in the visual field of the slide. To help with the identification analysis, the points on the fecal slides were also photographed. The structures identified on the fecal slides were compared to the structures identified on the forage to determine the plant material consumed. The species identified per point on the slides were recorded in a spreadsheet and the frequency of species per slide was then calculated to determine the composition of the selected diet.

2.3. Chemical analysis

To determine the chemical composition of the plant species (Table 3), plant and fecal samples were identified, weighed and pre-dried (Detmann et al., 2012; INCT-CA G-001/1 method). Then they were ground to 1 mm and stored in plastic containers for the determination of dry matter (Detmann et al., 2012; INCT-CA G-003/1 method), mineral matter (AOAC, 2005; method number 942.05), crude protein (Detmann et al., 2012; INCT-CA N-001/1) and fiber constituents (NDF, ADF and HEM) according to the sequential methodology of Van Soest et al. (1991).

Table 3
– Chemical composition of the concentrate supplement and plants selected by sheep in the caatinga area (%DM), in Cariré-CE£

	DM*	MM	OM	CP	NDF	ADF	HEM
Concentrate supplement	85.46	7.10	-	13.07	24.32	8.94	-
Grasses							
Barba-de-bode *(Aristida longiseta)*	28.80	16.01	83.99	13.61	63.41	36.32	27.09
Grama-touceira *(Paspalum paniculatum)*	32.81	12.88	87.12	15.66	66.08	32.38	33.70
Grama-seda *(Cynodon dactylon)*	19.47	21.78	78.22	10.41	66.54	41.39	25.16
Panasco *(Aristida adscensionis)*	31.91	13.35	86.65	8.79	69.69	39.03	30.66
Sorgo (*Sorghum bicolor*)	26.24	3.26	86.74	13.76	62.52	48.82	13.70
Tiririca *(Cyperus rotundus)*	27.72	11.31	88.69	14.47	67.26	33.11	34.15
Legumes							
Amendoim-forrageiro (*Arachis dardani*)	23.98	8.27	68.09	19.11	55.34	41.21	14.13
Estilosante (*Stylosanthes humilis*)	23.47	14.00	86.00	16.19	51.90	33.44	18.46
Mata-pasto (*Senna obtusifolia*)	30.83	15.11	84.89	15.85	42.25	20.78	21.47
Sabiá (*Mimosa caesalpinifolia*)	37.35	4.94	75.06	18.77	59.61	45.70	13.91
Other Dicotyledons							
Bamburral (*Hyptissua veolens*)	13.56	7.35	78.34	11.66	55.39	41.98	13.41
Cabeça-branca (*Alternanthera tenella* Colla)	11.96	13.12	86.88	14.66	65.18	36.88	28.29
Capa-bode (*Melochia tomentosa* L.)	22.47	7.28	68.72	8.20	52.36	41.65	14.37
Centrosema (*Centrosema sp.*)	23.05	8.27	67.23	16.86	47.95	32.51	15.44
Ervanço (*Alternanthera brasiliana*)	14.54	12.24	87.76	21.70	52.35	25.56	26.79

£Mean values obtained from 2015 to 2017; *DM = dry matter; MM = mineral matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber and HEM = hemicellulose.

	DM*	MM	OM	CP	NDF	ADF	HEM
Jucá (*Libidibia ferrea*)	46.60	4.47	75.53	19.47	54.78	29.63	25.15
Jurema-branca *(Piptadenia stipulacea)*	39.50	3.28	86.72	18.99	56.12	36.68	19.44
Jurema-preta (*Mimosa tenuiflora*)	40.33	3.30	79.70	16.31	56.22	36.52	19.70
Malva (*Sida cordifolia*)	29.69	7.95	82.05	9.94	63.80	38.18	25.62
Malva-branca (*Herissanta tiubae*)	22.83	8.01	81.99	14.78	45.30	20.68	24.62
Marianinha (*Commelina diffusa*)	9.32	18.05	81.95	31.22	58.50	36.22	22.28
Marmeleiro (*Croton sonderianus*)	37.54	7.57	72.43	14.82	69.00	49.50	19.50
Mofumbo (*Combretum leprosum*)	35.52	7.64	82.36	12.12	56.63	53.12	3.52
Mororó (*Bauhinia cheilantha* Steud)	43.35	7.83	79.17	12.62	54.53	38.73	15.80
Paco-paco (*Wissadula rostrata*)	22.46	9.27	80.73	20.50	58.83	31.30	27.53
Pau-branco*(Auxemma oncocalix)*	31.10	9.72	90.28	13.49	66.99	47.60	19.39
Pau-mocó *(Luetzelburgia auriculata)*	32.53	7.08	78.92	14.38	50.49	36.85	13.64
Pereiro (*Aspidosperma pyrifolium*)	30.62	8.72	91.28	12.80	44.32	27.68	16.64

[£]Mean values obtained from 2015 to 2017; *DM = dry matter; MM = mineral matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber and HEM = hemicellulose.

2.4. Diet quality

The proportion of plants consumed by the sheep was estimated by the number of fragments identified per species as a function of the total number of species observed in the fecal slide, recorded on the spreadsheet. Plants classified as “other dicotyledons” were the species with a frequency of less than 15%, participating in the diet in small proportions.

The nutritional value of the ingested pasture was estimated according to the McInnis and Vavra (1987) equation, with the values of DM, MM, OM, CP, NDF, ADF and hemicellulose considering the composition (%) of each species identified in the fecal slides.

n

$N_i = \sum a_{ij} x_j$

i=1

Where:

N_i = participation of nutrient *i* on feed composition;

a_{ij} = content of nutrient *i* of forage species *j;*

x_j = percentage composition in terms of dry weight of the forage species *j*.

2.5. Experimental design

It was adopted a completely randomized design, with levels of concentrate supplementation (0; 200; 350 and 500g) with eight replications in three seasons (rainy, transition and dry). The data was subjected to normality tests using the PROC UNIVARIATE procedure in the SAS software (2016) and was then subjected to analysis of variance using PROC MIXED, with the diets considered as a fixed effect and the years as random effect. Diet effects were explored using regression analysis through PROC REG also in the SAS software (2016).

The statistics proposed by Costa et al. (2002) for classifying CVs were adopted to define the preference degree classification ranges, based on the percentage of selection of each forage consumed, and adapted for plant frequency data as: Low preference ≤ Md - PS and high preference > Md + PS. Md = (Q1 + Q3)/2 is the median of the frequencies. Q1 and Q3 are the first and third quartiles, respectively, which delimit 25% of each end of the distribution and PS = (IQR/1.35), where PS is the pseudo-sigma and IQR is the interquartile range (Q3-Q1).

3. Results

There was no effect of interaction between the level of supplementation offered and the season ($P > 0.05$). Analyzing the factors individually, the evaluation of the frequency of selection of the strata in the three seasons indicated a greater preference for low-growing species (grasses, herbaceous legumes and other dicotyledons) in the rainy season (Table 4).

Table 4
Centesimal composition (%) of plant genera selected by sheep in a caatinga area according to the season

Genre	**Season***		
	Rain	**Transition**	**Dry**
Grasses	38.30	24.56	26.32
Woody legumes	27.66	38.60	39.47
Herbaceous and Other Dicotyledons	34.04	36.84	34.21
*Rainy = referring to the month of March; Transition = referring to the month of June; Dry = referring to the month of July. Average data for the years 2015, 2016 and 2017.			

As for selection according to the amount of supplementation offered to the sheep, selection for grasses was greater for concentrate supplementation up to 350 g animal^{-1} day^{-1}, with a severe decline for the treatment offering 500 g animal^{-1} day^{-1} (Table 5). On the other hand, in this treatment animals showed a higher frequency of selection for herbaceous species and other dicotyledonsin comparison to the other treatments.

Table 5
Centesimal composition (%) of plant genera selected by sheep in a caatinga area according to levels of concentrate supplementation*

Stratum	**Concentrate supplementation (g animal-1 day-1)**			
	0	**200**	**350**	**500**
Grasses	41.41	47.75	45.69	28.18
Woody legumes	19.79	16.86	17.92	15.89
Herbaceous and Other Dicotyledons	38.80	35.39	36.39	55.93
*Average data for the years 2015, 2016 and 2017.				

Regarding the botanical composition selected during the rainy season, the most selected species by the sheep in the pasture were the legume *Stylosantheshumilis*, and the grasses *Cynodondactylon*, *Paspalumpaniculatum* and *Melochiatomentosa* L., followed by other species (Fig. 3).

In the transition season, there was greater selection for the grass *Melochia tomentosa* L., the legume *Mimosa caesalpinifolia*, and the dicotyledons *Alternanthera brasiliana* and *Alternanthera tenella Colla*, followed by other species. During the dry season, there was a greater demand for *Aristida adscensionis* and the legume *Mimosa caesalpinifolia*, followed by *Croton sonderianus* and other species. During the rainy season, the sheep selected 60.79% of grasses, 27.45% of legumes, followed by other species. During the transition season, selectivity was more balanced, with greater demand for herbaceous dicotyledons (38.78%) followed by grasses (26.53%), legumes (24.49%) and other species (10.20%). In the dry season, selection was greater for grasses, followed by legumes, dicotyledons and other species.

The presence of the legume *M. caesalpiniaefolia*, a species selected during the transition and dry periods is highlighted. The presence of the same key species was not observed for all periods evaluated (Fig. 3). The grass *Melochiatomentosa* L. had its selection importance in the rainy and transition seasons, and the legume *M. caesalpiniaefolia*in the transition and dry seasons.

Regarding the effect of concentrate supplementation for the sheep, offering 200 g day^{-1} of concentrate caused greater selection for the herbaceous dicotyledons *Alternanthera brasiliana* and *Alternanthera tenella Colla* (42.6%), followed by *Cynodon dactylon* (24.07%) and *Stylosanthes humilis* (20.37%) in the rainy season (Fig. 4). These species have a high CP content, reaching 21.70%, 14.66% and 16.19% (*Alternanthera brasiliana*, *Alternanthera tenella Colla* and *Stylosanthes humilis*, respectively) (Table 3).

During the transition season, there was greater selection for herbaceous dicotyledons (44.9%), followed by *M. caesalpiniaefolia* (22.45%), *Cynodon dactylon* (20.41%) and other species (12.24%). During the dry season, *Aristida adscensionis* was the most selected species, followed by *M. caesalpinifolia*, *Combretumleprosum* and others.

When the sheep were supplemented with 350 g day^{-1} of concentrate feed in the rainy season there was a greater selection for grasses, totaling 46.81%, made up mainly of *Aristida adscensionis* and *Cynodon dactylon*, followed by 40.42% of legumes such as *Arachis dardani* and *Stylosanthes humilis*, and 12.77% of other species with less frequency in the grazing area (Fig. 5).

In the transition season, *Aristida adscensionis* was the most selected grass. The variation in the availability of grasses as the seasons progressed, the presence of ephemeral species, and the frequency of *Aristida adscensionis* in the area, led the animals to select this grass over others, keeping it in the diet in all seasons with supplementation of 350 g day^{-1} of concentrate feed.

Herbaceous dicotyledons made up 39.58% (*Herissanta tiubae* and *Commelina diffusa*) of the sheep's diet during the transition season, followed by *Stylosanthes humilis* (22.92%) and other species less frequent (Fig. 5). The higher frequency of herbaceous dicotyledons in the diet of the sheep supplemented with 350 g day^{-1} of concentrate may have contributed to the higher intake of CP.

During the dry season, *Aristida adscensionis* was more commonly selected, followed by *Croton sonderianus*, *Mimosa caesalpinifolia* and other species. The second species with the highest relative density in the grazing area during the dry season was *Mimosa caesalpinifolia* (23.58%), making an effective contribution to the selection and composition of the animals' diet.

Supplementing the animals with 500 g day^{-1} of concentrate feed during the rainy season resulted in greater intake of the species with the highest CP contents (Table 3): *Stylosanthes humilis*, *Arachis dardani* and *Alternanthera tenella Colla* (Fig. 6). Although the selection of *Arachis dardani* was equivalent to that of *Cynodon dactylon*, as the proportion of concentrate increased, the intake of CP increased to the detriment of the other species. This result corresponds to the greater selectivity for other dicotyledons, grasses and legumes with supplementation of 500 g day^{-1} (Table 5).

Sheep's selection behavior during the transition season was similar to that observed during the rainy season. In general, the animals selected more species with high protein content, followed by grasses and other species less frequently. *Aristida longiseta*, for example, has a high CP content, which may indicate a high preference at that time, since energy was being supplied by the concentrate. In the dry season, there was greater selection for *Aristida adscensionis*, followed by *M. Caesalpiniaefolia*, *C. Sonderianus* and other species.

In short, non-supplemented sheep tried to compensate for the absence of the supplement in the diet (Fig. 3) by selecting species with higher CP content and a lower content of fiberconstituents (Table 3). In the dry season there was a greater selection of species that are not common in sheep diets (*C. Sonderianus*, *C. leprosum* and *Piptadenia stipulacea*), indicating that as the seasons progressed and due to the absence of herbaceous species, the animals modified their diet. The high frequency of these species in the grazing areas during the dry season also contributed to high selection by the animals, as well as being an indicative of secondary succession.

Although the sheep consumed a wide variety of forage species, seven species were selected the most, and were considered key species. Regardless of the level of supplementation, in the rainy season *Stylosanthes humilis* and *Cynodon dactylon* were the key species. In the transition season, the key species were *Aristida longiseta*, *Mimosa caesalpinifolia*, *Herissanta tiubae* and *Commelina diffusa*. While in the dry season, *Aristida adscensionis* and *Mimosa caesalpinifolia* were the key species.

Of the total of 63 species present in the area, 26 were selected by the sheep and of these, 20 showed a high preference. Of this total, 75% were herbaceous species (Table 6), which corroborates the sheep's feeding habits. The great variability of herbaceous species with high preference allows for the possibility of selecting better quality fiber and protein components, which are the main components selected during the rainy and transition seasons. By identifying the key species in a caatinga environment, it is possible to make rational use of the pasture, seeking to control species with low or no forage potential, and ensuring the establishment, preservation and dispersal of the key species, thus providing areas with higher frequencies of this group of species.

Table 6
Classification of species consumed according to average frequency of selection by sheep kept in Caatinga areas from 2015 to 2017

SPECIES	FREQUENCY	SELECTIVITY
Amburana (*Amburana cearenses)*	7.07	Low
Amendoim-forrageiro (*Arachis dardani*)	13.50	High
Azedinha (*Rumexa cestosella)*	13.67	High
Barba-de-bode (*Aristida longiseta*)	13.46	High
Cabeça-branca (*Alternanthera tenella*)	12.78	High
Capa-bode (*Melochia tomentosa*)	14.33	High
Centrosema (*Centrosema sp.)*	11.89	Low
Ervanço (*Alternanthera brasiliana*)	13.08	High
Estilosantes (*Stylosanthes humilis*)	13.73	High
Feijão-de-rola (*Macroptilium lathyroides)*	12.48	Low
Grama-seda *(Cynodon dactylon)*	13.36	High
Grama-touceira *(Paspalum paniculatum)*	13.25	High
Jurema-preta *(Mimosa tenuiflora)*	12.35	Low
Jurema-branca *(Piptadenia stipulacea)*	14.31	High
Malva *(Sida cordifolia)*	13.18	High
Malva-branca *(Herissanta tiubae)*	11.11	Low
Marianinha *(Commelina diffusa)*	13.47	High
Marmeleiro *(Croton sonderianus)*	13.43	High
Mata-pasto *(Senna obtusifolia)*	13.62	High
Mofumbo (*Combretum leprosum)*	12.84	High
Paco-paco *(Wissadula rostrata)*	12.61	High
Panasco *(Aristida adscensionis)*	13.70	High
Pau-branco *(Auxemma oncocalix)*	13.80	High
Sabiá *(Mimosa caesalpinifolia)*	13.75	High
Tiririca *(Cyperus rotundus)*	15.21	High

Concentrate supplementation had a decreasing linear effect ($P < 0.05$) on DM and OM selection (Table 7). For every gram of concentrate added to the diet there was a reduction of 0.0379% of DM. Similar behavior was observed for the demand for DM in the transition and dry seasons, with a reduction occurring as the level of supplementation increased (Table 7). In the transition season, the reduction in the search for DM occurred more slowly as the dry season approached, probably due to the gradual decrease in forage availability.

Table 7
Averages of the percentage (%) of selection for nutrients in the pasture by sheep kept in caatinga areas under different levels of concentrate supplementation, from 2015 to 2017

Season	Dry matter							*p*-value	
	0	200	350	500	S.E.M	Regression	R^2	Linear	Quadratic
Rainy	36.01	24.40	25.53	21.44		y = 37.822-0.0379x	0.6112	< 0.0001	< 0.0001
Transition	34.50	28.87	24.27	22.84	0.7723	y = 34.052-0.0254x	0.4822	< 0.0001	< 0.0001
Dry	36.52	32.64	26.50	27.44		y = 36.991-0.0235x	0.4916	< 0.0001	< 0.0001
Mineral matter									
Rainy	6.43	5.51	6.27	6.06		y = 6.395	0.0201	0.4463	0.2372
Transition	4.54	6.16	5.63	4.57	0.1330	y = 6.063	0.0318	0.3206	0.0762
Dry	4.57	3.78	4.72	4.24		y = 4.303	0.0069	0.6504	0.7495
Organic matter									
Rainy	49.38	48.00	45.02	43.19		y = 49.707-0.0147x	0.4006	0.0001	0.0006
Transition	51.07	49.24	46.35	40.46	0.5513	y = 52.262-0.0212x	0.6657	< 0.0001	< 0.0001
Dry	54.04	48.79	48.56	44.40		y = 56.359-0.0258x	0.6128	< 0.0001	< 0.0001
Crude protein									
Rainy	9.97	9.39	8.98	11.62		y = 10.131-0.0131x + 0.00003x²	0.4322	0.1149	0.0004
Transition	10.01	10.75	8.63	9.79	0.1331	y = 10.472	0.0928	0.0847	0.2319
Dry	10.89	10.01	8.61	10.52		y = 11.086-0.0114x + 0.00001x²	0.3335	0.0892	0.0028
Neutral detergent fiber									
Rainy	30.59	30.58	29.56	29.45		y = 30.076	0.0018	0.8199	0.7889
Transition	30.70	30.16	29.71	29.62	0.2811	y = 30.689	0.0093	0.5937	0.7267
Dry	34.22	32.18	31.88	31.40		y = 34.148-0.006x	0.1529	0.0269	0.0818
Acid detergent fiber									
Rainy	18.95	18.58	18.78	18.88		y = 18.045	0.0421	0.2682	0.4175

Season					Dry matter			p-value	
	0	200	350	500	S.E.M	Regression	R²	Linear	Quadratic
Transition	19.88	19.65	18.31	18.20	0.2705	y = 19.663	0.1277	0.0612	0.0811
Dry	23.50	21.94	21.14	20.47		y = 23.724-0.006x	0.2056	0.0091	0.0068
Hemicellulose									
Rainy	13.30	11.71	11.39	11.34		y = 12.992-0.003x	0.1857	0.0383	0.0563
Transition	13.62	11.26	11.88	11.30	0.1685	y = 13.457-0.0104x + 0.00001x2	0.2505	0.0093	0.0132
Dry	13.20	11.17	11.09	10.64		y = 12.866-0.005x	0.5379	< 0.0001	< 0.0001

This behavior could probably be characterized by the substitution effect, due to the intake of the supplement with higher energy availability compared to the intake of pasture. In addition to the higher energy concentration, the supplement may contribute to the intake of CP during this period. Although there are a variety of legume species on the animal's grazing sites with high protein value (Table 3), the lignification process of shrub and tree species can limit the availability of protein.

Regarding the MM intake in native caatinga pasture, there was no diet effect ($P > 0.05$), with average intake of 6.04% in the rainy season, 5.22% in the transition and 4.32% in the dry season, showing lower intake in the dry season. There was no effect of supplementation in the transition season, with an average of 10.47%. However, the intake of CP in the rainy and dry seasons showed similar response, with a reduction in the intake of this nutrient up to the supply of 350 g day^{-1} of concentrate, decreasing as the amount of supplement increased. There was an increase in CP intake when the sheep were supplemented with 500 g day^{-1}, probably due to the high availability of energy from the concentrate and the search for higher amounts of protein.

As for the intake of fiber constituents (NDF and ADF), there was no effect ($P > 0.05$) during the rainy and transition seasons. In the dry season, there was a linear decreasing effect ($P < 0.05$) on the average intake of both components. This may be associated with the fact that during this season the selected diet included a greater quantity of tree species with a high lignin content, probably making some of the other fiber constituents unavailable.

As for the behavior of hemicellulose, it was higher in the rainy and dry seasons, with a decreasing linear effect ($P < 0.05$). As the level of supplementation increased, the amount of hemicellulose decreased. It can be inferred that selection during these seasons led to the consumption of species with lower levels of fiber constituents. However, in the dry season, this behavior may be due to the lower availability of forage and the higher proportion of anti-nutritional factors, such as tannins and lignin.

4. Discussion

In addition to the feeding habits of sheep (Hoffmann, 1989) and their preference for these genera (AraújoFilho and Crispim, 2002), these species are more readily available in the rainy season (Table 2), which favored selection. Most low-growing species have a short phenological cycle, so the availability and nutritional value of these species is gradually reduced from the end of the rainy season. Therefore, selection for grasses in the transition and dry periods tends to be lower (Table 4).

In the transition season, there was an increase in the selection of species from the woody stratum. The xerophytic characteristic of most woody species in the caatinga results in leaf fall during the transition and dry season. As the leaves fall, there is an increase in the litter component (Table 2) and, consequently, greater selection of the shrub and tree component by the sheep (Table 4). According to Santos et al. (2010), most of the woody species present in the diet of animals in the caatinga are selected after the leaves that make up the litter fall. Due to the height of the trees and shrubs, the reach to the branches and twigs by the animals is limited.

Although their nutritional value is lower than that observed in the rainy season, the greater proportion of legumes consumed as the transition to the dry season progresses is relevant as a source of protein in this period. The presence of other dicotyledonous species maintains a high degree of selectivity over time, as it covers a greater diversity of species. These results may indicate the beginning of the adoption of management of areas destined for grazing, with the favoring of herbaceous species with greater selectivity, from the adoption of thinning, which consequently promotes the emergence of open areas favorable to the herbaceous stratum.

Concentrate supplementation can have a substitutive effect on forage intake (Araújo et al., 2018). When this occurs, sheep choose to select forage that meets their fiber needs to maintain rumen functions, as the energy and protein demand can be met by concentrate supplementation (Carvalho et al., 2021). Araújo Filho et al. (1996) evaluated the intake of sheep and goats in the caatinga during the rainy-dry transition, dry, and the dry-rainy transition seasonsand found that the selection of grasses by sheep remained above 20% of the total floristic composition selected. The preference of sheep for herbaceous dicotyledons can also be explained by the greater frequency of these species in the rainy season, the ease with which they can be obtained by the animals and the feeding habits of the animal species (Santos et al., 2010).

According to Araújo Filho (2013), the importance of *M. caesalpiniaefolia* stems from the nutritional value of the leaves, which are rich in crude protein (18.77%, Table 3) and are an important component of the diet of ruminants in the caatinga. Selection by the sheep was related to the time of year and the composition of the species selected in the pasture. The presence of *Croton sonderianus* in the animals' diet during the dry season is noteworthy, as this species was more frequent in the grazing area during the dry season. In addition, as the availability of different grass species decreased, there was an increase in the intake of *Croton sonderianus* by the sheep, as also reported by Santos et al. (2008).

In the dry season, *Croton sonderianus* had a relative density of 27.65%, which was the highest among the species observed in this season, and that may explain the selection of this species by the animals, since it is not common in the diet of sheep, in addition to the fact that in the dry season there is a substantial reduction in the herbaceous stratum preferred by the animals, which leads them to select lesser desirable species present in the area (Carvalho et al., 2009). In addition, the high density of shrubs in this species is indicative of the secondary succession stage (Araújo Filho, 2013).

Pfíster (1983) reported that the diet selected by sheep in the caatinga can vary from 0.7 to 59% for grasses. This variation depends on the type of grass, its availability and density in the area.Of the 63 species cataloged in the caatinga native pasture area evaluated, the fecal micro-histological technique allowed the identification of 26 species in the botanical composition of the diet selected by sheep, 20 of which were highly preferred and 7 were considered key species: *Stylosanthes humilis* and *Cynodon dactylon*in the rainy season, *Aristida longiseta*, *Mimosa caesalpinifolia*, *Herissanta tiubae* and *Commelina diffusa*in the transition, and *Aristida adscensionis* and *Mimosa caesalpinifolia*in the dry season.

Sheep managed on native caatinga pasture change their selection strategy according to the supplementation they receive. The preference for species with a higher protein value is evident in the rainy, transition and dry seasons.

Declarations

Statement of Animal Rights

The procedures using animals in this research were approved by the Ethics Committee for the Use of Animals at Embrapa Goats and Sheep (Protocol No. 09/2015) and have therefore been performed in accordance with the ethical standards laid down in the Declaration of Helsinki and its later amendments. All applicable institutional and national guidelines for the care and use of animals were followed.The manuscript does not contain clinical studies or patient data.

Conflict of Interest Statement

No potential conflict of interest was reported by the authors.

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Author contributions

MCPR, FEPF and RCFFP formulated the idea; EBM, DSO and HQM developed the methodology; EBM, WFC and DSO conducted field work; DSO and LFG performed statistical analyses; EBM, LFG, DSO, MCPR, AAA, RCFFP, DSO and AAA drafted the manuscript. MCPR and RCFFP reviewed and edited the manuscript.

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Data Availability

The datasets generated during and/or analysed during the current study are not publicly available as contain sensitive information, but are available from the corresponding author on reasonable request.

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Figures

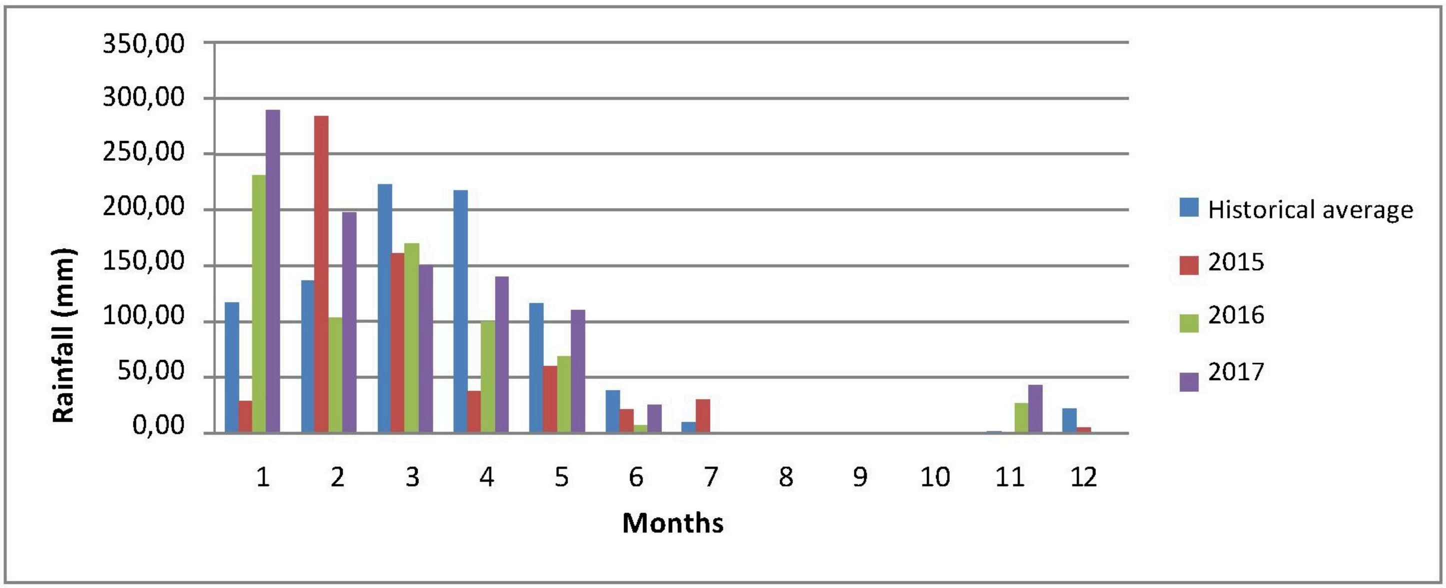

Figure 1 - Average historical monthly rainfall (1974 to 2017) and during the experimental period (2015 to 2017).

Figure 1

See image above for figure legend.

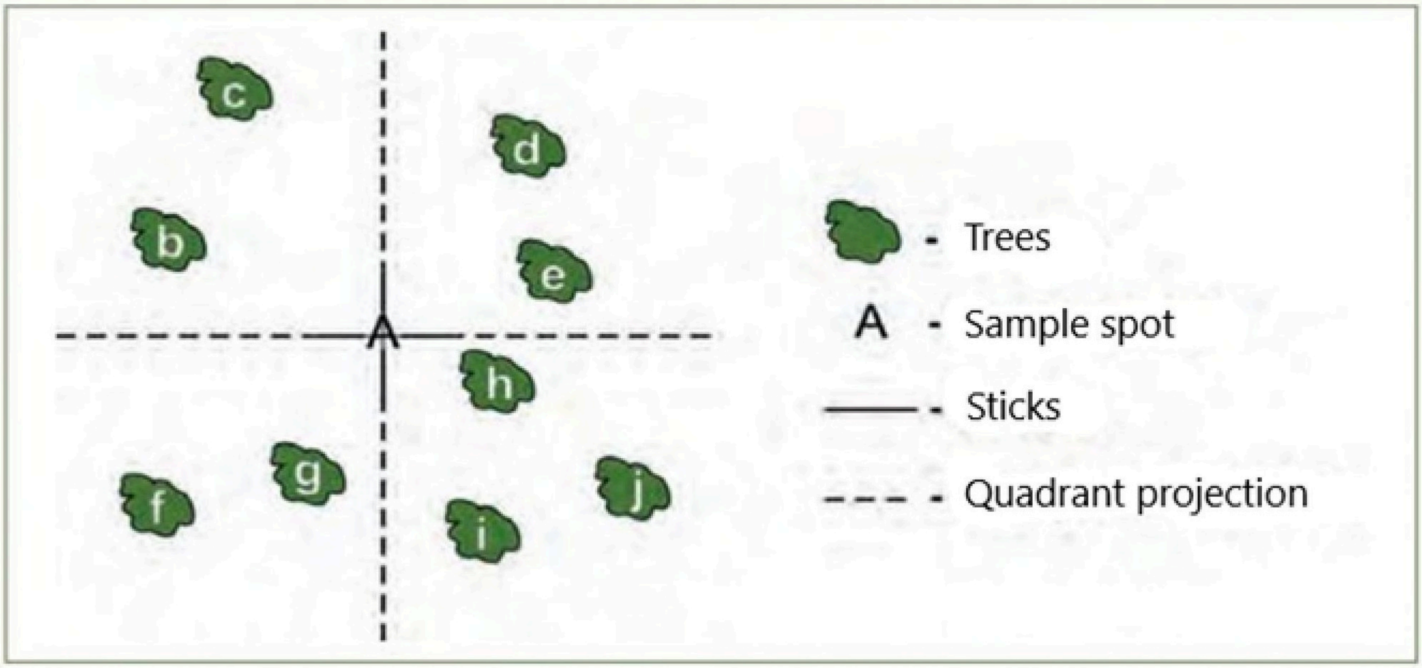

Figure 2 - Illustrative representation of the quadrant method according to Araújo Filho (2013).

Figure 2

See image above for figure legend.

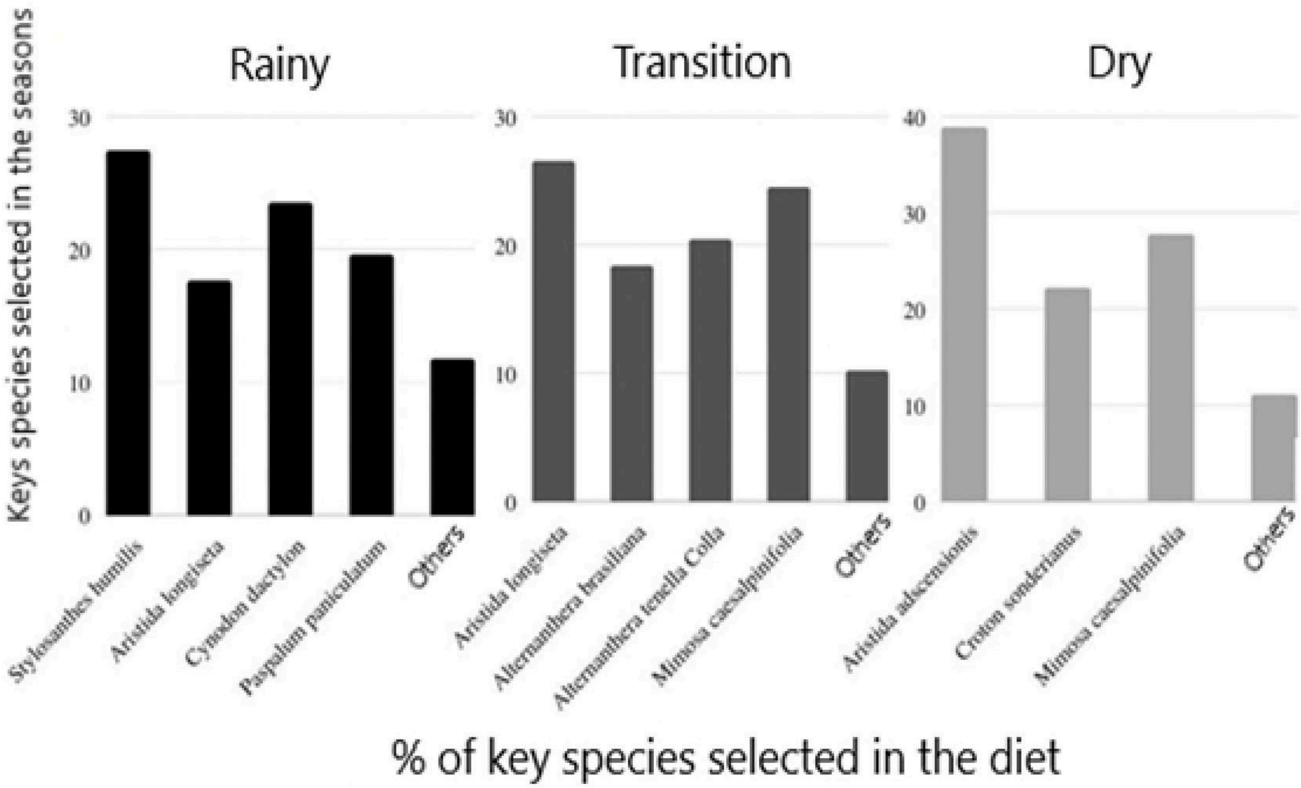

Figure 3 - Proportion (%) of species selected in the pasture by non-supplemented sheep kept in a Caatinga area.

Figure 3

See image above for figure legend.

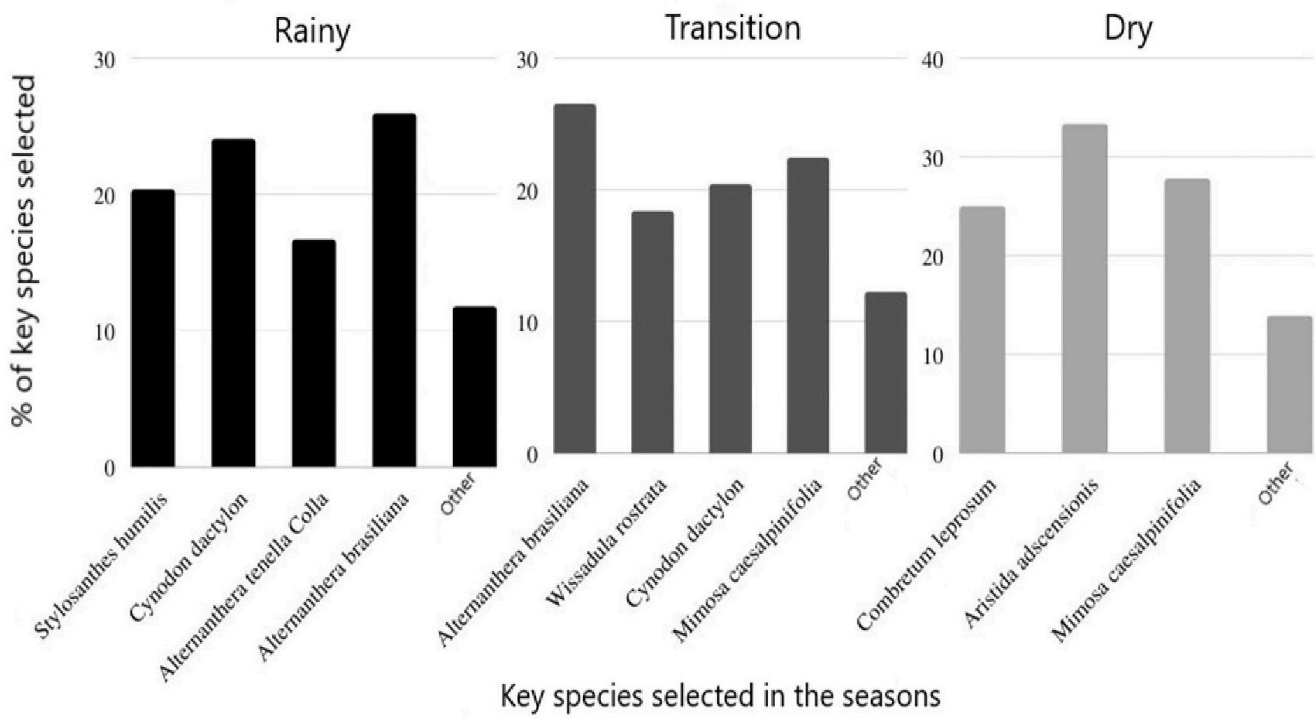

Figure 4 - Proportion (%) of species selected by sheep supplemented with 200 g day^{-1} of concentrate feed and kept in a caatinga area.

Figure 4

See image above for figure legend.

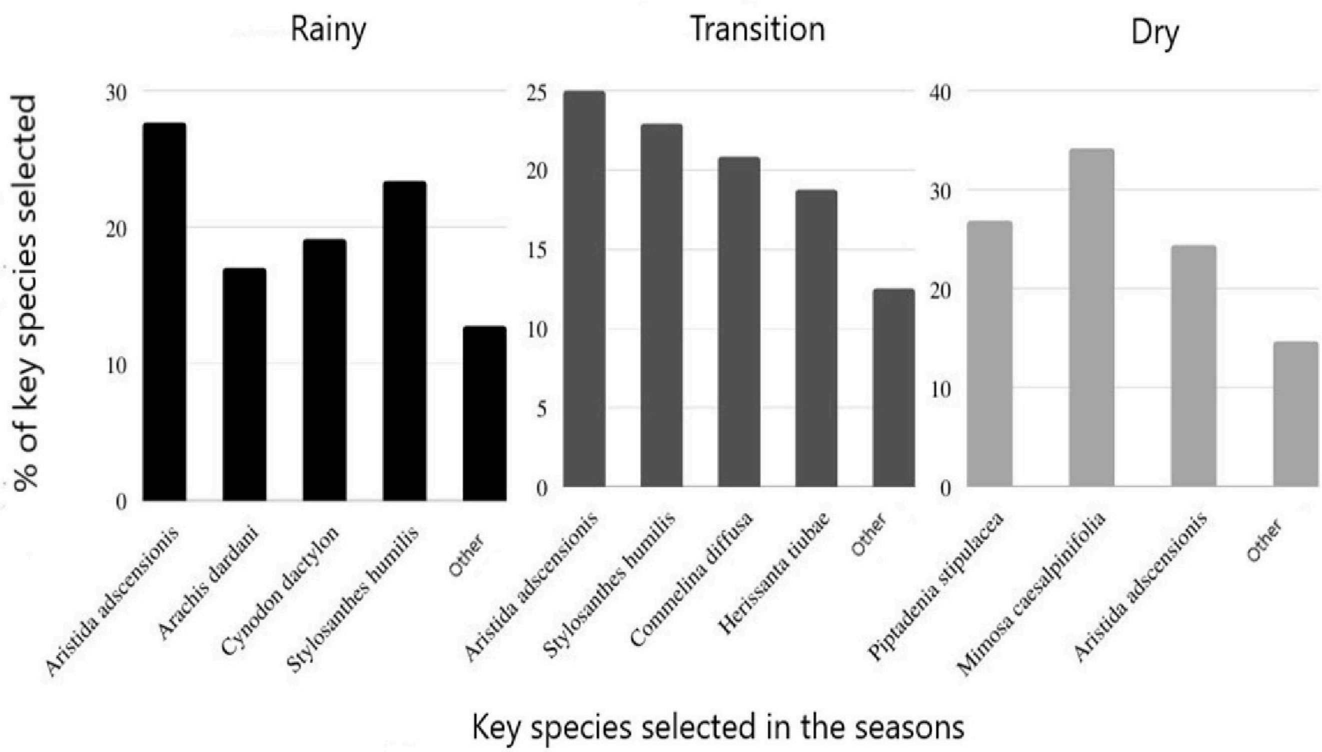

Figure 5 - Proportion (%) of species selected by sheep supplemented with 350 g day^{-1} of concentrate feed and kept in a caatinga area.

Figure 5

See image above for figure legend.

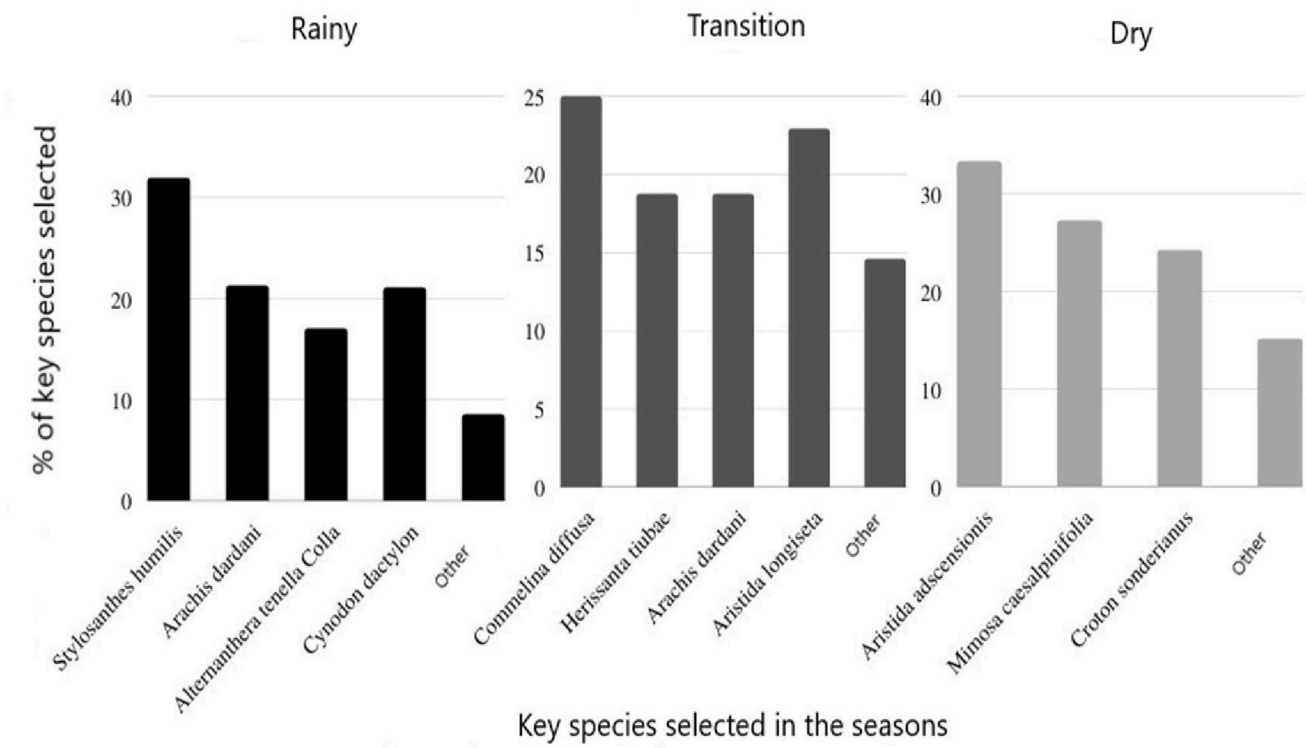

Figure 6 - Proportion (%) of species selected by sheep supplemented with 500 g day^{-1} of concentrate feed and kept in a caatinga area.

Figure 6

See image above for figure legend.