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Research Article
Chemical and Nutritional Variability of Cactus Pear Cladodes, Genera *Opuntia* and *Nopalea*

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Abstract
Background and Objectives: The cactus pear is a culture adapted the climatic conditions of the Brazilian semi-arid and extremely important in the diet of livestock in the region. Studies have revealed that the cladodes of cactus pear have several chemical compounds that can be considered natural herbal medicines and provide additional value to their products. The objectives of this study were to characterize the chemical and nutritional variability per order of cladode of 7 varieties of cactus pear, genera *Opuntia* and *Nopalea* grown in the semi-arid region of Brazil. **Materials and Methods:** The study was conducted using randomly designed blocks with three replicates. The materials IPA-100003, IPA-200016, IPA-200008, IPA-100004, IPA-200021, IPA-200205 and IPA-200149 with three-years-old were evaluated for their bromatological and mineral composition. The collected data were analyzed by analysis of variance by F test and the means grouped by the Scott-Knott test ($p<0.05$). **Results:** The content of nutrients varied: Dry Matter (DM) (5.60±0.50 to 7.57±1.20%), crude protein (CP) (5.03±0.01 to 9.13±0.64% DM), ether extract (EE) (0.78±0.01 to 1.99±0.16% DM), crude fiber (CF) (6.03±0.01 to 14.43±7.34% DM), nitrogen-free extract (NFE) (30.48±0.01 to 79.33±0.01% DM), mineral matter (MM) (7.62±1.47 to 13.05±0.01% DM), nitrogen (N) (8.00±0.01 to 14.60±1.04 g kg^{-1} DM), phosphorus (P) (1.92±0.28 to 4.56±0.27 g kg^{-1} DM), potassium (K) (4.65±1.95 to 42.00±7.10 g kg^{-1} DM), calcium (Ca) (21.46±6.86 to 62.75±0.01 g kg^{-1} DM), magnesium (Mg) (9.95±1.82 to 22.02±0.01 g kg^{-1} DM), sodium (Na) (1.40±0.53 to 2.90±0.70 g kg^{-1} DM), sulfur (S) (36.67±0.22 to 1,315.59±414.35 mg kg^{-1} DM), iron (Fe) (59.38±8.28 to 208.21±90.75 mg kg^{-1} DM), copper (Cu) (9.01±0.01 to 39.65±0.01 mg kg^{-1} DM), zinc (Zn) (19.19±7.68 to 81.14±0.01 mg kg^{-1} DM) and manganese (Mn) (102.50±26.32 to 704.57±3.91 mg kg^{-1} DM). **Conclusion:** The varieties of cactus pear present genetic variability in the chemical and nutritional contents, both among genotypes and in the order of cladodes within the genotype. The content of proteins and nutrients (N, K, Ca, Mg, S, Fe, Cu, Zn and Mn) tend to be higher in younger cladodes. The ether extract, nitrogen-free extract, crude fiber, phosphorus and sodium tend to be higher in mature cladodes.

Key words: Brazilian semi-arid, bromatological composition, cactaceous, characterization of forage, food analysis, forage palm, mineral composition

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Climatically defined regions, such as arid and semi-arid, represent approximately 48 million km^2, distributed in two thirds of the world's countries, where lives a population estimated at 630 million of people[1]. These regions are characterized by low humidity and little rainfall volume. Moreover, these regions are recognized by the high variability of rainfall that are infrequent, mild, unpredictable and random[1,2].

In Brazil, the territorial range considered as semi-arid covers an area of approximately 969,589.4 km^2, representing 11.39% of the national territory and includes the states of Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia and North of Minas Gerais[3]. This region is characterized by having a high index of annual evaporation, higher than 2,000 mm and average annual precipitation of less than 750 mm, concentrated in a single period of 3-5 months[4]. In addition, many areas in the region are salinized (>4.0 dS m^{-1}). These conditions impose certain limitations on plant and animal production, reflecting on the regional economy and quality of life of the inhabitants[4].

One of the main activities in the semi-arid region of Brazil is livestock, especially, cattle, goats and sheep. It is estimated that in absolute numbers, the population of these animals in this region are on the order of 29,350,651, 10,126,799 and 8,109,672 head, values which represent 13.82, 57.49 and 91.62% of the national herd, respectively[5]. Overall, these flocks are raised extensively, feeding exclusively of native vegetation. Due to seasonal characteristics of the plants, adverse conditions of climate and soil and mainly because the native vegetation is not fodder plants, they have low bearing capacity and consequently, the cattle industry has low productivity[4]. Thus, it is necessary to find sustainable alternatives for crop production, enabling man to settle in the field, granting him an income and quality of life[4].

An important alternative of crop production to the Brazilian semi-arid region is the cultivation of plants of the genera *Opuntia* and *Nopalea*, because these plants have anatomical, physiological and chemical characteristics that allow their growth and development in areas subject to drought[2]. This enables human and animal food besides the generation of income to the population living in these areas, since these plants are used for various purposes such as production of fruits and vegetables for human consumption, fodder for animal feed, soil conservation, biomass for energy (biogas and ethanol), cochineal for production of carmine and numerous by-products, such as drinks, vegetarian cheese, medicines and cosmetics[4].

Studies have revealed that the cladodes have several chemical compounds that can be considered natural herbal medicines and provide additional value to their products[6]. Components such as fiber, hydrocolloids, pigments, minerals and vitamins are found in them, for providing products and foods that are important source of nutrients for humans and animals[6]. The recognition of the nutritional value of palm cladodes as a strategic food for food security and nutrition as well as nutritious fodder for adding value to animal products, is of paramount importance for certification of healthy products.

Many factors affect the chemical composition of cladodes, including soil and climatic conditions, plant age, time of year, varieties, species, etc[7]. Few studies are focused on the difference between the cladode orders between cultivated varieties. The cactus pear is a perennial plant, thus the knowledge of the nutritional value for order of cladodes is important when recommending the order of cladodes more nutritious at harvest time.

The obtainment of data on the composition of Brazilian foods has been stimulated in order to gather information up to date, reliable and appropriate to the national reality. Data on the composition of foods are important for numerous activities: Evaluate the supply and food consumption of a country, check the nutritional adequacy of the diet of individuals and populations, assess nutritional status, to develop research on the relationship between diet and disease in agricultural planning, in the food industry and others. Despite the obvious importance of this need, it can be said that do not there are in Brazil information or complete and updated tables on the nutrient composition and not nutrients with physiological action of cactus pear varieties cultivated in Brazil[8].

Thus, the objectives of this study were to characterize the chemical and nutritional variability per order of cladodes of 7 varieties of cactus pear, genera *Opuntia* and *Nopalea* cultivated in a semi-arid region of Brazil.

MATERIALS AND METHODS

Location of the experiment: The study was conducted at the Experimental Station Arcoverde, of the Agronomic Institute of Pernambuco (IPA), located in Arcoverde-PE (8°25' S, 37°05' W), 680.70 m altitude, average annual temperature 22.90±1.68°C, average annual relative humidity 69.60±5.30%, average annual wind speed 3.92±0.48 m sec^{-1}, average cumulative evaporation 1,700.40 mm, average annual cumulative rainfall 798.1 mm, micro region of Sertão do Moxotó[9].

Table 1: Varieties of cactus pear, genera *Opuntia* and *Nopalea* used in the study and grown in the state of Pernambuco, Brazil

Varieties	Species	Common name
IPA-100003	*Opuntia ficus indica*	IPA-20
IPA-200016	*Opuntia stricta*	Elephant Ear Mexican
IPA-200008	*Opuntia atropes*	F-08
IPA-100004	*Nopalea cochenillifera*	Small palm
IPA-200021	*Nopalea cochenillifera*	F-21
IPA-200205	*Nopalea cochenillifera*	IPA-Sertânia
IPA-200149	*Opuntia larreri*	-

Plant material and conducting the experiment: The materials used are listed in Table 1. The cladodes of the clones were planted on April 22 and 23, 2010, spaced 1.0×0.5 m; using one cladode per hole. The experimental design was a randomized block design with three replications. Each block consisted of three rows planted with 8 plants of each variety. The experimental plot was composed by the middle row, with six useful plants, 3.0 m^2 of useful area. The soil was fertilized 30 days after planting, with 20 t ha^{-1} of manure spread between the lines. Periodically, cultural practices were carried out in the form of weeding with hoe in all the cultivated area[3].

The collection of materials (cladodes) was held at 8:00 am on January 24, 2014 (dry season). After collection, the material was cleaned, cut into small pieces (2-3 cm in length) and dried in a forced-air oven at 55°C, where it remained for 72 h until constant weight in which the air-dried mass was obtained[3]. The dried material was crushed in a Willey® type mill and packed in sealed plastic containers for the chemical and nutritional determinations.

Determination of chemical and nutritional characteristics: These contents were determined: Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sulfur (S), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), dry matter (DM), mineral matter (MM), crude protein (CP), ether extract (EE), crude fiber (CF) and nitrogen-free extract (NFE).

The N, P, K, Ca, Mg, Na, S, Fe, Cu, Zn and Mn were determined according to Malavolta *et al.*[7] and the results were expressed in g kg^{-1} or mg kg^{-1}. The DM, MM, CP, EE, CF and NFE were determined as Messias *et al.*[10] and the results were expressed as percentage in the DM.

Statistical analysis: The data were initially evaluated by analysis of variance (ANOVA) and the means were compared by the Scott and Knott[11] test, at the level of 5% probability. Data analyzes were performed with the help of the statistical application[12] Assistat® 7.7.

RESULTS AND DISCUSSION

The results of the chemical and bromatological composition per order of cladodes of the studied varieties are shown in Table 2-8. No significant differences were observed ($p \leq 0.05$) by the Scott and Knott test between the order of the cladodes for dry matter (DM) (IPA-100003, IPA-200016, IPA-200008, IPA-100004, IPA-200021, IPA-200149), crude protein (CP) (IPA-200016, IPA-200008, IPA-100004, IPA-200021, IPA-200205, IPA-200149), ether extract (EE) (IPA-200016, IPA-200008, IPA-100004, IPA-200021, IPA-200205), crude fiber (CF) (IPA-100003, IPA-200008, IPA-200021, IPA-200205), nitrogen-free extract (NFE) (IPA-100003, IPA-200016, IPA-200008, IPA-100004, IPA-200205), mineral material (MM) (IPA-100003, IPA-200016, IPA-100004, IPA-200021, IPA-200205, IPA-200149), nitrogen (N) (IPA-200008, IPA-100004, IPA-200021, IPA-200205, IPA-200149), phosphorus (P) (IPA-100003, IPA-200016, IPA-200008, IPA-100004, IPA-200021, IPA-200205, IPA-200149), potassium (K) (IPA-100003, IPA-200021), calcium (Ca) (IPA-100003, IPA-200016, IPA-100004, IPA-200205, IPA-200149), magnesium (Mg) (IPA-100003, IPA-200016, IPA-200021, IPA-200205, IPA-200149), sodium (Na) (IPA-100003, IPA-200016, IPA-200008, IPA-100004, IPA-200021, IPA-200205, IPA-200149), sulfur (S) (IPA-100003), iron (Fe) (IPA 200016, IPA-200205), copper (Cu) (IPA-200021), zinc (Zn) (IPA-200016, IPA-100004, IPA-200021, IPA-200205, IPA-200149) and manganese (Mn) (IPA-100004, IPA-200149).

In the variety IPA-100003, we observed differences between the order of the cladodes for CP (6.02±0.47 to 8.35% ±0.64 DM), EE (1.27±0.17 to 1.82±0.11 DM), N (9.63±0.78 to 13.35±1.05 g kg^{-1} DM), Fe (71.99±8.58 to 170.84±15.62 mg kg^{-1} DM), Cu (18.33±0.25 to 28.99±3.80 mg kg^{-1} DM), Zn (27.38±0.49 to 52.65±13.51 mg kg^{-1} DM) and Mn (231.49±90.92 to 375.99±90.33 mg kg^{-1} DM) (Table 2).

In the variety IPA-200016, differences were observed between the order of cladodes for CF (7.85±0.77 to 9.54% ±0.66 DM), N (12.05±1.05 to 14.60±1.04 g kg^{-1} DM), K (5.35±1.35 to 15.00±4.20 g kg^{-1} DM), S (36.68±0.22 to 423.53±125.67 mg kg^{-1} DM), Cu (30.24±3.14 to 35.85±0.23 mg kg^{-1} DM) and Mn (228.56±29.92 to 512.53±27.70 mg kg^{-1} DM) (Table 3).

In the variety IPA-200008, differences between the order cladodes were noted for MM (7.86±1.19 to 13.05% ±0.01 DM), K (12.00±0.01 to 33.90±5.80 g kg^{-1} DM), Ca (40.43±6.45 to 62.75±0.01 g kg^{-1} DM), Mg (9.95±1.82 to 22.02±0.01 g kg^{-1} DM), S (219.48±0.01 to 1,315.59±414.35 mg kg^{-1} DM), Fe (59.38±8.28 to

Table 2: Chemical and bromatological composition of second, third and fourth-order cladodes of cactus pear, variety IPA-100003

		DM (%)					DM (g kg^{-1})		
Cladode order	DM (%)	CP	EE	CF	NFE	MM	N	P	K
Second	93.95±0.16^{a}	6.02±0.47^{b}	1.79±0.26^{a}	10.97±2.97^{a}	72.95±5.45^{a}	8.27±2.28^{a}	9.63±0.78^{b}	3.09±0.31^{a}	19.30±6.00^{a}
Third	93.82±0.64^{a}	6.81±1.22^{b}	1.82±0.11^{a}	9.84±2.52^{a}	71.09±3.27^{a}	10.44±1.41^{a}	10.87±1.95^{b}	2.81±0.14^{a}	13.25±0.05^{a}
Fourth	92.75±1.26^{a}	8.35±0.64^{a}	1.27±0.17^{b}	9.11±0.44^{a}	68.59±0.42^{a}	12.69±0.39^{a}	13.35±1.05^{a}	2.59±0.04^{a}	25.75±8.45^{a}
Mean	93.51	7.06	1.63	9.97	70.87	10.47	11.28	2.83	19.43
CV (%)	0.88	11.88	11.63	22.69	5.19	14.91	12.01	7.09	30.79

		DM (g kg^{-1})			DM (mg kg^{-1})				
Cladode order	DM (%)	Ca	Mg	Na	S	Fe	Cu	Zn	Mn
Second	93.95±0.16^{a}	29.69±1.22^{a}	13.80±3.27^{a}	2.90±0.50^{a}	73.00±0.12^{a}	79.10±12.05^{b}	21.54±3.92^{b}	52.65±13.51^{a}	375.99±90.33^{b}
Third	93.82±0.64^{a}	33.12±4.88^{a}	15.06±0.87^{a}	2.27±1.26^{a}	401.91±256.55^{a}	71.99±8.58^{b}	28.99±3.80^{a}	46.86±9.78^{a}	540.45±94.99^{a}
Fourth	92.75±1.26^{a}	31.42±0.70^{a}	17.36±0.24^{a}	2.55±1.25^{a}	277.32±14.77^{a}	170.84±15.62^{a}	18.33±0.25^{b}	27.38±0.49^{b}	231.49±90.92^{b}
Mean	93.51	31.41	15.41	2.57	250.74	107.31	22.95	42.29	382.64
CV (%)	0.88	9.33	12.69	41.36	59.17	11.58	13.74	22.77	24.07

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, MM: Mineral matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Na: Sodium, S: Sulfur, Fe: Iron, Cu: Copper, Zn: Zinc, Mn: Manganese, Means±Standard Deviation (n = 3), means followed by the same letter in the column do not differ statistically from each other. The Scott-Knott test was applied at 5% probability

Table 3: Chemical and bromatological composition of second and third-order cladodes of cactus pear, variety IPA-200016

		DM (%)					DM (g kg^{-1})		
Cladode order	DM (%)	CP	EE	CF	NFE	MM	N	P	K
Second	93.60±0.60^{a}	6.60±1.76^{a}	1.31±0.18^{a}	9.54±0.66^{a}	72.97±1.40^{a}	9.57±1.08^{a}	12.05±1.05^{b}	2.28±0.78^{a}	5.35±1.35^{b}
Third	92.43±1.20^{a}	9.13±0.64^{a}	1.15±0.45^{a}	7.85±0.77^{b}	72.83±1.35^{a}	9.04±0.98^{a}	14.60±1.04^{a}	2.38±0.27^{a}	15.00±4.20^{a}
Mean	93.02	7.87	1.23	8.69	72.90	9.31	13.32	2.33	10.18
CV (%)	1.02	16.84	28.14	8.24	1.88	11.07	7.84	24.94	30.66

		DM (g kg^{-1})			DM (mg kg^{-1})				
Cladode order	DM (%)	Ca	Mg	Na	S	Fe	Cu	Zn	Mn
Second	93.60±0.60^{a}	41.64±7.20^{a}	13.61±0.61^{a}	1.50±0.30^{a}	36.68±0.22^{b}	72.85±4.83^{a}	30.24±3.14^{b}	19.19±7.68^{a}	228.56±29.92^{b}
Third	92.43±1.20^{a}	38.51±6.40^{a}	13.49±1.36^{a}	1.63±0.85^{a}	423.53±125.67^{a}	139.64±47.15^{a}	35.85±0.23^{a}	22.09±1.88^{a}	512.53±27.70^{a}
Mean	93.02	40.07	13.55	1.57	230.10	106.25	33.04	20.64	370.55
CV (%)	1.02	17.00	7.78	40.70	38.62	31.54	6.73	27.08	7.78

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, MM: Mineral matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Na: Sodium, S: Sulfur, Fe: Iron, Cu: Copper, Zn: Zinc, Mn: Manganese, Means±Standard Deviation (n = 3), means followed by the same letter in the column do not differ statistically from each other. The Scott-Knott test was applied at 5% probability

Table 4: Chemical and bromatological composition of second, third, fourth, fifth and sixth-order cladodes of cactus pear, variety IPA-200008

		DM (%)					DM (g kg^{-1})		
Cladode order	DM (%)	CP	EE	CF	NFE	MM	N	P	K
Second	93.80±0.55^{a}	7.72±1.18^{a}	1.10±0.36^{a}	14.43±7.34^{a}	68.90±6.14^{a}	7.86±1.19^{c}	12.33±1.91^{a}	2.27±0.38^{a}	14.20±2.00^{d}
Third	94.03±0.61^{a}	6.84±1.62^{a}	1.00±0.30^{a}	10.76±3.69^{a}	69.99±4.05^{a}	11.40±0.77^{b}	10.97±2.61^{a}	2.41±0.70^{a}	33.90±5.80^{a}
Fourth	93.81±0.01^{a}	6.45±0.01^{a}	1.11±0.01^{a}	11.46±0.01^{a}	69.82±0.01^{a}	11.15±0.01^{b}	10.30±0.01^{a}	2.77±0.01^{a}	26.60±0.01^{b}
Fifth	93.79±0.01^{a}	6.81±0.01^{a}	1.07±0.01^{a}	8.85±0.01^{a}	71.22±0.01^{a}	12.04±0.01^{b}	10.90±0.01^{a}	2.77±0.01^{a}	21.30±0.01^{c}
Sixth	93.54±0.01^{a}	7.82±0.01^{a}	0.78±0.01^{a}	9.53±0.01^{a}	68.83±0.01^{a}	13.05±0.01^{a}	12.50±0.01^{a}	2.78±0.01^{a}	12.00±0.01^{d}
Mean	93.80	7.13	1.01	11.00	69.75	11.10	11.40	2.60	21.60
CV (%)	0.39	12.60	20.58	33.39	4.71	5.70	12.70	13.75	12.70

		DM (g kg^{-1})			DM (mg kg^{-1})				
Cladode order	DM (%)	Ca	Mg	Na	S	Fe	Cu	Zn	Mn
Second	93.80±0.55^{a}	40.43±6.45^{c}	9.95±1.82^{b}	2.90±0.70^{a}	1,315.59±414.36^{a}	59.38±8.28^{d}	33.15±5.02^{b}	34.70±9.93^{c}	102.50±26.32^{e}
Third	94.03±0.61^{a}	51.20±4.03^{b}	17.47±3.04^{a}	2.73±1.10^{a}	399.93±36.00^{c}	79.39±16.59^{c}	14.70±1.26^{d}	57.33±19.44^{b}	139.47±23.40^{d}
Fourth	93.81±0.01^{a}	61.51±0.01^{a}	18.65±0.01^{a}	2.10±0.01^{a}	219.48±0.01^{c}	104.14±0.01^{b}	39.65±0.01^{a}	55.96±0.01^{b}	258.39±0.01^{c}
Fifth	93.79±0.01^{a}	60.24±0.01^{a}	20.04±0.01^{a}	1.70±0.01^{a}	731.81±0.01^{b}	95.42±0.01^{b}	36.68±0.01^{a}	81.14±0.01^{a}	297.78±0.01^{b}
Sixth	93.54±0.01^{a}	62.75±0.01^{a}	22.02±0.01^{a}	2.70±0.01^{a}	1,247.46±0.01^{a}	197.99±0.01^{a}	22.66±0.01^{c}	62.75±0.01^{b}	537.40±0.01^{a}
Mean	93.80 ^{a}	55.23	17.63	2.43	782.85	107.26	29.37	58.38	267.11
CV (%)	0.39	6.16	9.00	24.05	23.76	7.73	7.88	16.72	5.90

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, MM: Mineral matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Na: Sodium, S: Sulfur, Fe: Iron, Cu: Copper, Zn: Zinc, Mn: Manganese, Means±Standard Deviation (n = 3), means followed by the same letter in the column do not differ statistically from each other. The Scott-Knott test was applied at 5% probability

Table 5: Chemical and bromatological composition of second, third, fourth and fifth-order cladodes of cactus pear, variety IPA-100004

		DM (%)					DM (g kg^{-1})		
Cladode order	DM (%)	CP	EE	CF	NFE	MM	N	P	K
Second	94.08±0.63^{a}	6.47±2.16^{a}	1.46±0.30^{a}	12.43±1.69^{a}	71.69±5.24^{a}	7.96±1.61^{a}	10.37±3.42^{a}	3.16±1.28^{a}	10.65±0.05^{c}
Third	93.86±0.54^{a}	6.49±1.68^{a}	1.51±0.12^{a}	7.85±0.77^{b}	74.26±2.05^{a}	9.88±0.23^{a}	10.40±2.72^{a}	2.73±0.91^{a}	20.05±3.95^{b}
Fourth	93.73±0.33^{a}	6.79±1.84^{a}	1.23±0.18^{a}	6.90±0.66^{b}	74.90±3.97^{a}	10.19±1.54^{a}	10.87±2.97^{a}	1.92±0.28^{a}	17.95±0.65^{b}
Fifth	93.03±1.29^{a}	6.96±1.46^{a}	1.11±0.32^{a}	6.62±1.31^{b}	74.58±3.06^{a}	10.72±0.41^{a}	11.17±2.33^{a}	2.30±0.72^{a}	42.00±7.10^{a}
Mean	93.67	6.68	1.33	8.45	73.86	9.69	10.70	2.53	22.66
CV (%)	0.84	27.01	18.23	14.02	2.16	11.74	26.99	34.62	17.98

		DM (g kg^{-1})			DM (mg kg^{-1})				
Cladode order	DM (%)	Ca	Mg	Na	S	Fe	Cu	Zn	Mn
Second	94.08±0.63^{a}	31.38±17.57^{a}	12.51±1.67^{b}	1.73±0.32^{a}	279.45±137.06^{b}	66.25±10.56^{b}	13.18±4.40^{b}	25.56±6.39^{a}	356.28±36.84^{a}
Third	93.86±0.54^{a}	46.62±11.53^{a}	15.77±2.19^{b}	1.60±0.62^{a}	510.48±1.40^{a}	98.36±6.42^{b}	35.56±8.80^{a}	33.56±11.31^{a}	377.29±69.08^{a}
Fourth	93.73±0.33^{a}	49.74±14.19^{a}	17.99±0.95^{a}	2.07±0.55^{a}	54.92±18.18^{c}	134.34±12.30^{a}	17.93±3.82^{b}	37.87±13.35^{a}	381.48±108.79^{a}
Fifth	93.03±1.29^{a}	44.65±8.82^{a}	19.94±2.10^{a}	2.27±0.47^{a}	91.23±54.39^{c}	168.77±54.30^{a}	28.51±7.87^{a}	31.98±7.41^{a}	359.87±13.25^{a}
Mean	93.67	43.10	16.55	1.92	234.02	116.93	23.80	32.24	368.73
CV (%)	0.84	31.15	10.86	26.35	31.74	24.39	27.67	31.09	18.26

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, MM: Mineral matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Na: Sodium, S: Sulfur, Fe: Iron, Cu: Copper, Zn: Zinc, Mn: Manganese, Means±Standard Deviation (n = 3), means followed by the same letter in the column do not differ statistically from each other. The Scott-Knott test was applied at 5% probability

Table 6: Chemical and bromatological composition of second, third, fourth, fifth, sixth and seventh-order cladodes cactus pear, variety IPA-200021

		DM (%)					DM (g kg^{-1})		
Cladode order	DM (%)	CP	EE	CF	NFE	MM	N	P	K
Second	93.45±0.59^{a}	6.29±1.33^{a}	1.64±0.38^{a}	13.71±5.98^{a}	69.21±5.36^{a}	9.16±2.56^{a}	10.07±2.15^{a}	4.56±0.27^{a}	32.75±11.55^{a}
Third	92.76±1.62^{a}	5.88±2.03^{a}	1.33±0.35^{a}	10.21±4.23^{a}	73.02±4.96^{a}	9.56±1.83^{a}	11.20±1.00^{a}	2.88±1.37^{a}	22.10±15.37^{a}
Fourth	94.40±0.50^{a}	6.64±1.31^{a}	1.82±0.09^{a}	9.22±1.70^{a}	71.84±3.82^{a}	10.49±0.90^{a}	10.60±2.10^{a}	4.04±2.14^{a}	20.55±4.75^{a}
Fifth	94.15±0.36^{a}	6.51±0.85^{a}	1.59±0.25^{a}	7.99±0.38^{a}	73.91±1.86^{a}	10.02±0.38^{a}	10.40±1.40^{a}	2.71±1.02^{a}	18.60±5.40^{a}
Sixth	93.82±0.74^{a}	7.40±0.85^{a}	1.99±0.16^{a}	7.51±0.18^{a}	50.01±22.71^{b}	11.93±0.69^{a}	11.85±1.35^{a}	2.55±0.73^{a}	24.70±6.20^{a}
Seventh	93.62±0.01^{a}	8.14±0.01^{a}	1.33±0.01^{a}	6.40±0.01^{a}	30.48±0.01^{c}	10.93±0.01^{a}	13.00±0.01^{a}	2.67±0.01^{a}	18.70±0.01^{a}
Mean	93.70	6.81	1.62	9.17	61.41	10.35	11.19	3.24	22.90
CV (%)	0.86	18.05	15.17	33.52	16.11	13.29	13.58	35.87	38.23

		DM (g kg^{-1})			DM (mg kg^{-1})				
Cladode order	DM (%)	Ca	Mg	Na	S	Fe	Cu	Zn	Mn
Second	93.45±0.59^{a}	51.28±13.14^{a}	14.75±3.84^{a}	1.90±0.20^{a}	73.68±0.03^{d}	169.02±44.15^{a}	26.93±8.25^{a}	26.64±7.14^{a}	128.62±48.79^{b}
Third	92.76±1.62^{a}	21.46±6.86^{b}	13.28±1.64^{a}	1.67±0.23^{a}	246.49±18.69^{d}	201.61±24.47^{a}	29.82±9.51^{a}	29.25±3.08^{a}	212.76±98.57^{b}
Fourth	94.40±0.50^{a}	38.36±2.53^{a}	14.35±0.02^{a}	1.50±0.10^{a}	542.86±469.81^{c}	200.14±85.38^{a}	24.75±2.51^{a}	36.39±10.15^{a}	281.58±118.53^{b}
Fifth	94.15±0.36^{a}	42.52±8.24^{a}	15.88±0.65^{a}	2.65±1.45^{a}	893.40±94.55^{b}	113.81±13.82^{b}	25.01±11.78^{a}	32.43±8.41^{a}	313.07±81.27^{b}
Sixth	93.82±0.74^{a}	45.57±0.44^{a}	14.81±0.42^{a}	2.40±0.30^{a}	1,298.10±81.29^{a}	122.65±21.85^{b}	27.95±9.76^{a}	34.36±2.45^{a}	618.17±222.40^{a}
Seventh	93.62±0.01^{a}	44.22±0.01^{a}	14.74±0.01^{a}	2.00±0.01^{a}	1,246.37±0.01^{a}	100.40±0.01^{b}	15.38±0.01^{a}	32.58±0.01^{a}	378.75±0.01^{b}
Mean	93.70	40.57	14.64	2.02	716.82	151.27	24.97	31.94	322.16
CV (%)	0.86	17.26	11.85	30.63	27.70	27.66	32.65	19.81	36.34

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, MM: Mineral matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Na: Sodium, S: Sulfur, Fe: Iron, Cu: Copper, Zn: Zinc, Mn: Manganese, Means±Standard Deviation (n = 3), means followed by the same letter in the column do not differ statistically from each other. The Scott-Knott test was applied at 5% probability

197.99±0.01 mg kg^{-1} DM), Cu (14.70±1.26 to 39.65±0.01 mg kg^{-1} DM), Zn (34.70±9.93 to 81.14±0.01 mg kg^{-1} DM) and Mn (102.50±26.32 to 537.40±0.01 mg kg^{-1} DM) (Table 4).

In the variety IPA-100004, we verified differences between the order of the cladodes for CF (6.62±1.31 to 12.43±1.69% DM), K (10.65±0.05 to 42.00±7.10 g kg^{-1} DM), Mg (12.51±1.67 to 19.94±2.10 g kg^{-1} DM), S (54.92±18.18 to 510.48±1.40 mg kg^{-1} DM), Fe (66.25±10.56 to 168.77±54.30 mg kg^{-1} DM) and Cu (13.18±4.40 to 35.56±8.80 mg kg^{-1} DM) (Table 5).

In the IPA-200021, disparity between cladodes was found for NFE (30.48±0.01 to 73.91±1.86% DM), Ca (21.46±6.86 to 51.28±13.14 g kg^{-1} DM), S (73.68±0.03 to 1,298.10±81.29 mg kg^{-1} DM), Fe (100.40±0.01 to 201.61±24.47 mg kg^{-1} DM) and Mn (128.62±48.79 to 618.17±222.40 mg kg^{-1} DM) (Table 6).

Table 7: Chemical and bromatological composition of second and third-order cladodes of cactus pear, variety IPA-200205

		DM (%)					DM (g kg^{-1})		
Cladode order	DM (%)	CP	EE	CF	NFE	MM	N	P	K
Second	93.72±0.34^{a}	6.09±1.72^{a}	1.09±0.11^{a}	7.15±1.82^{a}	78.05±4.34^{a}	7.62±1.47^{a}	9.73±2.76^{a}	2.24±0.29^{a}	4.65±1.95^{b}
Third	92.49±0.54^{b}	6.07±0.63^{a}	1.20±0.35^{a}	7.59±1.41^{a}	76.70±3.21^{a}	8.44±1.44^{a}	9.70±0.96^{a}	2.05±0.56^{a}	33.65±8.05^{a}
Mean	93.11	6.08	1.15	7.37	77.38	8.03	9.72	2.15	19.15
CV (%)	0.49	21.28	22.65	22.05	4.93	18.09	21.27	20.81	30.58
		DM (g kg^{-1})			DM (mg kg^{-1})				
Cladode order	DM (%)	Ca	Mg	Na	S	Fe	Cu	Zn	Mn
Second	93.72±0.34^{a}	29.70±1.06^{a}	13.55±0.86^{a}	2.05±0.85^{a}	36.68±0.00^{b}	196.44±87.28^{a}	19.87±3.51^{b}	40.31±23.33^{a}	704.57±3.91^{a}
Third	92.49±0.54^{b}	32.58±16.53^{a}	17.22±2.59^{a}	1.50±0.61^{a}	185.59±64.47^{a}	208.21±90.75^{a}	31.98±2.30^{a}	34.22±4.11^{a}	205.19±44.46^{b}
Mean	93.11	31.14	15.39	1.78	111.14	202.32	25.92	37.27	454.88
CV (%)	0.49	37.62	12.53	41.64	41.02	44.01	11.44	44.94	6.94

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, MM: Mineral matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Na: Sodium, S: Sulfur, Fe: Iron, Cu: Copper, Zn: Zinc, Mn: Manganese, Means±Standard Deviation (n = 3), means followed by the same letter in the column do not differ statistically from each other. The Scott-Knott test was applied at 5% probability

Table 8: Chemical and bromatological composition of second, third and fourth-order cladodes of cactus pear, variety IPA-200149

		DM (%)					DM (g kg^{-1})		
Cladode order	DM (%)	CP	EE	CF	NFE	MM	N	P	K
Second	93.02±0.80^{a}	7.03±1.97^{a}	1.61±0.19^{a}	8.37±0.31^{a}	74.38±1.33^{b}	8.60±0.87^{a}	11.27±3.16^{a}	2.69±0.58^{a}	7.35±0.65^{c}
Third	92.70±1.07^{a}	6.98±1.45^{a}	1.20±0.34^{b}	7.29±0.69^{b}	74.34±1.34^{b}	10.19±1.83^{a}	11.20±2.33^{a}	2.63±0.71^{a}	10.70±2.70^{b}
Fourth	93.19±0.01^{a}	5.03±0.01^{a}	1.04±0.01^{b}	6.03±0.01^{c}	79.33±0.01^{a}	8.57±0.01^{a}	8.00±0.01^{a}	2.36±0.01^{a}	24.10±0.01^{a}
Mean	92.97	6.35	1.28	7.23	76.02	9.12	10.16	2.56	14.05
CV (%)	0.83	22.23	17.60	6.03	1.44	12.85	22.33	20.69	11.41
		DM (g kg^{-1})			DM (mg kg^{-1})				
Cladode order	DM (%)	Ca	Mg	Na	S	Fe	Cu	Zn	Mn
Second	93.02±0.80^{a}	25.72±7.51^{a}	15.19±2.26^{a}	2.10±0.60^{a}	490.75±221.28^{b}	120.47±0.58^{a}	27.02±12.42^{a}	68.52±20.15^{a}	323.54±179.74^{a}
Third	92.70±1.07^{a}	30.93±9.27^{a}	14.73±3.28^{a}	1.40±0.53^{a}	735.89±39.36^{a}	89.07±0.01^{c}	33.59±8.57^{a}	52.41±12.02^{a}	501.50±193.96^{a}
Fourth	93.19±0.01^{a}	28.01±0.01^{a}	12.45±0.01^{a}	1.90±0.01^{a}	957.49±0.01^{a}	105.27±0.01^{a}	9.01±0.01^{b}	39.27±0.01^{a}	523.98±0.01^{a}
Mean	92.97	28.22	14.13	1.80	728.04	104.94	23.21	53.40	449.67
CV (%)	0.83	24.40	16.26	25.66	17.82	0.32	37.54	25.37	33.95

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, MM: Mineral matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Na: Sodium, S: Sulfur, Fe: Iron, Cu: Copper, Zn: Zinc, Mn: Manganese, Means±Standard Deviation (n = 3), means followed by the same letter in the column do not differ statistically from each other. The Scott-Knott test was applied at 5% probability

In the variety IPA-200205, diversity was recorded between cladodes for DM (6.28±0.34 to 7.51±0.54%), K (4.65±1.95 to 33.65±8.05 g kg^{-1} DM), S (36.68±0.00 to 185.59±64.47 mg kg^{-1} DM), Cu (19.87±3.51 to 31.98±2.30 mg kg^{-1} DM) and Mn (205.19±44.46 to 704.57±3.91 mg kg^{-1} DM) (Table 7).

In the variety IPA-200149, differences were noted between the cladodes for EE (1.04±0.01 to 1.61% ±0.19 DM), CF (6.03±0.01 to 8.37±0.31% DM), NFE (74.34±1.34 to 79.33±0.01% DM), K (7.35±0.65 to 24.10±0.01 g kg^{-1} DM), S (490.75±221.28 to 957.49±0.01 mg kg^{-1} DM), Fe (89.07±0.01 to 120.47±0.58 mg kg^{-1} DM) and Cu (9.01±0.01 to 33.59±8.57 mg kg^{-1} DM) (Table 8).

The contents of proteins and mineral matter (nitrogen, potassium, calcium, magnesium, sulfur, iron, copper, zinc and manganese) have a tendency to be higher in younger cladodes, in the development phase. The content of ether extract, nitrogen-free extract, crude fiber, phosphorus and sodium tends to be lower in younger cladodes. However, the content of nutrients analyzed do not present a defined accumulation pattern between the orders of cladodes among varieties.

Contreras-Padilla *et al.*[13], Hernandez-Urbiola *et al.*[14], Ribeiro *et al.*[15] and Rodriguez-Garcia *et al.*[16] in the study of the chemical composition of cladodes of cactus pear (*Opuntiaficus indica*), report an increase in the content of total carbohydrates, protein, crude fiber and mineral material (P, Ca and Fe) with the age of the cladodes. However, the researchers mentioned reductions in the total fat content with the age of cladodes. Saenz[17] reported that the protein content and ash are higher in younger cladodes and the fiber and fat contents are lower in these cladodes, corroborating our results.

The result for the minerals and nitrogen-free extract was expected, given that excess of nutrients and photosynthates (products of photosynthesis) are translocated from the absorption or production areas (mature tissue) to growing areas with active (young tissues) or storage metabolism[18].

The mineral materials N, P, K, Mg, S, Fe, Cu, Zn and Mn are found in all plant tissues, including the phloem and can be redistributed from older to younger tissues[18-20]. However, Ca, S and Fe tend to be concentrated in older tissues, because of their low mobility in the phloem and because they are part of the structure of various molecules[18].

Redistribution (mobility or remobilization) of mineral nutrients or photosynthates from mature tissues to growing or storage areas is essential for the life cycle of the plant. The dynamics of nutrients in plants varies according to the species, age, phenological stage of the organ, soil and climatic conditions, management practices adopted, etc. Throughout the life cycle, the content of some nutrients in shoots increases, while the content of other nutrients decreases, leading to translocation of elements from senescent organs to growing regions of the plants, such as young tissues and reproductive structures[19,20]. Therefore, the wide variation in the concentration of some nutrients between the orders of cladodes of varieties of cactus pear.

Vegetable crude fiber consists mainly of cellulose, hemicellulose and lignin components, found in high concentrations in the cell walls of plants[10]. Therefore, its low value in young tissues compared to fully mature tissues.

The older cladodes have CO_2 assimilating surfaces greater than cladodes in development and are responsible for the greater production of photosynthates and distribution of nutrients and water to the other organs[21]. The sodium and phosphorus content probably tends to be higher in those cladodes, given that they are important nutrients in photosynthetic processes of CAM plants (Crassulacean acid metabolism). The first, for acting in the recomposition of phosphoenol pyruvate and the second, for participating in the transport and transduction of chemical energy (ATP and NADPH)[18,19]. Even though Na^+ is an essential element for cactus pear, the excess of this ion is harmful to its growth and development[22,23]. Thus, plants tend to retain this ion in older tissues, avoiding its translocation to young tissues more sensitive to salt stress[24,25].

The ether extract or crude fat is composed mainly of lipids, organic acids, alcohol and pigments. The nitrogen-free extract consists of starch and sugars. These two classes of nutrients are the reserve substances of energy and carbon that plants use to make their biochemical and physiological processes. Furthermore, both lipids and starch are transformed into sucrose, which is transported by the phloem to the drain heterotrophic tissues (growing or storagetissues)[18].

The accumulation of carbohydrates and lipids in mature tissues is an adaptation of cactus pear for survival in environments where water availability is a limiting factor to plant growth and development. The plants use these nutrients as an energy source during periods of water or saline stress. Furthermore, accumulation of carbohydrates (sucrose, hexose and polyhydric alcohols) acts as osmoprotectors during water deficit, reducing the harmful effects of osmotic stress, helping in the maintenance of turgor, stabilization of cell membranes and protection against cell degradation caused by Reactive Oxygen Species (ROS)[26].

Analyzing the accumulation of nutrients among the cactus pear varieties in the second and third cladodes, weobserved variation in the results in relation to the order of the analyzed cladode. When the second-order cladodewas analyzed, there were no significant differences among varieties for DM, CP, EE, CF, NFE, MM, N and Mg. However, differences were observed among genotypes for P (2.24 ± 0.29 to 4.56 ± 0.27 g kg^{-1} DM), K (4.65 ± 1.95 to 32.75 ± 11.15 g kg^{-1} DM), Ca (25.72 ± 7.51 to 51.28 ± 13.14 g kg^{-1} DM), Na (1.50 ± 0.30 to 2.90 ± 0.70 g kg^{-1} DM), S (36.67 ± 0.22 to $1{,}315.59\pm414.35$ mg kg^{-1} DM), Fe (59.38 ± 8.28 to 196.44 ± 87.28 mg kg^{-1} DM), Cu (13.18 ± 4.40 to 33.15 ± 5.02 mg kg^{-1} DM), Zn (19.19 ± 7.68 to 68.52 ± 20.15 mg kg^{-1} DM) and Mn (102.50 ± 26.32 to 704.57 ± 3.91 mg kg^{-1} DM) (Table 9).

When the third-order cladode was studied, no significant difference was observed among genotypes for CP, EE, CF, NFE, MM, N, P, Ca, Mg and Na. However, significant differences were observed among genotypes for DM (5.97 ± 0.61 to 7.57 ± 1.20%), K (10.70 ± 2.70 to 33.90 ± 5.80 g kg^{-1} DM), S (185.59 ± 64.47 to 735.89 ± 39.36 mg kg^{-1} DM), Fe (71.99 ± 8.58 to 208.21 ± 90.75 mg kg^{-1} DM), Cu (14.70 ± 1.26 to 35.85 ± 0.23 mg kg^{-1} DM), Zn (22.09 ± 1.88 to 57.33 ± 19.44 mg kg^{-1} DM) and Mn (139.47 ± 23.40 to 540.45 ± 94.99 mg kg^{-1} DM) (Table 10).

The results highlight differences in the chemical and nutritional content between varieties and order of the analyzed cladode within each genotype. The content of nutrients varied: DM (5.60 ± 0.50 to 7.57 ± 1.20%), CP (5.03 ± 0.01 to 9.13 ± 0.64% DM), EE (0.78 ± 0.01 to 1.99 ± 0.16% DM), CF (6.03 ± 0.01 to 14.43 ± 7.34% DM), NFE (30.48 ± 0.01 to 79.33 ± 0.01% DM), MM (7.62 ± 1.47 to

Table 9: Chemical and bromatological composition of the secondary cladodes of cactus pear varieties, genera *Opuntia* and *Nopalea*

		DM (%)					DM (g kg^{-1})		
Varieties	DM (%)	CP	EE	CF	NFE	MM	N	P	K
IPA-100003	93.95±0.16^{a}	6.02±0.47^{a}	1.79±0.26^{a}	10.98±2.97^{a}	72.95±5.45^{a}	8.27±2.28^{a}	9.63±0.78^{a}	3.09±0.31^{b}	19.30±6.00^{b}
IPA-200016	93.60±0.60^{a}	6.60±1.76^{a}	1.31±0.18^{a}	9.54±0.66^{a}	72.97±1.40^{a}	9.57±1.08^{a}	12.05±1.05^{a}	2.28±0.78^{b}	5.35±1.35^{c}
IPA-200008	93.80±0.55^{a}	7.72±1.18^{a}	1.10±0.36^{a}	14.43±7.34^{a}	68.90±6.14^{a}	7.86±1.19^{a}	12.33±1.91^{a}	2.27±0.38^{b}	14.20±2.00^{c}
IPA-100004	94.08±0.63^{a}	6.47±2.16^{a}	1.46±0.30^{a}	12.43±1.69^{a}	71.69±5.24^{a}	7.96±1.61^{a}	10.37±3.42^{a}	3.16±1.28^{b}	10.65±0.05^{c}
IPA-200021	93.45±0.59^{a}	6.29±1.33^{a}	1.64±0.38^{a}	13.71±5.98^{a}	69.21±5.36^{a}	9.16±2.56^{a}	10.07±2.15^{a}	4.56±0.27^{b}	32.75±11.15^{c}
IPA-200205	93.72±0.34^{a}	6.09±1.72^{a}	1.08±0.11^{a}	7.15±1.82^{a}	78.05±4.34^{a}	7.62±1.47^{a}	9.73±2.76^{a}	2.24±0.29^{b}	4.65±1.95^{c}
IPA-200149	93.02±0.80^{a}	7.03±1.97^{a}	1.61±0.19^{a}	8.37±0.31^{a}	74.38±1.33^{a}	8.60±0.87^{a}	11.27±3.16^{a}	2.68±0.58^{b}	7.35±0.65^{c}
Mean	93.66	6.60	1.43	10.94	72.59	8.43	10.78	2.90	13.46
CV (%)	0.31	23.11	19.86	32.85	6.21	12.37	21.94	23.55	35.71

		DM (g kg^{-1})			DM (mg kg^{-1})				
Varieties	DM (%)	Ca	Mg	Na	S	Fe	Cu	Zn	Mn
IPA-100003	93.95±0.16^{a}	29.69±1.22^{b}	13.80±3.27^{a}	2.90±0.50^{a}	72.99±0.12^{c}	79.10±12.05^{b}	21.54±3.92^{b}	52.65±13.51^{a}	375.99±90.33^{b}
IPA-200016	93.60±0.60^{a}	41.64±7.20^{a}	13.61±0.61^{a}	1.50±0.30^{b}	36.67±0.22^{c}	72.85±4.83^{b}	30.24±3.14^{a}	19.19±7.68^{b}	228.56±29.92^{c}
IPA-200008	93.80±0.55^{a}	40.43±6.45^{a}	9.95±1.82^{a}	2.90±0.70^{a}	1,315.59±414.35^{a}	59.38±8.28^{b}	33.15±5.02^{a}	34.70±9.93^{b}	102.50±26.32^{c}
IPA-100004	94.08±0.63^{a}	31.38±17.57^{b}	12.51±1.67^{a}	1.73±0.32^{b}	279.45±137.06^{b}	66.25±10.56^{b}	13.18±4.40^{b}	25.56±6.39^{b}	356.28±36.84^{b}
IPA-200021	93.45±0.59^{a}	51.28±13.14^{a}	14.75±3.84^{a}	1.90±0.20^{b}	73.68±0.03^{c}	169.02±44.14^{a}	26.93±8.25^{a}	26.64±7.14^{b}	128.62±48.79^{c}
IPA-200205	93.72±0.34^{a}	29.70±1.06^{b}	13.55±0.86^{a}	2.05±0.85^{b}	36.68±0.00^{c}	196.44±87.28^{a}	19.87±3.51^{b}	40.31±23.33^{b}	704.57±3.91^{a}
IPA-200149	93.02±0.80^{a}	25.72±7.51^{b}	15.19±2.26^{a}	2.10±0.60^{b}	490.75±221.28^{b}	120.47±0.58^{b}	27.02±12.42^{a}	68.52±20.15^{a}	323.54±179.74^{b}
Mean	93.66	35.69	13.34	2.15	329.40	109.07	24.56	38.23	317.15
CV (%)	0.31	24.76	12.97	24.43	49.28	35.77	24.87	38.29	24.45

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, MM: Mineral matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Na: Sodium, S: Sulfur, Fe: Iron, Cu: Copper, Zn: Zinc, Mn: Manganese, Means±Standard Deviation (n = 3), means followed by the same letter in the column do not differ statistically from each other. The Scott-Knott test was applied at 5% probability

Table 10: Chemical and bromatological composition of tertiary cladodes of cactus pear varieties, genera *Opuntia* and *Nopalea*

		DM (%)					DM (g kg^{-1})		
Varieties	DM (%)	CP	EE	CF	NFE	MM	N	P	K
IPA-100003	93.82±0.64^{a}	6.81±1.22^{a}	1.82±0.11^{a}	9.84±2.52^{a}	71.09±3.27^{a}	10.44±1.41^{a}	10.87±1.95^{a}	2.81±0.14^{a}	13.25±0.05^{b}
IPA-200016	92.43±1.20^{b}	9.13±0.64^{a}	1.15±0.45^{a}	7.85±0.77^{a}	72.83±1.35^{a}	9.05±0.98^{a}	14.60±1.04^{a}	2.38±0.27^{a}	15.00±4.20^{b}
IPA-200008	94.03±0.61^{a}	6.84±1.62^{a}	1.00±0.30^{a}	10.76±3.69^{a}	69.99±4.05^{a}	11.40±0.77^{a}	10.97±2.61^{a}	2.41±0.70^{a}	33.90±5.80^{a}
IPA-100004	93.86±0.54^{a}	6.49±1.68^{a}	1.51±0.12^{a}	7.85±0.77^{a}	74.26±2.05^{a}	9.88±0.23^{a}	10.40±2.72^{a}	2.73±0.91^{a}	20.05±3.95^{b}
IPA-200021	92.76±1.62^{b}	5.88±2.03^{a}	1.33±0.35^{a}	10.21±4.23^{a}	73.02±4.96^{a}	9.56±1.83^{a}	11.20±1.00^{a}	2.88±1.37^{a}	22.10±15.37^{b}
IPA-200205	92.49±0.54^{b}	6.07±0.63^{a}	1.20±0.35^{a}	7.59±1.41^{a}	76.70±3.21^{a}	8.44±1.44^{a}	9.70±0.96^{a}	2.05±0.56^{a}	33.65±8.05^{a}
IPA-200149	92.70±1.07^{b}	6.98±1.45^{a}	1.20±0.34^{a}	7.29±0.69^{a}	74.34±1.34^{a}	10.19±1.83^{a}	11.20±2.33^{a}	2.63±0.71^{a}	10.70±2.70^{b}
Mean	93.16	6.89	1.32	8.77	73.18	9.85	11.28	2.56	21.24
CV (%)	0.88	19.42	23.32	26.21	4.21	12.36	16.52	28.05	34.97

		DM (g kg^{-1})			DM (mg kg^{-1})				
Varieties	DM (%)	Ca	Mg	Na	S	Fe	Cu	Zn	Mn
IPA-100003	93.82±0.64^{a}	33.12±4.88^{a}	15.06±0.87^{a}	2.27±1.26^{a}	401.91±256.55^{c}	71.99±8.58^{b}	28.99±155.22^{a}	46.86±9.78^{a}	540.45±94.99^{a}
IPA-200016	92.43±1.20^{b}	38.51±6.40^{a}	13.49±1.36^{a}	1.63±0.85^{a}	423.53±125.67^{c}	139.64±47.15^{b}	35.85±0.23^{a}	22.09±1.88^{b}	512.53±27.70^{a}
IPA-200008	94.03±0.61^{a}	51.20±4.03^{a}	17.47±3.04^{a}	2.73±1.10^{a}	399.93±36.00^{c}	79.39±16.59^{b}	14.70±1.26^{b}	57.33±19.44^{a}	139.47±23.40^{a}
IPA-100004	93.86±0.54^{a}	46.62±11.53^{a}	15.77±2.19^{a}	1.60±0.62^{a}	510.48±1.40^{b}	98.36±6.42^{b}	35.56±8.80^{a}	33.32±11.31^{b}	377.29±69.08^{a}
IPA-200021	92.76±1.62^{b}	21.46±6.86^{a}	13.27±1.64^{a}	1.67±0.23^{a}	246.49±18.69^{d}	201.61±24.47^{a}	29.82±9.51^{a}	29.25±3.08^{b}	212.76±98.57^{a}
IPA-200205	92.49±0.54^{b}	32.58±16.53^{a}	17.21±2.59^{a}	1.50±0.61^{a}	185.59±64.47^{d}	208.21±90.75^{a}	31.98±2.30^{a}	34.22±4.11^{b}	205.19±44.46^{a}
IPA-200149	92.70±1.07^{b}	30.93±9.27^{a}	14.73±3.28^{a}	1.40±0.53^{a}	735.89±39.36^{a}	89.07±0.01^{b}	33.59±8.57^{a}	52.40±12.02^{a}	501.50±193.96^{a}
Mean	93.16	36.35	15.29	1.83	414.83	126.90	30.07	39.39	355.60
CV (%)	0.88	25.52	15.39	44.98	27.09	30.77	18.11	27.94	23.50

DM: Dry matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen-free extract, MM: Mineral matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Na: Sodium, S: Sulfur, Fe: Iron, Cu: Copper, Zn: Zinc, Mn: Manganese, Means±Standard Deviation (n = 3), means followed by the same letter in the column do not differ statistically from each other. The Scott-Knott test was applied at 5% probability

13.05±0.01% DM), N (8.00±0.01 to 14.60±1.04 g kg^{-1} DM), P (1.92±0.28 to 4.56±0.27 g kg^{-1} DM), K (4.65±1.95 to 42.00±7.10 g kg^{-1} DM), Ca (21.46±6.86 to 62.75±0.01 g kg^{-1} DM), Mg (9.95±1.82 to 22.02±0.01 g kg^{-1} DM), Na (1.40±0.53 to 2.90±0.70 g kg^{-1} DM), S (36.67±0.22 to

1,315.59±414.35 mg kg^{-1} DM), Fe (59.38±8.28 to 208.21±90.75 mg kg^{-1} DM), Cu (9.01±0.01 to 39.65±0.01 mg kg^{-1} DM), Zn (19.19±7.68 to 81.14±0.01 mg kg^{-1} DM) and Mn (102.50±26.32 to 704.57±3.91 mg kg^{-1} DM). These values are consistent with those reported in the literature for cactus pear, with the exception of S, whose value varied from 1,500-5,100 mg kg^{-1} DM[27-32].

The chemical components of plants have a wide variation, both in composition and in content and vary between species and within species. Factors contributing to this difference in genera *Opuntia* and *Nopalea* are genetic, environmental growth conditions, soil, cultivation, collection period, stress, age of the plants, order of analyzed cladode, analyzed tissues, form of material collection, cladode drying temperature, extraction methods and differences in methodologies used in determinations[14,15,33,34].

The cactus pear cladodes have a high quality in terms of nutritional and functional properties. Thus, the results of this study can help in future breeding programs of cactus pear for nutritional and nutraceutical characteristics. In addition, this study contributes significantly as reference material for quality certification of fodder for animals and palm food and products for human consumption, because the addition of cactus pear cladodes as an ingredient for functional foods would have economic and health benefits for populations living in arid and semi-arid regions. Additional studies need to be done in order to identify and quantify chemical compounds present in the varieties at different times of the year.

CONCLUSION

The varieties of cactus pear IPA-100003, IPA-200016, IPA-200008, IPA-100004, IPA-200021, IPA-200205 and IPA-200149 have genetic variability in the chemical and nutritional content, both among genotypes and in the order of cladodes within the genotype.

The contents of protein and nutrients (nitrogen, potassium, calcium, magnesium, sulfur, iron, copper, zinc and manganese) tend to be higher in younger cladodes, at the development phase. The ether extract, nitrogen-free extract, crude fiber, phosphorus and sodium tend to be higher in mature cladodes.

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