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Chemical characterization of *Opuntia dillenii* and *Opuntia ficus indica* fruits

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Abstract

The chemical compositions (moisture, °Brix, total fibre, protein, fat, ash, pH, acidity, ascorbic acid, total phenolics, Na, K, Ca, Mg, Fe, Cu, Zn, Mn, Ni and Cr) were determined in fruits belonging to two species of prickly pear, *Opuntia ficus indica* and *Opuntia dillenii*, from Tenerife Island. The chemical compositions of the two species were clearly different. However, no important differences were observed between orange and green prickly pears within the specie *O. ficus indica*. An important contribution to the intakes of fibre, ascorbic acid, Mn, Cr and total phenolics is provided by the consumption of prickly pears, particularly from fruits of *O. dillenii*. Applying factor and/or discriminant analysis, the prickly pear samples were differentiated according to the species, altitude and region of cultivation in the island.

Keywords: Prickly pear; Chemical composition; Nutrient intake; Multivariate analysis; Tenerife island

1. Introduction

The species of the genus *Opuntia* proceeded from Central America (east coast of Mexico) and were brought to Cadiz (Spain) in 1820. The introduction to the Canary Islands took place in 1824, where its cultivation became widespread in areas with a semi-arid bioclime (150–200 mm median annual precipitation). In the island of Tenerife, these plants are especially found in the southern part of the island, mixed with typical vegetation, such as succulent endemic species. There are several species belonging to the genus *Opuntia* (Fam. Cactaceae) described in the Canary Islands: *O. ficus indica*, *O. dillenii* (Ker-Gawl), *O. robusta*, *O. tormentosa* and *O. tuna*. The first two are the most important since they exist in all the islands, and their production is the greatest (Pérez de Paz & Medina Medina, 1988; Pérez de Paz & Hernández Padrón, 1999).

The plants of the genus *Opuntia* have been used for several purposes. (1) production of carminic acid; (2) food use; (3) functional properties; (4) other uses. In relation to the production of carminic acid, this acid is extracted, after milling and desiccation, from the females of a parasite worm named ‘‘cochinilla’’, which grows on the surface of the succulent branches of these plants. The red carmin or grana colorant is used in the food industry, in accordance with the European law, as (E-120). In the 19th century, the production of carminic acid represented 90% of total exports from the Canary Islands. The production has decreased considerably since the 1980s as a result of the production of synthetic colorants, which are cheaper. However, an increase in the demand for these natural colorants has grown in recent years, and therefore the perspectives for its production are better. Two parts of the plant have been used as food, the fruits or the prickly pears and the ‘‘nopal’’. The prickly pears can be consumed fresh, after desiccation in sun, or in marmalades. The nopal is consumed in Mexican regions as a constituent of salads. In the Canary Islands, there is hardly any consumption of one prickly pear, *O. dillenii*, due to its acidic taste and the presence of

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a large number of seeds. The fruit of the prickly pear *O. ficus indica*, is mainly consumed as fresh fruit.

In the Canary Islands, the ripe fruit of *O. dillenii* has been used in folk medicine as an unrefined antidiabetic drug (Pérez de Paz & Medina Medina, 1988; Pérez de Paz & Hernández Padrón, 1999). Scientific studies have indicated that several parts of the species *O. ficus indica* have diuretic and antigotous effects (Galati, Tripodo, Trovato, Miceli, & Monforte, 2002b). The fruits of both species, *O. ficus indica* and *O. dillenii*, have antinflammatory and analgesic effects (Loro, del Rio, & Pérez-Santana, 1999; Park, Kahng, Lee, & Shin, 2001). Antiulcerous effects have been demonstrated in the nopal of *O. ficus indica* (Galati, Monforte, Tripodo, d'Aquino, & Mondello, 2001; Galati, Pergolizzi, Miceli, Monforte, & Tripodo, 2002a; Lee, Hyun, Li, & Moon, 2002). Moreover, antihyperglycemic and hypocholesterolemic effects have been attributed to the "nopal" of *O. ficus indica* (Frati, Jiménez, & Ariza, 1990; Cárdenas Medellín, Serna Saldívar, & Velazco de la Garza, 1998) and the fruits of *O. dillenii* (Roman-Ramos, Flores-Saenz, & Alarcon-Aguilar, 1995; Perfumi & Tacconi, 1996).

In this paper, we determined the chemical composition of the fruit of *O. dillenii* and *O. ficus indica.* The contributions to the human diet nutrient intakes as a result of the consumption of a serving of both species of prickly pear were estimated. In addition, applying multivariate analysis techniques, the prickly pears were classified according to the specie and pulp colour, altitude and region of production.

2. Materials and methods

2.1. Samples

Seventy fruit samples of prickly pear were analyzed: 12 belonging to the specie *O. dillenii* and 58 to *O. ficus indica*. These latter samples were divided according to the pulp colours, green ($n = 33$) and orange ($n = 25$). The sampling was carried out from different points on the island of Tenerife between August and December, 2002. The distribution of prickly pear samples according to the species and pulp colour is shown in Table 1. The region (north or south) and altitude (coast 0–300 m; medium 300–800 m; and high altitude >800 m) of the sampling points are also indicated.

Each sample was made up of 6–8 units of fruits, which were collected from several plants in the same sampling point. The samples were transported to the laboratory under refrigeration. The prickly pears were then weighed, before and after being peeled, to calculate the percentage of edible portion. Then, they were stored at −20 °C prior to the analysis.

Several portions of different fruits, after defrosting, were weighed and the seeds were separated, washed with water and dried at room temperature to calculate the percentage of seeds in the edible fraction. The rest of the analysis was carried out with peeled fruit, including the seeds. The analyses of ascorbic acid and total phenolics were carried out independently on two units of prickly pears. For the other analyses, three or four units of prickly pears were homogenized using a model T-25 Basic Turmix (Ika-Werke, Staufen, Germany), resulting in a prickly pear paste. This paste was divided into two fractions. One fraction was used for analyzing acidity, pH, moisture, ash, refraction index and °Brix. These analysis were carried out immediately, particularly the analysis of ascorbic acid and total phenolics. The other fraction was desiccated at 100 °C, and the dried extract was used for the determination of fat, proteins, fibre and minerals such as Na, K, Ca, Mg, Fe, Cu, Zn, Mn, Ni and Cr.

2.2. Analytical methods

Moisture was determined on three replicates by desiccation at 105 °C for 24 h, in accordance with the method described by the Association Official of Analytical Chemists (AOAC, 1990). Ash was determined by triplicate ashings of the residue of moisture determination at 550 °C for 24 h. The rest of the analyses were performed in duplicate. Ascorbic acid was determined by the dichlorophenol indophenol (DIP) titration procedure (AOAC, 1990). The ascorbic acid was previously extracted using an acetic acid and metaphosphoric acid solution. In this determination, a pink colour in the aqueous extract of *O. dillenii* was observed, which made difficult the observation of the endpoint of the titration. Therefore, a titration curve, representing the absorbance (520 nm) against the volume of DIP added, was constructed for each sample. Before the endpoint, the absorbance did not change with the volume

Table 1
Descriptions of the prickly pear samples according to species, pulp colour, altitude and region of production

		Weight (g/unit)	% edible portion	% of seeds	No total	Region of production		Altitude		
						North	South	Coast	Medium	High
O. dillenii	Total	40.3[a]	58.0[b]	10.6[b]	12	0	12	6	6	–
O. ficus indica	Total	98.2[b]	46.6[a]	5.6[a]	58	25	33	8	28	22
	Green pulp	100.3**	45.3*	5.9*	33	12	21	3	15	15
	Orange pulp	95.4*	48.5**	5.1*	25	13	12	5	13	7

Results in the same column with the same letter (*O. dillenii versus O. ficus indica*) or asterisk (green pulp *versus* orange pulp) were not significantly ($p < 0.05$) different.

of DIP added but, after the endpoint, a lineal increase of the absorbance was observed due to the excess of DIP (pink colour). The intersection of both defined lines indicates the endpoint of the titration.

Nitrogen concentration was obtained by applying the Kjeldahl method (AOAC, 1990), and the protein concentration was estimated using a nitrogen factor of 6.25. Total dietary fibre was determined according to the method proposed by Prosky et al. (1985). Fat was measured by extraction with petroleum ether using a Soxhlet apparatus (AOAC, 1990). The pH was determined by potentiometric measurement at 20 °C with a pH meter (AOAC, 1990). The acidity was determined by titration with 0.1 N NaOH to pH 8.1, expressing the results in g of anhydrous citric acid/100 g (AOAC, 1990). The °Brix and the refractive index were obtained by refractometric measurement at 20 °C in the juice. Contents of total phenolics were determined by Folin-Ciocalteu's reagent at 750 nm, expressing the results in mg of gallic acid/100 g. Portions of 0.5–1 g of prickly pear were weighed into polystyrene tubes and mixed with 10 ml of methanol/water mixture (50:50, v/v). An aliquot (1.0 ml) of this extract was mixed with 1.0 ml of Folin–Ciocalteu's reagent/water mixture (50:50, v/v), and then the procedure described by Kujala, Loponen, Klika, and Pihlaja (2000) was applied. The apparatus, reagents, solutions and methods for the determination of minerals and trace elements were similar to those described in a previous paper (Forster, Rodríguez Rodríguez, Darias Martín, & Díaz Romero, 2002).

2.3. Quality control

Methods were validated with certified reference material (CRM). The Rye CRM-381 was used for protein, fat, ash, total dietary fibre. Moisture was not certified. The recovery percentage ranged from 97.5% to 102%. The standard deviation percentage ranged from 0.68% to 5.62%. The ascorbic acid method used quality control samples which were spiked and checked with standards from Sigma. Spike recoveries and check standards for ascorbic acid were typically within ±3% of their true value.

Wheat flour reference material (ARC/CL3, LGC Deselaers) was used for metals, except for Mn, Ni and Cr. Quality control for both metals (Mn, Ni and Cr) was checked by using prickly pear samples spiked or not spiked with known amounts of Mn, Ni and Cr standards. The percent of recovery ranged from 84.5% to 102%. Coefficient of variations were always <5%, ranging between 2.9% and 4.8%. The contents of the metals in these samples were clearly higher than the detection and the determination limits observed. Therefore, the determinations are sufficiently accurate, precise and safe.

2.4. Statistics

All the statistics were performed by means of the SPSS version 12.0 software for Windows. The Kolmogorov–Smirnov's test was applied to verify whether the variables had a normal distribution ($p < 0.05$). When the statistical distribution was not normal, the variables were transformed by applying Naperian logarithms to convert them into a normal distribution. Mean values obtained for the variables studied in the different groups were compared by one-way ANOVA and *t*-test, assuming that there were significant differences among them when the statistical comparison gives $p < 0.05$. Simple linear and logarithmic correlation analysis was used to indicate a measure of the correlation and the strength of the relationship between two variables. Factor analysis, using principal components as the method of factor extraction, was employed to summarize information in a reduced number of factors. Linear discriminant analysis (LDA) was used to classify the samples according to several criteria or categories. Two processes would be applied in DA: (1) stepwise DA, that selected the quantitative variables that enhance discrimination of the groups established by the dependent variable and (2) introduction of all independent variables.

3. Results and discussion

Large differences were observed between the characteristics of the fruits belonging to both species. The fruit from *O. dillenii* weighed less ($p < 0.05$) and had a higher ($p < 0.05$) percentage of seeds and edible portion than the other specie (Table 1). The results (mean ± standard deviation) of the analyzed parameters for the two species of prickly pear studied, and differentiation of the samples according to the colour of the pulp within the specie *O. ficus indica*, are presented in Table 2. In relation to the chemical compounds analyzed, the fruit from *O. dillenii* had higher ($p < 0.05$) contents of fibre, fat, ash, acidity, ascorbic acid, total phenolics, Na, Ca, Mg, Mn and Cr, and lower values of °Brix, proteins, pH, K, Fe, Zn and Ni. When the two types of prickly pears, green and orange, belonging to the specie *O. ficus indica*, were compared, no significant differences were found between the mean values for most of the parameters. Only the green prickly pears presented higher ($p < 0.05$) pH, fibre and Mg concentrations and a lower ($p < 0.05$) percentage of edible portion and Ca than did the corresponding orange ones.

The mean consumption of prickly pears in the Canary population is very low, estimated at 2–3 g/person/day. But, there was a large segment (≈25%) of consumers who reflected that their daily consumption was above 100 g (edible portion of two average-sized units of prickly pear) (Serra-Majem, Armas Navarro, & Ribas Barba, 1999). Table 3 shows the contributions to the dietary daily intakes of protein, fibre, ascorbic acid, K, Mg, Mn and Cr from the consumption of one serving (150 g) of both species of prickly pear in relation to the recommended dietary intakes (RDI) for the Spanish population (Mataix, 1996). The contribution to the protein intake was low for both

Table 2
Chemical composition (mean ± standard deviation) for the prickly pears, *O. dillenii* and *O. ficus indica,* differentiating green and orange colour of pulp in *O. ficus indica*

	O. dillenii	*O. ficus indica*		
	Total	Total	Green pulp	Orange pulp
Moisture (%)	81.68 ± 2.42^{a}	82.27 ± 2.22^{a}	$82.01 \pm 2.55^{*}$	$82.61 \pm 1.68^{*}$
°Brix	10.35 ± 1.13^{a}	14.58 ± 2.39^{b}	$14.98 \pm 2.68^{*}$	$14.05 \pm 1.87^{*}$
Refractive index	1.3482 ± 0.0017^{a}	1.3546 ± 0.0036^{b}	$1.3552 \pm 0.0040^{*}$	$1.3538 \pm 0.0028^{*}$
Total fibre (%)	9.49 ± 1.51^{b}	5.37 ± 0.87^{a}	$5.65 \pm 0.94^{**}$	$4.86 \pm 0.42^{*}$
Protein (%)	0.52 ± 0.12^{a}	0.90 ± 0.26^{b}	$0.87 \pm 0.24^{*}$	$0.94 \pm 0.29^{*}$
Fat (%)	0.71 ± 0.19^{b}	0.50 ± 0.13^{a}	$0.48 \pm 0.14^{*}$	$0.53 \pm 0.11^{*}$
Ash (%)	0.437 ± 0.062^{b}	0.392 ± 0.085^{a}	$0.409 \pm 0.092^{*}$	$0.370 \pm 0.071^{*}$
pH	3.34 ± 0.11^{a}	6.32 ± 0.17^{b}	$6.39 \pm 0.13^{**}$	$6.22 \pm 0.17^{*}$
Acidity (g/100 g)	1.23 ± 0.272^{b}	0.078 ± 0.034^{a}	$0.072 \pm 0.032^{*}$	$0.086 \pm 0.035^{*}$
Ascorbic acid (mg/100 g)	29.7 ± 2.95^{b}	17.2 ± 4.43^{a}	$17.1 \pm 4.46^{*}$	$17.2 \pm 4.48^{*}$
Phenolics (mg/100 g)	117 ± 10^{b}	45.2 ± 7.4^{a}	$45.0 \pm 6.3^{*}$	$45.4 \pm 8.7^{*}$
Na (mg/kg)	153 ± 162^{b}	6.25 ± 8.22^{a}	$5.24 \pm 7.09^{*}$	$7.58 \pm 9.49^{*}$
K (mg/kg)	908 ± 251^{a}	1583 ± 328^{b}	$1595 \pm 305^{*}$	$1567 \pm 362^{*}$
Ca (mg/kg)	535 ± 187^{b}	263 ± 76^{a}	$244 \pm 73^{*}$	$288 \pm 75^{**}$
Mg (mg/kg)	454 ± 102^{b}	251 ± 57^{a}	$267 \pm 55^{**}$	$231 \pm 54^{*}$
Fe (mg/kg)	1.53 ± 0.31^{a}	1.98 ± 0.57^{b}	$2.00 \pm 0.50^{*}$	$1.95 \pm 0.67^{*}$
Cu (mg/kg)	0.334 ± 0.054^{a}	0.389 ± 0.095^{a}	$0.384 \pm 0.106^{*}$	$0.396 \pm 0.080^{*}$
Zn (mg/kg)	1.29 ± 0.49^{a}	2.05 ± 0.51^{b}	$2.04 \pm 0.53^{*}$	$2.07 \pm 0.49^{*}$
Mn (mg/kg)	5.09 ± 3.80^{b}	3.03 ± 1.58^{a}	$3.01 \pm 1.56^{*}$	$3.06 \pm 1.65^{*}$
Ni (mg/kg)	0.204 ± 0.082^{a}	0.285 ± 0.105^{b}	$0.298 \pm 0.121^{*}$	$0.268 \pm 0.079^{*}$
Cr (mg/kg)	0.144 ± 0.036^{b}	0.109 ± 0.036^{a}	$0.115 \pm 0.043^{*}$	$0.102 \pm 0.041^{*}$

Results in the same line with the same letter (*O. dillenii versus O. ficus indica*) or asterisk (green pulp *versus* orange pulp) were not significantly ($p < 0.05$) different.

Table 3
Contribution to daily dietary intake of several nutrients of the Spanish adult population for the consumption of a serving (150 g of edible portion) of *O. ficus indica* or *O. dillenii*

Nutrient	RDI[a] or MR[b] (mg/day)	*O. ficus indica*		*O. dillenii*	
		Intake (g/day)	% RDI or MR	Intake (g/day)	% RDI or MR
Protein (g/day)	54 (41)	1.35	2.5 (3.3)	0.78	1.4 (1.9)
Fibre (g/day)	>25	8.06	32.2	14.3	57.0
Ascorbic acid (mg/day)	60	25.8	43.0	44.6	74.3
Na (mg/day)[c]	500[b]	0.95	0.19	23.0	4.6
K (mg/day)[c]	2000[b]	237	11.9	136	6.8
Ca (mg/day)	800[a]	39.5	4.9	80.3	10.0
Mg (mg/day)	350 (330)[a]	37.7	10.8 (11.4)	68.1	19.5 (20.6)
Fe (mg/day)	10 (18)[a]	0.30	3.0 (1.7)	0.23	2.3 (1.3)
Cu (mg/day)[d]	0.9[a]	0.060	6.7	0.045	5.0
Zn (mg/day)	15[a]	0.32	2.1	0.20	1.3
Mn (mg/day)[d]	2.3 (1.8)[a]	0.45	19.6 (25.0)	0.77	33.3 (42.5)
Cr (μg/day)[d]	35[a]	16.4	46.7	21.6	61.7

Between brackets the data for women are indicated.
[a] RDI = Recommended daily intake.
[b] MR = Minimum requirements.
[c] Na and K (Food & Nutrition Board, 1989).
[d] Cu, Mn and Cr (Food & Nutrition Board, 2001).

species, and similar to those of other vegetable foods. The contribution to the intake of fibre was important, representing approximately 57% and 32% of the minimum recommended (25 g) when *O. dillenii* and *O. ficus indica* are consumed, respectively. The consumption of prickly pears, particularly of *O. dillenii*, can contribute significantly to the intake of antioxidant substances such as ascorbic acid and phenols. There is no recommended dietary intake (RDI) for phenolics. However, the American Cancer Society (Krebs-Smith, Cook, Subar, Cleveland, & Friday, 1995) has established 100 mg/day of flavonoids as an adequate amount for the prevention of cancer and degenerative illness. The consumption of one serving of *O. dillenii* represents an intake of ascorbic acid and total phenolics of 74% and 176%, respectively, of these recommendations or estimations of adequate intakes. If the other species,

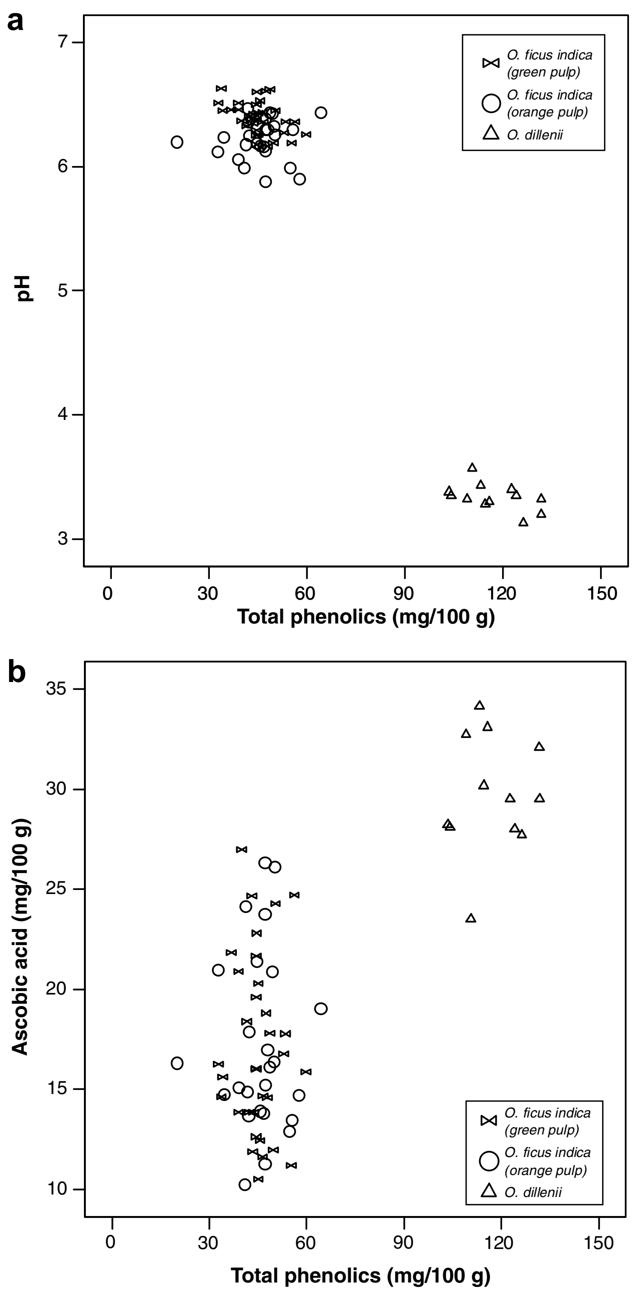

Fig. 1. Correlations between total phenolics and pH (a) and between total phenolics and ascorbic acid (b) differentiating the prickly pears according to the species and pulp color.

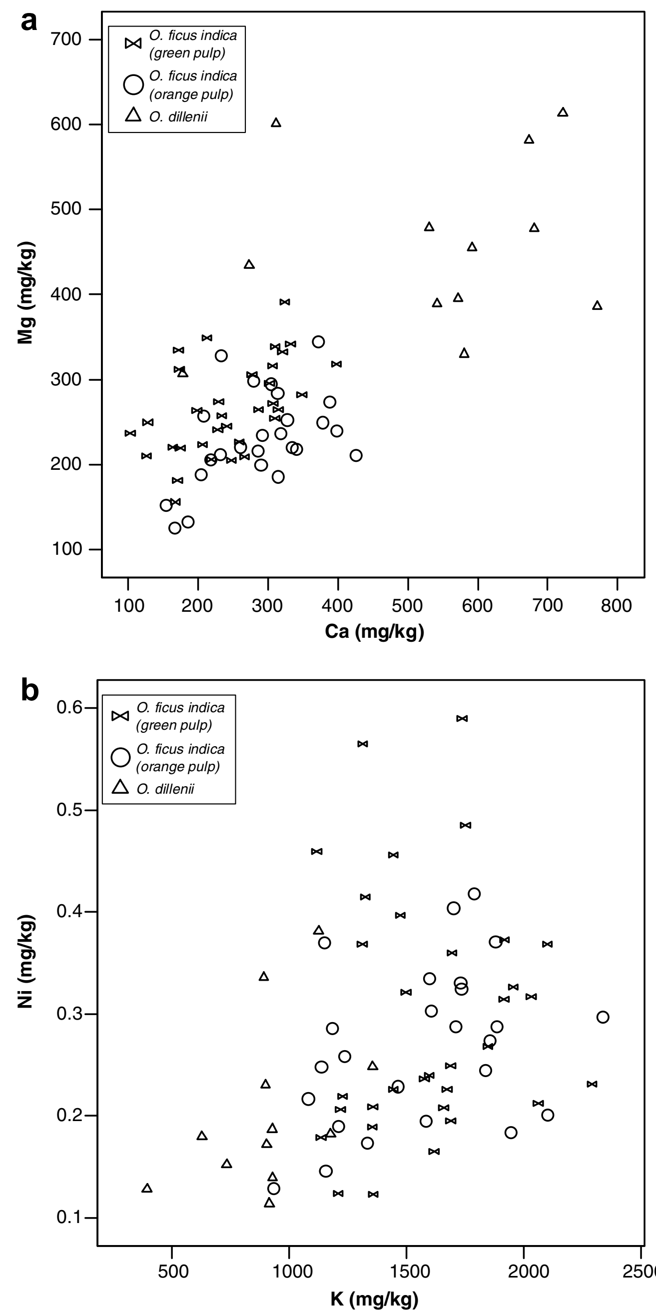

Fig. 2. Correlations between Ca and Mg (a) and between K and Ni (b) differentiating the prickly pears according to the species and pulp colour.

O. ficus indica, were consumed, these percentages would go down to 43% and 68%, respectively. In relation to the intake of minerals, one can deduce that the contributions of K and Mg are moderate, with values of nearly 10% for both minerals, with slight differences between species of prickly pear. Important contributions to the intakes of Mn and Cr were observed for the consumption of one serving of both species of prickly pear. Both trace elements, Mn (Mataix, 2002) and Cr (Hsing-Hsien, Ming-Hoang, Wen-Chi, & Chen-Ling, 2004), have been associated with protection against oxidative damage of biological membranes due to the presence of free radicals. Besides which, Cr constitutes the glucose tolerance factor, a molecule that improves the response of the tissues to insulin activity. One serving (150 g) of both species, *O. dillenii* and *O. ficus indica*, contributes 33% and 20% of the RDI of Mn and 63% and 47% of Cr, respectively. The high contribution to the Cr intake, as well as the high levels of fibre and other bioactive substances, could explain the antihypergycemic effect attributed to these food products (Roman-Ramos et al., 1995; Cárdenas Medellín et al., 1998). Therefore, if the food habits for the Canary population change and the consumption of prickly pear (particularly of *O. dillenii*) increases, the contribution to the daily intakes of fibre and antioxidant substances, such as ascorbic acid, phenolics, Mn and Cr, as well as some minerals, such as K or Mg, could increase.

A study of correlation among the quantitative variables for all the data was carried out. Many significant ($p < 0.05$) correlations were observed. Fig. 1 shows the correlation between total phenolics and pH (a) and total phenolics and ascorbic acid (b) differentiating the three types of prickly pears considered: *O. dillenii* and the green and orange *O. ficus indica*. These figures show that the prickly pears *O. dillenii* are well separated graphically from the samples of *O.ficus indica*. However, no differentiation was observed between green and orange samples within the species *O. ficus indica*. Considering the intermetallic correlations, Ca–Mg and K–Ni show notably high correlation coefficients. When these correlations are graphically represented (Fig. 2a and b), no clear separation between the groups of prickly pears studied were observed. Thus, it can be deduced that the specie and pulp colour of the prickly pear did not influence mineral contents. There are probably other factors, such as the nature of the soil or the climatic conditions, that have more effect on the mineral contents than the type of prickly pear.

Factor analysis was applied to all the samples of prickly pears studied to establish a more simplified view of the relationship among the nutrients analyzed. The first six factors, explaining 79.6% of the total variance, were chosen because their eigenvalues were above 1, and, therefore, they explain more variance than of the original variables. A Varimax rotation was carried out to minimize the number of variables that influence each factor and then to facilitate the interpretation of the results. The first factor that explains the higher percentage of variance (38.5%) is strongly associated with the total phenolics, ascorbic acid, pH, Mg and acidity. The second factor is related to °Brix and the refraction index and the third factor is negatively associated with moisture. The fourth factor is associated with Fe, Zn and Cu, and the fifth and sixth factors are related to Mn and with Cr and ash, respectively. From the representation of the scores plot for all the prickly pears on the first and second factor (Fig. 3), it can be observed that the samples of

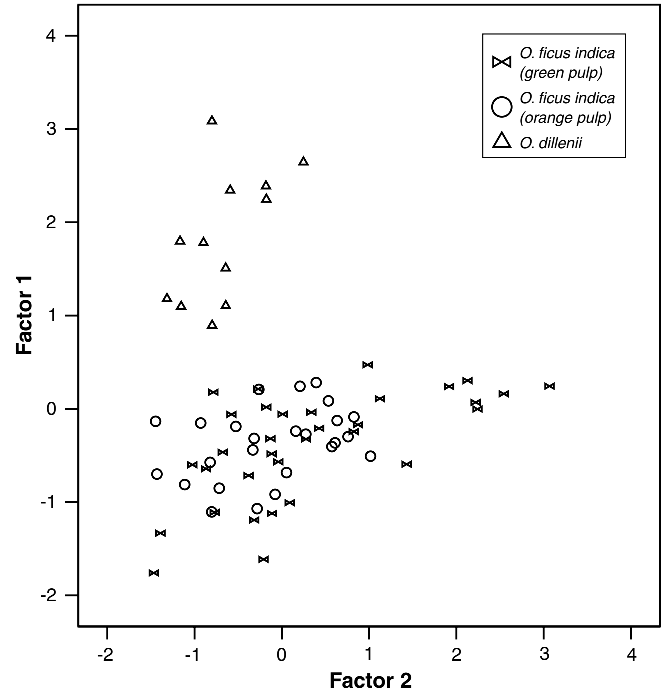

Fig. 3. Scores of the prickly pears samples on axes representing the two first factors differentiating the prickly pears according to the specie and pulp colour.

O. dillenii are well separated from the samples of the other species. No separation was observed between the green and orange prickly pears belonging to the *O. ficus indica* species.

In this work, we have performed three studies of DA, each one considering different qualitative variables (specie and pulp colour, region of production and altitude for sampling) and the chemical parameters analyzed as quantitative variables. Considering the criteria species and colour of prickly pear, and applying stepwise DA to the data (Table 4), a high percentage (84.3%, and 80.0% after cross-validation) of correct classification was obtained when selecting the variables protein, pH, acidity, Ca, Mg and Zn. All the prickly pears belonging to the *O. dillenii* species were correctly classified, and six green and five orange prickly pears, from *O. ficus indica*, were incorrectly classified as belonging to the other colour group. When the

Table 4
Results of the stepwise discriminant analysis of all the samples according to type, species and pulp colour

	Type of prickly pear	Predicted group		
		O. ficus indica (green pulp)	*O. ficus indica* (orange pulp)	*O. dillenii*
Initial group	*O. ficus indica* (green pulp)	27 (81.8%)	6 (18.2%)	0 (0.0%)
	O. ficus indica (orange pulp)	5 (20.0%)	20 (80.0%)	0 (0.0%)
	O. dillenii	0 (0.0%)	0 (0.0%)	12 (100%)
Cross-validation	*O. ficus indica* (green pulp)	26 (78.8%)	7 (21.2%)	0 (0.0%)
	O. ficus indica (orange pulp)	7 (28.0%)	18 (72.0%)	0 (0.0%)
	O. dillenii	0 (0.0%)	0 (0.0%)	12 (100%)

84.3% samples well classified (80.0% after cross-validation).

values of the two discriminant functions, linear combination of these quantitative variables, were represented, a clear differentiation of *O. dillenii* was observed. Also, a clear tendency to the differentiation of the samples of *O. ficus indica* according to pulp color was apparent.

Subsequent analyses on several groups of the prickly pears were carried out (Table 5). As regards the prickly pears of *O. dillenii*, a stepwise DA was developed, using the altitude of sampling as a criterion for the comparison. All the samples (100%) were correctly classified according to the altitude of sampling, coast (0–300 m) or medium (300–800 m), selecting only the variables ash, Fe and Zn. For the green prickly pears, 81.8% of prickly pears were correctly classified within their altitude of sampling (coast, medium and high altitude) using the following variables: ash, acidity, Na and Cu. For the orange prickly pear, the results of the stepwise DA showed a correct classification of 96.0% of the samples with the variables K, Mg, Mn and Cr. There was an overlapping between the prickly pears from medium altitude with the other zones of sampling. Fig. 4 shows that the green prickly pears (a) were well differentiated, and the orange prickly pears (b) tended to be differentiated, according to the altitude of sampling.

A new DA study was developed considering the green and orange prickly pears in an independent manner and using the region (north or south) of cultivation as the criterion for the comparison (Table 6). This study was not applied to the prickly pears of the *O. dillenii* species as all the samples of this specie come from the south. Using the stepwise process, the variables moisture, ash, Na and Mn were selected, making the complete differentiation of the green prickly pears possible. All the orange prickly pears were correctly classified in the region of production when using only moisture, protein, ash, Ca, Zn, Mn and Ni.

Table 5
Results of the stepwise discriminant analysis of the prickly pears of *O. dillenii* and green and orange samples of *O. ficus indica* according to the altitude of sampling

	Altitude	Predicted group		
		Coast	Medium	High
(a) *O. dillenii*				
Initial group	Coast	6 (100%)	0 (100%)	–
	Medium	0 (0.0%)	6 (100%)	–
Cross-validation	Coast	6 (100%)	0 (100%)	–
	Medium	0 (0.0%)	6 (100%)	–
(100% samples well classified; 100% after cross-validation)				
(b) O. ficus indica (green pulp)				
Initial group	Coast	2 (66.7%)	1 (33.3%)	0 (0.0%)
	Medium	2 (13.3%)	11 (73.3%)	2 (13.3%)
	High	0 (0.0%)	1 (6.7%)	14 (93.3%)
Cross-validation	Coast	2 (66.7%)	1 (33.3%)	0 (0.0%)
	Medium	2 (13.3%)	10 (66.7%)	3 (20.0%)
	High	0 (0.0%)	2 (13.3%)	13 (86.7%)
(81.8% samples well classified; 75.8% after cross-validation)				
(c) O. ficus indica (orange pulp)				
Initial group	Coast	5 (100%)	0 (0.0%)	0 (0.0%)
	Medium	1 (7.7%)	12 (92.3%)	0 (0.0%)
	High	0 (0.0%)	0 (0.0%)	7 (100%)
Cross-validation	Coast	4 (80.0%)	0 (0.0%)	1 (20.0%)
	Medium	2 (15.4%)	11 (84.6%)	0 (0.0%)
	High	1 (14.3%)	0 (0.0%)	6 (85.7%)
(96.0% samples well classified; 84.0% after cross-validation)				

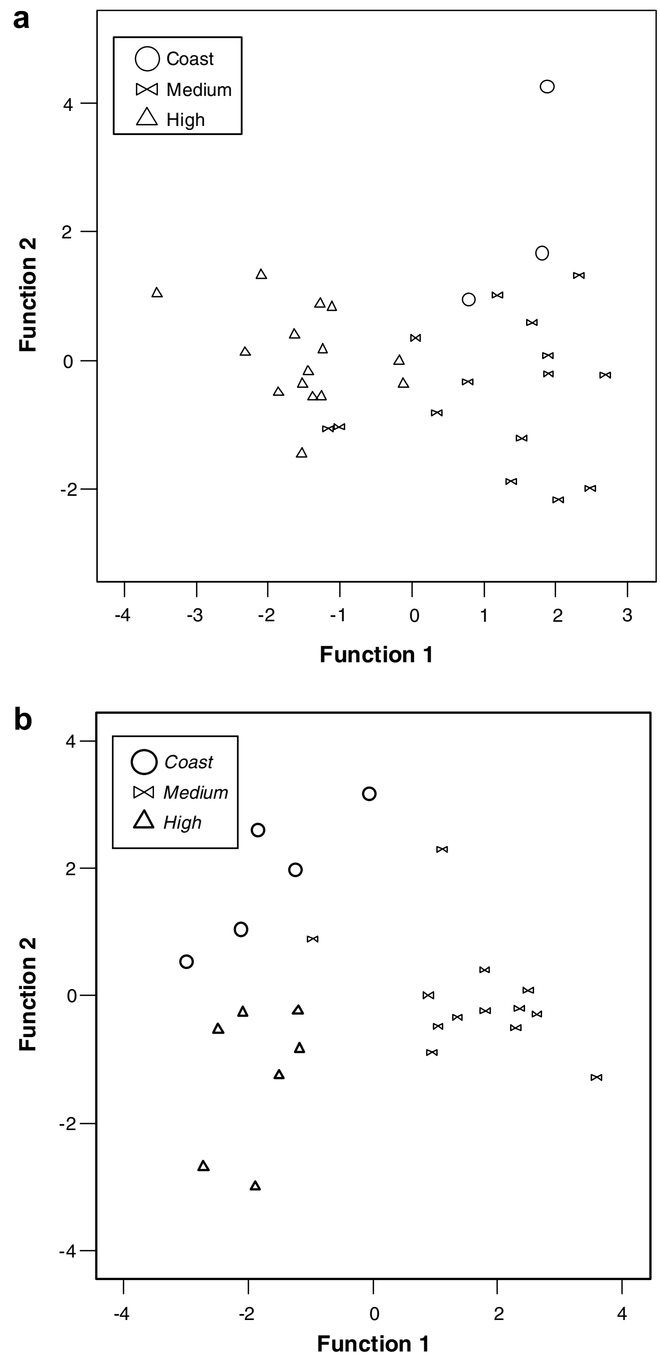

Fig. 4. Scatter diagram of green (a) and orange (b) prickly pear samples of *O. ficus indica* on the axes representing the first two discriminant functions according to the altitude of sampling.

Table 6
Results of the stepwise discriminant analysis of green and orange samples of *O. ficus indica* according to the region of cultivation

	Zone	Predicted group	
		North	South
(a) O. ficus indica (green pulp)			
Initial group	North	11 (91.7%)	1 (8.3%)
	South	1 (4.8%)	20 (95.2%)
Cross-validation	North	11 (91.7%)	1 (8.3%)
	South	2 (9.5%)	19 (90.5%)
(93.9% samples well classified; 90.9% after cross-validation)			
(b) O. ficus indica (orange pulp)			
Initial group	North	13 (100%)	0 (0.0%)
	South	0 (0%)	12 (100%)
Cross-validation	North	13 (100%)	0 (0.0%)
	South	0 (0%)	12 (100%)
(100% samples well classified; 100% after cross-validation)			

4. Conclusions

The fruits of *O. ficus indica* and *O. dillenii* presented significant differences in all the parameters except moisture and Cu. The green prickly pears of the *O. ficus indica* species had higher pH, fibre and Mg concentrations and lower percentages of edible portion and Ca than had the orange prickly pears. The consumption of prickly pears, particularly of *O. dillenii*, represents an important contribution to the intakes of fibre, ascorbic acid, Mn, Cr and total phenolics. Factor and discriminant analyses allow the differentiation of the prickly pears according to species, altitude and region of cultivation in the island. A tendency to differentiation as a function of pulp colour in the specie *O. ficus indica*, was observed.

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