

CHEMICAL AND NUTRITIONAL COMPOSITION OF COPAO FRUIT (*Eulychnia acida* PHIL.) UNDER THREE ENVIRONMENTAL CONDITIONS IN THE COQUIMBO REGION

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Copao (*Eulychnia acida* Phil.) is an endemic arborescent cactus restricted mainly to the semi-arid Coquimbo Region (29°54'28" S, 71°15'15" W), Chile. The area of distribution is from sea level to 1200 m.a.s.l. The edible fruit called *rumpa* is generally round, with green or pink peel and small scales on its surface, showing wide variability in size and weight. The aim of this work was to characterize the *rumpa* harvested in January 2009 and 2010 in three sectors of Coquimbo Region to determine chemical and nutritional composition in three fractions: pulp with seeds, juice, and peel. The research showed that this fruit is a good natural source of mainly soluble dietary fiber, which has a jellied texture and is present in the three fractions analyzed: 2% for juice, 3% for pulp with seeds, and approximately 5% for peel, making it potentially a good source of hydrocolloids for the food industry. The fruit is also a good source of vitamin C; around 55 mg 100 g⁻¹ in peel, and 30 mg 100 g⁻¹ in pulp with seeds and juice, values considered high compared to 18 mg 100 g⁻¹ for prickly pear (*Opuntia ficus-indica* [L.] Mill.) The main minerals were: K, Mg, Ca, and P. Total polyphenols and betalain pigments were also determined in the pulp with seeds and pink peel fractions, respectively. The nutritional characteristics, together with its high water content of around 96%, make *rumpa* a promising raw material for agro-industrial development of natural juices or isotonic drinks. This characterization helps in the recovery of an endemic native species by reducing potential threats to destroy wild populations of *E. acid*, especially near agricultural areas, and by promoting habitat conservation of the species in the region.

Key words: Rumpa, arborescent cactus, vitamin C, minerals.

The cactaceae family is xerophile and its cultivation has been commercially developed since the mid-twentieth century. This family is native to Central Mexico, where the largest germplasm variability is found (Nefzaoui *et al.*, 2008). Traditional Mexican medicine has historically used fruits or flowers of cactus cladodes to reduce serum cholesterol levels, regulate blood pressure, control gastric disturbances, and treat various diseases such as gastric ulcers, glaucoma, capillary fragility, rheumatic pains, etc. (Muñoz de Chávez *et al.*, 1995; Domínguez-López, 1995; Gurrieri *et al.*, 2000; Nefzaoui *et al.*, 2008). Nopal fruits (*Opuntia ficus-indica* [L.] Mill.) are not only nutritious, but also a good source of functional components such as soluble dietary fiber, betalain and carotenoid pigments, minerals, and other compounds, such as highly appreciated antioxidants and

gastro protective products. This is a real advantage for using this species as a source of bioactive compounds in the development of new functional foods (Sáenz, 2006; Nefzaoui *et al.*, 2008).

Eulychnia is a genus present in Peru and Chile (Ritter, cited by Nyffeler *et al.*, 1997), of which copao (*Eulychnia acida* Phil.) is an endemic species of arid regions, widely distributed in Coquimbo. It grows especially on hillsides facing north, from sea level up to 1200 m.a.s.l. (Bustamante, 1996). The fruit, called *rumpa*, is round or slightly elongated, with green or pink peel with very small scales. It presents a great variability in color, weight, and size. This morphological variability may be a response to environmental conditions (annual rainfall, altitude, temperature) and soil conditions, or it may have a genetic basis, as is the case with *Stenocereus stellatus* (Casas *et al.*, 1999) and *Stenocereus pruinosus* (Luna, 2006). The raw pulp with seeds (fruit), with some sugar added, as well as its juice, is consumed locally, and the fruit is used as animal feed in the dry season. Once the fruit ripens, the peel becomes brightly colored, with a firm appearance, and the pulp tastes acidic and fruity. Although this species is widely distributed in the Coquimbo Region, practically no information on its chemical composition and nutritional

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value has been published. The information available to date on this species is related to its distribution and conservation status (Bustamante 1996), taxonomy, the morpho-anatomical characteristics of its stems (Nyffeler *et al.*, 1997), and infestation by the leafless mistletoe *Tristerix aphyllus*. Therefore, the aim of this research was to characterize the chemical-nutritional composition of diverse fractions of the fruit to determine its potential use in agro-industry and thus help protect wild populations of this endemic native resource.

MATERIALS AND METHODS

Samples

Samples of ripe fruit from wild *E. acida* populations growing in the Coquimbo Region, Chile, were collected by hand during the fruit harvest period in January 2009 and 2010. Three sectors were chosen considering the differences of the wild population of cactus *E. acida* and climatic differences: 1) Manquehua sector (30°57' S, 71°10' W; 660 m.a.s.l.), an intermediate zone in Limari Valley with an annual mean temperature 16 °C and lower humidity than Gualliguaica; 2) Gualliguaica sector (30°00' S, 70°48' W; 633 m.a.s.l.) located in Elqui Valley (Figure 1), with an annual mean temperature of 17 °C and an average relative humidity of around 60%, and 3) the coastal Quebrada Honda sector (29°34' S, 71°10' W; 399 m.a.s.l.), this area is normally cloudy, with an annual mean temperature of 14 °C and an average relative humidity of around 80%. Mean rainfall in the region during 2008 and 2009 was 125 and 61 mm, respectively (CEAZA, 2010). Each sector was divided into three sub-sectors, approximately 6 ha each, with slope and northwest exposure, where the fruit samples

were taken according to a previously designed sampling plan. On average, 70 plants full of fruits with good appearance were harvested at random per sub-sector, sampling between one to five ripe fruits per plant, located in the upper third of the stems. Due to the lack of information about the harvest index in this species, the fruits were harvested by direct appreciation according to experience of local inhabitants; then the parameters used were the brightness of the peel and the turgor of the fruits, detected visually, as indicators of the firmness and maturity of the fruits. As well, the fruits have different skin colors, so they were harvested in separate batches according to color, green or red, observed in the field (Figure 2).

Regarding peel color, green and pink peel fruits were collected separately only in Manquehua sector. In the other two sectors of Gualliguaica and Quebrada Honda, only green peel fruits were collected. Each lot taken in each sub-sector was around 15 kg, with the following distribution: 1) Manquehua: three green and three pink peel fruit lots; 2) Gualliguaica: three green peel fruit lots; and 3) Quebrada Honda: three green peel fruit lots, with a total 12 lots. Each fruit was put in a special soft plastic bag commonly used in the country for exporting fruit, to protect them, labeled with its respective identification considering sector, subsector, peel color, date, lot number, and weight (kg), and was delivered to the laboratory for analysis in a special refrigerated container.

In January 2010, a restricted fruit sampling procedure was conducted in the same three sectors sampled in 2009, applying the same criteria, the area of each sub-sector was smaller (2 ha), and the number of harvested plants was approximately 30 in total, sampling one to five fruits per plant. The sampling was smaller because of lower raw material requirements for chemical analysis. Each lot represented around 7 kg of fruits, taken randomly within the three subsectors previously defined per sector sampled, with the following distribution: Manquehua: one green and one pink peel fruit lot; Gualliguaica: one green and one pink peel fruit lot; and Quebrada Honda: one green peel fruit lot, for a total of five lots, three with green peel and two pink. The same procedure was used as in 2009 for packaging, labeling, and delivering the fruit lots to the laboratory.

Soil samples were taken from each sector and analyzed to determine organic matter content, pH, and available N P, and K. The pH was neutral for the three sectors, ranging between 6.2 and 7.1. The content of N, P, and K in soil was higher in Quebrada Honda. The soil N content was 36, 19, and 23 mg kg⁻¹ for Q. Honda, Gualliguaica, and Manquehua, respectively. While, the soil P content was 33, 20, and 24 mg kg⁻¹ for Q. Honda, Gualliguaica, and Manquehua, respectively. Finally, the soil K content was 572, 316, and 139 mg kg⁻¹ for Quebrada Honda, Gualliguaica, and Manquehua, respectively.

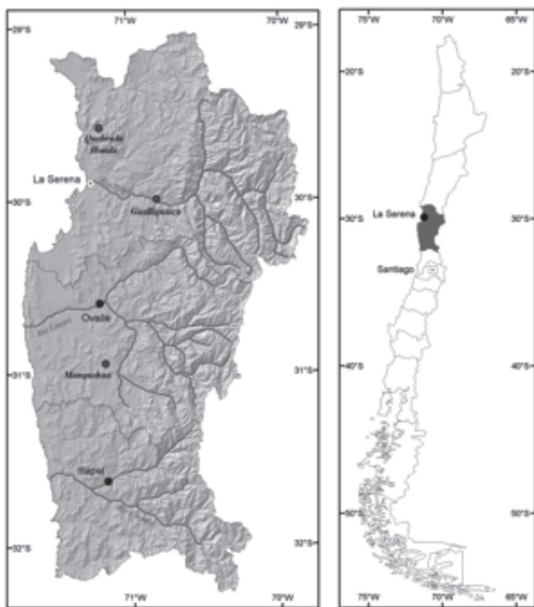


Figure 1. Region of Coquimbo: Three sectors sampled where fruits of *Eulychnia acida* were taken.



Figure 2. *Rumpu* fruits, pink and green peel; view of pulp with seeds.

Analytical samples

All fruit received in the laboratory was immediately weighed individually. Thus, more than 1700 individual fruits were assessed. Each lot was maintained at -80 ± 2 °C in a vertical freezer (Labtech Model LDF-8514, Namyangju, South Korea) until its analysis.

The analytical sample was approximately 3 kg (average of 24 fruits). Each fruit was again weighed, halved longitudinally, the pulp with seeds was removed with a spoon. Because this is the edible fraction and thus more likely to be used in industry, it was collected in a weighted beaker for calculating the yield expressed as a percentage (weight ratios among the whole fruit, peel and pulp with seeds). The pulp and seed fractions obtained from 12 fruits from each sampling were homogenized in a commercial blender (Braun, Cincinnati, USA) until the seeds were completely ground. The homogenized samples were stored individually in labeled 250 mL plastic jars and submitted immediately to analytical determinations. Control samples of each analytical sample from fruit harvested in 2009 were kept at -23 ± 1 °C (Freezer FENSA model FFH4450, Santiago, Chile). In the case of the 2010 sample, the same procedures described above for the analytical sample preparation were used for the five lots of sampled *rumpu*, with the difference that in this case two fractions from each analytical sample were obtained: five peel and five juice samples, for a total of 10. Peel fractions were collected, weighed and homogenized in the same commercial blender. For the juice fraction, the seeds were separated from the pulp using an adequate sieve and the liquid was collected in labeled individual 250 mL plastic jars, and submitted immediately to analytical determination. A control sample of each analytical sample from fruit harvested in 2010 was kept at -23 ± 1 °C. As a result of the 2009 and 2010 sampling procedures, three homogenized fruit fractions were analyzed: 12 analytical samples of pulp with seeds from *rumpas* harvested in 2009; and 10 analytical samples, five samples of peel and five of juice from *rumpas* harvested in 2010, 22 total samples. They were analyzed for proximate composition, including

water, dietary fiber, available carbohydrates, lipids, nitrogen (protein), related to micronutrients, vitamin C, Ca, Fe, P, K, Mg, and Cu.

Total polyphenols were only measured in the pulp with seeds fraction from fruits sampled from the three sectors during summer time 2009, and betalains pigments were determined in the pink peel fraction of fruit obtained from Manquehua sector sampled in 2009 and Gualliguaica and Manquehua sectors sampled in 2010. Each analytical determination was run at least in duplicate.

Chemical analysis

Moisture and volatile matter: The AOAC Official Method 934.01 (AOAC, 1995) was used with a forced-draft oven (MTB Binder, USA) at 103 ± 2 °C, with 5 g of sand added (Merck, Darmstadt, Germany). Total nitrogen was determined using the AOAC Official Method 954.01 (AOAC, 1995) through digestion and distillation (Büchi model 426, Flawil, Switzerland). Crude protein was calculated by multiplying total N by the universal factor 6.25. Total lipids were determined by the method of Blich and Dyer (1959) with chloroform, methanol, and water in the indicated proportions. The anthrone spectrophotometric method described by Osborne and Voegt (1986) was used to determine available carbohydrates. The glucose concentration in the sample test was calculated measuring its absorbance and results were expressed as a percentage (%). Dietary fiber was determined by the AOAC Official Method 985.29 (AOAC, 1990) with the enzyme kit BIOQUANT® Total Dietary Fiber (Merck, Darmstadt, Germany). Ash was determined by the AOAC Official Method 930.05 (AOAC, 1995). Minerals were determined by the AOAC Official methods for each respective mineral as described in Volume 1 AOAC (1995). The method described by Schmidt-Hebbel (1977) was used to determine total ascorbic acid or vitamin C. The vitamin C in the juice fraction was stabilized with an oxalic acid solution 0.5%, and was measured in the spectrophotometer (Hitachi U-2900, Tokyo, Japan). The results were expressed as mg of total ascorbic acid or vitamin C 100 g^{-1} of fresh weight juice. The presence of polyphenols in the pulp with seeds fraction of fruits from 2009 was tested in an aqueous extract using the Folin Ciocalteu method (Singleton and Rossi, 1965). Total phenolic content was expressed as milligrams of gallic acid equivalents per 100 g of fresh pulp weight ($\text{mg GAE g}^{-1} \text{ FW}$). Betacyanins and betaxanthin content was determined in a preliminary assay of the red peel fractions of fruits harvested in Manquehua in 2009, and repeated in the pink peel fraction harvested in Manquehua and Gualliguaica in 2010. They were determined in an aqueous peel extract using the spectrophotometric method proposed by Stintzing *et al.* (2005). Betacyanin and betaxanthin were expressed as mg of betanine and indicaxantin $100 \text{ g}^{-1} \text{ FW}$ respectively.

Statistical analysis

The data obtained were analyzed with an ANOVA. Means were compared with the Tukey test at a 95% confidence level. The values of the weight of pulp and peel with respect to total fruit weight were determined by a non-parametric ANOVA (Kruskal-Wallis test). All statistical analyses were performed using the Statgraphic Plus 5.1 statistical software.

RESULTS AND DISCUSSION

Physical characteristics

The weight of the 1700 fruit sampled in January 2009 and 2010 ranged between 71 g up to 185 g. The fruit weight showed significant interactions among sectors and between years (Table 1). The fruits harvested in Manquehua in 2009 and 2010 were the smallest, with an average weight of 100 g, which was significantly different ($p < 0.05$) from the fruit from the other two sectors, 30% lower than fruit from Gualliguaica and 50% less than fruit from Quebrada Honda. Fruit from both Gualliguaica and Quebrada were larger. However, there was significant variation in fruit weight between the two seasons in each sector, Manquehua being the sector with the smallest fruits in both years. The weight differences may be a consequence of physiological conditions of the plants, such as photoassimilate supply during fruit development (Inglese *et al.*, 1999), climatic conditions such as rainfall (García Suárez *et al.*, 2007) and soil moisture variations (Gugliuzza *et al.*, 2002) in the three sectors during the two seasons. Considering pink and green peel color and the weight of fruits harvested in Manquehua in 2009 and Gualliguaica in 2010, Table 2 shows that Manquehua green peel fruits were smaller than pink peel fruits collected in the same sector, with a significant difference ($p < 0.05$). The weight difference was not significantly related to peel color in fruit from Gualliguaica, and therefore it is not easy to determine if peel color is related

to weight. In any event, it is important to note that the number of fruits weighed in 2009 was much higher than in 2010. Regarding peel and pulp fruit color, in some cases the pink peel matched with the pulp, in other cases no relation was observed. The pulp of green-peeled fruits was always translucent white. All the green or pink-peeled fruits had small scales on their surfaces, with very thin harmless thorns. Most of the fruits were round but some were slightly elongated (Figure 2).

Table 3 presents the yield percentage obtained for the pulp with seeds and peel fractions of *E. acida* according to sector and year sampled. In the three sectors, the peel fraction represented more than 50% of total weight. The highest yield of pulp with seeds was obtained in fruit from Manquehua, where the lowest fruit weight was also obtained (Table 1). In contrast, fruit from Quebrada Honda had the lowest pulp with seeds fraction yield and high average weight. Fruit from Gualliguaica had intermediate values. Yields were significantly different among the three sectors ($p < 0.05$). This means that the smallest fruits had a better pulp with seeds yield because their peels were thinner than the fruits grown in the other two sectors sampled in 2009 and 2010. Peel thickness increases with soil moisture (Mulas and D'hallewin, 1997), which may be caused by air humidity. As mentioned earlier, fruits from the three sectors showed morphological variations that are a phenotype expression influenced by environment, soil and genetic characteristics. It is necessary to do further research on these topics.

Each fraction of the fruit has its own physical characteristics; for example, the pulp with seeds has a jellied and filamentous texture, is yellow-brown, with small pieces of seeds in suspension, is acidic and has a fruity taste. The juice fraction is light yellow or pink, depending on the pulp color, the same jellied and filamentous texture and tastes acidic and fruity. Finally, the peel fraction has the same jellied texture, is green or pink, depending on the sampled sector, and tastes acidic.

Table 1. Fruit weight of rumpas (*Eulychnia acida*) sampled in three sectors of the Region of Coquimbo during summer 2009 and 2010.

Sector	2009	2010
	Fruit weight (g)	
Gualliguaica	147.88 ± 37Aa	133.33 ± 29Bb
Manquehua	95.70 ± 24Bc	111.64 ± 23Ac
Quebrada Honda	127.78 ± 37Bb	149.63 ± 30Aa

Mean value ± standard deviation. ANOVA ($P < 0.05$) detected interaction between sector and year. Mean values followed by different uppercase letters on the same row, or followed by different lowercase letters in the same column denote significant differences according to Tukey's test ($P < 0.05$).

Table 2. Fruit weight of rumpas (*Eulychnia acida*) according to their peel color, sampled in two sectors, during 2009 and 2010.

Sector	n	Peel color	Fruit weight (g)
Manquehua	392	Green	88 ± 23a
	458	Pink	104 ± 23b
Gualliguaica	28	Green	133 ± 25c
	20	Pink	136 ± 34c

Means value ± standard deviation. Mean values with different letters denote significant differences ($P < 0.05$).

Nutritional composition

The principal component was water with mean content at 92% for the pulp with seeds fraction, from fruits collected in 2009 in the three sectors. The water content was 93% and 96% for the peel and juice fractions respectively, obtained from green or pink-peeled fruits collected in 2010 in the same three sectors (Table 4). No clear influence was observed of peel color on water

Table 3. Proportion of fruit fractions in rumpas (*Eulychnia acida*) sampled in three sectors in the Region of Coquimbo.

Sector	n	Pulp with seeds (edible fraction)	Peel
		—— (%) ——	
Manquehua	223	49.2a	50.7c
Gualliguaica	184	47.1b	52.9b
Quebrada Honda	99	41.4c	58.6a

Mean values obtained in 2009 and 2010. Mean values followed by different letters denote significant differences by Tukey's Test ($P < 0.05$). Values were transformed to square roots.

Table 4. Proximal analysis of different fractions in fresh weight of *rump* (*Eulychnia acida*) fruits in three sectors in the Region of Coquimbo.

Fruit fraction	Sector	Peel color	Water	Total N	Protein (N*6.25)	Lipids	Carbo-hydrates	Fiber	Ash
			g 100g ⁻¹	mg 100g ⁻¹			g 100g ⁻¹		
Pulp with seeds	Manquehua	Green	92.5 ± 0.3ab	191 ± 9a	1.0	1.2 ± 0.1a	0.56 ± 0.03a	3.1 ± 0.1a	0.62 ± 0.05b
		Pink	92.2 ± 0.5a	187 ± 5a	1.0	1.4 ± 0.1ab	0.57 ± 0.06a	3.2 ± 0.1a	0.68 ± 0.07b
	Gualliguaica Q. Honda	Green	93.1 ± 0.4b	148 ± 4b	0.8	1.3 ± 0.1ab	0.48 ± 0.06b	2.9 ± 0.4a	0.59 ± 0.03a
		Green	90.9 ± 0.7c	197 ± 10a	1.0	1.5 ± 0.1b	0.59 ± 0.03a	3.5 ± 0.3a	0.86 ± 0.04c
Peel	Manquehua	Green	93.3 ± 0.1bc	56 ± 1a	0.35	0.13 ± 0.01b	0.82 ± 0.06a	4.7 ± 0.2a	0.76 ± 0.01a
		Pink	93.4 ± 0.1c	48 ± 0a	0.30	0.09 ± 0.01a	0.80 ± 0.06a	4.5 ± 0.1a	0.94 ± 0.01bc
	Gualliguaica	Green	92.2 ± 0.1a	53 ± 3a	0.33	0.14 ± 0.01b	0.86 ± 0.03a	5.5 ± 0.1b	0.92 ± 0.04bc
		Pink	93.0 ± 0.1b	49 ± 3a	0.30	0.15 ± 0.01b	0.87 ± 0.06a	4.8 ± 0.2a	0.86 ± 0.01b
	Q. Honda	Green	92.0 ± 0.1a	48 ± 2a	0.30	0.18 ± 0.01c	0.93 ± 0.03a	5.6 ± 0.1b	1.00 ± 0.03c
Juice without seeds	Manquehua	Green	96.5 ± 0.1b	38 ± 1c	0.24	0.09 ± 0.00a	0.50 ± 0.03b	2.1 ± 0.1a	0.52 ± 0.01ab
		Pink	96.5 ± 0.1b	33 ± 0b	0.21	0.11 ± 0.00c	0.43 ± 0.01b	2.1 ± 0.0a	0.66 ± 0.02c
	Gualliguaica	Green	96.8 ± 0.1c	28 ± 1a	0.17	0.10 ± 0.00b	0.24 ± 0.00a	2.2 ± 0.1a	0.55 ± 0.01b
		Pink	96.8 ± 0.1c	30 ± 1a	0.18	0.10 ± 0.00b	0.25 ± 0.00a	2.2 ± 0.1a	0.48 ± 0.01a
	Q. Honda	Green	96.3 ± 0.1a	28 ± 0a	0.18	0.15 ± 0.00d	0.31 ± 0.01a	2.4 ± 0.1a	0.65 ± 0.01c

Mean value ± standard deviation; pulp with three replicates; peel and juice of two replicates; Mean values in the same fruit fraction followed by different letters within a column denote significant differences at P < 0.05.

content of the fractions. The juice fraction presented significantly higher water content, (96%) than the other two fractions, as expected ($p < 0.05$). High water content plays an important function for fruit as physiological water reserves for the plant during the stressful hot and dry season after blooming. The values obtained for pulp with seeds were comparable to those found in other fruits, such as papaw (*Vasconcellea pubescens* (Lenne' et C. Koch) Badillo), sweet cucumber (*Solanum muricatum* Aiton) and watermelon (*Citrullus lanatus* (Thunb.), with 93.2, 92.4, and 93.5%, respectively (Schmidt-Hebbel *et al.*, 1992). On the other hand, the water values obtained were higher than those in the literature for nopal fruit from the genus *Opuntia cacti*, such as the prickly pear, with values between 83.8% and 91.0% (Askar and El-Samahy, 1981; Sawaya *et al.*, 1983; Muñoz de Chavez *et al.*, 1995; Pimienta, 1990; Sepúlveda and Sáenz, 1990; Schmidt-Hebbel *et al.*, 1992; Rodríguez *et al.*, 1996).

Regarding N in the three fractions, the values were low, from 30 mg 100 g⁻¹ for juice and as high as almost 200 mg 100 g⁻¹ for pulp with seeds, which is normal in fruits due to their high water content. The presence of the seeds, which represents a good N source, accounts for the higher content. These results are comparable to those with prickly pear fruit, with an N content between 34 mg 100 g⁻¹ and 256 mg 100 g⁻¹ (Sawaya *et al.*, 1983; Pimienta, 1990; Sepúlveda and Sáenz, 1990; Schmidt-Hebbel *et al.*, 1992; Muñoz de Chavez *et al.*, 1995; Gurrieri *et al.*, 2000). We found no literature for N for *rump* fruit. The N content of *rump* fractions is also comparable to those of other typical fruits such as apple (*Malus domestica* Borkh.) 32 mg 100 g⁻¹, pear (*Pyrus communis* L.), lemon (*Citrus limon* (L.) Burm f.) 48 mg 100 g⁻¹, apricot (*Prunus armeniaca* L.) 64 mg 100 g⁻¹, pineapple (*Ananas comosus* (L.) Merr., plums (*Prunus domestica* L.) 80 mg 100 g⁻¹, melon (*Cucumis melo*), grapes (*Vitis vinifera* L.) 96 mg 100 g⁻¹, orange (*Citrus sinensis* (L.) Osbeck) 112 mg 100 g⁻¹, peach (*Prunus persica* (L.) Batsch) 128 mg 100

g⁻¹, and strawberry (*Fragaria × ananassa* Duchesne ex Rozier) 114 mg 100 g⁻¹, (Cappelli and Vannucchi, 1990; Schmidt-Hebbel *et al.*, 1992; Belitz and Grosch, 1999). The conversion to proteins presented values from 0.2% for the juice fraction up to 1% for pulp with seeds.

The lipid content is also low; the values obtained for the peel and juice fractions were close to 0.15%, while the pulp with seeds presented a higher mean value of 1.4%. The seeds represent a good source of this nutrient, as has been demonstrated in papaw (*V. pubescens*), cherimoya (*Annona cherimola*), and prickly pear seeds obtained from these fruits cultivated in Chile, with mean lipid contents of 32.5, 18.5, and 5.5%, respectively (Masson *et al.*, 2008).

Regarding available carbohydrates, in the pulp with seeds and juice fractions the values were around 0.5% expressed in glucose. In the peel fraction, carbohydrates were comparatively higher than the percentage found in the other two fractions, at 0.8-0.9%. The higher content could be explained by the peel texture, which is strong and thick, with a jellied texture that requires more structural materials.

Dietary fiber was the principal component in the three fractions, the peel presented a significantly higher value, of around 5%, ($p < 0.05$) than the other two fractions, at 2 to 3%, which coincides with the higher content of carbohydrate found in the same fraction, confirming that the peel contains more components to maintain a strong external cover. The peel color did not have any influence on fiber content.

It is important to mention the special characteristics of the texture of the three fractions, as a result of the carbohydrate and dietary fiber values found. Dietary fiber in this fruit is mainly soluble fiber with a high proportion of thickening or gelling agents. These are considered water-soluble gums or hydrocolloids, composed of macromolecules that are easily dispersed in water, increasing viscosity and having a gelling effect

(Multon, 2000). The high soluble dietary fiber content is a biological tool of the plant to capture and retain as much water as possible in dry areas. This content, from the technological point of view, is important because it could be a significant natural source of a thickening agent used as an additive in food industry (Multon, 2000).

The mineral content was around 0.5 to 1% in the three fractions and was slightly higher than the value reported for prickly pear fruit, with 0.40 and 0.51% (Askar and El-Samahy, 1981; Sawaya *et al.*, 1983; Pimienta, 1990; Sepúlveda and Sáenz, 1990, Schmidt-Hebbel *et al.*, 1992, Muñoz de Chávez *et al.*, 1995; Rodríguez *et al.*, 1996).

K, Mg, P, and Ca were the principal minerals determined in the three fruit fractions (Table 5). K was the most homogeneous mineral with around 200 mg 100 g⁻¹ in the three fractions. Mg showed a significantly different distribution among the fractions ($p < 0.05$): in juice from 23 to 29 mg 100 g⁻¹, in pulp with seeds from 29-43 mg 100 g⁻¹ and the highest values in peel, with means between 41-44 mg 100 g⁻¹. This distribution is probably related to physiological plant functions. Since green and pink peel fruits must have more chlorophyll pigments than the other fractions, Mg content would be higher in that fraction. P also showed variable fraction distribution, being clearly more concentrated in the juice fraction, with around 40 mg 100 g⁻¹; pulp with seeds between 28-35 mg 100 g⁻¹; and peel 5-8 mg 100 g⁻¹, the latter being very low. In contrast, Ca presented low values in juice, 6-7 mg 100 g⁻¹; intermediate values in pulp with seeds, 12-16 mg 100 g⁻¹; and the highest values in peel, 50-60 mg 100 g⁻¹, which could be because this mineral plays a role as structural material that is normally associated with pectin substances that contribute to maintaining structure and shape (Sáenz, 2006). Fe and Cu were very low; Fe presented a more homogeneous distribution between pulp with seeds and peel, around 20 mg 100 g⁻¹, with lower values in juice. Cu was very low in all three fractions < 0.1 mg 100 g⁻¹.

Na is one of the most abundant cations in nature and it showed great variation among the three fractions, with a tendency to be more concentrated in the peel. In relation to the sampling sectors, green-peeled fruit from the coastal zone of Quebrada Honda showed significantly higher values ($p < 0.05$) in pulp with seeds for K, Mg, P and Ca compared to fruit from the other two sectors sampled in summer 2009. The same tendency was observed for the peel fraction obtained for fruits harvested in summer 2010, with the exception of Ca. These significantly higher values for minerals in pulp with seeds and peel in the coastal zone could be related to a different chemical soil composition or to other abiotic factors (Lester, 2006). Mineral soil conditions for N, P and K varied among the evaluated sectors, but K content was higher at Quebrada Honda than at Gualliguaica and Manquehua. The presence of the components in the fruits is highly regulated by both genetic and environmental (soil and climate), factors (Lester and Crosby, 2002; Lester, 2006; Guzmán-Maldonado *et al.*, 2010; Szakiel *et al.*, 2010).

In addition, the seven minerals and water content were determined in samples of pulp with seeds of fruits harvested in 2010 in the same three sectors, in order to check if the data obtained in 2009 maintained the same order of magnitude. The mean values for each mineral did not show significant differences from those in determined in 2009, as shown in Table 5, with the exception of P content, which was lower than in 2009 for the same fraction (data not shown). Mg values were within the ranges in the literature for prickly pear pulp, with 16.1 to 98.5 mg 100 g⁻¹ (Sáenz, 2006). Mg is essential for humans due to its physiological role in adenosine triphosphate (ATP), and it has recently been suggested that moderate Mg deficiency could be a risk factor for chronic health problems, such as osteoporosis, cardiovascular disease and diabetes (Fleet and Cashman, 2003). Considering that Mg requirements for adult men and women are 320

Table 5. Element content of fruit fractions in fresh weight for *rumpá* (*Eulychnia acida*) from three sectors in the region of Coquimbo.

Fruit fraction	Sector	Peel color	Mg	Ca	P	F	Cu	K	Na
Pulp with seeds	Manquehua	Green	34.3 ± 2.8a	12.2 ± 1.1a	27.0 ± 3.2a	0.13 ± 0.05a	< 0.1	222 ± 19a	12.4 ± 7.2a
		Pink	39.7 ± 3.4c	12.2 ± 0.4a	29.8 ± 2.5ab	0.15 ± 0.02ab	< 0.1	233 ± 14a	18.1 ± 10.4a
	Quebrada Honda	Green	29.5 ± 1.1b	12.9 ± 0.2a	25.2 ± 3.4a	0.22 ± 0.04bc	< 0.1	185 ± 6b	11.2 ± 7.3a
		Green	43.3 ± 2.8c	16.4 ± 2.1b	35.0 ± 3.6b	0.20 ± 0.01c	< 0.1	286 ± 17c	9.0 ± 2.3a
Peel	Manquehua	Green	41.9 ± 2.0ab	51.2 ± 1.9a	5.3 ± 0.4ab	0.20 ± 0.00a	0.05 ± 0.01b	163 ± 8a	48.5 ± 1.6d
		Pink	45.6 ± 0.1b	56.0 ± 1.6ab	5.7 ± 0.2b	0.19 ± 0.01a	0.05 ± 0.00a	206 ± 1b	48.3 ± 1.1d
	Quebrada Honda	Green	41.3 ± 0.2a	63.9 ± 0.2c	8.2 ± 0.1c	0.19 ± 0.01a	0.05 ± 0.01a	207 ± 3b	5.7 ± 0.3a
		Pink	41.6 ± 0.8a	56.2 ± 1.2b	4.5 ± 0.0a	0.24 ± 0.02a	0.07 ± 0.00b	221 ± 9b	21.9 ± 0.3c
Juice n	Manquehua	Green	44.2 ± 0.1ab	64.7 ± 0.3c	4.8 ± 0.0a	0.24 ± 0.00a	0.04 ± 0.00a	249 ± 1c	15.0 ± 0.3b
		Green	29.3 ± 0.1c	7.1 ± 0.0c	35.2 ± 0.6a	0.04 ± 0.00a	0.04 ± 0.00b	139 ± 1a	33.6 ± 0.0e
	Quebrada Honda	Pink	28.6 ± 0.1b	6.8 ± 0.2bc	42.6 ± 0.9b	0.04 ± 0.00a	0.02 ± 0.00a	213 ± 2c	6.9 ± 0.4c
		Green	24.1 ± 0.0a	6.6 ± 0.1b	47.7 ± 1.6c	0.04 ± 0.00a	0.03 ± 0.00a	210 ± 1c	2.1 ± 0.0a
Gualliguaica	Green	22.3 ± 0.1c	5.4 ± 0.0a	45.7 ± 0.6bc	0.03 ± 0.00a	0.02 ± 0.00a	180 ± 8b	12.3 ± 0.3d	
	Green	28.8 ± 0.1a	6.7 ± 0.1b	42.5 ± 1.1b	0.03 ± 0.00a	0.02 ± 0.00a	174 ± 1b	4.7 ± 0.1b	

Mean value of three analytical samples ± standard deviation.

Mean values in the same fruit fraction followed by different letters denote significant differences at $P < 0.05$.

and 420 mg per d⁻¹, respectively, 100 g of pulp with seeds obtained from two *rumpas* fruit will contribute 10% of the Mg daily requirement (Fleet and Cashman, 2003). Regarding Ca content, Sáenz (2006) reported between 12.8 and 57 mg 100 g⁻¹ for prickly pear, values which are in the range of the values found in this work for *E. acida*. The Daily Dose Reference (DDR) for adults, teens and children over 4 years of age old used in Chile is 800 mg d⁻¹, (Ministerio de Salud, 2005), and although *rumpa* contribution would be low, any contribution to the diet is important. In addition, a low intake of this mineral has long been related to osteoporosis, and several new relationships between dietary Ca and optimal human health (Weaver, 2003) have recently been established. For P, the values for pulp with seeds and juice were in the range in the literature (Sáenz, 2006). Fe content was low compared to the literature (Sáenz, 2006), which reported 1.2 mg 100 g⁻¹ for prickly pear. Literature data for Cu was not found. K data were within the range of those reported in the literature for prickly pear, between 90 and 220 mg 100 g⁻¹ (Sáenz, 2006). K is the main intracellular cation and has a crucial role in various physiological processes. It enters all tissues and exerts deep effects on the function of some organs, in particular, the depolarization and contraction of the heart muscle (Preuss, 2003). Regarding Na, prickly pear presents low values, 0.6-1.2 mg 100 g⁻¹, compared to those in *rumpa* fractions (Sáenz, 2006).

Concerning bioactive components, *rumpa* can be considered a good source of vitamin C, the peel fraction being the principal source with the highest mean values around 53-57 mg 100 g⁻¹, followed by juice and pulp with seeds, with an average close to 35 and a range between 18-37 mg 100 g⁻¹, respectively (Table 6). It was observed that the peel color had some influence on the vitamin C content, because the green peel fraction presented higher vitamin C content than the pink peel. This difference was significant for the Manquehua sector ($p < 0.5$), where the green peel fraction showed the highest values of the three sectors sampled, with 61 mg 100 g⁻¹, followed by the

Table 6. Total vitamin C content of fruit fraction in fresh weight in rumpa for three sectors in the Region of Coquimbo.

Fruit fraction	Season	Sector	Peel color	Total vitamin C
Pulp with seeds	2009	Manquehua	Green	28.5 ± 1.3c
			Pink	36.7 ± 1.5d
		Gualliguaica Quebrada Honda	Green	25.7 ± 3.4b
			Green	17.7 ± 1.6a
Peel	2010	Manquehua	Green	61.0 ± 0.6a
			Pink	54.1 ± 0.7b
		Gualliguaica	Green	55.2 ± 1.1b
			Pink	50.5 ± 1.4b
Q, Honda	Green	52.7 ± 1.9b		
	Juice without seeds	2010	Manquehua	Green
Pink				32.7 ± 0.3b
Gualliguaica		Green	34.0 ± 0.1b	
		Pink	34.2 ± 3.9b	
Quebrada Honda	Green	21.7 ± 2.6a		

Mean value of four replications ± standard deviation; Mean values in the same fruit fraction followed by different letters denote significant differences at $P < 0.05$.

Gualliguaica sector with 55 mg 100 g⁻¹. The lowest value for the pink peel fraction was from the Gualliguaica sector, with 50 mg 100 g⁻¹. As mentioned above, the juice fraction was also important for vitamin C contribution obtained from green peel fruits harvested in the Manquehua and Gualliguaica sectors, confirming that the Quebrada Honda coastal sector, presented the lowest values. The pulp with seeds also presented high total vitamin C content, mainly in pink peel fruits from Manquehua. Fruit from Quebrada Honda again presented the lowest values. The different contents of vitamin C could be related to the environmental conditions of the three sectors (Lester, 2006). This interesting contribution of vitamin C from the three fruit fractions must be enhanced because they exceed largely those reported for several commonly consumed fruits such as plums (*P. domestica*) 3 mg 100 g⁻¹, watermelon (*Citrullus lanatus*) 3.6 mg 100 g⁻¹, pear (*P. communis*), banana (*Musa paradisiaca*) 4 mg 100 g⁻¹, apple (*M. domestica*) 6 mg 100 g, peach (*P. persica*) 7 mg 100 g⁻¹, apricot (*P. armeniaca*) 9 mg 100 g⁻¹, pineapple (*A. comosus*) 25 mg 100 g⁻¹, fresh papaw (*V. pubescens*) and pepino (*Solanum muricatum* Aiton) 26 mg 100 g⁻¹; and only less than fruits recognized as good source of vitamin C such as strawberries (*Fragaria × ananassa*) 60 mg 100 g⁻¹, lemon (*C. medica*) 61 mg 100 g⁻¹, orange (*Citrus sinensis* (L.) Osbeck) 83 mg 100 g⁻¹ and kiwi (*Actinia chinensis* Planch.) 96 mg 100 g⁻¹. *Rumpa* also presented higher values than prickly pear with 18 mg 100 g⁻¹ (Cappelli and Vannucchi, 1990, Schmidt-Hebbel *et al.*, 1992, Belitz and Grosch, 1999). It is important to note that the 100 g vitamin C content of *rumpa* pulp with seeds or 100 g of juice (around two *rumpa* fruits) can contribute practically 50% of the vitamin C DDR or 60 mg d⁻¹ (Ministerio de Salud, 2005).

The lowest value of total polyphenol content, expressed as a gallic acid equivalent (GAE) per 100 g⁻¹, was found in fruit from Manquehua. Fruit from Gualliguaica presented intermediate values and the highest were found in fruit from the coastal area of Quebrada Honda. The general range was between 44.3 and 78.1 mg percent GAE (Table 7). These data are within the range reported in the literature for prickly pear juice of round 65 mg of polyphenols per 100 mL of juice (Nazareno and González, 2008). This information is important for the antioxidant activity of this bioactive component.

Table 7. Total polyphenols, rumpa (*Eulychnia acida*) fruits, expressed as equivalents of gallic acid (EGA), in pulp with seed fraction in three sectors sampled in summer 2009.

Sector	Manquehua		Gualliguaica	Quebrada Honda
	Green	Pink	Green	Green
Peel color	mg 100g ⁻¹			
Total polyphenols	54.3 ± 6.4a	55.6 ± 10.7a	65.6 ± 1.4a	71.0 ± 9.4a
mg % EGA				
Range mg % EGA	49.4 – 61.6	44.3 – 65.6	65.1 – 67.2	60.4 – 78.1

Mean value ± standard deviation; N = 3. Mean values in the same letters indicate no significant differences at $P < 0.05$.

Other interesting bioactive components were the pigments, principally betalains in cacti. These pigments are classified as betacyanin (expressed as betanin equivalents) and betaxanthin (expressed as indicaxantin equivalents). In 2009, a preliminary determination was done of *rump*a pink peel samples from the Manquehua sector. In 2010, a second analysis of these pigments was done on pink peels obtained from *rump*a collected in the central valley areas of Gualliguaica and Manquehua (Table 8). Total betalain pigment content of fruit from Manquehua in 2010 was lower than the values obtained in the three sub-sectors sampled in 2009, but higher than the ones obtained from Gualliguaica. The content of both pigments was lower than what is reported in the literature for red prickly pears, which has 28 mg 100 g⁻¹ of betacyanin equivalents and 10 mg 100 g⁻¹ of betaxanthin equivalents in red pulp (Sepúlveda and Sáenz, 1990). This difference in red pigment content compared to that of the red *Opuntia* sp. is because the Mexican nopal has quite strong red pulp and peel, while *rump*a peel is light pink, closer to pink prickly pear fruit, which has a total betalain content of approximately 1.1-4.1 mg 100 g⁻¹ (Sáenz, 2006). The differences in betalain pigment content in pink-peeled *rump*a sampled from different sectors and two summer seasons suggests that further research is necessary in this area to quantify the variations in different years of harvesting in the same sectors and thus clarify their natural behavior.

Table 8. Total betalains, betacyanin (expressed as equivalents of betanin) and betaxanthin (expressed as equivalents of indicaxantins) content in pink peel in fresh weight of *rump*a (*Eulychnia acida*) fruits, sampled in summer 2009 and 2010.

Year	Sector	Sub Sector	Betacyanin equiv., betanine	Betaxanthin equiv., indicaxantin	Total betalains
			mg 100g ⁻¹		
2009	Manquehua (Limari Valley)	El Espinal	1.2	0.6	1.80
		El Infernillo	1.4	0.6	2.00
		Los Cardos	2.5	1.7	4.20
2010	Gualliguaica (Elqui Valley)		0.40 ± 0.1	0.40 ± 0.1	0.80
	Manquehua (Limari Valley)		0.75 ± 0.0	0.86 ± 0.1	1.61

CONCLUSIONS

This research generated the chemical and nutritional information about *E. acid* Phil. fruit, in its three fractions: pulp with seeds, peel, and juice.

Regarding weight, fruits from Manquehua were smaller than those from the other two sectors in the two evaluated seasons, but they presented a better yield between pulps with seeds related to peel. The peel represented more than 50% of the whole fruit in all the sampled *rump*as. Regarding the nutritional chemical composition of the three fractions, dietary fiber was the main component, which presented a jellied and filamentous texture characteristic of these fruits. Regarding micronutrients, there was a notably higher content of vitamin C in the

three studied fractions compared to other common fruits. The presence of mainly K and Mg and its high water content makes *rump*a a promising raw material for agro-industrial development of products such as natural juices or isotonic drinks. The preliminary information about total polyphenol and betalain pigment content in fruit fractions indicates low values compared to other fruits. It is necessary to study which aspects of climate and soil may affect the chemical composition of *rump*a for a better evaluation of the potential development of innovative products from *rump*a fruit and its fractions.

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Características químicas y composición nutricional de los frutos de copao (*Eulychnia acida* Phil.) bajo tres condiciones ambientales de la Región de Coquimbo. El copao (*Eulychnia acida* Phil.) es un cactus arborescente endémico restringido principalmente a la región semi árida de Coquimbo (29°54'28" S, 71°15'15" O), Chile. El área de distribución comprende desde el nivel del mar hasta los 1200 m de altitud. Los frutos llamados "rump", son redondos, piel de color verde o rosado con pequeñas escamas, y amplia variabilidad en peso y tamaño. El objetivo del trabajo fue caracterizar el fruto en tres sectores de la Región de Coquimbo de acuerdo a parámetros químico-nutricionales y componentes bioactivos en diversas fracciones del fruto: pulpa con semilla, jugo y piel, con el fin de visualizar posibles aplicaciones en la industria. Esta investigación mostró que la "rump" es una buena fuente natural principalmente de fibra dietética soluble, de consistencia gelatinosa, presente en las tres fracciones analizadas con valores de 2% para jugo, 3% pulpa con semilla y alrededor de 5% para piel, constituyéndose en una buena fuente potencial de hidro coloides para la industria de alimentos. Además es una buena fuente de vitamina C alrededor de 55 mg 100 g⁻¹ en la piel y 30 mg 100 g⁻¹ en pulpa con semillas y jugo, valores altos comparados con el contenido en tunas (*Opuntia ficus-indica* [L.] Mill.) Los principales minerales fueron Mg, Ca, P, y K. En la pulpa con semillas se determinaron polifenoles totales y en la cáscara rosada se determinaron los pigmentos betalainas. Las características nutricionales, junto al alto contenido de agua, alrededor de 96%, hacen de la "rump" una materia prima promisoría para el desarrollo de jugos o bebidas isotónicas naturales. Esta caracterización contribuye a una valorización productiva de una especie nativa endémica disminuyendo las potenciales amenazas de destrucción

de las poblaciones silvestres de *E. acida*, especialmente aquellas cercanas a sectores agrícolas, favoreciendo la conservación de su hábitat en la región.

Palabras clave: Rumpa, cactus arborescente, minerales, vitamina C.

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