Food Products From Cladodes and Cactus Pears

Carmen Sáenz H.
Department of Agroindustry and Food Science
Faculty of Agriculture and Forestry Science
University of Chile

INTRODUCTION

The use of processed cactus pears and cladodes by the food industry is very low in the majority of the producing countries. Except in Mexico, the fruit is consumed mainly as a fresh commodity.

Because of the great interest in growing cactus pear in semiarid regions, the Ministry of Agriculture of Chile has funded a research project to develop different products from cactus pear. Some of the results reported here are described are described in more detail elsewhere (Sáenz et al., 1996a).

NUTRITIVE VALUE

The cactus pear has vitamin and sugar contents that make it a good potential raw food source for processing (Table 1). The caloric value of its pulp is about 50 cal/100 g, comparable to that of other fruits, such as apple, pear, orange, cherimoya, and apricot. The protein, fat, crude fiber, and ash content are similar to other fruits. Cactus pear fruits are rich in calcium and phosphorous. Cactus pears are one of the fruits that can contribute a large amount of calcium to the diet.

Table 1. Chemical Composition of Cactus-Pear Pulp

Parameter	Average
Moisture (g/100 g)	83.80
Protein (g/100 g)	0.82
Fat (g/100 g)	0.09
Crude fiber (g/100 g)	0.23
Ash (g/100 g)	0.44
Vitamin C (mg %)	20.33
β-carotene (mg %)	0.53

Sepúlveda and Sáenz (1990)

PRODUCTS FROM CACTUS FRUIT

Cactus-pear processing must be based on the characteristics of the pulp. Table 2 shows some of the technological characteristics of the pulp (Sáenz, 1996; Sáenz, 1995).

Table 2. Technological Characteristics of Cactus-Pear Pulp

Characteristic		Average
pH		6.37
Acidity (% citric acid)		0.059
Total solids (%)		16.20
Soluble solids (°Brix, 20°C)		14.06
Color	L*	26.7
	a*	5.5
	b*	6.5
Viscosity (mPa s)		73.9
Pectin (%)		0.17

Sáenz, 1996; Sáenz et al., 1996a

The fruit has a fairly high sugar content (Table 2); most of the sugars are glucose and fructose which give it a very sweet taste. The soluble-solids content is greater than that of other fruits, such as prunes, apricots, cherries, peaches, apples, and melons. The majority of sugars are the reducing type, about 53% is glucose and the rest is fructose. The fruit has usually low acidity (pH 6.37) which influences its processing. Most fruits are considerably more acidic with a pH below 4.2. This higher acidity controls the growth of food pathogenic microorganisms, so such fruits can be preserved by pasteurization, or heating, to about 80°C for a few minutes. Due to its lower acidity and higher pH, cactus pear can support the growth of potentially dangerous food pathogenic organisms, which means that it has to be heated to 121°C in a sterilizer to ensure safe preservation, in a similar way to vegetables. This treatment causes a loss of flavor and color, and the juice does not resemble the original fruit. The most important problem is the growth of Lactobacillus, even in the pasteurized juice (98°C–100°C for 15 s to 20 s) (Sáenz, 1985; Sáenz, 1996).

pH is not the only characteristic that causes problems in processing cactus pear to obtain juices. The presence of chlorophyll is another problem. In Chile, green fruit predominates and it is necessary to lower the pH of the juice (with citric acid or lemon juice) to protect it. This heat treatment transforms the chlorophyll to pheophytin of a dark color. To obtain the juice, the fruit is peeled, pulped, pressed (hydraulic press), pasteurized (α-Laval-plates heat exchanger) and bottled under ultraviolet light in an aseptic chamber (Sáenz et al., 1996a). The flavor of the juice changes with the heat treatment, resulting in an unpleasant herbaceous aroma and taste.

Another possibility with cactus-pear juices is to obtain concentrated juices (Almendares et al., 1994). The lower water-activity value (a_w) of the concentrates relative to the natural juices is a clear protection against the growth of microorganisms, and this can extend the shelf life of the juice. Experiments done at the University of Chile show that concentrated juices with 63–67°Brix can be obtained; the juice was prepared in an α-Laval centrifuge vacuum evaporator, working near 40°C. While the stability of the juice against growth of the microorganisms was good, the acceptability was only 5.0 (Hedonic scale 1–9 points), which is not satisfactory. The low acceptability was due to the change in color and the herbaceous, hay-like aroma that appears after the concentration process (Sáenz et al., 1996a; Sáenz et al., 1993)

While the cactus pears in Chile are predominantly green fruit, an experimental plantation of purple cactus pear is being studied in the Faculty of Agriculture and Forestry Sciences (Table 3). The juice from this fruit is very attractive due to the presence of betalains, which give it a dark purple color.

Table 3. Characteristics of Purple-Cactus-Pear Juice

Characteristic		Average
Soluble solids (°Brix)		14
pH		5.4
Acidity (% citric acid)		0.04
Color	L*	20.3
	a*	3.2
	b*	0.08

Sáenz et al., 1995a

Due to the viscosity of the juice (Sáenz and Costell, 1990), it was diluted 1:1 and adjustments were made to the °Brix (12.5) with sugar, and the acidity (0.1%) with citric acid. Then it was tasted and compared with another sample without adjustment. The acceptability of both samples was similar and near 7 (Hedonic scale 1–9 points).

Because of the great amount of sugar in the cactus-pear fruit, another product that can be obtained from the juice is a natural liquid sweetener. The high sugar content and its composition, principally fructose and glucose, make this process very interesting. The process to obtain the syrup begins with cactus-pear juice extraction. The juice (16.5°Brix) is then enzymatically clarified (different treatments were tested), decolorated, and vacuum concentrated to 60°Brix (Sáenz et al., 1996b) (Table 4).

Physical and chemical characterization of the cactus-pear syrup is presented in Tables 4 and 5.

Table 4. Chemical Characterization of the Cactus-Pear Syrup

Characteristic	Average
Soluble solids (°Brix)	60
Acidity (% citric acid)	0.74
pH	4.31
Ash (%)	1.4
Glucose (% total sugars)	57.2

Sáenz et al., 1996b

The acidity of the syrup was higher than that of the fruit because, in order to maximize the activity of the enzyme used to clarify the juice, it was necessary to adjust the pH to 4.5 with citric acid.

The cactus-pear syrup color was light yellow (Table 5) with viscosity similar to that of sucrose solutions (55% p/p) of 28 cps. The density values are similar to those of grape sugar (60°Brix). The water-activity value (a_w) suggests that this syrup can be classified as an intermediate-moisture food. The a_w of the syrup, which is between 0.6 and 0.9, is similar to honey and jams and gives it an advantage for storage and microbiological stability.

Table 5. Physical Characteristics of Cactus-Pear Liquid Sweetener

Characteristic	Average
OD (420 nm)	0.66
Viscosity (cps)	27.05
Density (g/ml)	1.2900
a_w	0.83

Sáenz et al., 1996b

With respect to the sensory analysis, the relative sweetness of cactus-pear syrup is similar to that of glucose (65.5) and lower than fructose (151), having a value of 67 with respect to sucrose (100). The syrup yield was 15.7% of the volume of juice.

Another way to process cactus-pear fruit is by freezing. This process involves peeling the fruit, cutting it in half or in 1/4-inch slices, and freezing the pieces in an individual quick-frozen (IQF) system at –40°C. The product, packed in polyethylene bags, is stored at –20°C. These products show very good color and taste, but during defrosting the tendency to drip is an important cause of low acceptability. It is probable that the use of cryoprotectors such as sucrose solutions, pectin, or calcium chloride will increase the quality of the product (Sáenz et al., 1988).

Dehydration is an old technique to preserve foods. In the USA, several dehydrated products from fruit pulp known as "fruit leather" or "fruit sheet" have appeared. These products have very good acceptability due mainly to the change in lifestyles of people in many countries of the world. People don't have so much time to eat and prefer the ready-to-eat foods. These fruit leathers belong to this type of food (Sepúlveda et al., 1996).

At the University of Chile a mixture of cactus-pear pulp with quince pulp was made with the acidity of the mixture being increased with natural acidity from the quince. Sugar, olive oil, citric acid, and cinnamon were added, if necessary. The product has 80%–85% soluble solids, pH 3.7–3.9; low a_w values between 0.55 and 0.60; and a caloric value of about 319–327 cal/100 g.

Fruit gels are another product that can be obtained from the cactus-pear fruit. Fruit gels are commonly consumed in the world and can be made from fruits such as quince and apple. Cactus pear is one of the alternatives for fruit gels that appears to have a good possibility to add value to this crop of semiarid regions (Sáenz et al., 1996c) There are several ways to make cactus pear gels. All of these techniques involve obtaining the pulp of the fruit without the seeds, adding sugar and some gelling agent. The cooking must be with low heat over a short time because, when green cactus pears are used, the color changes to an olive (not attractive) color. This product has a consistency that allows it to be cut with a knife. The gel can be consumed with bread, like dessert, with cheese, or alone. The cactus-pear gel has good acceptability and can replace other fruits. Like other products obtained from cactus-pear pulp, citric acid can be added to the gels as a preservative, but this addition causes the color to change markedly. If the pH of the natural pulp is maintained (6.1), the color is green but if citric acid is added to improve the taste and the microbiological stability, the color changes to yellow, and the product loses acceptability.

FOOD PRODUCTS FROM CLADODES

The most common product made from cladodes is marmalade. In this case, pectin in the lemon peel and lemon juice assist in gel formation. The product obtained has 67.2°Brix, pH 3.8, and 0.97% acidity (citric acid) (Table 6). The acceptability was 7.5 (Hedonic scale 1–9 points).

Table 6. Marmalade from Cladodes and Lemon Peel

Characteristics	Average
Soluble solids (°Brix)	67
a_w	0.82
Acidity (% citric acid)	0.97
pH	3.8
Consistence (cm/min)	2.9

Sáenz et al., 1995b

Crystallized cladodes are another product we have examined. This product resembles crystallized melon peel and has great acceptability by the consumers. Sucrose or sugar cane syrup can be used to make this product. Like other crystallized fruits, the crystallized cactus cladodes can be added to plum cakes. They can also be used as an energy snack for children (Sáenz et al., 1994). To obtain this product, the cladodes are cut into pieces 1.8 x 4.0 cm, washed, and treated with calcium hydroxide to remove the mucilage. The cladodes are osmotically dehydrated with sucrose solutions of increasing concentrations. Then they are dehydrated in a forced-air tunnel at 60°C. The final product has a pH 3.7, 0.26% acidity (citric acid), a_w of 0.61, and a moisture content of 15.8%. They can be classified as an intermediate-moisture food. This product can be made more attractive if covered with sweet or bitter chocolate (Sáenz et al., 1996a).

Another possibility is to transform the cladodes into flour, which is very rich in dietary fiber (nearly 40%) and can be used for confectionery products. Table 7 presents the characteristics of this flour.

Table 7. Analytical Characterization of Flour from Cladodes

Characteristic	%
Moisture	7.5
Ash	21.3
Protein (x 6.25)	5.0
Fat	2.2
NNE (x dif)	57.6
Crude fiber	6.4

Sepúlveda et al., 1995

This flour can partially replace wheat flour in cookies or other confectionery products. The replacements tested were 2.5%, 5%, and 10%. The 10% replacement had good acceptability of nearly 7 (Hedonic scale 1–9 points) (Sáenz et al., 1995c).

BY-PRODUCTS

There are significant opportunities to use the "waste products" resulting from cactus-pear and cladode food preparations. The proportions of different parts of the fruit appear in Table 8. The use of by-products from the wastes can further increase the value of the different processes.

Table 8. Proportions of Different Parts of the Fruit

Part of the Fruit	Percentage of Fresh Fruit
Pulp and seeds	49.6
Peel	50.4

Sepúlveda and Sáenz, 1990

One by-product that can be obtained is the mucilage. Cactus-pear mucilages from fruit pulp or cladodes are complex polysaccharides, capable of imbibing large amounts of water, dissolving and dispersing themselves in it, to form viscous or gelatinous colloids. The mucilage is composed of rhamnose, arabinose, galactose, and galacturonic acid, the latter in proportions near 18%. A clear effect of pH on the viscosity of a dispersion of the mucilage was produced, reaching values of 58.1 cps at a pH of 6.6 with a 1% concentration (Sáenz et al., 1992).

Edible oil can be obtained from the seeds, with yields of nearly 6%. The oil has a high degree of unsaturation, with a high linoleic acid content (57.7%) (Sepúlveda and Sáenz, 1988). Table 9 presents the composition of the seed oil obtained from cactus-pear fruit. Table 10 presents the physical and chemical composition of the seed oil. The composition of the oil and other physical and chemical characteristics, such as refractive index, iodine number, and saponification number, are similar to other edible vegetable oils (corn or grape-seed oils).

Table 9. Cactus-Pear Seed-Oil Composition

Fatty acid	# carbon	%
Myristic acid	C14:0	0.2
Palmitic acid	C16:0	16.2
Palmitoleic acid	C16:1	1.5
Estearic acid	C18:0	3.3
Oleic acid	C18:1	19.9
Linoleic acid	C18:2	57.7
Linolenic acid	C18:3	1.2

Sepúlveda and Sáenz, 1988

Table 10. Physical and Chemical Composition of Cactus-Pear Seed Oil

Characteristic	Value
Refractive index (20°C)	1.4741
Specific weight (25°C)	0.913
Free fatty acid (% oleic acid)	0.1
Iodine number	127
Saponification number	182

Sepúlveda and Sáenz, 1988

CONCLUSIONS

Many food products can be obtained from cactus pear and cladodes, and it is desirable to develop and increase the processing technologies applicable to this crop.

REFERENCES

Sáenz, C. 1996. Food products from cactus pear *(Opuntia ficus indica)*. *Food Chain* 18:10–11.

Sáenz, C., Sepúlveda, E. and Moreno, M. 1996a. Final Report to the Ministry of Agriculture (Chile). Project: "New technologies for processing nopal and cactus pear". 103 p. (Unpublished)

Sáenz, C., Mecklenburg, P., Estévez, A.M. and Sepúlveda, E. 1996b. Natural liquid sweetener from cactus pear: obtention and characteristics. *Acta Horticulturae*. (In preparation)

Sáenz, C. , Arriagada, S., Fizsman, S. and Calvo, C. 1996c. Influence of pH and contents of carrageenan during the storage of cactus pear gels. *Acta Horticulturae*. (In preparation)

Sepúlveda, E., Sáenz, C. y Alvarez, M. 1996. Fruit leather obtention: cactus pear (*Opuntia ficus indica* (L) Mill) and quince (*Cydonia oblonga* Mill). CICTA - 5. Complete texts. PSM Publicaciones Soporte Magnético, La Habana, Cuba. 6 pp.

Sáenz, C. 1995. "Food Manufacture and by-products". pp. 137–143. In: "Agro-ecology, cultivation and uses of cactus pear". Ed. by Barbera, G., Inglese, P. and Pimienta Barrios, E. FAO Plant Production and Protection Paper Nº 132. 216 p.

Sáenz, C., Sepúlveda, E. y Moreno, M. 1995a. Characteristics of purple cactus pear pulp. XI National Congress of Food Science and Technology. 15–17 Oct. (Viña del Mar, Chile)

Sáenz, C., Sepúlveda, E. y Moreno, M. 1995b. Different formulations of nopal (*Opuntia ficus indica*) marmalades. XI National Congress of Food Science and Technology. 15–17 Oct. (Viña del Mar, Chile)

Sepúlveda, E.; Sáenz, C. y Moreno, M. 1995. Obtention and characteristics of nopal flour. Memorias del 6º Congreso Nacional, 4º Internacional "Conocimiento y Aprovechamiento del Nopal." Guadalajara, Jalisco, México. pp. 28–31

Sáenz, C.; Sepúlveda, E.; Moreno, M. y Pak, N. 1995b. Functional properties of nopal flour: uses in cookies preparation. Memorias del 6º Congreso Nacional, 4º Internacional "Conocimiento y Aprovechamiento del Nopal." Guadalajara, Jalisco, México. pp. 24–27

Sáenz, C.; Sepúlveda, E. y Moreno, M. 1994. Obtention of crystallized nopal. VIII Latin-American and Caribbean Seminar of Food Science and Technology. 16–21 Oct. Montevideo, Uruguay.

Almendares, L.; Sáenz, C. y Berger, H. 1993. Elaboración y concentración de jugo de tuna (*Opuntia ficus indica* (L) Mill), obtenido a partir de fruta fresca y con almacenaje refrigerado. X National Congress of Food Science and technology. 11–13 de Noviembre, (Pucón, Chile).

Sáenz, C.; Sepúlveda, E.; Araya, E. and Calvo, C. 1993. Colour changes in concentrated juices of prickly pear (*Opuntia ficus indica*) during storage at different temperatures. *Lebensmittel-Wissenschaft und Technologie.* 26:417–421.

Sáenz, C. and Sepúlveda, E. 1993. Agroindustrial uses for cactus pear. *Alimentos* 18(3):29–32

Sáenz, C.; Vásquez, M.; Trumper, S. y Fluxá, C. 1992. Extraction and chemical composition of cactus pear mucilages (*Opuntia ficus indica*). II Congreso Internacional de Tuna y Cochinilla. Santiago, Chile.

Sáenz, C. y Costell, E. 1990. Rheology of prickly pear (*Opuntia ficus indica*) concentrated juices. In: Engineering and Food. Ed. by Spiess and Schubert. Elsevier Applied Science. Vol. 1:133–142. London, U.K.

Sepúlveda, E. and Sáenz, C. 1990. Chemical and physical characteristics of prickly pear (*Opuntia ficus indica*) pulp. *Rev. Agroquim. Tecnol. Aliment.* 30(4):551–555.

Sáenz, C.; Sepúlveda, E. y Araya, E. 1988. Preliminary assays to prepare frozen cactus pear. III Congreso Nacional y VI Seminario Latinoamericano de Ciencia y Tecnología de Alimentos. Bogotá, Colombia.

Sepúlveda, E. y Sáenz, C. 1988. Prickly pear (*Opuntia ficus indica)* processing: I. Seed oil. *Alimentos* 13(1):35–38.

Sáenz, C. 1985. The prickly pear (*Opuntia ficus indica*): a cultivar with prospects. *Alimentos* 10(3):47–49.