Cactus Pear Sheet and Pasteurized and Sterilized Cactus Pear Juices♦

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ABSTRACT

Orange-yellow cactus pear pulp was evaluated for some technological and chemical characteristics. The pulp was used to produce dehydrated cactus pulp sheet and pasteurized and sterilized cactus pear juices. A preliminary study was carried out to evaluate the effects of drying temperature (60 and 70ºC) and pulp thickness (5, 10, and 15mm) on the dehydration rate of cactus pear pulp. Cactus pear pulp was prepared for dehydration by adding different ratios of sucrose (0, 1, 2, 3, 4, 5, and 10%). The prepared pulps were dehydrated in an air oven, and then evaluated organoleptically. The most accepted sheets were those prepared with 2 and 3% sucrose. For cactus pear juices, pulp was mixed with sugar solution in a ratio of (1:1), and adjusted before thermal treatment at 15ºBrix and pH 5. This prepared juice divided into three parts, the first was pasteurized directly at 95ºC, the second was treated with 100 ppm sodium benzoate and then pasteurized at 95ºC, and the third was sterilized directly at 121ºC. Some technological, chemical, microbiological, and sensory characteristics of the three produced juices were evaluated during storage at room (28±5ºC) and refrigeration (8±2ºC) temperatures for six months. All produced juices were microbiologically stable for the storage period, and the pasteurized juices were the best organoleptically.

Key words: Cactus pear pulp, sheet, pasteurization, sterilization, juices.

INTRODUCTION

Opuntia cactus pear can be considered as a plant of the future. It is a promising plant, widely distributed in many countries such as Mexico, United States, South Africa, Australia, and Mediterranean basin countries. It is one of the most suitable plants to cultivate in arid and semiarid regions around the world (Nobel, 1995; Mizrahi et al., 1997; Inglese et al., 2002; Piga, 2004). The plant is grown for fruits, vegetables, forage, and fodder production (Russel and Felker, 1987; Pimienta-Barrios and Munoz-Urias, 1995; Rodriguez-Felix, 2002). It supplies two edible parts, the fleshy stem (cladode) and highly attractive and nutritious fruit.

The fruit contains a delicately flavored juicy edible pulp. This pulp has an attractive color that varies from a soft green, greenish-white, canary-yellow, orange-yellow, lemon-yellow, red, and cherry-red to purple hues (Munoz De Chavez *et al.,* 1995; Gurrieri *et al*., 2000; Saenz and Sepulveda, 2001). These attractive colors are due to the betalains comprising the red-violet betacyanins and the yellow-orange betaxanthins (Odoux and Dominguez-Lopez, 1996; Stintzing *et al.,* 1999b; Fernandez-Lopez and Almela, 2001; Saenz, 2002; Stintzing *et al.,* 2002). These colorants maintain their appearance over a wide pH range (from 4 to 7), which makes them ideal pigments for coloring many foods (Montefiori, 1990; Krifa *et al*., 1994; Saenz, 2000; Stintzing *et al.,* 2000).

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The pulp exhibits a high pH value (5.3 to 7.1), low acidity (0.01% to 0.18% as citric acid equivalents), and total soluble solids content ranging from 10.7° to 17°Brix, mainly due to reducing sugars (Askar and EL-Samahy, 1981; Sawaya *et al.*, 1983; Saenz, 1985; Russell and Felker, 1987; Parish and Felker, 1997; Saenz and Sepulveda, 1999; Gurrieri *et al.*, 2000; Abdel-Nabey, 2001; Piga *et al*., 2003; EL-Samahy *et al*. 2006a,b). These characteristics make the pulp a very good medium for microbial spoilage (Saenz, 2000) but, on the other hand, very suitable to be added to low-acid foods. Sugar, protein, dietary fibers, and ash contents are similar to those of other fruits (Saenz-Hernandez, 1995 and Stintzing *et al*., 2001). In general, pulp is rich in nutraceuticals and functional properties (Stintzing *et al*., 1999a, 2000, 2001; Saenz, 2002; Piga *et al.*, 2003; Piga, 2004; Moßhammer *et al*., 2006). Also, the fruit contents of pectin and mucilaginous components influence the pleasant flavor of pulp and could serve as thickening agents by forming viscous colloids (Saenz *et al*., 1992; Stintzing, *et al* 2001; Piga, 2004).

The pulp could be processed into many different products such as juices, dehydrated sheets, marmalades, jellies, jams, natural sweeteners, wines and other alcoholic beverages, candies, canned and frozen fruit, etc. (Sawaya *et al.*, 1983; Ewaidah and Hassan, 1992; Barbera, 1995; Saenz-Hernandez, 1995; Gurrieri *et al*., 2000; Saenz, 2000; Sepulveda *et al*., 2000; Saenz and Sepulveda, 2001; Abdel-Nabey, 2001; Moßhammer *et al*., 2006).

Many fruits could be preserved by drying as dried fruit, such as dried prunes, or as dried pulp sheet, such as dried apricot sheet. The dried sheets of fruit pulps (fruit leathers) and fruit juices have an attractive taste and good nutritional value. These characteristics make them desirable products for consumers. Some fruit pulps, such as cactus pear pulp, have high pH and low acidity, which make them more susceptible to microbial spoilage. From these points of view the aims of this study were to produce delicate and nutritive dehydrated sheet and juices from cactus pear pulp.

MATERIALS AND METHODS

Materials

Cactus Pear Fruits
Orange-yellow cactus pear fruits were collected from a specialized orchard located in the Al-Sharqiyah region of Egypt. The fruits were collected at the end of July and at the same ripening stage (half ripening).

Cactus Pear Pulp
Cactus fruits were washed, and then manually peeled. Separation of seeds was carried out as mentioned by El-Samahy *et al.* (2006b). The fresh extracted pulp was evaluated for some technological and chemical characteristics.

Methods

Methods Of Processing
Cactus Pear Sheet
First, the effects of two different drying temperatures (60 and 70ºC) at the same pulp thickness (15mm) were evaluated. Also, three pulp thicknesses (5, 10, and 15mm) at the same drying temperature (60ºC) were evaluated. The size of sheet used was 20 × 15cm for all treatments and the weight was 7400 g/m^2 for 5mm pulp thickness. Drying was carried out at moderate air velocity (4.0m/s) using an air oven (WT binder, type F115, USA). Some parameters, M_O (initial moisture content), M_C (critical moisture content), M_E (equilibrium moisture content), M_F (final moisture content), $(dM/d\theta)_C$ (the rate during the constant drying rate period) and θ_{Exp} (time required for the dehydration process) were determined for all dehydration processes.

Then, pulp was used to produce cactus pear sheets that different in sucrose addition. The sheets were prepared by thoroughly mixing pulp in differed sucrose ratios (0, 1, 2, 3, 4, 5, and 10%). The formulas had TSS values 13.5, 14.5, 15.5, 16.5, 17.5 18.5, and 23.5ºBrix, respectively. The preparations were spread in 10mm thickness, and then dried at 60ºC for 44 hours. Sensory evaluation of produced cactus pear sheets was carried out for taste, odor, color, texture, and overall acceptability.

Cactus Pear Juice

Pulp, filtered through two folds of cotton cloth, was mixed with sugar solution (16.5°Brix) in a 1:1 ratio to obtain the final total soluble solids (15°Brix). The pH of the mixture was adjusted to pH 5.0 with citric acid. After that, the mixture was divided into three parts. The first part was directly filled into 100ml glass bottles after heating to 80°C, and then pasteurized in boiling water for 25 minutes (the temperature inside the bottles was 95°C). The second part was treated with 100ppm sodium benzoate before heating to 80°C and then filled immediately in glass bottles and pasteurized in boiling water for 25 minutes. The third part was directly filled into glass bottles after heating to 80°C, and then sterilized at 121°C for 10 minutes. All bottles were suddenly cooled with water after heat treatments. The juice bottles were stored at two temperatures, room temperature (28±5°C) and refrigeration temperature (8±2°C) as shown in Figure 1.

Methods of Analysis

Technological and Chemical Analysis

All technological and chemical characteristics of cactus pulp, sheet and juice (except color index, color attributes, and viscosity) were measured according to AOAC (1990).

Color index was determined according to Meydov *et al*. (1977). The juice sample was centrifuged at 2000 rpm for 20 minutes. The supernatant was diluted with 95% ethanol (1:1), and then filtered through a Wattman No. 4 filter. Transmittance of light through the sample was measured at 420 nm wavelength.
Color attributes (L^*, a^*, b^*, C^*, and H^*) were evaluated using a Minolta Color Reader CR-10 (Minolta Co. Ltd., Tokyo, Japan).

Viscosity of juices given in mPa•s was measured in a Brookfield Digital Rheometer Model DV-III+ (Brookfield, Middleboro, USA) at 25ºC using an Sc_4-21 spindle at 200 rpm speed.

Microbiological Analysis for Juices

The plate count agar was used for aerobic mesophiles and spore formers. Lactobacillus-MRS agar was used for lactic-acid bacteria. MacConkey broth was used for the coliform group. Yeast extract-glucose chloramphenicol agar was used for yeasts and molds. Aerobic mesophiles and spore formers were incubated at 35°C for 2 days; lactic acid bacteria were anaerobically incubated at 35°C for 2 days. The coliform group was incubated at 37°C for 2 days, while yeasts were incubated at 25°C for 4 days, as described by Shatta (1994).

Sensory Evaluation For Sheets

Staff members and semitrained panelists judged the cactus pear sheets for taste (10), aroma (10), color (10), and texture (10). The total acceptability (40) was calculated from the total scores of tested attributes.

Sensory Evaluation For Juices

Staff members and semitrained panelists evaluated the cactus pear juice for taste (10), odor (10), color (10), mouth feel (10), and appearance (10). The total acceptability (50) was calculated from the total scores of tested attributes.

Statistical Analysis

The results are presented as means, plus or minus standard deviation, from three replicates of each experiment, except color attributes (10 replicates). The analysis of variance (ANOVA) was carried out to test the possible significance ($p \leq 0.05$) among mean values of sensory evaluation using Fisher's Least Significance Difference (LSD) as described by Ott, 1984.

RESULTS AND DISCUSSION

Technological and Chemical Characteristics of Cactus Pear Pulp

Values presented in Table1 indicate that cactus pear pulp has a high pH value and low acidity (in citric acid), which make it very suitable media for microorganisms. Pulp has attractive colors and good contents of sugars, dietary fibers, pectin, vitamin C, and a high sugar/acid ratio (Askar and EL-Samahy, 1981; Saenz, 1985; Parish and Felker, 1997; Saenz and Sepulveda, 1999; Abdel-Nabey, 2001; El-Samahy *et al*. 2006a,b).

Factors Affecting The Drying Rate Of Cactus Pear Pulp

Results presented in Table 2 and plotted in Figure 2 show the effect of drying air temperatures (60 and 70ºC) at constant drying air velocity (4.0 m/s) and thickness of cactus pear pulp layer (15.0 mm). Obtained curves indicated that the drying rate at 70ºC was faster compared to the drying rate at 60ºC, whereas drying time at 70ºC (20 hours) was less than at 60ºC (46 hours). Final moisture contents (M_F) were 0.14 $g \bullet 100g^{-1}$ after 46 hours and 0.15 $g \bullet 100g^{-1}$ after 20 hours of drying at 60 and 70ºC, respectively. The critical moisture contents (M_C), measured at the intersection of the constant rate line with the falling rate line were 2.63 and 1.23 during dehydration at 60 and 70ºC, respectively. Drying rates at the constant rate period $(dM/d\theta)_C$ were 0.37 and 0.42 during drying at 60 and 70ºC, respectively.

Results presented in Table 3 and plotted in Figure 3 show that the drying rate decreased by increasing the thickness of cactus pear layer on the tray, whereas times required for dehydration process were 26, 42, and 46 hours at 5, 10, and 15 mm thickness, respectively, to reach a final moisture content (M_F) 0.14.

Sensory Evaluation of Cactus Pear Sheets

Cactus pear sheets prepared with 0, 1, 2, 3, 4, 5, and 10% sucrose had moisture contents 11.22, 11.8, 11.26, 11.65, 12.35, 12.56, and 13.22%, respectively. Results presented in Table 4 show that sheets containing 2 and 3% sugar had the highest scores of total acceptability, and there were no significant differences ($p \leq 0.05$) between the control sample and sheets containing 1, 2, and 3% sugar in aroma, color, and texture. In general, we can say that cactus pear sheets could be produced without or with added sugar up to 3% with good sensory characteristics.

Technological and Chemical Characteristics of Cactus Pear Juices

Results presented in Table 5 show that pH values for all treatments were relatively stable during storage. Also, sterilized juices had the highest values of pH values, which may be due to the effect of heat treatment on some components of the pulp, such as proteins, whereas cactus pulp has high content of basic amino acids (Stintzing *et al*., 1999a).

Color index values of pasteurized juices were higher than those of sterilized juices, which may be due to the effect of high heat treatment of sterilization on cactus pear pigments (Drdák and Vallová, 1990). Color

index values decreased during the storage period either at room or refrigeration temperatures, but the decrement was higher in the case of juices stored at room temperature than those stored at refrigeration temperature. It may be due to the effect of storage temperature and light on the cactus pear pigments (Von Elbe *et al*., 1974).

Viscosity values of sterilized juices were higher than those of pasteurized juices, which may be due to the effect of high thermal treatment on some components of the juice, such as pectin, sugar, etc., whereas viscosity is a function of temperature and the concentration of dissolved solids (Bayindirli, 1992; El-Samahy *et al*. 2006a, b).

Color Attributes of Cactus Pear Juices

Values presented in Table 6 show that there are differences in color attributes between pasteurized and sterilized juices. Lightness (L^*) values of sterilized juices were higher than those of pasteurized juices. Lightness (L^*) values of bottles stored at room temperature were slightly higher than those bottles stored at refrigeration temperature. It may be due to degradation of cactus pear pigments during storage, which agrees with data obtained for color index values. The sterilized juices had redness a^* and yellowness b^* values lower than that for pasteurized juices. Redness (a^*) and yellowness (b^*) values decreased for all treatments during the storage period at both storage temperatures. Juices stored at room temperature had yellowness (b^*) values lower than those stored at refrigeration temperature.

In general, sterilized juices had low a^*, b^* and C^* values and high L^* and H^* values compared with both pasteurized juices, which make it less acceptable especially for color and appearance as a result of the effect of high thermal treatment on pulp pigments.

Microbiological Status of Cactus Pear Juices

Data presented in Table 7 indicate that the log numbers of total bacterial count, lactic-acid bacteria and spore formers were less than one (<1) for all treatments during the storage period at room and refrigeration temperatures. Yeast, molds, and coliform groups were absent during the storage period for all juices stored at room or refrigeration temperatures. These results agree with the strict limits of microbiological standards for fruit juices (Egyptian Standards, 1996a,b), and indicated that produced cactus juices had good quality and could be microbiologically stable for long storage periods.

Sensory Evaluation of Cactus Pear Juices

Sensory characteristics of juices presented in Table 8 and the overall means in Table 9 show that total acceptability of sterilized juice to be significantly lower ($p \leq 0.05$) than those of pasteurized juices (with or without sodium benzoate), whereas sterilized juices had the lowest values for color, taste, and aroma. The serious deterioration of color, taste, and odor of sterilized juices may be due to the destructive effect of the thermal process on pigments, chemical composition, and aroma compounds of cactus pear pulp. Most of aroma compounds of cactus pulp are volatiles, such as alcohols, esters, ethers, and volatile acids (Flath and Takahashi, 1978; Di Cesare and Nani, 1992; Arena *et al*., 2001; Weckerle *et al*., 2001). The obtained values of color and appearance agree with values of color index and color attributes for all juices.

Juices stored at refrigeration temperature had overall acceptability scores significantly higher than juices stored at room temperature, which may be due to the low temperature that reduced the changes in juice characteristics. In general, pasteurized yellow-orange cactus pear juices may be produced with good

chemical, microbiological, and sensory characteristics as well as stability, especially when stored at refrigeration temperature.

CONCLUSION

In conclusion, this investigation shows the potential value of cactus pear pulp as a good natural source of energy and nutritive components and also the possibility of producing unique and delectable products from cactus pear pulp, such as sheets and plain juices. Sensory characteristics of produced cactus pear sheets were enhanced by adding sugar up to 3%. Pasteurized cactus pear juices (with or without sodium benzoate), especially stored at refrigeration temperature, had sensory characteristics better than those of sterilized juice. Both pasteurized and sterilized juices were microbiologically stable during storage for six months.

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Figure 1. Flow sheet of preparation of cactus pear juice

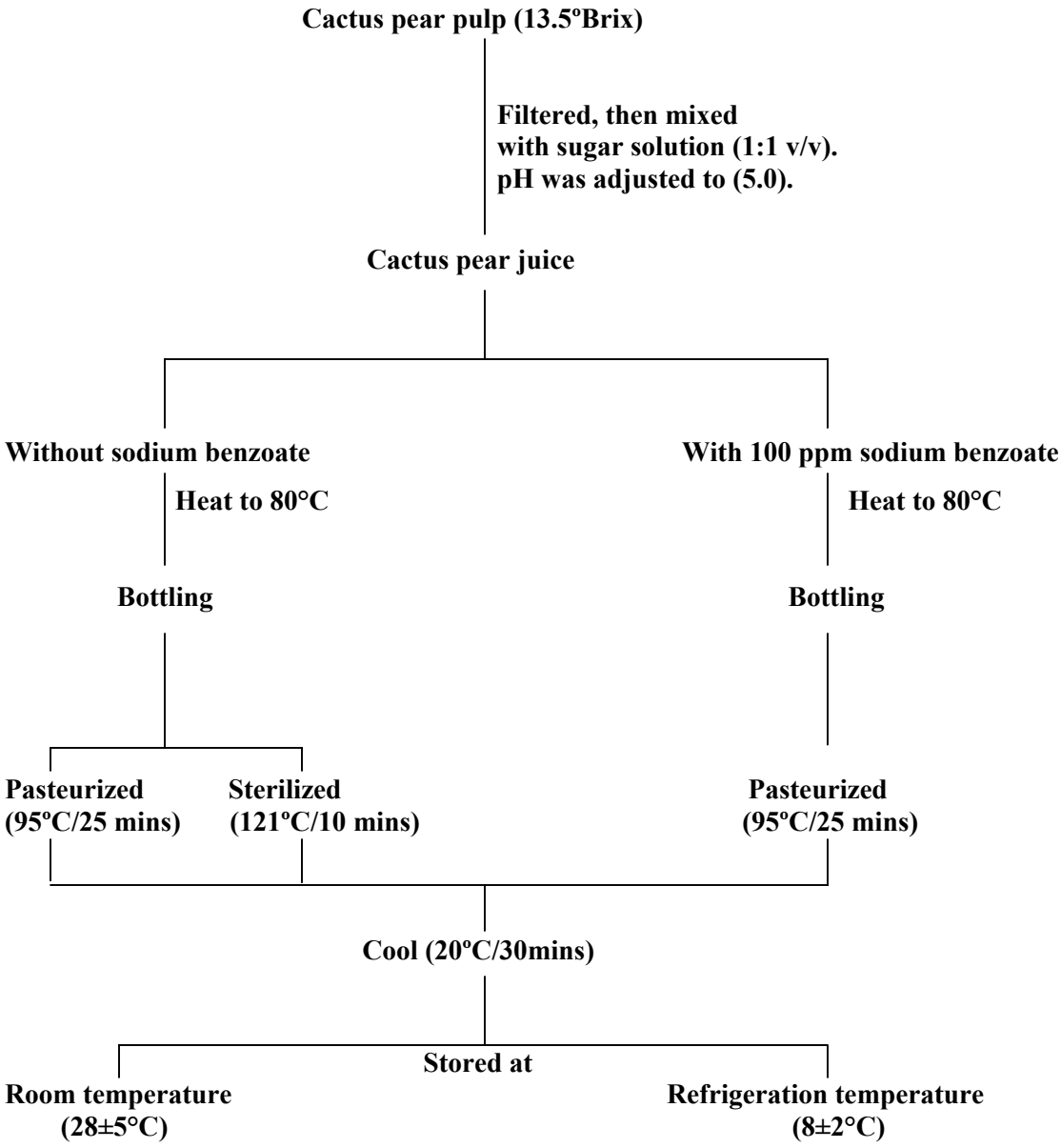

Figure 2. Effect of drying air temperatures on drying curve of cactus pear pulp

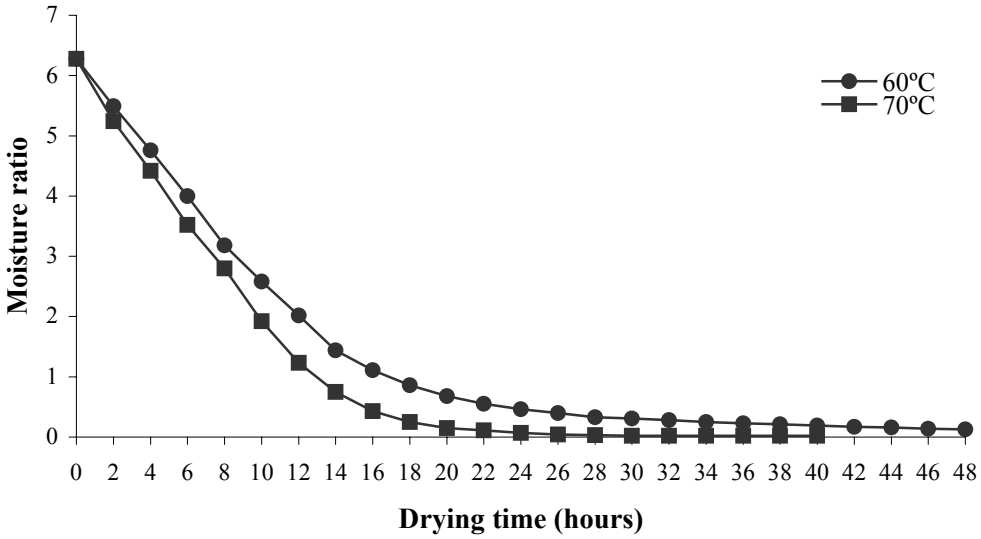

Figure 3. Effect of thickness on drying curve of cactus pear pulp

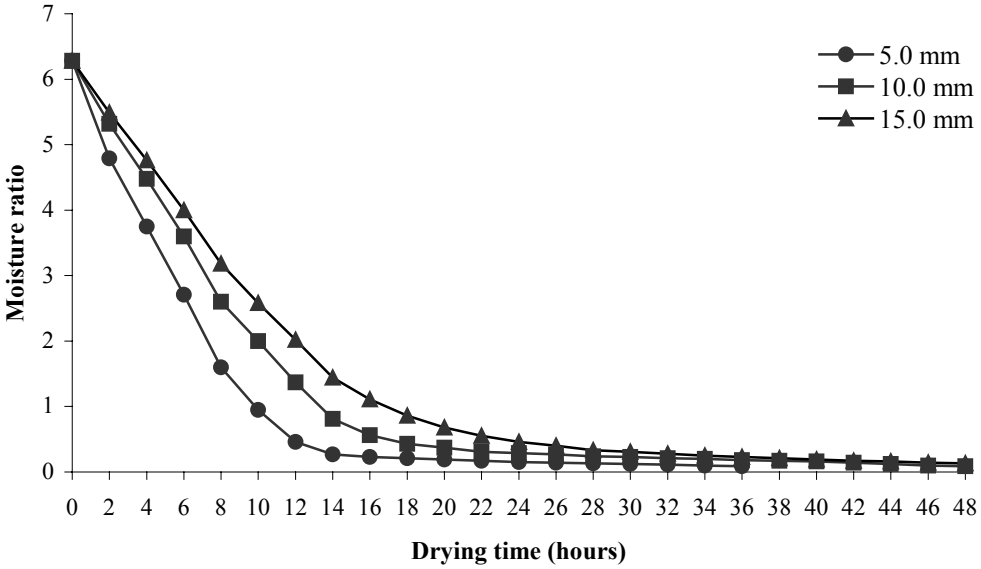

Table 1. Some technological and chemical characteristics of cactus pear pulp

Characteristics	Cactus pear pulp
pH value	6.20 ± 0.1
Acidity (%)	0.049 ± 0.002
TSS (°Brix)	13.50 ± 0.2
Vitamin C (mg $100g^{-1}$)	21.50 ± 1.2
Color attributes L^*	30.60 ± 0.8
a^*	1.60 ± 0.1
b^*	10.90 ± 0.1
C^*	11.00 ± 0.1
H^*	81.65 ± 0.1
Moisture ($g \bullet 100g^{-1}$)	86.27 ± 0.2
Total Sugars (%)*	88.02 ± 1.0
Reducing sugars (%)*	85.24 ± 1.0
Pectin (%)*	2.39 ± 0.2
Fiber (%)*	1.40 ± 0.03
Sugar/acidity ratio	246.6 ± 2.6

* Calculated on dry-weight basis.
- Values are means ± SD (n = 3).

Table 2. Initial, critical, equilibrium, and final moisture contents, $(dM/d\theta)_C$, and θ_{Exp} at different temperatures

Temperature (°C)	M_O	M_C	M_E	M_F	$(dM/d\theta)_C$	θ_{Exp} (hours)
60	6.28	2.63	0.09	0.14	0.37	46
70	6.28	1.23	0.09	0.15	0.42	20

M_O= Initial moisture content (dry basis)
M_C= Critical moisture content (dry basis)
M_E= Equilibrium moisture content (dry basis)
M_F= Final moisture content (dry basis)
$(dM/d\theta)_C$= The rate during the constant-drying-rate period
θ_{Exp}= Time required for the dehydration process

Table 3. Initial, critical, equilibrium, and final moisture contents, $(dM/d\theta)_C$, and θ_{Exp} at different thicknesses

Thickness (mm)	M_O	M_C	M_E	M_F	$(dM/d\theta)_C$	θ_{Exp} (hours)
5.0	6.28	1.60	0.09	0.14	0.49	26
10.0	6.28	2.00	0.09	0.14	0.43	42
15.0	6.28	2.63	0.09	0.14	0.37	46

M_O= Initial moisture content (dry basis)
M_C= Critical moisture content (dry basis)
M_E= Equilibrium moisture content (dry basis)
M_F= Final moisture content (dry basis)
$(dM/d\theta)_C$= The rate during the constant-drying-rate period
θ_{Exp}= Time required for the dehydration process

Table 4. Sensory characteristics of cactus pear sheets

Cactus pear sheets prepared from:	Taste (10)	Odor (10)	Color (10)	Texture (10)	Total acceptability (40)
CPP + 0 % S	8.25[b]	8.25[a]	7.50[b]	7.75[a,b]	31.75[b,c]
CPP + 1 % S	8.25[b]	8.50[a]	7.75[b]	8.25[a]	32.75[b]
CPP + 2 % S	9.50[a]	8.75[a]	8.00[a,b]	8.00[a]	34.25[a]
CPP + 3 % S	9.75[a]	8.25[a]	8.00[a,b]	8.25[a]	34.25[a]
CPP + 4 % S	7.75[b]	7.50[b]	8.25[a,b]	7.25[b]	30.75[c]
CPP + 5 % S	7.75[b]	6.75[c]	8.75[a]	5.50[c]	28.75[d]
CPP + 10 % S	5.75[c]	5.75[d]	6.50[c]	4.75[d]	22.75[e]

CPP = Cactus pear pulp. S = sugar.
Means having the same letter within each property are not significantly different at $p \leq 0.05$ ($n = 3$).

Table 5. Changes in pH values, acidity %, color index and viscosity of cactus pear juices during storage

Parameter	Storage temp.	Treatment	Storage period (month)						
			0	1	2	3	4	5	6
pH value	28±5ºC	Pasteurization	5.38±0.00	5.38±0.01	5.37±0.01	5.35±0.02	5.34±0.01	5.34±0.01	5.32±0.01
		Past.+Sod.benz.	5.37±0.00	5.37±0.01	5.36±0.01	5.36±0.02	5.35±0.01	5.33±0.01	5.33±0.01
		Sterilization	5.56±0.00	5.53±0.01	5.53±0.01	5.53±0.01	5.52±0.01	5.52±0.01	5.50±0.01
	8±2ºC	Pasteurization	5.38±0.00	5.36±0.01	5.35±0.01	5.34±0.02	5.34±0.01	5.33±0.01	5.33±0.01
		Past.+Sod.benz.	5.37±0.00	5.36±0.01	5.36±0.01	5.35±0.02	5.35±0.01	5.34±0.01	5.33±0.01
		Sterilization	5.56±0.00	5.56±0.01	5.56±0.01	5.55±0.02	5.54±0.01	5.52±0.01	5.53±0.01
Color index (O. D. at 420nm)	28±5ºC	Pasteurization	0.233±0.003	0.128±0.003	0.111±0.006	0.108±0.003	0.102±0	0.100±0.002	0.098±0.002
		Past.+Sod.benz.	0.220±0.003	0.146±0.003	0.109±0.006	0.105±0.003	0.103±0	0.094±0.002	0.091±0.002
		Sterilization	0.149±0.003	0.147±0.003	0.143±0.006	0.139±0.003	0.135±0	0.133±0.002	0.133±0.002
	8±2ºC	Pasteurization	0.233±0.003	0.216±0.003	0.191±0.006	0.182±0.003	0.175±0	0.171±0.002	0.168±0.002
		Past.+Sod.benz.	0.220±0.003	0.214±0.003	0.193±0.006	0.183±0.003	0.171±0	0.167±0.002	0.160±0.002
		Sterilization	0.149±0.003	0.148±0.003	0.146±0.006	0.145±0.003	0.143±0	0.141±0.002	0.139±0.002
Viscosity (mPa.S)	28±5ºC	Pasteurization	6.25±0.25	6.25±0.25	6.00±0.25	6.25±0.25	6.25±0.25	6.25±0.25	6.00±0.25
		Past.+Sod.benz.	6.25±0.25	6.25±0.25	6.00±0.25	6.25±0.25	6.25±0.25	6.00±0.25	6.25±0.25
		Sterilization	6.50±0.25	6.50±0.25	6.25±0.25	6.25±0.25	6.25±0.25	6.25±0.25	6.25±0.25
	8±2ºC	Pasteurization	6.25±0.25	6.25±0.25	6.25±0.25	6.25±0.25	6.25±0.25	6.25±0.25	6.00±0.25
		Past.+Sod.benz.	6.25±0.25	6.00±0.25	6.25±0.25	6.25±0.25	6.00±0.25	6.25±0.25	6.25±0.25
		Sterilization	6.50±0.25	6.50±0.25	6.50±0.25	6.25±0.25	6.50±0.25	6.25±0.25	6.25±0.25

Past.+Sod.benz. = Pasteurization + Sodium benzoate.
Values are means ± SD ($n = 3$).

Table 6. Changes in color attributes (L^*, a^*, b^*, C^*, H^*) of cactus pear juices during storage

Parameter	Storage temp.	Treatment	Storage period (month)						
			0	1	2	3	4	5	6
L^*	28±5ºC	Pasteurization	26.4 ± 0.3	27.0 ± 0.6	27.0 ± 0.4	27.6 ± 0.4	27.2 ± 0.3	27.9 ± 0.4	28.3 ± 0.4
		Past.+Sod.benz.	26.4 ± 0.3	26.8 ± 0.6	26.9 ± 0.4	26.8 ± 0.4	27.2 ± 0.3	27.9 ± 0.4	28.1 ± 0.4
		Sterilization	28.2 ± 0.3	28.2 ± 0.6	28.3 ± 0.4	28.6 ± 0.4	28.7 ± 0.3	29.1 ± 0.4	29.5 ± 0.4
	8±2ºC	Pasteurization	26.4 ± 0.3	26.4 ± 0.6	27.2 ± 0.4	26.8 ± 0.4	26.3 ± 0.3	26.0 ± 0.4	26.7 ± 0.4
		Past.+Sod.benz.	26.4 ± 0.3	27.1 ± 0.6	26.5 ± 0.4	26.0 ± 0.4	26.4 ± 0.3	26.9 ± 0.4	26.8 ± 0.4
		Sterilization	28.2 ± 0.3	28.2 ± 0.6	28.2 ± 0.4	28.1 ± 0.4	28.4 ± 0.3	28.4 ± 0.4	28.5 ± 0.4
a^*	28±5ºC	Pasteurization	3.6 ± 0.2	3.4 ± 0.1	3.4 ± 0.1	3.0 ± 0.1	2.9 ± 0.2	2.2 ± 0.1	2.0 ± 0.1
		Past.+Sod.benz.	3.3 ± 0.2	3.5 ± 0.1	3.5 ± 0.1	3.2 ± 0.1	3.0 ± 0.2	3.0 ± 0.1	3.0 ± 0.1
		Sterilization	1.8 ± 0.2	1.9 ± 0.1	1.8 ± 0.1	1.6 ± 0.1	1.4 ± 0.2	1.2 ± 0.1	1.1 ± 0.1
	8±2ºC	Pasteurization	3.6 ± 0.2	3.2 ± 0.1	3.7 ± 0.1	3.8 ± 0.1	3.9 ± 0.2	3.1 ± 0.1	3.0 ± 0.1
		Past.+Sod.benz.	3.3 ± 0.2	3.4 ± 0.1	3.5 ± 0.1	3.5 ± 0.1	3.4 ± 0.2	3.9 ± 0.1	3.3 ± 0.1
		Sterilization	1.8 ± 0.2	1.8 ± 0.1	1.6 ± 0.1	1.4 ± 0.1	1.4 ± 0.2	1.2 ± 0.1	1.4 ± 0.1
b^*	28±5ºC	Pasteurization	4.5 ± 0.2	4.2 ± 0.1	3.0 ± 0.1	2.7 ± 0.1	3.0 ± 0.2	3.9 ± 0.1	3.4 ± 0.1
		Past.+Sod.benz.	4.8 ± 0.2	3.8 ± 0.1	3.7 ± 0.1	3.5 ± 0.1	3.9 ± 0.2	3.6 ± 0.1	3.4 ± 0.1
		Sterilization	3.4 ± 0.2	3.5 ± 0.1	3.3 ± 0.1	3.3 ± 0.1	3.1 ± 0.2	3.0 ± 0.1	2.8 ± 0.1
	8±2ºC	Pasteurization	4.5 ± 0.2	5.2 ± 0.1	5.0 ± 0.1	5.0 ± 0.1	5.0 ± 0.2	4.9 ± 0.1	4.6 ± 0.1
		Past.+Sod.benz.	4.8 ± 0.2	5.3 ± 0.1	5.3 ± 0.1	5.2 ± 0.1	5.1 ± 0.2	5.3 ± 0.1	5.3 ± 0.1
		Sterilization	3.4 ± 0.2	3.5 ± 0.1	3.7 ± 0.1	3.8 ± 0.1	3.8 ± 0.2	3.9 ± 0.1	4.0 ± 0.1
C^*	28±5ºC	Pasteurization	5.7 ± 0.2	5.4 ± 0.1	4.5 ± 0.1	4.0 ± 0.1	4.2 ± 0.2	4.5 ± 0.1	3.9 ± 0.1
		Past.+Sod.benz.	5.8 ± 0.2	5.2 ± 0.1	5.1 ± 0.1	4.7 ± 0.1	4.9 ± 0.2	4.7 ± 0.1	4.5 ± 0.1
		Sterilization	3.8 ± 0.2	4.0 ± 0.1	3.8 ± 0.1	3.7 ± 0.1	3.4 ± 0.2	3.2 ± 0.1	3.0 ± 0.1
	8±2ºC	Pasteurization	5.7 ± 0.2	6.1 ± 0.1	6.2 ± 0.1	6.3 ± 0.1	6.3 ± 0.2	5.8 ± 0.1	5.5 ± 0.1
		Past.+Sod.benz.	5.8 ± 0.2	6.3 ± 0.1	6.3 ± 0.1	6.3 ± 0.1	6.1 ± 0.2	6.6 ± 0.1	6.2 ± 0.1
		Sterilization	3.8 ± 0.2	3.9 ± 0.1	4.0 ± 0.1	4.0 ± 0.1	4.0 ± 0.2	4.1 ± 0.1	4.2 ± 0.1
H^*	28±5ºC	Pasteurization	51.3 ± 0.2	51.0 ± 0.1	41.4 ± 0.1	42.0 ± 0.1	46.0 ± 0.2	60.5 ± 0.1	59.5 ± 0.1
		Past.+Sod.benz.	55.4 ± 0.2	47.3 ± 0.1	46.6 ± 0.1	47.5 ± 0.1	52.4 ± 0.2	50.2 ± 0.1	48.6 ± 0.1
		Sterilization	62.1 ± 0.2	61.5 ± 0.1	61.4 ± 0.1	64.1 ± 0.1	65.7 ± 0.2	68.2 ± 0.1	68.5 ± 0.1
	8±2ºC	Pasteurization	51.3 ± 0.2	58.4 ± 0.1	53.5 ± 0.1	52.7 ± 0.1	52.0 ± 0.2	57.7 ± 0.1	56.9 ± 0.1
		Past.+Sod.benz.	55.4 ± 0.2	57.3 ± 0.1	56.5 ± 0.1	56.0 ± 0.1	56.3 ± 0.2	53.6 ± 0.1	58.1 ± 0.1
		Sterilization	62.1 ± 0.2	62.8 ± 0.1	66.6 ± 0.1	69.7 ± 0.1	69.7 ± 0.2	72.9 ± 0.1	70.7 ± 0.1

Past.+Sod.benz. = Pasteurization + Sodium benzoate.
Values are means ± SD (n = 10).

Table 7. Microbiological status of cactus pear juices during storage

Parameter	Storage temp.	Treatment	Storage period (month)						
			0	1	2	3	4	5	6
Total bacterial count	28±5ºC	Pasteurization	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		Past.+Sod.benz.	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		Sterilization	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	8±2ºC	Pasteurization	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		Past.+Sod.benz.	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		Sterilization	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Lactic-acid bacteria	28±5ºC	Pasteurization	NC	NC	NC	NC	NC	< 1	< 1
		Past.+Sod.benz.	NC	NC	NC	NC	NC	NC	< 1
		Sterilization	NC	NC	NC	NC	NC	NC	< 1
	8±2ºC	Pasteurization	NC	NC	NC	NC	NC	< 1	< 1
		Past.+Sod.benz.	NC	NC	NC	NC	NC	NC	< 1
		Sterilization	NC	NC	NC	NC	NC	NC	< 1
Spore formers	28±5ºC	Pasteurization	< 1	< 1	< 1	< 1	< 1	< 1	-
		Past.+Sod.benz.	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		Sterilization	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	8±2ºC	Pasteurization	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		Past.+Sod.benz.	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		Sterilization	< 1	< 1	< 1	< 1	< 1	< 1	< 1

NC = no count.
All treatments had no count of coliform group, yeasts, and molds during storage at room or refrigeration temperatures.
n = 3.

Table 8. Sensory evaluation of cactus pear nectars during storage

Parameter	Storage temp.	Treatment	Storage period (month)						
			0	1	2	3	4	5	6
Taste (10)	28±5ºC	Pasteurization	9.0	8.4	7.8	7.4	6.8	6.2	5.8
		Past.+Sod.benz.	9.2	8.4	7.6	7.2	6.8	6.4	6.0
		Sterilization	8.0	6.8	6.0	5.6	5.2	5.0	4.6
	8±2ºC	Pasteurization	9.0	8.8	8.4	8.2	8.4	8.2	8.0
		Past.+Sod.benz.	9.2	8.8	8.6	8.6	8.4	8.2	8.4
		Sterilization	8.0	7.0	6.8	6.4	6.6	6.2	6.0
Odor (10)	28±5ºC	Pasteurization	8.4	7.8	7.6	7.2	6.6	6.2	6.0
		Past.+Sod.benz.	8.6	7.8	7.4	7.2	6.8	6.2	5.6
		Sterilization	7.8	7.0	6.2	5.6	5.2	5.0	4.4
	8±2ºC	Pasteurization	8.4	8.2	8.2	8.0	8.0	7.8	7.6
		Past.+Sod.benz.	8.6	8.4	8.9	8.2	8.2	7.8	8.0
		Sterilization	7.8	7.6	7.0	6.2	6.0	5.8	6.0
Color (10)	28±5ºC	Pasteurization	9.0	8.2	7.8	7.2	6.6	6.2	6.0
		Past.+Sod.benz.	9.2	8.4	7.8	7.6	7.0	6.6	6.2
		Sterilization	8.8	7.4	7.6	7.2	6.4	6.0	5.2
	8±2ºC	Pasteurization	9.0	8.8	8.4	8.4	8.4	8.2	8.2
		Past.+Sod.benz.	9.2	8.8	8.4	8.6	8.6	8.4	8.2
		Sterilization	8.8	8.2	8.4	8.0	8.0	7.8	7.8
Appearance (10)	28±5ºC	Pasteurization	9.4	8.2	7.8	7.2	6.8	6.4	6.2
		Past.+Sod.benz.	9.6	8.2	7.8	7.0	6.8	6.4	6.0
		Sterilization	9.2	7.6	7.2	7.0	6.6	5.8	5.2
	8±2ºC	Pasteurization	9.4	8.6	8.2	8.4	8.4	8.2	8.4
		Past.+Sod.benz.	9.6	8.8	8.6	8.6	8.8	8.6	8.6
		Sterilization	9.2	8.8	8.0	7.8	8.0	7.8	8.0
Mouthfeel (10)	28±5ºC	Pasteurization	8.6	7.8	7.2	7.0	7.0	6.4	6.2
		Past.+Sod.benz.	9.0	8.2	7.8	7.2	6.8	6.8	6.4
		Sterilization	8.8	8.0	7.6	7.0	6.4	5.6	5.0
	8±2ºC	Pasteurization	8.6	8.4	8.2	7.8	7.6	7.6	7.8
		Past.+Sod.benz.	9.0	8.6	8.2	8.0	8.2	8.0	8.0
		Sterilization	8.8	8.2	7.8	7.4	7.0	7.0	6.6
Overall acceptability (50)	28±5ºC	Pasteurization	44.4	40.4	38.2	36.0	33.8	31.4	30.2
		Past.+Sod.benz.	45.6	41.0	38.4	36.2	34.2	32.4	30.2
		Sterilization	42.6	36.8	34.6	32.4	29.8	27.4	24.4
	8±2ºC	Pasteurization	44.4	42.8	41.4	40.8	40.8	40.0	40.0
		Past.+Sod.benz.	45.6	43.4	42.7	42.0	42.2	41.0	41.2
		Sterilization	42.6	39.8	38.0	35.8	35.6	34.6	34.4

Each value is mean of ten replicates.
Past.+Sod.benz. = Pasteurization + Sodium benzoate.

Table 9. Overall means (Table 8) of sensory characteristics of juices as affected by different factors tested for significance using Duncan multiple range test

Taste (10)	**Treatment**	**Pasteurization**		**Past.+Sod.benzoate**			**Sterilization**	
		7.9[a]		**8.0[a]**			**6.3[b]**	
	Storage period (months)	0	1	2	3	4	5	6
		8.7[a]	8.0[b]	7.5[b,c]	7.2[c,d]	7.0[c,d,e]	6.7[d,e]	6.5[e]
	Storage temp.	28±5ºC					8±2ºC	
		6.9[b]					7.9[a]	
Odor (10)	Treatment	Pasteurization		Past.+Sod.benzoate			Sterilization	
		7.6[a]		7.7[a]			6.3[b]	
	Storage period (months)	0	1	2	3	4	5	6
		8.3[a]	7.8[a,b]	7.6[a,b]	7.1[b,c]	6.8[c,d]	6.5[c,d]	6.3[d]
	Storage temp.	28±5ºC					8±2ºC	
		6.7[b]					7.7[a]	
Color (10)	Treatment	Pasteurization		Past.+Sod.benzoate			Sterilization	
		7.9[a]		8.1[a]			7.5[b]	
	Storage period (months)	0	1	2	3	4	5	6
		9.0[a]	8.3[b]	8.1[b,c]	7.8[b,c,d]	7.5[c,d,e]	7.2[d,e]	6.9[e]
	Storage temp.	28±5ºC					8±2ºC	
		7.3[b]					8.4[a]	
Appearance (10)	Treatment	Pasteurization		Past.+Sod.benzoate			Sterilization	
		8.0[a]		8.1[a]			7.6[b]	
	Storage period (months)	0	1	2	3	4	5	6
		9.4[a]	8.4[b]	7.9[b,c]	7.7[b,c]	7.6[b,c]	7.2[c]	7.1[c]
	Storage temp.	28±5ºC					8±2ºC	
		7.3[b]					8.5[a]	
Mouthfeel (10)	Treatment	Pasteurization		Past.+Sod.benzoate			Sterilization	
		7.6[a,b]		7.9[a]			7.2[b]	
	Storage period (months)	0	1	2	3	4	5	6
		8.8[a]	8.2[a,b]	7.8[b,c]	7.4[c,d]	7.2[c,d]	6.9[d]	6.7[d]
	Storage temp.	28±5ºC					8±2ºC	
		7.2[b]					7.9[a]	
Total acceptability	Treatment	Pasteurization		Past.+Sod.benzoate			Sterilization	
		38.9[a]		39.7[a]			34.9[b]	
	Storage period (months)	0	1	2	3	4	5	6
		44.2[a]	40.7[b]	38.9[b,c]	37.2[c,d]	36.1[c,d,e]	34.5[d,e]	33.4[e]
	Storage temp.	28±5ºC					8±2ºC	
		35.3[b]					40.4[a]	

Means in the same row with different letters are significantly different at $p \leq 0.05$ ($n = 3$).
Past.+Sod.benzoate = Pasteurization + Sodium benzoate.