Producing ice cream with concentrated cactus pear pulp: A preliminary study

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Abstract

Red cactus pear (*Opuntia ficus–indica*) pulp was tested for some technological and chemical characteristics. The pulp was concentrated up to 30°Brix then added at four levels (0, 5, 10 and 15%) to basic ice cream mix. The basic mix contained 0.5% gelatin, 8% fat and 10.5% milk solids non–fat (MSNF), and 16% sucrose. Some of rheological parameters of both mixes and resultant ice cream samples, in addition to some technological characteristics of resultant ice cream samples were measured. The rheological properties of all ice cream mixes before and after aging showed that the flow behavior of mixes is non–Newtonian besides being pseudoplastic behavior. While specific gravity and weight per gallon of resultant ice cream samples increased by increasing of added pulp, overrun decreased. Sensory evaluation of resultant ice cream samples showed that sample with 5% cactus was very desirable and very close to control sample. This work shows the possibility of producing a new product of ice cream using cactus pear pulp as a good fruit substitute.

Key words: Cactus pear pulp, ice cream, rheological properties, sensory evaluation.

Introduction

In recent years, the light has focused on foods rich in nutraceuticals and functional properties. From this point of view, the consumer's trend has been toward foods with more natural antioxidants, dietary fibers, natural colorants, minerals, vitamins, low calories, low cholesterol, and low fat and free of synthetic additives, etc. While ice cream could be poor in some of these characteristics, cactus pear fruit is one of the good natural sources of these nutraceuticals and functional components.

Cactus pear fruit, which usually eaten fresh and could be processed into many different products (Saenz, 2000), is a fleshy berry varying in shape, size and color and consists of a thick peel and a delicate flavored juicy edible pulp with many hard seeds. The attractive color of the fruit's peel and pulp varies between soft green, greenish-white, canary-yellow, orange- yellow, lemon–yellow, red, cherry–red and purple hues (Gurrieri *et al*., 2000; Muñoz de Chavez *et al.* 1995; Saenz and Sepulveda, 2001). These attractive colors due to being the fruit the main source of the natural colorants betalains, betacyanins (red–violet) and betaxanthin (yellow–orange) (Fernandez–Lopez and Almela, 2001; Odoux and Dominguez-Lopez, 1996; Saenz, 2002; Stintzing *et al.,* 1999b, 2002). These colors in contrast to anthocyanins maintain their appearance over a wide pH range from 4 to 7, and this property makes them ideal pigments for coloring foodstuff of different kinds especially the low-acidic foods (Krifa *et al*., 1994; Saenz, 2002; Stintzing *et al.,* 2000).

The fruit pulp has high pH value (5.3 to 7.1), very low acidity (0.01% to 0.18% in citric acid) and total soluble solids content (10.7°Brix to 17°Brix) which are mainly reducing sugars (glucose as the predominant sugar and fructose) (Abdel–Nabey, 2001; Askar and EL–Samahy, 1981; Barbera *et al*., 1992; Barbagallo *et al.*, 1998; El–Samahy et al., 2006a,b; Gurrieri *et al.*, 2000; Kuti, 1992; Parish and Felker, 1997; Piga *et al*., 2003; Russell and Felker, 1987; Saenz, 1985; Saenz and Sepulveda, 1999; Sawaya *et al.*, 1983; Sepulveda and Saenz, 1999; Sepulveda *et al.*, 2000). The high pH and very low acidity make the cactus pear pulp very suitable as substitutions in low–acid foods which influenced by acidity like ice cream.

Cactus pear is a source of natural antioxidants (such as vitamin C, betalins, plyphenols, flavonoids, and taurine) and also source of pectin and mucilaginous components (complex plysaccharides, mainly composed of arabinose, galactose, rhamnose, and galacturonic acid), which have been shown to serve as thickening agents and form viscous colloids (Galati *et al*., 2003; Kuti, 2004; Piga, 2004; Piga *et al.*, 2003; Saenz, 2002; Saenz-Hernandez, 1995; Saenz *et al*., 1992; Stintzing *et al.*, 2000, 2001). The fruit has good content of amino acids, especially proline and taurine (Stintzing *et al*., 1999a, 2001). Taurine (2-aminoethane sulfonic acid) is a conditional essential non-proteinogenic amino acid and has been used in some treatments of many diseases and disorders. Taurine widely distributes in many animal food sources, exception of cow's milk, and is virtually absent in the higher plants especially fruits (AACE, 2003; Cho, *et al*., 2006; Kindler, 1989; Lombardini, 1991; Parcell, 2002; Stintzing *et al*., 1999a;).

Ice cream is considered as a food of high nutritional and caloric density. Commercially ice cream is made from a mixture of milk and other ingredients such as fat milk, non–fat solids including proteins, lactose, sweeteners, stabilizers and emulsifiers, in addition to flavors and colorants. Although ice cream is rich in calories, it is poor in dietary fibers and some of natural antioxidants such as taurine, vitamine C, colors and polyphenolic compounds.

The aim of this investigation is to study the possibility of producing a new accepted product of ice cream using concentrated cactus pear pulp, and to evaluate the rheological behavior of mixes and some characteristics of resultant ice cream.

Materials and methods

Materials

Cactus pear pulp

Representative half–ripened red cactus pear fruits were collected from a specialized orchard located in Al Sharqiyah region, Egypt. Figures 1–3 show the fruit and plant. The fruits were washed, manually peeled and blended for five seconds in a blender (Moulinex, 300W, type 721, France) to facilitate seeds separation, and then were sieved to separate the seeds only from the full pulp. The pulp were pasteurized at 80ºC for 10 minutes and then concentrated by evaporation under vacuum at 60°C until reached 30°Brix using an evaporator device (Büchi Rotavapor, RE 111, Switzerland).

Other Ingredients

Fresh buffalo's milk (6% fat) was obtained from a private farm. Skim milk powder, gelatin, fresh cream (25% fat) and sugar were brought from the local market.

Basic Ice Cream Mix

According to the Egyptian standards of ice cream (2005), the basic ice cream mix contained 0.5% gelatin, 8% fat and 10.5% milk solids non–fat (MSNF). The sugar content was adjusted at 16% by sucrose in the control mixture. The concentrated pulp was added to the basic ice cream mixture at four levels (0, 5, 10 and 15%) with keeping content of other ingredients at stable level.

Processing Method

The processing method used was as follows: the required amounts of skim milk powder was mixed with gelatin and sucrose, and then added slowly to the liquid ingredients (milk and cream) at 45°C under vigorous agitation. The basic mixes were pasteurized at 80°C for 10 minutes in water bath, and then cooled to 4°C in ice bath. The required amounts of concentrated pulp, which already pasteurized before, were blended with the cooled basic mixes in a blender for 2 minutes. After that all mixes were aged for 24 hours at 4°C before frozen in an ice cream machine (Taylor-male, Model 156, Italy). The produced ice cream was packaged in cups (100cc) and placed in a freezing cabinet at –18°C for 24 hours at least before evaluation.

Assessment of chemical and Technological Properties

All chemical properties of cactus pear pulps were determined according to AOAC, 1990. Color attributes (L^*, a^* and b^*) were evaluated using a Minolta Color Reader CR-10 (Minolta Co. Ltd., Japan).

Specific gravity of resultant ice cream samples was determined as described by Winton (1958) at 20°C. Specific gravity of ice creams was determined by means of filling a cool cup (with known weight and volume), with the resultant ice cream and then weighted.

$$\text{Specific gravity} = \frac{\text{Weight of ice cream}}{\text{Cup volume}}$$

The weight per gallon of ice cream in kilograms was determined according to Burake (1947) by multiplying the specific gravity of the frozen ice cream by the factor 4.5461.

Overrun of ice cream (%) was calculated as mentioned by Arbuckle (1977) by application of the following equation:

$$\%\text{Overrun} = \left(\frac{\text{Weight of mix} - \text{Weight of the same volume of ice cream}}{\text{Weight of the same volume of ice cream}}\right)(100)$$

Rheological properties

Rheological properties parameters of prepared ice cream mixes before and after aging (24 hours at 4°C) were measured by the Brookfield Digital Rheometer model DV–III at 5ºC. The Brookfield small sample adapter and Sc_4-14 spindle were used. The data were analyzed by using the Bingham plastic, IPC paste and Power Law mathematical models to provide a numerically and graphically analysis of the behavior of data sets (Hegedusic *et al.*, 1995). These models are:

$$\tau = \tau_o + \eta\gamma,\ \eta = KR^n,\ \tau = K\gamma^n \text{, respectively.}$$

Where:

τ = sheer stress ($N\ m^{-2}$)

τ_o = yield stress, shear stress at zero shear rate (N m^{-2})
η = plastic viscosity (m Pa s) for Bingham and 10 rpm viscosity (m Pa s) for IPC paste
γ = shear rate (s^{-1})
K = consistency multiplier (m Pa s) for IPC paste and
K = consistency index (m Pa s) for Power Law
R = rotational speed (rpm)
n = shear sensitivity factor for IPC paste and flow index for Power Law.

Sensory evaluation

Sensory evaluation of the resultant ice cream samples was carried out by the staff members and semi–trained panelists. Before evaluation ice cream samples were moved from the hardening cabinet and placed in a freezer with a temperature ranging from –15 to –12°C in order to temper the samples uniformly. Scoring was carried out according to Nelson and Trout (1951) for flavor (45) and body and texture (30).

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=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 red cactus pear pulp

Technological and chemical characteristics pulp (Table 1) indicate that cactus pear pulp has a high pH vale and low acidity (in citric acid) which make it a very suitable as a food substitution especially with low acid foods like ice cream. In addition to that, cactus pulp has very attractive colors and good contents of sugars, protein, dietary fibers, pectin, ash, vitamin C, and free amino acids which expressed as phormol number (Abdel–Nabey, 2001; Askar and El–Samahy, 1981; El–Samahy *et al*. 2006a, 2006b; Parish and Felker, 1997; Saenz, 1985; Saenz and Sepulveda, 1999; Sawaya *et al*., 1983; Sepulveda and Saenz, 1999; Sepulveda *et al*., 2000). Also the high sugar/acid ratio gives more sweetness to cactus pulp. Obtained data shows clearly that cactus pear pulp could be a good source of energy and nutritive components.

Effect of cactus pulp on rheological properties of ice cream mixes before and after aging

Viscosity greatly influences overrun (Arbuckle, 1977; Goff, *et al*. 1994; Muse, 2004). So, measurement of viscosity is very important to measure the effect of cactus pulp on characteristics of ice cream mixes.

Shear stress (τ) was measured at different rotation velocities at different shear rates (γ) and rheological parameters at 5°C before and after aging of all ice cream mixes. The obtained relations were plotted in Figures 4a,b and the rheological parameters were recorded for all mixes in Table 2.

From the given figures, it appears that shear stress-shear rate curves were non–linear, which related to non–Newtonian behavior. All mixes had pseudoplastic behavior either before or after aging. Recorded results in Table 2. For all mixes before and after aging showed that consistency coefficient, plastic viscosity, yield stress, 10 RPM viscosity and shear sensitivity were increased by adding concentrated pulp to basic ice cream mix, but the flow behavior index (n) decreased. These trends of rheological parameters values may be due to the pulp contents of polysaccharides such as fibers, pectin and the mucilaginous components. Aging caused an increase in all rheological parameters, except flow behavior index (n), it may due to the effect of many factors such complexes which could be formed during aging between the components like pectin and sugars, in addition to hardening of fat particles.

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

Characteristic	Value
pH value	6.14 ± 0.03
Acidity, %	0.05 ± 0.002
TSS (°Brix)	11.25 ± 0.2
Vitamin C (mg 100 g^{-1})	18.65 ± 0.3
Formol number (mg 100 g^{-1})	23.06 ± 0.4
Color attributes, *L**	25.00 ± 0.7
*A**	6.90 ± 0.3
*b**	2.10 ± 0.1
Moisture, %	87.10 ± 1.2
TS, %	12.90 ± 0.9
Total Sugars, % *	86.85 ± 0.8
Reducing sugars, % *	82.98 ± 0.8
AIS, %*	7.35 ± 0.3
Protein, %*	5.26 ± 0.15
Pectin, %*	2.44 ± 0.2
Fiber, %*	1.44 ± 0.05
Ash, %*	2.27 ± 0.06
Sugar/ acidity ratio	224.07 ± 3.5

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

Figure 1. Red cactus pear fruit.

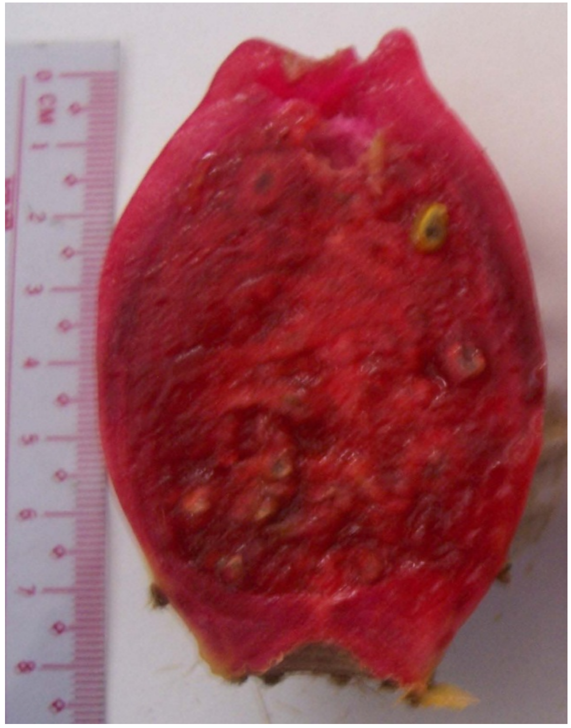
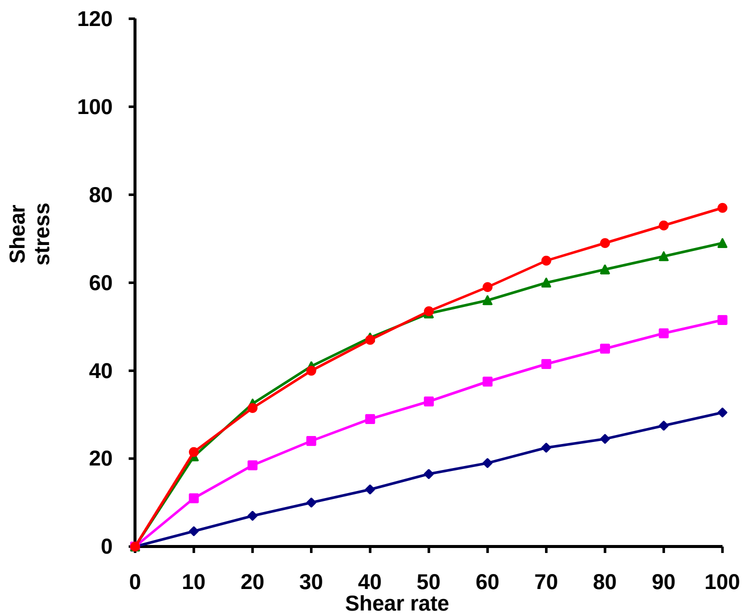
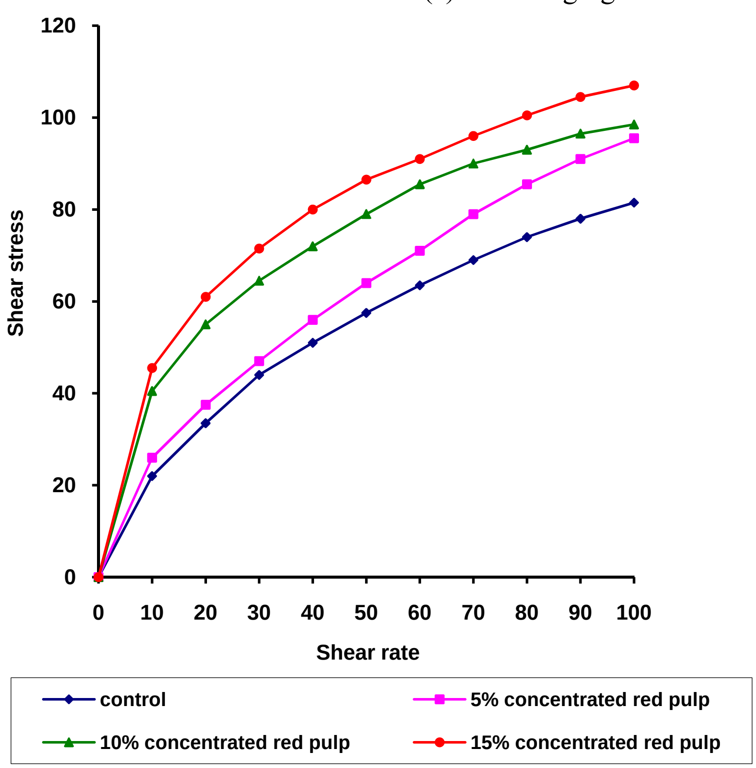


Figure 2. Internal longitudinal view of the fruit.

Figure 3. Overview of cactus pear plant and orchard.



(a) Before aging



Shear stress (N m^{-2}), Shear rate (s^{-1})

(b) After aging

Figure 4. Shear stress–shear rate curves of ice cream mixes with different ratios of concentrated red cactus pear pulp.

Table 2. Rheological parameters (5ºC) before and after aging of ice cream mixes for 24 hours at 4ºC.

Ice cream mix	Parameters for different models					
	Power law		Bingham		IPC paste	
	K	n	H	τ_o	10 RPM viscosity	N_1
Before Aging						
0% cactus pulp	59.1	0.85	288.9	1.98	483.5	0.15
5% cactus pulp	226.1	0.68	445.7	8.46	1444	0.32
10% cactus pulp	474.8	0.58	547.1	17.0	2655	0.42
15% cactus pulp	554.9	0.57	614.8	18.6	3055	0.43
After Aging						
0% cactus pulp	524.3	0.59	663.7	18.3	2989	0.41
5% cactus pulp	687.2	0.57	726.8	22.5	3782	0.43
10% cactus pulp	935.8	0.51	766.8	30.0	4740	0.49
15% cactus pulp	1104	0.49	769.7	34.0	5439	0.51

K= consistency coefficient (mPa.S^n); n = Flow behavior index (dimensionless); η = plastic viscosity (mPa S); τ_o = yield stress (N/m^2); 10 RPM viscosity (mPa S); N_1= shear sensitivity (dimensionless).

Some characteristics of resultant ice cream

Results recorded in Table 3 indicated that overrun (in %) values of ice cream were decreased as cactus pulp level increased ranging from 55.71% to 43.11% for ice creams with substitution levels 0 to 15% of concentrated cactus pulp, respectively. An opposite trend of the specific gravity and weight per gallon of the resultant ice cream with the increment of adding pulp was evidenced. The decrement of overrun and increment of both specific gravity and weight per gallon of ice cream by increasing of substitution levels of concentrated pulp may be attributed to increment of mix's viscosity which extremely affects on whipping rate of mixes (Arbuckle, 1977).

Table 3. Effect of adding of concentrated cactus pear pulp on characteristics of resultant ice cream.

Ice cream characteristics	Ratio of added concentrated cactus pulp			
	0%	5%	10%	15%
Specific gravity (g cm^{-3})	0.71 ± 0.08	0.83 ± 0.08	0.84 ± 0.065	0.86 ± 0.05
Weight per gallon (kg)	3.25 ± 0.30	3.76 ± 0.3	3.84 ± 0.3	3.91 ± 0.3
Overrun (%)	55.71 ± 3.75	46.67 ± 3.2	43.78 ± 3.5	43.11 ± 3.5

Values are means ± SD (n = 3)

Sensory evaluation of ice cream

Table 4 shows that characteristics of resultant ice cream were influenced by adding cactus pulp. The resultant ice cream with substitution levels 5 and 10% of concentrated pulp were very desirable. The samples with 5% level were very close to the control samples organoleptically.

Conclusions

This primary study shows the potential value of cactus pear fruits as a good natural source of energy and nutritive components. Based on its low acidity, high sweetness, nutritive value and attractive stable colors, cactus pear fruit may be a good suitable source of natural additives or substituted materials for production of many foods like ice cream. Addition of concentrated cactus pulp to ice cream mix resulted a very desirable product especially at 5% substitution, therefore we extremely believe in the possibility of producing highly delicate and nutritive cactus pear ice cream on the industrial scale.

Table 4. Effect of concentrated cactus pear pulp on organoleptic properties of resultant ice cream.

Organoleptic characteristic	Ratio of added concentrated cactus pulp			
	0%	5%	10%	15%
Flavor (45)	43.9[a]	41.0[b]	38.0[c]	37.0[c]
Body & texture (30)	29.1[a]	29.6[a]	28.4[b]	26.9[c]
Total score (75)	73.0[a]	70.6[b]	68.4[c]	63.9[d]

Means having the same letter with each property are not significantly different at $p \leq 0.05$.
Very desirable (65-75), desirable (55-64), acceptable (45-54), fair (35-44), unacceptable (<34).

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