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Physicochemical and Sensory Characterization of Pitaya (*Stenocereus thurberi*) Jelly

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Abstract

The pitayo (*Stenocereus thurberi*) is an indigenous cactus from northern Mexico and the southwest region of United States which produces a small, sweet fruit known as pitaya, which is closely related to pitahaya (Hylocereus genus) or dragon fruit. In this study, pitaya fruit were processed to obtain a jelly. The fruit was harvested from wild plants of the Sonora desert to formulate four different jellies using sugar (33 % or 50 %) and pectin (0.8 % or 1.2 %), which were then sensory evaluated. The total soluble solids concentration of jellies varied from 65 % -67.5 %; the pH from 3.6 - 4.2; the water activity (aw) was measured at 0.69 - 0.77; and the reducing sugars fluctuated between 23 % - 33 %. The product composed of 49.2 % fruit, 50 % sugar and 0.8 % pectin had the lowest spreadability score, as well as the lowest viscosity value of 2.64. This food product could be profitable for local communities due to the high perishability of the pitaya fruit, which also has a very short harvest period.

Keywords: Pitaya; Jelly; Viscosity

Introduction

There is a great variety of fruit that are in high demand locally, and worldwide. These include vine, mango, tomatoes, citrus, strawberries and others, which are generally high-water demanding crops, and frequently attacked by diseases; thus, affecting their production yield or/and increasing their retail price [1-3].

Mexico within its territorial surface, has 80,000,000 ha of arid and semi-arid of regions mostly distributed in the northern, center and southwest regions of the country [4]. The main limitation for these regions to be used as farmlands is the lack of irrigation water [5]. Due to the low availability of water on the surface of the land, both annual crops and perennials are irrigated during their cultivation with water from underground sources [6,7]. Of these rains, surface runoff is mostly stored in reservoirs within the Yaqui and Sonora rivers pluvial system. For instance, Sonora, a semi-desert region of northwestern Mexico, receives approximately 80 % of its rainwater during July, August, and September, through a phenomenon known as the Mexican monsoon characterized by a dramatic increase in rainfall [8]. The pecan walnut and the vine are the main perennial crops in the region representing around 30 % of the total cultivated area, and they consume more than 50 % of the aquifers annual recharge [9].

In contrast, there are other non-conventional fruit species marginally exploited including some species that are not very demanding in terms of water requirements. Thus, being able to develop in arid and semi-arid conditions due to physiological and morphological adaptations allowing them to grow in these environments [10]. These modifications includes: stems capable of storing water; absence of leaves or modified leaves; waxy cuticles; ribs and tubers that allow the stem to expand and contract in response to changes in water availability; and roots that are generally shallow and non-succulent. These characteristics allows these plants to be very efficient in the use of water, typically, 5 to 10 times more than conventional crops [11]. Typical examples of these plant species are cacti which have had great importance in subsistence agriculture for the inhabitants of these regions. Of note, those known as garambullo from *Myrtillocatus geometrizans* (Martius), console, tuna or “cactus pear” (Opuntia spp.), and pitaya (Stenocereus spp.) [12]. The commercial exploitation of these fruit species in arid and semi-arid is limited. However, some cactus species such as pitaya-producing plants stand out, with potential for regional, national and international markets [13]. The fruit is usually obtained from wild plants, sold in local markets and transported to nearby cities [12]. Due to its organoleptic properties (color, flavor, and aroma), pitaya fruit is in great demand for consumption during the season as fresh fruit, frozen products, and jams. However, processing is challenging due to its low acidity and high pH [14]. These characteristics have posed problems related with the stability of pitaya pigments in the elaboration of juices and confectionery [15-8].

The current use of processed pitaya fruit in Sonora is the preparation of a homemade sweet. More recently it has been marketed as frozen products such as popsicles and ice-cream. In this region, pitaya-producing plants have not been systematically cultivated, and are only found in the wild, from which the fruits are collected to be consumed and marketed as fresh. The lack of information regarding the behavior of this fruit, as well as the lack of knowledge concerning its transformation are the main reasons why its commercialization has not been achieved. Therefore, in this work, the feasibility of making a jelly-like product based on pitaya fruit is proposed, portraying an industrialized process.

Materials and Methods

Plant Material

Pitaya fruit (*Stenocereus thurberi*) was harvested near Carbó Municipality (29°34'29.79"N 111°0'51.02"W), Sonora, Mexico during June, and July. Ripe and over-ripe red fruits (closed and open) were used to produce the jelly. The seeds were eliminated by porous sieves until obtaining the fruit juice.

Jelly formulation

The total soluble solids of the extracted juice were determined using a refractometer Abbe (model 10450) to calculate the weight of the final product and pectin by equation (1) and (2):

$$F = \frac{A(X_a)+A_z}{X_f} \quad (1)$$

where:

F: Weight of the final product (g)

A: Weight of the fruit per load (g)

Xa: % fraction of the °Brix of the fruit.

Az: Weight of sugar per load (g)

Xf: % fraction of the desired ° Brix.

$$P = F \times W_p \quad (2)$$

where:

P: Weight of pectin (g)

F: Weight of the final product (g)

Wp: % of pectin required

The proportion of commercial sugar, pectin (150 grade, USA-SAG, IFT 1959) and commercial citric acid were determined according to (Table 1).

Table 1: Formulation of pitaya fruit jelly.

Pulp/sugar ratio	Pulp (%)	Sugar (%)	Pectin (%)	Citric acid (%)
1:01	50	50	0.5	0.1
2:01	66	33	0.8	0.3
3:01	75	25	1.2	0.5
4:01	80	20		

Jelly making process

Pitaya juice, to which pH and total soluble solids content (°Brix) were initially determined, was placed in a 2 L stainless steel pot. Heating, using a commercial stove (VWR, 1324, Cornelius, OR, USA) was started with continuous stirring until the product was brought to a boil (90-95 °C). From this moment, the monitoring of the concentration of total soluble solids began, sampling at intervals of 3-5 min. Once 20-24 °Brix were reached, a homogeneous hot sugar syrup was added with 50 % of the total citric acid obtaining the inversion of sucrose to prevent its crystallization during storage [19]. After the syrup was added, the boiling continued as well as controlling the total soluble solids content. The process was maintained until reaching 62 °Brix, at that time, the product was removed from the heat source. When the product cooled, total soluble solids content, and pH were determined, and the jam was packed in plastic containers with hermetic lids.

Physicochemical determinations

Direct Reducing Sugars, ° Brix and pH

Direct Reducing Sugars, ° Brix and pH were determined according to the [20].

Water activity

The water activity (Aw) of jellies was determined at a constant temperature using a thermo-hygrometer (Higroline HTC-2, Beckman Industrial) provided with a relative humidity sensor. The instrument was previously calibrated using the standard salts provided by the manufacturer, corresponding to three relative humidity points: 11.3 %, 52.9 %, and 90.2 %. The Aw determination was assayed by placing 3 g of each sample in the appropriate containers to reach its relative equilibrium humidity (approximately after 5 h) and then, Aw was calculated using the equation 3:

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$$A_w = \%RH / 100 \quad (3)$$

where:

A_w: Water activity

% RH: equilibrium relative humidity between food and environment

Viscosity

The viscosity of the jellies (pour in a 100 mL beaker), was determined by means of a rotational viscometer (Brookfield, LVTD). The 4 LV needle (radius 0.1588 cm; effective length 3.4 cm) was selected, based on preliminary tests, allowing the generation of viscosity readings within the range between 10 and 100 Brookfield units (BU). According to Canovas, et al. [21], the jellies of some fruits follow a non-Newtonian type flow behavior independent of time. The previous behavior was taken as a basis for the pitaya jelly. The working formula used for the development of the power law model for the rotational viscometer was the following:

$$\log \Omega = \left[\frac{1}{n}\log M\right]\left[\frac{1}{2\pi h\eta}\right]\left[\frac{n}{2} - \frac{1}{Rb^{\frac{2}{n}}} - \frac{1}{Rc^{\frac{2}{n}}}\right] \quad (4)$$

where:

Ω : Rotor angular speed (Rad s^{-1})

M: Torque (N m)

h: Effective length of cylinder (m)

Rb = Radius of the container (m)

Rc = Radius of cylinder (m)

η : consistency coefficient (Pa s)

n: Flow behavior index

This formula corresponds to the equation of a line. Thus, to obtain each parameter of this equation, the values of Brookfield Units, as well as the speed of the rotor, underwent transformations and were adjusted by means of least squares. The flow behavior index (n) was obtained as the inverse of the slop (m) value. The ordinate to the origin was used to calculate the consistency coefficient according to the following equation:

$$K = 2\pi h\left(\frac{10^b}{\left(\frac{n}{2}\left(\frac{1}{Rb^{\frac{2}{n}}} - \frac{1}{Rc^{\frac{2}{n}}}\right)\right)^n}\right) \quad (5)$$

where:

K: Consistency coefficient (Pa s^n)

n: Flow behavior index

b: Intercept

h: Effective length of cylinder (m)

Rb = Radius of the container (m)

Rc = Radius of cylinder (m)

To calculate the flow behavior index (n) and the consistency coefficient (K), readings were obtained at different rotor speeds (12, 30 and 60 rpm), obtaining values of 10-100 BU, with all samples previously equilibrated at 24 °C.

Sensory evaluation

Judges

A semi-trained sensory panel of 24 judges of both sexes was gathered. The panelists ages varied from 22 to 31 years old. Before the session, an explanation regarding the mechanism for completing the questionnaire was provided.

Sensory methods

Four pitaya jellies were selected for sensory evaluation. They contained the same acid concentration (0.3 %), two different proportions of sugar (33 % and 50 %), as well as two different proportions of pectin (0.8 % and 1.2 %). Acceptability tests included attributes of color, flavor, texture (consistency) and general acceptability. A hedonic or acceptability questionnaire (very good, good, slightly good, neither good nor bad, slightly bad, bad, very bad) was developed to score samples.

Statistical analysis

Data from the sensory evaluation was examined by two-way analysis of variance for each one of the sensory attributes studied, using the information provided by the judges during the evaluation session. The two factors were, on the one hand, the experimental treatments (samples of jellies) and on the other hand, the judges. Mathematical transformations of hedonic responses to numerical scales was perform. A value of 7 was be given to the highest evaluation point up to a value of 1 to the lowest rating. The data was analyzed using the STATPACK statistical package.

Results and Discussion

Physicochemical parameters

The initial plan of the experiment was to determine the most acceptable jelly by altering the amount of fruit, sugar, pectin, and ascorbic acid. However, it was evident that the maximum acid content that the jelly could present was at 0.3 %. Higher levels of acidity in the jelly derived on lower acceptability scores. Therefore, four jellies were chosen as the most acceptable according to the previous consideration. The formulation of the selected jellies is presented in Table 2.

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Table 2: Physicochemical characteristics of the four jellies produced from pitaya fruit.

Jelly	Sugar (%)	Pectin (%)	° Brix	pH	Reducing sugars.	Aw
I	50	0.8	66.5	3.6	24.2	0.77
II	50	1.2	67.3	3.85	32.9	0.69
III	33	0.8	67.8	4.2	23.9	0.74
IV	33	1.2	65	4.1	23.6	0.77

Quality parameters

The total soluble solid values obtained for each jelly were maintained in a range of 65 to 67.8 ° Brix, which are adequate for the gel formation (Table 2). To be optimal as a gelling agent, pectin should be in a matrix with at least 65 °Brix [22]. The pH value for each of the jellies is also presented in Table 2. It can be noted that similar to the total soluble solid content, the pH of the jellies allowed the jellification. In addition, it is important to note that a grade 150 + 5 pectin was used in this study. This is a high-grade rapid gelling citrus pectin capable to gel up to 150 parts of sugar under specific conditions. This type of pectin can perform effectively in a pH range from 3.4 to 4.2 [22]. Therefore, the prepared jellies also met this condition, since none exceeded this range (Table 3).

Table 3: Rheological parameters of different pitaya jellies formulations.

Formulation	Consistency coefficient* (K)	Index flow behavior (n)	Flow behavior
I	2.64	0.73	Pseudoplastic
II	8.9	0.7	Pseudoplastic
III	9.87	0.62	Pseudoplastic
IV	8.5	0.65	Pseudoplastic

The nutritional composition of the pitaya fruit jellies (Table 2) was comparable to the values found in dragon fruit (Hylocereus undatus) reported by [23]. Where the content of pectin and sugar for at least one pair of jellies, was 33 % of sugar. Likewise, the direct reducing sugars values (32.9 % and 23.6 %) were related to those described for strawberry jam by Cano [24], and for dragon fruit (Hylocereus undatus), registered by [23]. The Aw values included in Table 2 place the pitaya jelly as an intermediate moisture food, since it presented an Aw value in the range of 0.6 to 0.92 [25]. These foods must not allow microbial growth, nor the development of deteriorating reactions, and must also have adequate sensory characteristics. A comparative study carried out by Cano [24] reported values in the range of 0.9 to 0.93 for Mexican candies including jams, viznagas and jamoncillo; the jellies on the other hand had a lower Aw at 0.69 to 0.77. All bacterial growth is drastically reduced at Aw values less than 0.85, yeast growth is reduced at Aw values less than 0.78, and fungal growth is reduced in environments with less than 0.62 Aw values [26]. Thus, fungal growth can be expected if the jellies are stored at high temperatures. Therefore, a food preservative could be considered to prevent the growth of fungi. Sodium benzoate could be incorporated in the jelly at a concentration of 0.1 % and to obtain a more stable product.

Viscosity

The rotational viscometer allowed the generation of data applicable to the proposed model to establish the rheological characterization of the pitaya jellies. The values of consistency coefficients (K) and flow index behavior (n) for the jellies are shown in Table 3. The jelly I exhibited a lower consistency value compared to the other formulations, which were kept in a narrow range of 8.50-9.86 Pa s (Table 3). The decrease in the consistency coefficient was associated with a poor gelling effect of pectin in the medium. Additionally, this jelly was also classified as "very soft" by the panelists (Table 4). In the case of vegetable-origin products, such as the case of the jelly, the consistency coefficient of a suspension mainly depend on the solids content, as well as the viscosity of the suspending medium [27]. In the formulation I, the solids content was similar to other jellies, confirming that jelly consistency is related to the gelling activity of pectin. On the other hand, the lowest pH value of all formulations was observed on jelly I (3.60). Thus, it would have been expected to this formulation formed the best gel, yet it was the least firmness the gel of all. This might have been related with a deficient pectin activity in that formulation.

Table 4: Sensory evaluation of pitaya jellies.

Formulation	Spreadability	Odor	Flavor	Color	General acceptability*
I	1.38^{a*}	4.91^{a}	3.04^{a}	3.29^{a}	3.04^{a}
II	2.66^{b}	5.04^{a}	3.20^{a}	3.29^{a}	3.42^{a}
III	3.17^{b}	4.75^{a}	2.83^{a}	3.16^{a}	3.16^{a}
IV	3.04^{b}	5.00^{a}	3.16^{a}	3.50^{a}	3.33^{a}

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Formulations II, III and IV were very similar in terms of their consistency values. Even though jelly III was slightly higher at 9.87 Pa.s (Table 3), this jelly was also the one with the highest solids content. The flow behavior index values obtained (<1.0) ensured that the pitaya jelly behaves like a non-Newtonian pseudoplastic fluid [28]. This is in agreement with other studies, including concentrated apple juice (65 °Brix, n=0.65) [21]; tomato puree (n=0.44) [29], as well as that of mustard with (n=0.33) [30]. Rao [27], have described that in suspensions of vegetable-origin, such as concentrated juices, the content of pulp is very important on flow parameters. In concentrated orange juice (65 °Brix), this author has reported consistency coefficient values of 13.92 Pa s. Also, in similar matrices, there is an important effect of the serum, or the medium in which the solids are suspended, and its consistency is determined by the sugar and the pectin content. Furthermore, these two factors have a high correlation, and even the pectin content alone is a good parameter to estimate the serum viscosity [31]. Once this value has been obtained, along with the pulp content, it is possible to predict the consistency coefficient of the complete system. The relevance of the prior is that they demonstrate that pectin plays an important role on the product viscosity. It should be highlighted that when examining non-Newtonian type fluids, the viscosity should not be evaluated with a single point, since there is no linear function between the shear rate (γ) and the consistency coefficient (η) [32]. Thus, different rotor speeds were selected, to obtain various readings and more reliable results. The obtained parameters are of practical relevance since friction factors and the Reynolds number, necessary for the design of industrial processes, can be directly estimated [33].

Sensory evaluation

The global results of the sensory analysis of the four jellies are tabulated in Table 4. The 5 attributes studied, and the means of the 24 replicates are included. Of all attributes, significant differences ($p < 0.05$) were only observed on spreadability from the formulation I (50 % sugar 0.8 % pectin, and 66.2 °Brix). The rest of the jellies had similar spreadability values and corresponded to a texture that was neither soft nor hard. In jellies I and II, which contained the highest proportion of sugar but different pectin content, the firmness improved when the pectin content increased, similar to that reported for dragon fruit [23]. This was reflected in the sensory evaluation of the panelists to jelly I, giving it the lowest rating for the spreadability attribute, being significantly different from jelly II which contained 1.2% pectin in its formulation. The samples were also evaluated for the attributes of aroma, flavor, color and general acceptability. The scores are shown in Table 4, where no significant differences were found among the evaluated attributes in the four samples. Nevertheless, it was observed that the formulations with the highest percentage of pectin achieved the best scores. A similar trend was observed for Dragon fruit jelly, although in his case, statistically significant differences were found in color and general acceptability [23]. On the other hand, it has been reported, that the low pectin content is insufficient to achieve a good quality prickly pear jellies, due to the use of ripe and overripe fruits [14]. This might have been the case in this study where the pectin content in pitaya fruit decreases considerably when is overripe.

Conclusion

The information provided by this study sets the tone for future research for the use of this fruit on unutilized land on arid regions. As well as the feasibility to establish micro-industries in rural areas capable to transform the pitaya fruit in food products which could increase the development of those regions.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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