Physico-chemical characteristics, and bioactive compounds of red fruits of sweet pitaya (S*tenocereus thurberi*)

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ABSTRACT

The objective of this study was to determine the physical and chemical characteristics and the content of bioactive compounds of ripe fruits of red sweet pitaya (*Stenocereus thurberi*). Sweet pitaya fruits are spherical, with a high moisture content (85.8%), a pulp percentage of 71.6%, soft texture (3.4 N), low acidity (0.18%), a total soluble solids content of 12.83 °Brix, with glucose and fructose being the main sugars with a content of 35.65 and 17.48 g 100 g^{-1} dry weight, respectively. The fruit has a low protein content (0.86% fresh weight) with tyrosine, glutamate, and methionine are the main essential amino acids. The pitaya flesh showed traces of carotenes, low content of L-ascorbic acid (12.45 mg 100 g^{-1} fresh weight), a content per gram of dry weight of total phenols of 11.31 mg gallic acid equivalents (GAE), total flavonoids of 13.70 mg quercetin equivalent (QE) and total betalains of 2.43 mg. The peel had a higher content of phenols and total flavonoids (5.5 and 4.3 times higher, respectively) than the flesh, which could be considered a potential source of these compounds. The red fruits of sweet pitaya can be considered a source of phenolic compounds and betalains with potential benefits to human health.

Keywords: betalains, ascorbic acid, phenolics, sweet pitaya, wild communities.

INTRODUCTION

The pitaya, fruit of wild communities of the genus *Stenocereus* spp., has been an important food in the diet of Mexicans since pre-Hispanic times. In Mexico there are 21 species of this genus, of which *S. stellatus, S. queretaroensis, S. griseus, and S. pruinosus* are currently produced in commercial plantations and family orchards; while *S. thurberi* var. thurberi or sweet pitaya, continues to be collected from wild communities and marketed in local markets (Pimienta-Barrios, 1999; Santacruz-Vázquez *et al*., 2009; Chuck-Hernández *et al*., 2016). The fruits of the different varieties are named on the basis of flesh color which can be red, purple,

yellow, pink, orange or white (Santacruz-Vázquez *et al*., 2009; Campos-Rojas *et al*., 2011; Chuck-Hernández *et al*., 2016).

Campos-Rojas *et al*. (2011) indicated that in wild communities of pitaya (*Stenocereus* spp.) the number of fruits per plant varies from 234, 251, 256 to 287 in purple, yellow, red and white pitaya, respectively. It is mentioned that ripe pitaya fruits weigh 66 to 171 g, with differences between species (Muy *et al*., 1999; Campos-Rojas *et al*., 2011; Chuck-Hernández *et al*., 2016).

Pitayas have a polar to equatorial diameter quotient greater than 1, indicating a cylindrical-globose form. The percentage of fruit flesh is almost 75% and although fruit has abundant black seeds, these are small (1.5 to 2 mm long) and do not influence the acceptability of the fruit by the consumer (Pimienta-Barrios, 1999; Campos-Rojas *et al*., 2011; Chuck-Hernández *et al*., 2016).

This fruit is considered non-climacteric, for this reason, it should be harvested at its consumption maturity, which occurs when the fruit presents a marked change in the color of the peel from dark green to light green, reddish or purple, high turgidity in the peel, abscission of thorns and a change in the shape from ovoid to spherical (Muy *et al*., 1999; García-Cruz *et al*., 2016).

The fruits are harvested early in the day, and because it is a highly perishable fruit, they are immediately transported to local markets in cities close to production areas, where they are marketed (Pimienta-Barrios, 1999; Santacruz-Vazquez *et al*., 2009; García-Cruz *et al.,* 2016). García-Cruz *et al.* (2016) reported shelf life of 6 days at 24°C (90% R.H.) in pitayas of the species *S. pruinosus* and *S. stellatus*, indicating that this short shelf life was due to fungal growth.

S. thurberi var. thurberi, known as sweet pitaya, is one of the most abundant species in the Sonoran Desert (Muy *et al*., 1999; Santacruz-Vazquez *et al*., 2009; Chuck-Hernández *et al*., 2016). The red fruit of sweet pitaya is the most common in markets (Figure 1). Pitaya fruits collected from wild communities near the city of Hermosillo, Sonora, reach prices of MXN $ 7 pesos per fruit, which is equivalent to an estimated average price of approximately MXN $ 91 per kg (US$ 4.71 dollars per kg, exchange rate MXN $ 19.32 pesos per dollar).

The characteristic coloring of pitaya fruits is imparted by betalains, which may be present as red-violet betacyanins or yellow-orange betaxanthins, and the characteristic coloring of ripe fruits of each variety is determined by the relationship in the betacyanin/betaxanthin content (Muy *et al*., 1999, Chuck-Hernández *et al*., 2016). These pigments have beneficial effects on health since their antioxidant and antimicrobial activity has been documented; and it has also been indicated that these compounds boost the immune system, prevent cardiovascular diseases, neurodegenerative disorders and cancer (Choo, 2018; Hussain *et al*., 2018).

Various studies document the physicochemical characteristics and/or bioactive compounds of pitayas of *S. queretaroensis*, *S. griseus, S. stellatus*, and *S. pruinosus* (Beltrán-Orozco *et al*., 2009; García-Cruz *et al*., 2012; García-Cruz *et al*., 2013; Arriaga-Ruiz *et al*., 2015; García-Cruz *et al*., 2016; Pérez-Loredo *et al*., 2016; Sandate-Flores *et al.,* 2016). However, in sweet pitaya

fruits of *S. thurberi*, only its physicochemical and physiological characteristics had been evaluated (Muy *et al*. 1999).

The objective of this study was to determine the physical and chemical characteristics and the content of bioactive compounds of ripe red pitaya fruits (*Stenocereus thurberi*), from wild communities of the Sonoran Desert.

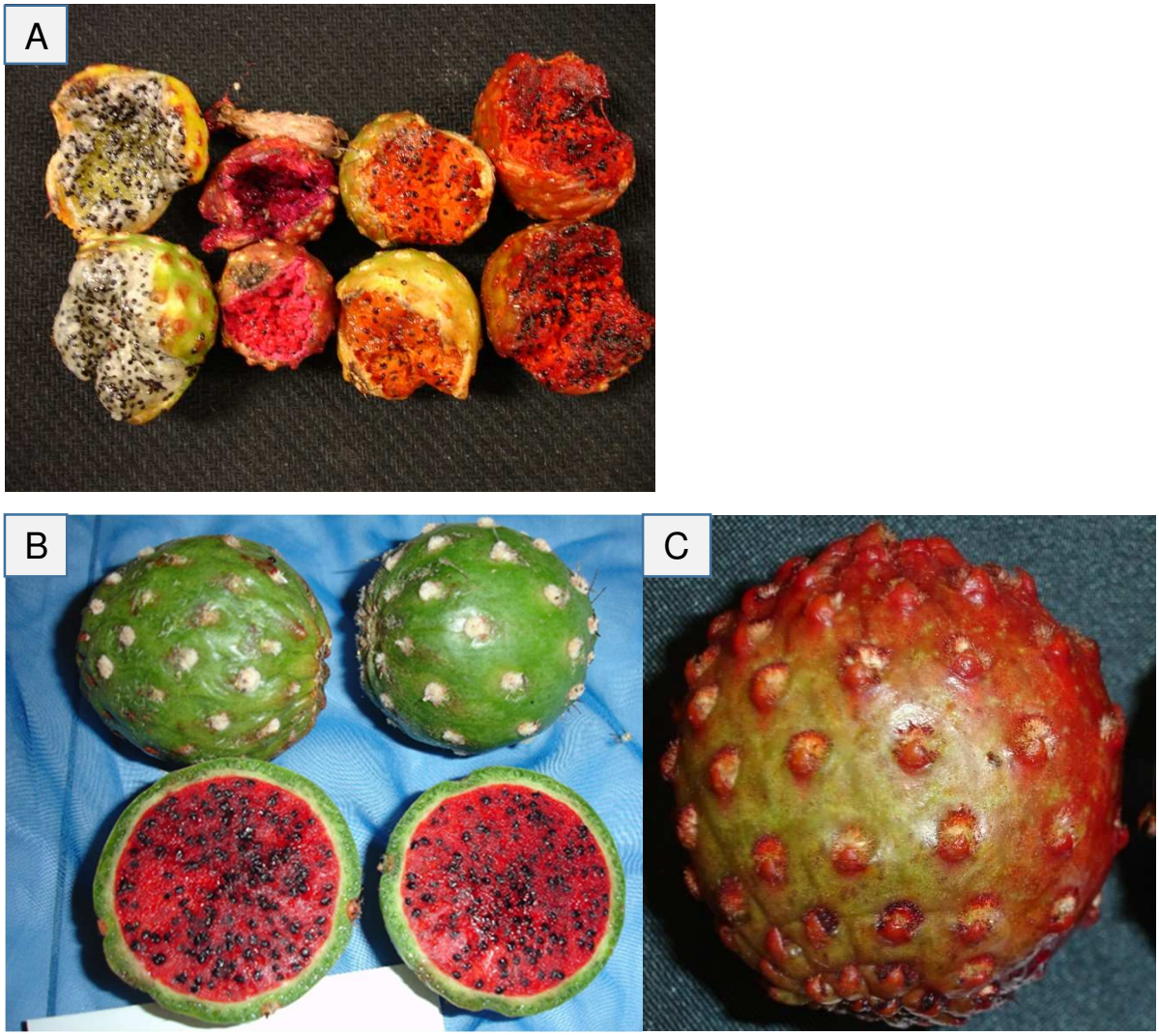

Figure 1. (A) Ripe sweet pitaya fruit in different colors; (B) Unripe red sweet pitaya; and (C) Rripe red fruit of sweet pitaya (*Stenocereus thurberi*).

MATERIALS AND METHODS

Red sweet pitaya fruit, completely closed and at commercial maturity, were obtained in August 2015 (26 fruits) and July 2016 (15 fruits) from wild communities of Carbo, Sonora (29°41' N; 110°57' W), at an average altitude of 620 meters above sea level. Physical characteristics were

performed on fruits and then were divided into two subsamples. One subsample kept frozen at -20°C, was used to measure pH, titratable acidity (TA), total soluble solids (TSS) in flesh and total chlorophyll (TCh) in peel were done in triplicate. The second subsample was frozen at -40°C and freeze-dried and used to analyze in triplicate soluble sugars, amino acid (AA) profile, carotenes in the flesh, ascorbic acid, total phenols, total flavonoids and betalains in flesh and peel.

Physical and chemical characteristics

Weight, external and internal color and firmness. Weight and percentage of flesh and peel were determined on a scale (Ohaus, Model Scout Pro, SP601, Brook, NJ, USA). The polar and equatorial diameter was evaluated with a vernier gauge. Peel (external) and flesh (internal) color (L*, a*, and b*) were measured using a CR-300 Minolta colorimeter (Minolta, Co., Ramsey, New Jersey, USA) with an observation angle of 10 degrees and illuminant D65. Hue angle (h°= arctangent b*/a*) and Chroma [$C^*= (a^{*2} + b^{*2})^{1/2}$] were calculated (McGuire, 1992). Firmness (N) was determined using a penetrometer (Chatillón DFG-50, Wagner Instruments, Greenwich, USA) provided with a punch of 1.2 mm of diameter.

pH, titratable acidity and total soluble solids. These variables were determined following the methodology proposed by the AOAC (1999). The titratable acidity result was expressed as the percentage of malic acid, pH as pH units, and total soluble solids as ºBrix.

Soluble sugars. The content of soluble sugars, glucose, fructose, sucrose and lactose (g carbohydrate 100 g^{-1} dry weight), were analyzed according to a modified method of Smith *et al*. (1986) in a high-pressure liquid chromatography (HPLC) system (Dionex Ultimate 3000, Thermo Scientific, San Jose, California, USA), equipped with a pump (Accela 600, Thermo Scientific) and a refractive index detector (RefractoMax 520, Thermo Scientific), using a Microsorb 100-3 NH_2 100 X 4.6 mm column for carbohydrates, an isocratic method with acetonitrile/water (80:20) as mobile phase at a flow rate of 1.0 mL min^{-1}. The sugars were quantified using external commercial standards.

Amino acid profile Analysis was determined in an HPLC (Dionex Ultimate 3000, Thermo Scientific) equipped with a pump (Accela 600, Thermo Scientific) and a fluorescence detector (Thermo Scientific). The amino acid separation was performed in a Microsorb column (100-3 C18 100 X 4.6 mm). A gradient method was used with a mobile phase of methanol and sodium acetate buffer (0.1 M) at a flow rate of 1.2 mL min^{-1}. The amino acids were identified by comparing them with the retention time of external standards, at an excitation wavelength of 340 nm and an emission wavelength of 455 nm (Vázquez-Ortiz *et al*., 1995). The results for each amino acid were expressed as g of amino acid 100 g^{-1} protein and mg of amino acid 100 g^{-1} dry weight.

Bioactive Compounds

Carotenes in the flesh. Samples of 1 g of lyophilized flesh were taken, mixed with 10 mL of tetrahydrofuran (THF), and filtered. The extraction was repeated with 10 mL of THF. The measurement was performed on a HPLC (1260 Infinity, Agilent Technologies, Santa Clara, California, USA) equipped with a diode array detector at 450 nm (Agilent Technologies), using

an isocratic method with a mobile phase of a mixture of acetonitrile:methanol: tetrahydrofuran (58:35:7 v/v/v), a Microsorb column (100-3 C18 100 X 4.6 mm) (Mejía *et al*., 1988). The results were expressed as µg of α or β carotene 100 g^{-1} dry weight.

L-Ascorbic acid. Samples of 0.5 g of lyophilized flesh were mixed with 10 mL of metaphosphoric acid (3%) and centrifuged (3000 g x 10 min. at 4˚C). The supernatant was filtered with a 0.22 µm nylon filter prior to analysis. The determination was made on an HPLC (Dionex Ultimate 3000, Thermo Scientific), equipped with an Accela 600 pump (Thermo Scientific), a diode array detector at 268 nm (Thermo Scientific) and a column µBondapak NH_2 (3.9 x 300 mm, 10µm, 125 A, Waters Co. Milford, MA, USA). An isocratic method was used to analyze the samples with acetonitrile: 0.05 M KH_2PO_4 (75:25, v/v) as a mobile phase. The flow rate was 1 mL min^{-1}. L-ascorbic acid was identified by comparing its retention time with that of a commercial standard. The analysis was performed under red light conditions to avoid oxidation of the compound. The results were expressed as mg ascorbic acid 100 g^{-1} fresh weight taking into account the moisture percentage of the sample (Doner and Hicks, 1981).

Total phenols and total flavonoids. Samples of 0.5 g of freeze-dried flesh or peel were extracted with 10 mL 80% (v/v) aqueous methanol using an ultrasonic bath. The samples were extracted successively with 10 mL of solvent for 1 h, 10 mL for 30 min, and 10 mL for 30 min. Another extraction with 10 mL of aqueous acetone (70% v/v) for 30 min was carried out on the residue. The extracts were then combined to a final volume of 50 mL. Total phenols [mg of gallic acid equivalents (GAE) g^{-1} dry weight] were determined according to the Folin-Ciocalteau colorimetric method (Singleton and Rossi, 1965). 50 µL of sample extract were placed in test tubes, 3 mL of distilled water and 250 µL of 1 N Folin Ciocalteau reagent were added, shaken in a vortex and left to stand for 8 minutes, and then 750 µL of 20% sodium carbonate was added and brought to a volume of 5 mL with distilled water. They were left to stand for 2 hours at room temperature in the dark. The absorbance was read at 765 nm in a spectrophotometer (CARY 50 UV-Visible, Agilent Technologies, Santa Clara, California, USA). Total flavonoids [mg quercetin equivalents (QE) g^{-1} dry weight] were assayed according to the method of Kim *et al*. (2003). 500 µL aliquot of the standard solution of quercetin (0.2 to 1 mg L^{-1}) or sample extract was added to a 5 mL volumetric flask containing 2 mL of distilled water. At zero time, 150 µL of a 5% $NaNO_2$ solution was added to the flask. After 5 min, 150 µL of a 10% $AlCl_3$ was added to the mixture. After 30 min, 1 mL of 1M NaOH was added and made up to 5 mL with distilled water. The solution was mixed well and the intensity of pink color was measured at 415 nm in a spectrophotometer (CARY 50 UV-Visible, Agilent Technologies, Santa Clara, California, USA) (Meda *et al*., 2005).

Total chlorophyll in the peel. Samples of 7 g of frozen tissue were extracted with 25 mL of acetone and homogenized for 1 min, filtered and the residue was extracted again by adding 10 mL of aqueous acetone (80% v/v) twice more. The extracts were then combined to a final volume of 50 mL. Absorbance was read from 450 to 750 nm in a spectrophotometer (Cary 50 UV-Visible). Chlorophyll content (mg 100 g^{-1} fresh weight) was calculated using the equation for 80% acetone proposed by Lichtenhaler (1987).

$$C_{a+b} = 7.15\ A_{663.2} + 18.71\ A_{646.8}$$

Where:

C_{a+b}: Total Chlorophyll

$A_{663.2}$: Absorbance at 663.2 nm

$A_{646.8}$: Absorbance at 646.8 nm

Betalains (betacyanins and betaxanthins) content in flesh and peel. Samples of 1 g of freeze-dried flesh or peel were homogenized with 10 mL of distilled water, centrifuged (11 739 x g x 15 min) in a centrifuge (Eppendorf 5430R), and the supernatant was filtered. The residue was successively washed with distilled water until it became colorless, all the washes were then combined with the first extract, and taken to 50 mL. Absorbance was read in a spectrophotometer (Cary 50 UV-Visible) at 538 nm and 480 nm, for betanin and indicaxanthin, respectively. In addition, the absorbance at 600 nm was read as a correction for possible sample impurities. The results were expressed as mg g^{-1} dry weight of betacyanins (Bc, as betanin), betaxanthins (Bx, as indicaxanthin), and total betalains (Bc+ Bx) (von Elbe, 2001; Castellanos-Santiago and Yahia, 2008).

RESULTS AND DISCUSSION

Physical and chemical characteristics

The fruits presented, as an average of the two years, an equatorial diameter of 5.3 ± 0.5 cm, a polar diameter of 5.1 ± 0.4 cm and a quotient between equatorial/polar diameters of 1.0 ± 0.1 that indicates a cylindrical-globose form. The average moisture content of flesh was 85.8% and of peel was 83.8%. The data presented correspond to the average of the 2015 and 2016 seasons.

Weight, external and internal color and firmness. Fruit average weight (76.2 g) (Table 1) of this study was similar to that reported by Muy *et al*. (1999), who recorded fruits of 66 g on average. The weight of *S. thurberi* fruits is lower than the pitayas of other species such as *S. pruinosus* and *S. stellatus*, with fruits of up to 195.5 g and 127.1 g, respectively (García-Cruz *et al*., 2016). Pimienta-Barrios (1999), pointed out that the fruits of cultivated varieties reach higher weights than those of wild varieties such as *S. thurberi*. The fruit percentage of flesh (71.6%), including small seeds, is similar to those of the pitaya of *S. pruinosus* (72.5%) (García-Cruz *et al*., 2013), and agrees with Pimienta-Barrios (1999), who mentioned that pitaya flesh is about 75%. Muy *et al*. (1999) indicated that species, cultivation (wild or cultivated) and plant age are among the factors that influence fruit weight.

Internal (flesh) hue value (Table 1), according to the color wheel (Minolta, 1998), is located in the red color area, and according to lightness (L*) and chroma (C*) values, pitaya flesh color corresponds to a dull dark red. External (peel) hue value of sweet pitaya, is located in the

orange area, and according to lightness (L*) and chroma (C*) values the color is dull dark orange. Internal (flesh) hue values of 46.98° and 18.17° have been found in *S. pruinosus* and *S. stellatus*, respectively; while chroma values of 12.07 and 13.53 were reported in *S. pruinosus* and *S. stellatus*, respectively. Furthermore, an external (peel) hue of 22.87° and 14.93° have been indicated in red fruits of *S. pruinosus* and *S. stellatus*, respectively; while chroma values of 30.93 and 11.36 were reported in *S. pruinosus* and *S. stellatus*, respectively (García-Cruz *et al.*, 2016). External (peel) hue values of *S. thurberi* fruits are higher than those of the red fruits of *S. pruinosus* and *S. stellatus*. This is due to the fact that the fruits of *S. thurberi* still presented areas of green color, which indicates that the chlorophyll had not been completely degraded. However, the internal hue of *S. thurberi* was similar to that of the fruits of *S. pruinosus*.

Table 1. Physical and chemical characteristics of red sweet pitaya (*S. thurberi*) fruit.

Characteristic	Average
Total fruit weight (g)[a]	76.2 ± 8.9*
Flesh (%)[a]	71.6 ± 4.8
Peel (%)[a]	28.4 ± 4.8
Peel Color[a]	
Lightness (L*)	43.93 ± 0.47
Hue (h°)	71.88 ± 5.86
Chroma (C*)	24.54 ± 2.13
Flesh Color[a]	
Lightness (L*)	23.81 ± 0.31
Hue (h°)	38.61 ± 8.46
Chroma (C*)	29.20 ± 3.56
Firmness (N)[b]	3.43 ± 0.71
Total Soluble Solids (SST, °Brix)[b]	12.83 ± 0.60
pH[b]	6.02 ± 0.25
Titratable acidity (TA, % malic acid)[b]	0.18 ± 0.04
Soluble sugars(g 100 g^{-1} dry weight)[c]	
Glucose	35.65 ± 0.35
Fructose	17.48 ± 0.37
Saccharose	ND
Lactose	ND

*The data represent the average of the two years of evaluation and its standard deviation. [a] n = 26 in 2015; n = 15 in 2016; [b]n = 3 replications each year; [c] n = 2. ND: No detected.

Pitaya is considered a soft-textured fruit and the value found in this study (3.4 N) (Table 1) is greater than those of fruits of *S. pruinosus* and *S. stellatus* (1.59 to 2.45 N) (García-Cruz *et al*., 2016). The low firmness values of pitaya can be attributed to the ripeness stage, commercial or ripe stage, at which these fruits are harvested due to its non-climacteric ripening pattern.

Total soluble solids, titratable acidity, and pH. TSS content of sweet pitaya fruit (Table 1) is similar to the 12.98 °Brix previously indicated for sweet pitaya of Sonora by Muy *et al*. (1999), but higher than those of red fruits of *S. stellatus* (9.67 °Brix) (Pérez-Loredo *et. al*., 2016), red fruits of *S. pruinosus* (9.3 °Brix) (García-Cruz *et al*., 2013), as well as those of four types of pitaya of *S. pruinosus* and *S. stellatus* (9 to 11 °Brix) (García-Cruz *et al*., 2016). TA value of the sweet pitaya fruits is similar to that of red pitaya fruits of *S. pruinosus* (0.17%) (García-Cruz *et al*., 2013), and lower than that of red fruits of *S. stellatus* (0.48%) (Pérez-Loredo *et al*., 2016). However, TA value is lower than 0.61% of sweet pitaya from Sonora (Muy *et al*., 1999), which could be attributed to differences in climatic conditions during the production period of these studies. In addition, low TA values (0.14 to 0.17%) have been found in red and orange fruits of *S. pruinosus*, while higher TA values (0.48 to 0.60%) have been reported in red and white fruits of *S. stellatus*, indicating differences in TA among species (García-Cruz *et al*., 2016).

The pH of sweet pitaya (6.02) (Table 1) is higher than that of 4.3 indicated by Muy *et al*. (1999) in fruits of the same species and higher than that of 4.19 and 4.39 of red and white fruits of *S. stellatus* (García-Cruz *et al*., 2016). However, it is similar to the 5.70 and 5.80 of red and orange fruits, respectively, of *S. pruinosus* (García-Cruz *et al.,* 2016). This behavior is consistent with the observed values of TA.

Soluble sugars. The main soluble sugars found in sweet pitaya were glucose and fructose, with glucose content twice as high as fructose. No lactose or sucrose was detected (Table 1). Glucose and fructose are also the main sugars of other cacti fruits such as pitahaya (*Hylocereus* sp.) (Hua *et al*., 2018) and cactus pear (*Opuntia* sp.) (Zenteno-Ramírez *et al*., 2015), with glucose also being higher in *Hylocereus* sp. and slightly higher in cactus pear fruits. However, in pitahaya (*Hylocereus* sp.) although in low content other sugars such as sucrose, inositol and sorbitol were also found (Hua *et al*., 2018), while in cactus pear traces of sucrose were found (Zenteno-Ramírez *et al*., 2015).

Amino acid profile. The protein content of pitaya flesh was 7.73% on a dry basis or 0.86% on a fresh basis (Table 2). Protein content (fresh basis) is similar to that of red (1.3%) and orange (1.2%) pitaya of *S. pruinosus* (García-Cruz *et al*., 2013), as well as to protein content (1.08 to 1.30) of red, white, yellow and purple pitaya of *S. stellatus* (Pérez-Loredo *et al*., 2016). The main AA of sweet pitaya was tyrosine, followed by glutamate and methionine (Table 2). This three main AA´s represent 41.67% of the 15 AA´s quantified. Tyrosine is an aromatic AA precursor of betalains, alkaloids (isoquinoline) and quinones (tocochromanols and plastoquinone (Maeda and Dudareva, 2012), and it has been indicated that glutamate is the first organic compound formed from nitrogen assimilation in plants (Anjum *et al*., 2014), while methionine is considered one of the most important essential AA´s because it is one of the most limiting AA´s in legumes (Galili and Höfgen, 2002).

Table 2. Amino acid profile of red sweet pitaya (*S. thurberi*) fruits.

Amino acids	Content	
	g AA 100 g^{-1} protein	mg AA 100 g^{-1} dry weight
Asparagine (Asp)	6.60±0.14*	510.36±10.50
Glutamate (Glu)	12.91±0.00	997.41±0.12
Serine (Ser)	436±0.10	336.83±7.78
Histidine (His)	4.85±0.10	375.06±7.44
Glycine (Gly)	5.66±0.48	437.70±37.06
Threonine (Thr)	7.45±0.28	575.74±21.91
Arginine (Arg)	4.53±0.13	350.18±10.27
Alanine (Ala)	3.72±0.04	287.34±3.00
Tyrosine (Tyr)	14.77±1.17	1141.57±90.22
Methionine (Met)	11.51±0.53	889.77±56.24
Valine (Val)	3.66±0.37	282.98±28.61
Phenylalanine (Phe)	3.47±0.22	268.46±16.78
Isoleucine (Isl)	4.17±0.24	322.24±18.58
Leucine (Leu)	5.87±0.33	453.88±25.67
Lysine (Lys)	0.52±0.08	39.79±5.82

*The data represent the average of the two years of evaluation and its standard deviation.
n = 2 in 2015. The protein content was 7.73 % on a dry basis.

Bioactive Compounds

Carotenes in the flesh. A very low carotene content was found in pitaya flesh (Table 3). Similarly, Muy *et al.* (1999) indicated traces of carotene content in sweet pitaya (*S. thurberi*) flesh.

L-Ascorbic acid. The L-ascorbic acid content of pitaya flesh (Table 3) is within the values indicated for other pitaya species such as *S. stellatus* (red, cherry, yellow and white varieties) whose content is from 8.5 to 17.0 mg 100 g^{-1} fresh weight (Beltrán-Orozco *et al.,* 2009). However, this content is lower than the 15 mg 100 g^{-1} of pitahaya (*H. undatus* cv. Shuijing) (Li *et a*l., 2017), and lower than the 26 to 48 mg 100 g^{-1} of cactus pear fruit (*O. megacantha* and *O. ficus-indica)* (Coria-Cayupán *et al.,* 2011). According to the values found in this study, sweet pitaya can be considered to have a low L-ascorbic acid content, similarly to other widely distributed commercial fruits such as bananas (Lee and Kader, 2000).

Total phenols and total flavonoids. Total phenol content (TPC) found in the flesh of sweet pitaya (Table 3) is greater than TPC found in the flesh of red pitaya fruit of *S. stellatus* (Pérez Loredo *et al*., (2016) and *S. griseus* (García-Cruz *et al*., 2012) with 5.79 and 1.66 mg GAE g^{-1} dry weight, respectively. TPC of sweet pitaya is similar to that found (13.84 mg GAE g^{-1} dry weight) in red pitaya fruits of *S. stellatus* Riccobono (Beltrán-Orozco *et al*., 2009). TPC in sweet pitaya flesh expressed on a fresh basis (1.60 ± 0.19 mg GAE g^{-1}) is similar to that shown (1.6 ± 0.2 mg g^{-1} fresh weight) in red fruits of *S. pruinosus* (García-Cruz *et al*., 2013). These differences can be attributed to the species and ecotypes as was indicated by Agati *et al*. (2012).

Table 3. Contents of bioactive compounds of red sweet pitaya fruits (*S. thurberi*) fruits.

Bioactive Compound	Content
Flesh carotenes (µg 100 g^{-1} dry weight)[a]	
α-carotene	3.39 ± 0.15*
β-carotene	21.35 ± 0.32
L-ascorbic acid (mg 100 g^{-1} fresh weight)[a]	12.45 ± 0.64
Total phenols (mg GAE g^{-1} dry weight)[b]	
Peel	62.26 ± 2.17
Flesh	11.31 ± 1.31
Total flavonoids (mg QE g^{-1} dry weight)[b]	
Peel	58.63 ± 1.47
Flesh	13.70 ± 0.46
Total chlorophylls in the peel	5.48 ± 1.58
(mg 100 g^{-1} fresh weight)[b]	
Flesh Betalains (mg g^{-1} dry weight)[b]	
Betacyanins (Bc) (BE)	0.97 ± 0.08
Betaxanthins (Bx) (IE)	1.46 ± 0.11
Total Betalains (Bc + Bx)	2.43 ± 0.17
Peel Betalains (mg g^{-1} dry weight)[b]	
Betacyanins (Bc) (BE)	0.18 ± 0.04
Betaxanthins (Bx) (IE)	0.40 ± 0.14
Total Betalains (Bc + Bx)	0.58 ± 0.11

*The data represent the average of the two years of evaluation and its standard deviation. [a]n = 2 in 2015; [b]n = 3. GAE = Gallic acid equivalents, QE = Quercetin Equivalents. BE = Betanine Equivalents, IE = Indicaxanthine Equivalents.

TPC in the peel of sweet pitaya of the present study is 5.5 times higher than that of the flesh. Hua *et al*. (2018), also found a higher TPC in the peel than in the flesh of pitahaya fruits (*Hylocereus* sp.). However, TPC of *Hylocereus* fruit peel (3 to 6 mg g^{-1} fresh basis) is lower than that of the peel of sweet pitaya fruit (10.1 ± 0.35 mg g^{-1} fresh basis).

Total flavonoids content (TFC) has not been previously reported in fruits of any of the species of *Stenocereus* (Table 3). TFC in the pulp of sweet pitaya is 1.94 ± 0.07 mg QE g^{-1} fresh weight. This content is in the range of that reported (0.5 to 2 mg QE g^{-1} fresh weight) in pitahaya (*Hylocereus*) fruits (Hua *et al*., 2018). TFC in the peel of sweet pitaya is 9.52 ± 0.24 mg QE g^{-1} fresh weight. This TFC is higher than those (1 to 3 mg QE g^{-1} of fresh weight) found in the pitahaya fruit (*Hylocereus*) peel (Hua *et al.,* 2018). These differences can be attributed to the species, variety, or environmental conditions of the growing areas (Agati *et al.,* 2012).

Total chlorophyll in the peel. Total chlorophyll content of sweet pitaya (Table 3) is greater than those (1.0 to 1.5 mg 100 g^{-1} fresh weight) of the fruits of three pitahaya cultivars (*Hylocereus* sp.) (Hua *et al*., 2018), and those (1.7 mg 100 g^{-1}) of pitahaya [*H. polyrhizus* (Weber) Britton and Rose]. These differences can be attributed to the color changes of the peel during the ripening of these fruits, since sweet pitaya, even when it is fully ripe, its peel presents green color areas; while in pitahaya fruits (*Hylocereus* sp.) the green color of the peel disappears almost completely in the ripe fruits, indicating the degradation of chlorophyll. However, the chlorophyll content found in sweet pitaya is similar to those (4.65 to 6.44 mg 100 g^{-1} fresh weight) of yellow and orange cactus pear fruit (*O. megacantha*), respectively (Coria-Cayupán *et al*., 2011).

Betalains. The betacyanins content in the flesh of red sweet pitaya (Table 3) is lower than the content (mg g^{-1} dry weight) in the flesh of other red *Stenocereus* fruits, such as *S. griseus* (1.996 ± 0.243) (García-Cruz *et al*., 2012), *S. pruinosus* (2.86 ± 0.38) (García-Cruz *et al*., 2013), *S. stellatus* (1.457 ± 0.055) (Pérez-Loredo *et al*., 2016), and *Stenocereus* spp. (2.048 ± 0.089) (Sandate-Flores *et al*., 2016). However, it is higher than the content of purple fruits of *S. stellatus* (0.538 ± 0.026) (Pérez-Loredo *et a*l., 2016). The betaxanthins content of sweet pitaya fruit flesh is also lower than the content of 3.21 (± 0.56) mg g^{-1} dry weight in red fruits of *S. pruinosus* (García-Cruz *et al*., 2013). However, this content is similar to the 1.476 and 1.511 mg g^{-1} dry weight found in red fruits of *S. griseus* (García-Cruz *et al*., 2012) and *S. stellatus,* respectively (Pérez-Loredo *et al*., 2016).

The betalains content in the flesh of sweet pitaya is higher than in the peel. This behavior agrees with those in fruit color, with redder tones and in the flesh than in peel fruit. Similar behavior in the betacyanin content was reported in pitaya fruits (*Stenocereus* spp.) (Sandate-Flores *et al*., 2016). On the contrary, Hua *et al.* (2018) found that the betacyanins and betaxanthins content of pitahaya fruits (*Hylocereus* sp.) was higher in the peel than in the flesh.

CONCLUSIONS

The red fruits of sweet pitaya (*Stenocereus thurberi*) of the Sonoran Desert have a cylindrical-globose shape with a high moisture content (85.8%), a flesh content of 71.6%, soft texture (3.4 N), low acidity (0.18%), a total soluble solids content of 12.83 °Brix, with glucose and fructose

(35.65 and 17.48 g 100 g^{-1} dry weight, respectively), being the main sugars. The fruit has a low protein content (0.86% on a fresh basis), with tyrosine, glutamate, and methionine, being the main essential amino acids. The bioactive compounds of pitaya flesh were present as traces of carotenes, low content of L-ascorbic acid (12.45 mg 100 g^{-1} fresh weight), with a higher content of total phenols than that of red pitaya of the species *S. stellatus* and *S. griseus* ; but similar to that of the red fruits of *S. stellatus* Riccobono. Pitaya fruits also presented a lower or similar betalain content than fruits of other *Stenocereus* species such as *S. pruinosus* or *S. stellatus*.

The peel of red fruits of sweet pitaya, which is not edible, represents 28.4% of the fruit weight, and although its betalains content is lower than the flesh, its content of total phenols and total flavonoids is 5.5 and 4.3 times higher, respectively than that of the flesh. The peel contains also 5.48 mg 100 g^{-1} fresh weight of chlorophyll. Therefore, the peel of red sweet pitaya fruits could be considered a potential source of these bioactive compounds.

The red fruit of sweet pitaya (*S. thurberi*) can be considered a source of phenolic compounds and betalains with potential health benefits.

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