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Physicochemical Characterization, Bioactive Compounds, and Antioxidant Capacity from *Stenocereus queretaroensis*: Mexican Endemic Fruits with High Potential Functionality

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Abstract: *Stenocereus queretaroensis* fruits are endemic to Mexico. They have an excellent advantage in cultivation because they require little water and fertilizers. These plants do not require fungicides and herbicides, drastically reducing production costs. However, the nutritional contribution and potential health benefits of *S. queretaroensis* fruits are unknown. The physicochemical characterization, the content of bioactive compounds, and the antioxidant capacity (AOX) of four *S. queretaroensis* fruits (red, purple, yellow, and white) were evaluated. All fruits had a low sugar content (7.04–8.96%) and provided 4–5% dietary fiber. The purple and red fruits presented 19.7–20.29 mg/100 g fresh weight (fw) of total betalains, respectively, while the yellow fruit presented 9.21 mg/100 g fw of total carotenoids. The total soluble phenols were 54.86–62.14 mg/100 g fw. Flavonoids, hydroxycinnamic, and hydroxybenzoic acids were also found in all fruits in ascending order. The red fruit exhibited the highest AOX, followed by the yellow, purple, and white fruits. In conclusion, these fruits are a rich source of antioxidants and nutrients, highlighting that they provide 20% of daily consumption of dietary fiber and have a low caloric content. *S. queretaroensis* fruits, therefore, may have a high potential functionality, especially in people with diabetes and living with obesity.

Keywords: *Stenocereus queretaroensis* fruits; physicochemical parameters; bioactive compounds

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1. Introduction

Cactaceae, the most abundant plant in arid and semiarid regions, originates in the Americas, extending from Canada to Argentina. In Mexico, there are more than 669 species of cacti out of the more than 1400 species currently known worldwide. There are 92 species in North America, and 61 are grown in Mexico, which stands out as the center of origin [1].

The fruits of these cacti have been studied for several decades and have various purposes, which have laid the foundations of our current understanding of their botanical, taxonomic, biochemical, and pharmacological characteristics [2,3]. The demand for exotic cacti fruits with high nutritional value and that are rich in antioxidants has increased in recent years because these fruits could decrease inflammation, blood pressure, and glucose in diabetic individuals [4]. The World Health Organization (WHO) continues to forecast these ailments as important long-term diseases [5]. Also, international markets are increasingly demanding plant species as a source of functional metabolites, new pigments of plant origin, and antioxidants for the food industry [6].

As mentioned above, people with these diseases and in situations of poverty should take advantage and consume these types of fruits from their region, for example, the *Stenocereus* genus, named "pitayas". There are 24 species in this genus, of which 21 are endemic

to Mexico [7]. The most well-known species in agricultural plantations are *S. stellatus*, *S. griseus*, *S. thurberi*, *S. pruinosus*, and *S. queretaroensis*. Nowadays, many Mexican towns grow *S. queretaroensis* fruits as a substitute or complementary to traditional crops because it impacts their economy [8]. These extensive cacti families do not require irrigation water or pre-harvest handling; there is no expenditure on insecticides, fertilizers, or fungicides, which makes this crop extremely inexpensive [8].

S. queretaroensis fruits are cacti native to Mexico and are grown in the semiarid zones of central and northern Mexico [9]. The fruits are distinguished by the diversity of striking colors in the pulp (red, purple, yellow, and white), which attract consumers and producers to formulate different traditional cool beverages or simply to eat and sell [10]. In addition to their pleasant organoleptic characteristics, *Stenocereus* fruits are attractive due to their associated components, including vitamins, minerals, crude fiber, betalains, carotenoids, and phenolic compounds [11–14]. These characteristics of the fruits could include a high antioxidant power that can stimulate the immune system and reduce inflammation, which reduces the risk of cardiovascular disease, degenerative disorders, and cancer [15].

Research on *S. queretaroensis* fruits is scarce, and only two reports specifically for this species exist. It was reported that *S. queretaroensis* fruits exhibited soluble solids values between 10 and 16 °Brix and low titratable acidity (0.15–0.5% citric acid) depending on the fruit color [9]. On the other hand, it was reported to be a highly digestible fruit with prebiotic effects [16].

Given the existence of variants with different coloration, *S. queretaroensis* fruits could be an essential source of nutrients and bioactive compounds. Therefore, this work aimed to determine the physicochemical parameters, proximal chemical composition, content of bioactive compounds, and antioxidant capacity of *S. queretaroensis* fruits.

2. Materials and Methods

2.1. Chemicals and Reagents

The chemicals and reagents were of analytical grade. Chloroform, acetone, sodium hydroxide, methanol, and ethanol were obtained from Jalmek Scientific (Guadalajara, Jalisco, Mexico). Folin Ciocalteu reagent, 2,2′-Azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) or ABTS, 2,4,6-tripyridyl-s-triazine, 1,1-diphenyl-2-picrylhydrazyl (DPPH), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), HPLC grade reagents (water, acetonitrile, and trifluoracetic acid), and standards of phenolic compounds were purchased from Sigma-Aldrich Chemical Co., Ltd. (St. Louis, MO, USA).

2.2. Plant Material

S. queretaroensis fruits (red, white, purple, and yellow pulp) (Figure 1) were collected in Techaluta De Montenegro, Jalisco, Mexico (20°04′27″ N 103°33′10″ O), in June 2023 by The Big Green Land Conception S. de R.L. de C.V., Company, Mexicali, Baja California, Mexico. Only this species is cultivated in this place. The fruits were chosen and harvested based on color (consumption maturity) without external damage and an average weight of 40.1–85.1 g. The fruits were donated to our institution, and they were peeled, and the fresh pulp was homogenized and analyzed.

2.3. Physicochemical Parameters

The homogenized pulp (5 g) was put on muslin cloth, and the juice was extracted by manual pressure. Total soluble solids (TSSs) were quantified in the juice extracted from the fruit using an ATAGO refractometer (PAL-1, Tokyo, Japan) previously calibrated with distilled water according to the official methodology of AOAC [17]. The results were expressed in °Brix.

Homogenized fresh pulp (1 g) was mixed with 50 mL of distilled water. One aliquot of the mixture was put on a fruit acidity meter (ATAGO, PAL-Easy ACIDF5 Master Kit, Tokyo, Japan) previously calibrated with distilled water. The acidity meter measured the acidity as percent citric acid (% citric acid).

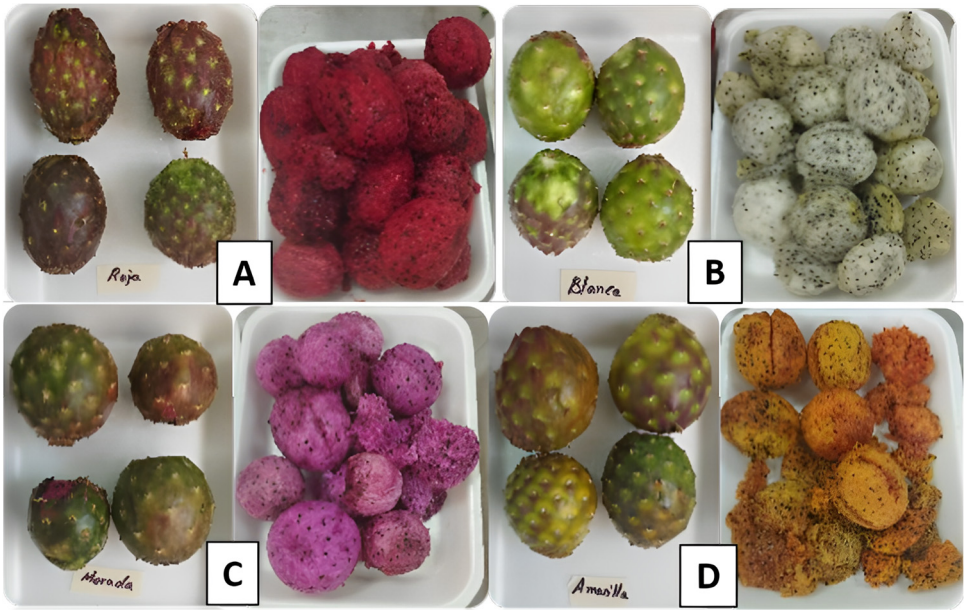

Figure 1. *Stenocereus queretaroensis* fruits; (**A**) Red, (**B**) White, (**C**) Purple, and (**D**) Yellow.

The hydrogen potential (pH) was determined directly in the homogenized fresh pulp using a potentiometer (Hanna Instrumental, 221 PH/MV, Padovana, Italy) according to the official AOAC methods [17].

Proximal Chemical Composition

The homogenized fresh pulp was used to evaluate moisture; however, the samples were dried using a convection oven (Memmert 854, Schwalbach, Western, Germany) at 35 °C and pulverized in a scientific mill (CGoldenWall HC-2000, San Francisco, CA, USA) to evaluate the other parameters. The content of moisture (method 934.06), ashes (method 940.26), proteins (method 978.04), and fats (method 950.54) were determined according to the official methodology of AOAC [17]. Soluble dietary fiber (SDF), insoluble dietary fiber (IDF), and total dietary fiber (TDF: the sum of SDF and IDF) were analyzed using the enzymatic-gravimetric method [18]. Reducing sugars was determined by the dinitro salicylic acid method (DNS) [19]. The results were expressed as grams per 100 g or percentage fresh weight (g/100 g fw or % fw).

2.4. Bioactive Compounds

2.4.1. Total Content of Betalains

The total content of betalains is the sum of betacyanins and betaxanthins. The extraction of betalains was completed by mixing 0.5 g of fresh pulp with 10 mL of 80% (v/v) aqueous methanol. The mixture was homogenized for 30 s in a homogenizer (Kaibrite FS-2A, Shanghai, China) and subsequently shaken for 20 min in an orbital shaker (Heildoph, Reax 2, Schwabach, Germany) at room temperature and in the dark. The sample was centrifuged at 16,058× g for 10 min at 4 °C (model Z32HK, Hermle, Wehingen, Germany). The supernatant was saved, and the residue was subjected to a second extraction with the described methodology [12].

The concentration of total betalains in the red, yellow, and purple fruits was determined. The content of betacyanins and betaxanthins was quantified by measuring the absorbance of the betalain extracts at 538 and 483 nm in a spectrophotometer (Jenway 6705, Dunmow, UK). Finally, the measured values were expressed in mg/100 g fw using the following equation [20]:

$$B(\text{mg}/100\ \text{gfw}) = \frac{A \times FD \times W \times V}{\varepsilon \times Q \times L} \times 100$$

B: betacyanins or betaxanthins content; *A*: absorbance (538 nm for betacyanins and 483 nm for betaxanthin); *FD*: dilution factor; *W*: molecular weight (550 g/mol for betanin and 308 g/mol for indicaxanthin); *V*: volume of the extract; ε: molar extinction coefficient (60,000 L/mol·cm for betanin a betacyanin and 48,000 L/mol·cm for indicaxanthin a betaxanthin); *Q*: quantity of sample (g); and *L*: cell length (1 cm).

2.4.2. Total Carotenoids

The total carotenoid content was performed according to Qin et al. [21], with some modifications. The fresh yellow pulp samples (0.5 g) were mixed with 1 mL of chloroform-methanol solution (2:1 v/v) and butylhydroxytoluene (0.05% w/v). The extracts were centrifuged at 21,380× g for 30 min at 4 °C (Mikro 200 R, Hettich GmbH, Germany). Subsequently, the procedure was repeated until the yellow color of the samples was eliminated. The absorbance of the extracts was measured at 448 nm with a microplate reader (800TS, Biotek, Winooski, VT, USA). The total carotenoids were calculated with a calibration curve, and results were expressed as milligrams of β-carotene equivalents per 100 g fresh weight (mg/100 g fw).

2.4.3. Total Soluble Phenols

Total soluble phenols (TSPs) were extracted using 2 g of fresh sample with 10 mL acidified methanol (2% HCl 2N). The mixture was homogenized for 30 s in a homogenizer (Kaibrite FS-2A, Shanghai, China), subsequently shaken in an orbital shaker (Heildoph, Reax 2, Schwabach, Germany) for 30 min, and then centrifuged at 16,058× g for 10 min at 4 °C (model Z32HK, Hermle, Wehingen, Germany). The supernatant was used to measure TSPs by the Montreau method [22]. The absorbance was measured at 750 nm with a microplate reader (800TS, Biotek, Winooski, VT, USA). Results were calculated using a calibration curve of gallic acid, and they were expressed as milligrams of gallic acid equivalents per 100 g of fresh weight (mg/100 g fw).

2.4.4. Profile of Phenolic Compounds

The profile of phenolic compounds was performed by liquid chromatography according to Nolasco-González et al. [23]. The phenolic extracts were obtained as described in Section 2.4.3. This extract was concentrated in a rotavapor at 35 °C (Yamato RE300, Tokyo, Japan). Then, this extract (10 µL) was injected into a high-performance liquid chromatograph or HPLC (Agilent Technologies 1260 Infinity, Waldbronn, Germany) with a diode array detector and a Poroshell 120 EC-C18 reverse-phase column (Agilent Technologies, Waldbronn, Germany). The mobile phase A consisted of acidified water with 0.1% trifluoroacetic acid and phase B of acetonitrile. The gradient program was 100% A and 0% B 0–10 min, 80% A and 20% B 10–15 min, 75% A and 25% B 15–20 min, 65% A and 35% B 20–35 min, 25% A and 75% B 35–55 min, 0% A and 100% B 55–57 min, 35% A and 65% B 57–62 min, 65% A and 35% B 62–65 min, and 100% A and 0% B 65–70 min. The peak areas were detected at 270–320 nm. Calibration curves of standards (for each phenolic compound, a calibration curve was realized as shown below) were achieved to quantify the phenolic compounds. The results were expressed in micrograms per 100 g fresh weight (µg/100 g fw).

2.5. Antioxidant Capacity

Three methods were used: the 2,2-difenil-1-picrilhidrazil (DPPH) method, the extracts (40 µL) were mixed with 260 µL of DPPH solution (190 µM), and the absorbance was measured at 517 nm according to the method described by Prior et al. [24]. Ferric reducing antioxidant power (FRAP) was used for this assay; 230 µL of FRAP solution (10:1:1, sodium acetate buffer (0.3 M, pH 3.6), 10 mM 2,4,6-tripyridyl-s-triazine, and 20 mM hexahydrate ferric chloride) was mixed with 70 µL of the extracts and 5 µL distilled water. The absorbance was measured at 595 nm after 30 min of stirring in the dark [25]. By the ABTS (2,2′azinobis (3-ethylbenzothiazoline-6-sulfonic acid)) method, the ABTS+ solution (7 mM, 265 µL) reacted with 35 µL of the extracts and was shaken in the dark for 10 min. The absorbance

was measured at 730 nm [26]. All absorbances were measured in the microplate reader. The results were expressed as millimole Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) equivalents per 100 g fresh weight (mmol Trolox/100 g fw).

2.6. Statistical Analysis

All tests were performed in triplicate (n = 3). Data analysis was performed by one-way analysis of variance (ANOVA) for each variable analyzed with statistical software v. 12 (StatSoft, Tulsa, OK, USA). The difference in means was analyzed with the least difference test or LSD Fisher ($p < 0.05$).

3. Results and Discussion

3.1. Physicochemical Parameters

Table 1 shows the physicochemical parameters of the evaluated *S. queretaroensis* fruits. The highest content of total soluble solids belonged to the yellow fruit (12.07 °Brix), exhibiting significant differences ($p < 0.05$) compared with the other fruits, which showed no differences among them (10.50–10.73 °Brix). The purple fruit had the lowest soluble solids content (10.50 °Brix). These findings align with previous reports for *S. queretaroensis* fruits (8.99–16.2 °Brix) [9,14]. The results indicate that these fruits do not provide a high level of simple sugars when consumed.

Table 1. Physicochemical parameters from the pulp of *S. queretaroensis* fruits.

Parameters	Fruits			
	Red	**White**	**Purple**	**Yellow**
Total soluble solids (°Brix)	10.53 ± 0.29 ^{b}	10.73 ± 0.06 ^{b}	10.50 ± 0.35 ^{b}	12.07 ± 0.21 ^{a}
Acidity percentage (% citric acid)	0.34 ± 0.03 ^{a}	0.45 ± 0.13 ^{a}	0.38 ± 0.03 ^{a}	0.36 ± 0.06 ^{a}
pH	4.60 ± 0.01 ^{a}	4.40 ± 0.01 ^{b}	4.47 ± 0.06 ^{b}	4.27 ± 0.12 ^{c}

Values are means ± standard deviation. Different letters in each file indicate significant statistical differences between varieties ($\alpha = 0.05$).

No significant differences ($p > 0.05$) were found in the percentage of acidity of the four types of fruits, presenting values (0.34–0.45%) similar to those reported in other studies for orange, red, yellow, and purple *S. queretaroensis* (0.1–0.88%) [9,14]. However, the results exceed those reported for the *S. thurberi* fruits (0.22%) [27]. Significant differences ($p < 0.05$) were observed between fruits in the pH values. The red fruit exhibited the highest pH (4.60), and the yellow fruit had the lowest pH (4.27). On the other hand, no significant differences ($p > 0.05$) in pH were found between the white and purple fruits. Similar values have been reported for the same species, concluding that *S. queretaroensis* fruits are not also acidic fruit [9,14].

3.2. Proximal Chemical Composition

The proximal chemical composition of *S. queretaroensis* fruits is presented in Table 2. The moisture content ranged between 83.76% and 87.70%. Significant differences ($p < 0.05$) were observed in the moisture content; the red and white fruits exhibited the highest and lowest moisture content, respectively. These findings are consistent with previous reports for different *Stenocereus* species (86.33%) [14]. However, the *S. thurberi* fruits contain a lower percentage of moisture (78.7–82%) [28]. The little differences in moisture depended on genotype; however, the high moisture content in fruits makes them highly perishable when stored at room temperature [14].

Table 2. Proximal chemical composition parameters from the pulp of *S. queretaroensis* fruits.

Parameters (g/100 g or % fw)	Fruits			
	Red	**White**	**Purple**	**Yellow**
Moisture	87.70 ± 0.54 ^{b}	83.76 ± 1.43 ^{a}	85.62 ± 1.12 ^{ab}	84.77 ± 1.56 ^{a}
Ashes	0.27 ± 0.05 ^{a}	0.35 ± 0.13 ^{a}	0.36 ± 0.12 ^{a}	0.36 ± 0.01 ^{a}
Fats	0.40 ± 0.02 ^{c}	0.42 ± 0.21 ^{ab}	0.19 ± 0.03 ^{bc}	0.62 ± 0.15 ^{a}
Proteins	0.72 ± 0.10 ^{b}	1.21 ± 0.11 ^{a}	1.18 ± 0.13 ^{a}	1.16 ± 0.06 ^{a}
Soluble dietary fiber	0.33 ± 0.06 ^{b}	0.49 ± 0.02 ^{a}	0.17 ± 0.01 ^{c}	0.19 ± 0.03 ^{c}
Insoluble dietary fiber	3.54 ± 0.52 ^{a}	4.80 ± 0.34 ^{b}	4.67 ± 0.58 ^{b}	4.31 ± 0.55 ^{b}
Total dietary fiber	3.87 ± 0.47 ^{d}	5.30 ± 0.35 ^{a}	4.83 ± 0.59 ^{b}	4.50 ± 0.55 ^{c}
Reducing sugars	5.70 ± 0.53 ^{b}	7.28 ± 0.19 ^{a}	6.60 ± 0.67 ^{b}	7.48 ± 0.47 ^{a}
Kilocalories (Kcal)	35	44	38	45

Values are means ± standard deviation. Different letters in each file indicate significant statistical differences between varieties ($\alpha = 0.05$).

The ash values (0.27–0.36%) showed no significant differences ($p > 0.05$) between fruits; however, they are slightly lower than those reported by Gaytán-Andrade et al. [14] (0.46–0.48%) for *S. stellatus* and *S. thurberi* fruits. This variation may be attributed to the harvest location, climate, soil nutrition, etc. [29]. The mineral content is noteworthy because these values are comparable to mango, soursop, and jackfruit, ranging from 0.01 g/100 g to 0.42 g/100 g [30–32].

The fat content ranged from 0.19% to 0.62%; nonetheless, the yellow fruit had the highest content, possibly due to carotenoids, which are lipidic components. However, the fat content in these fruits is low. No reports were found on the fat content of this species; they were only found for *S. griseus* and *S. stellatus*, with values ranging from 0.12 to 2.28% [14]. These differences can be precisely attributed to the fact that they are different species.

The protein content represents between 0.72% and 1.21% of the total weight of the fruit, which coincided within the range for these species (1.0–1.5%) [14]. The red fruit showed the lowest protein content ($p < 0.05$); however, among the other types of fruits, there were no significant differences ($p > 0.05$). This protein content aligns with that reported for fruits in general, as it is widely known that fruits are not a significant source of protein [33].

The content of soluble dietary fiber, insoluble dietary fiber, and total dietary fiber was 0.17–0.49%, 3.54–4.80%, and 3.87–5.30%, respectively, in all fruits. The white fruit exhibited the highest soluble fiber content. In contrast, the purple fruit had the lowest soluble fiber content, but the red fruit had the lowest contents of insoluble and total dietary fiber. Overall, the fiber contents of the fruits used in this study are higher than those reported for the same species [9,14] because the previous report only considered crude fiber, which does not include soluble dietary fiber. It can be inferred that the consumption of dietary fiber from *S. queretaroensis* fruits can be beneficial for digestive health by stimulating intestinal transit and preventing constipation, in addition to slowing carbohydrate digestion, which helps control blood sugar levels; also, it can be prebiotic for beneficial microorganisms or probiotics [9,14]. Furthermore, considering that the FAO and OMS recommend consuming 25 g of fiber daily, consuming five *S. queretaroensis* fruits would meet the recommended daily intake [34]. It is possible because one can consume up to ten of these fruits daily.

On the other hand, the content of reducing sugars found in this study was similar to the minimum values reported by Arriaga-Ruiz et al. [9] and Gaytan-Andrade et al. [14] for the same species. The authors reported values between 7.9% and 12.2%. This experiment found values between 5.70% and 7.48% in the present study. The yellow and purple fruits exhibited the highest and lowest content of this parameter, respectively, coinciding with the total soluble solids. This low sugar content indicates that it can be consumed by individuals who prefer fewer sweet fruits or those with high sugar sensitivity because there are only 35–45 Kcal per 100 g of fresh pulp.

3.3. Bioactive Compounds

The content of total betalains (betacyanins + betaxanthins) showed a significant difference ($p < 0.05$) between the types of fruits (Table 3). The red fruit had a higher content of total betalains (20.29 mg/100 g), followed by the purple fruit (19.70 mg/100 g) and, finally, the yellow fruit (14.81 mg/100 g). In the red and purple fruits, the content of betacyanins was predominant, with 13.95 mg/100 g and 12.27 mg/100 g, respectively, because betacyanins are associated with red-violet colors. In contrast, betaxanthins are related to the yellow color [12], so their presence was higher in the yellow fruit (8.59 mg/100 g).

Table 3. Bioactive compounds from the pulp of *S. queretaroensis* fruits.

Parameter (mg/100 g fw)	Fruits			
	Red	**White**	**Purple**	**Yellow**
Betacyanins	13.95 ± 0.20 [a]	n.d.	12.27 ± 0.21 [b]	6.22 ± 0.46 [c]
Betaxanthins	7.34 ± 0.74 [c]	n.d.	7.43 ± 0.06 [b]	8.59 ± 0.08 [a]
Total betalains	20.29 ± 0.72 [a]	n.d.	19.70 ± 0.09 [b]	14.81 ± 0.47 [c]
Carotenoids	n.d.	n.d.	n.d.	9.21 ± 0.14 [a]
Total soluble phenols	58.35 ± 1.98 [b]	68.33 ± 2.91 [a]	54.86 ± 1.89 [b]	62.14 ± 2.68 [b]

Values are means ± standard deviation. Different letters in each file indicate significant statistical differences between varieties ($\alpha = 0.05$). n.d. = not detected.

No reports of the content of total betalains were found in the evaluated species, but there are reports for other species. The total content of betalains was 35.76 mg/100 g fw for *S. stellatus* fruits [35] and 25.80 mg to 41.68 mg/100 g fw for *S. griseus* fruits [12]. For the *S pruinosus* species, a higher concentration was found in the yellow and red flesh [36]. However, it is essential to note that the difference in the content of betalains is because they are a different species of the *Stenocereus* genus. Betalains are natural pigments responsible for the vibrant colors of *Stenocereus* fruits, ranging from red to yellow. Therefore, they represent a healthy alternative for obtaining natural colorants for the food and cosmetic industry [37,38]. In addition, these compounds have potent antioxidant and anti-inflammatory properties, suggesting that they may help to decrease oxidative stress in the body and contribute to cardiovascular health [29,39].

The carotenoid content was only found in the yellow fruit, with 9.21 mg/100 g fw (Table 3). No reports were found of this parameter being evaluated in *Stenocereus queretaroensis* fruits. On the contrary, a very low content of carotenoids (0.3 mg/100 g fw) was found in the species *S. thurberi* [40]. Thus, it is important to highlight that carotenoids in yellow *S. queretaroensis* fruits are also known for their antioxidant properties. It has been suggested that these compounds may have protective effects against various chronic diseases, including cardiovascular diseases and certain types of cancer [41].

The content of TSPs was higher for the white fruit (68.33 mg/100 g fw); however, the yellow, red, and purple fruits did not present a significant difference ($p < 0.05$) between them in their content of TSPs with 62.14, 58.35, and 54.86 mg/100 g fw, respectively. The TSPs values of all fruits are higher than other fruits of different species of *Stenocereus* (42.4–51.98 mg gallic acid/100 g fw) [35,39]. Specifically, a low content of TSPs (19.98 and 6.34 mg gallic acid/100 g) was determined in the *Stenocereus griseus* fruits [12].

The different phenolic compounds in the TSPs extract from all fruits are shown in Table 4 and Figure 2. Nineteen phenolic compounds were identified. The white fruit exhibited the highest content of hydroxybenzoic acids (2058.56 µg/100 g fw), hydroxycinnamic acids (1544.84 µg/100 g fw), phenolic aldehydes (235.95 µg/100 g fw), hydroxyphenyl acetic acids (604.35 µg/100 g fw), and flavonoids (1650.01 µg/100 g fw), followed by the red, purple, and yellow fruits. It coincided with the reported findings of the white *S. stellatus* fruit with the highest numerical value in total phenolic compounds [36]. In this study, the compounds with the highest concentration in all fruits were gallic acid, vanillic acid, protocatechuic acid, chlorogenic acid, neochlorogenic acid, gallocatechin, epigallocatechin,

and catechin. This work is the first report identifying the types of synthesized phenolic compounds by *S. queretaroensis* fruits.

Table 4. Phenolic compounds' profile from the pulp of *S. queretaroensis* fruits.

Phenolic Compounds (μg/100 g fw)	TR (min)	nm	Equation	R^2	Fruits			
					Red	White	Purple	Yellow
Hydroxybenzoic acids								
Gallic acid	10.62	270	y = 262.9x − 402.9	0.9979	1348.13 ± 26.61 [a]	759.54 ±71.29 [c]	883.51 ± 68.74 [c]	1031.77 ± 40.56 [b]
Protocatechuic acid	14.01	270	y = 391.51x − 112.2	0.9997	253.98 ± 2.44[a]	241.56 ± 17.94[a]	196.45 ± 14.09[b]	167.82 ± 3.14[c]
4-Hydroxybenzoic acid	18.76	270	y = 376.93x − 287.2	0.9989	232.13 ± 45.28[a]	264.87 ± 27.31[a]	295.73 ± 38.39[a]	148.88 ± 15.43[b]
Syringic acid	20.57	280	y = 395.91x − 320.3	0.9993	185.53 ± 12.23 [b]	445.55 ± 21.01 [a]	152.08 ± 6.52 [b]	160.39 ± 20.40 [b]
Vanillic acid	19.86	270	y = 286.35x − 300.0	0.9997	207.50 ± 0.72 [a]	175.91 ± 7.78 [b]	139.82 ± 12.80 [c]	176.24 ± 11.18 [b]
Salicylic acid	30.85	300	y = 250.15x − 121.1	0.9996	56.57 ± 10.27 [c]	171.13 ± 15.76 [a]	130.97 ± 21.43 [b]	51.81 ± 10.48 [c]
Hydroxycinnamic acids								
Trans cinnamic acid	34.05	280	y = 1070.9x − 1271.9	0.9983	112.21 ± 1.32 [c]	170.02 ± 3.84 [b]	175.85 ± 2.76 [b]	187.81 ± 1.66 [a]
p-Coumaric acid	25.02	310	y = 496.93x + 1844.1	0.9695	346.74 ± 0.87 [a]	304.12 ± 0.39 [b]	290.86 ± 0.45 [c]	214.93 ± 1.11 [c]
Caffeic acid	21.56	320	y = 637.32x − 421.9	0.9995	109.93 ± 3.89 [b]	154.82 ± 1.13 [b]	142.12 ± 0.79 [c]	162.29 ± 2.34 [a]
Chlorogenic acid	19.01	320	y = 389.28x − 533.9	0.992	390.88 ± 69.57 [a]	340.63 ± 69.46 [a]	379.21 ± 60.01 [a]	307.67 ± 70.42 [a]
Neochlorogenic acid	17.75	270	y = 288.88x − 947.3	0.9984	417.11 ± 3.15 [a]	399.86 ± 3.95 [b]	390.96 ± 6.59 [b]	317.80 ± 2.79 [c]
Trans ferulic acid	25.39	320	y = 343.49x − 328.2	0.9984	105.85 ± 4.89 [b]	175.39 ± 4.35 [a]	102.68 ± 17.52 [b]	178.57 ± 0.48 [a]
Phenolic aldehydes								
4-Hydroxybenzaldehyde acid	22.06	285	y = 1083.8x + 415.7	0.9966	140.16 ± 0.96 [b]	235.95 ± 10.04 [a]	227.92 ± 0.94 [a]	241.73 ± 1.28 [a]
Hydroxyphenyl acetic acids								
3,4-dihydroxyphenylacetic acid	18.11	280	y = 47.712x − 21.511	0.9995	393.70 ± 4.05 [b]	604.35 ± 12.25 [a]	277.31 ± 12.99 [c]	280.01 ± 3.09 [c]
Flavonoids								
Catechin	21.95	280	y = 84.567x − 63.346	0.9992	230.35 ± 95.11 [c]	363.5 ± 33.16 [b]	517.70 ± 49.57 [a]	392.36 ± 6.67 [b]
Gallocatechin	16.22	270	y = 15.557x − 26.384	0.9980	880.98 ± 43.40 [a]	762.43 ± 22.86 [b]	724.98 ± 25.96 [b]	597.24 ± 25.50 [c]
Epigallocatechin	20.08	270	y = 23.341x − 31.289	0.9995	247.47 ± 15.01 [a]	213.09 ± 13.88 [a]	251.74 ± 26.92 [a]	296.10 ± 22.49 [a]
Naringenin	38.89	290	y = 587.5x − 304.69	0.9995	49.05 ± 0.84 [b]	94.97 ± 1.28 [a]	38.22 ± 0.78 [c]	37.66 ± 0.40 [c]
Myricetin	28.34	270	y = 298.06x − 154.5	0.9995	123.24 ± 9.20 [c]	216.02 ± 15.18 [a]	119.68 ± 16.78 [c]	148.92 ± 4.95 [b]

Values are means ± standard deviation. Different letters in each file indicate significant statistical differences between varieties (α = 0.05).

The results are highly relevant because the phenolic compounds are potent antioxidants that decrease inflammation, blood glucose, and cholesterol. After all, it has been demonstrated these compounds can inhibit hydrolases, cyclooxygenases, alkaline phosphatases, cAMP phosphodiesterases, ATP-ases, lyases, hydroxylases, transferases, oxidoreductases, proteinases, amyloglucosidases, and kinases, as well as other mediators of the inflammatory process, cancer, and chronic degenerative diseases [15,42].

3.4. Antioxidant Capacity

The behavior of the antioxidant capacity from the fruits was as follows: FRAP > DPPH > ABTS assay (Table 5). The highest antioxidant capacity by the FRAP assay could be attributed to flavonoids such as gallocatechin and epigallocatechin in all fruits because these compounds have chelating capacity [43]. The antioxidant capacity of the DPPH and ABTS assay is attributed to the soluble phenolic compounds, betalains, vitamin C, and carotenoids present in the fruits [44]. The yellow fruit presented the highest antioxidant capacity according to the DPPH method (265 mM Trolox/100 g fw). Conversely, the red fruit showed a greater antioxidant capacity based on the ABTS and FRAP methods (84.28 and 736.02 mM Trolox/100 g fw, respectively). These results are attributed to the differences in the content of bioactive compounds or antioxidants since red and purple fruits have phenolic compounds and betalains. At the same time, yellow fruit also has carotenoids [36]. It is important to note that although the antioxidant capacity of these types of fruits has not been extensively studied, it is crucial to understand that their antioxidants allow for the neutralization or counteraction of the detrimental effects of free radicals, which can lead to cellular and tissue damage and is associated with various health issues and premature aging [12]. The *S. Stellatus* fruits are the most studied in this parameter; however, they show significant variability in the antioxidant capacity compared with *S. queretaroensis* fruits. It can be attributed to the species; therefore, every species must be evaluated [4,11,35].

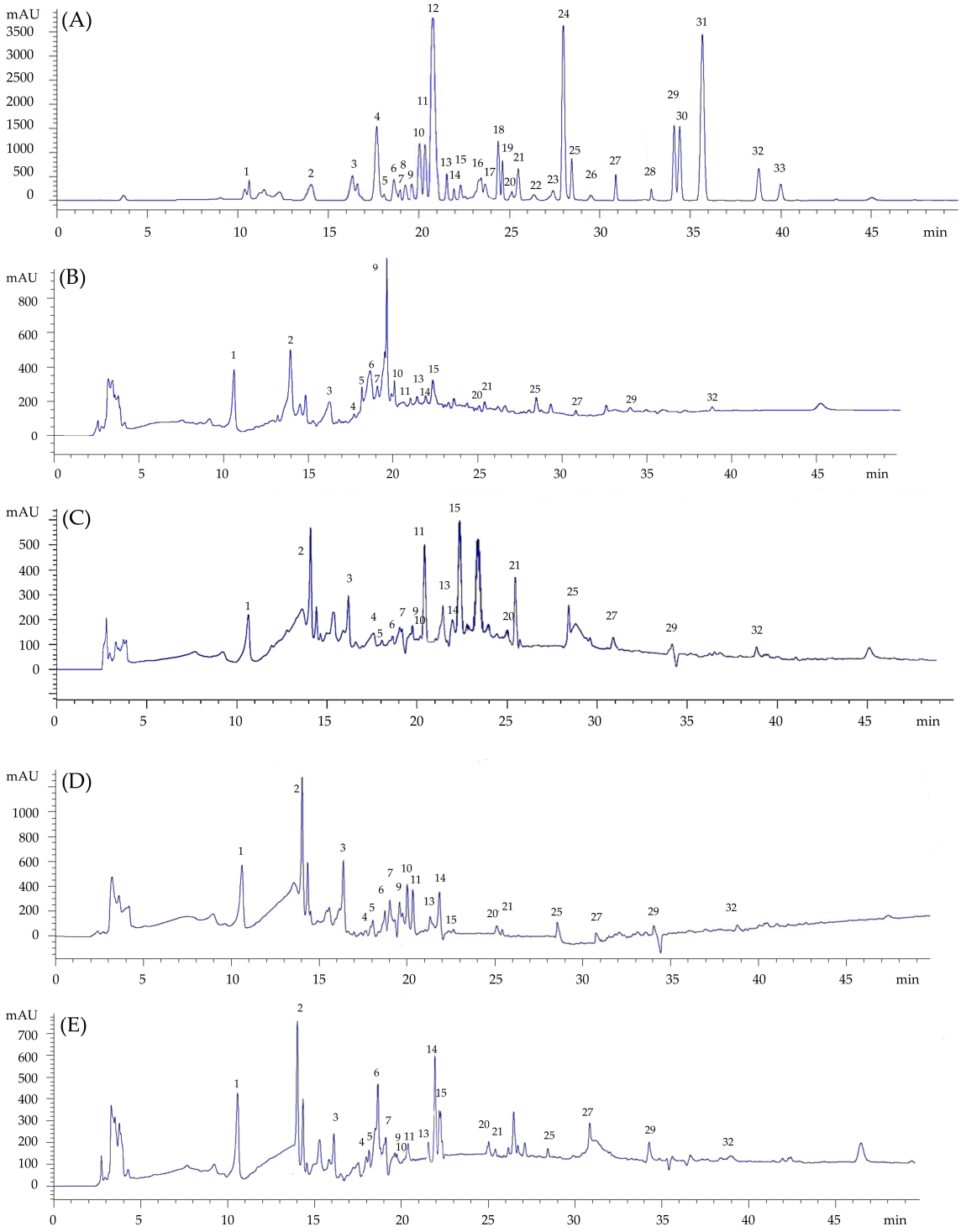

Figure 2. HPLC chromatogram of phenolic compounds. (**A**) Chromatogram of phenolic standards. (1) gallic acid, (2) protocatechuic acid, (3) gallocatechin, (4) neochlorogenic acid, (5) 3,4-dihydroxyphenylacetic, (6) 4-hydroxybenzoic acid, (7) chlorogenic acid, (8) 4-hydroxyphenyl acetic, (9) vanillic acid, (10) epigallocatechin, (11) syringic acid, (12) 3-hydroxybenzoic acid, (13) caffeic acid, (14) catechin, (15) 4-hydroxybenzaldehyde, (16) epicatechin, (17) homovanillic acid, (18) 3-(4-hydroxyphenylpropionic acid), (19) rutin, (20) coumaric acid, (21) trans-ferulic acid, (22) ellagic acid, (23) synaptic acid, (24) benzoic acid, (25) myricetin, (26) trans-hydroxycinnamic acid, (27) salicylic acid, (28) 2,5-dihydroxybenzoic, (29) trans-cinnamic acid, (30) quercetin, (31) luteolin, (32) naringenin, and (33) kaempferol. Chromatogram of phenolic compounds from red (**B**), white (**C**), purple (**D**), and yellow (**E**) *S. queretaroensis fruits*.

Table 5. Antioxidant capacity (AOX) from the pulp of *S. queretaroensis* fruits.

AOX (mM Trolox/100 g fw)	Fruits			
	Red	White	Purple	Yellow
DPPH	156.9 ± 67.63 [b]	188.50 ± 13.44 [b]	119.99 ± 7.96 [c]	265.20 ± 11.86 [a]
ABTS	84.28 ± 0.88 [a]	72.32 ± 3.86 [b]	77.51 ± 3.70 [b]	72.48 ± 6.35 [b]
FRAP	736.02 ± 65.30 [a]	580.48 ± 39.63 [b]	568.38 ± 59.16 [b]	512.66 ± 14.33 [b]

Values are means ± standard deviation. Different letters in each file indicate significant statistical differences between varieties ($\alpha = 0.05$).

4. Conclusions

These results indicate that *S. queretaroensis* fruits are potentially functional since bioactive compounds with AOX and dietary fiber could benefit health when consumed. The bioactive compounds found in this experiment are antioxidants that could combat oxidative stress and prevent chronic degenerative diseases. At the same time, dietary fiber could function for intestinal health, satiety, and the regulation of lipids and blood glucose. In addition, *S. queretaroensis* fruits could be used in the food industry to produce other functional products such as beverages (juices and nectars), yogurts, jellies, jams, etc.

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