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Phenotypic variation in physico-chemical properties among cactus pear fruits (*Opuntia ficus-indica* (L.) Miller) from Turkey

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ABSTRACT

Several physico-chemical properties such as fruit weight and dimensions, skin width, external and internal fruit color, vitamin A, vitamin C, acidity, pH, soluble solid content, antioxidant activity and total phenolic content of twenty five selected promising cactus pear accessions were determined. Antioxidant activity and total phenolic content of fruits were determined by β-Caroten bleaching and Folin-Ciocalteu assays. The results showed great qualitative and quantitative differences in the physico-chemical characteristics of cactus pear accessions. Vitamin A (beta carotene) and vitamin C (ascorbic acid) content of genotypes were found between 2.64 and 25.13 (μg/g) and 18.04 and 37.31 mg/100 g. Antioxidant activity and total phenolic content of cactus pear genotypes were between 45.5-76.8% and 19.4-49.4 mg gallic acid equivalent per g dry weight basis. The results provide important information on how to make the best use of cactus pear genotypes investigated for different uses, which is of significance for both technological research and processing practice.

Keywords: Antioxidant activities, cactus pear, *Opuntia ficus-indica,* phenolics.

INTRODUCTION

A number of potential health promoting effects have been ascribed to nutrients in horticultural plants. The vitamins A, C and E have received considerable attention in this regard because of their antioxidant properties. The polyphenols that are present in horticultural plants such as fruits, vegetables and grapes are more potent antioxidants than vitamins A, C and E (1, 2). Therefore, the consumers are being encouraged to eat more fruits and vegetables as a contribution to a balanced diet and because a number of nutrients in produce have been identified that may prevent diseases such as heart disease and cancer (3, 4).

Recent increasing interest in nutraceuticals and functional foods has led plant breeders to initiate selection of crops with higher than normal phenolic antioxidant contents such as blueberries (2), plums and peaches (5) and sea buckthorns (6). All these programs aim to set the baseline for establishing breeding efforts, with the intention of adding value to fruits with respect to the level and diversity of health benefit properties that crops could be improved.

In recent years increasing attention also has been paid by consumers to the lesser known fruits such as cactus pear, cornelian cherry, honeysuckle, hardy kiwifruit, lingonberry, elderberry, sea buckthorn, strawberry tree which had unusual flavors and qualities, and many are rich with antioxidants and anthocyanins (6, 7, 8). However, scientific information on physico-chemical properties of lesser known plants is still scarce. Therefore, the assessment of such properties remains an interesting and useful task, particularly for finding new sources for natural antioxidants, functional foods and nutraceuticals (9).

About 400 species of cactus, originated from Mexico, are in the genus *Opuntia*. They are distributed in Europe, Mediterranean countries, Africa, southwestern United States, northern Mexico and other areas. Low water requirements and a high water use efficiency ratio make cactus pear suitable for cultivation in arid and semi-arid marginal regions (10). In fact, owing to its crassulacean acid metabolism (CAM), this plant is characterized by a high potential of biomass production with very low water consumption (11). Many species of *Opuntia* produce edible and highly flavored fruits (12). Cactus pear fruits are a source of nutrients and vitamins and are eaten fresh, dried or preserved in jams, syrups or processed into candy-like products (13, 14).

Scientific studies have indicated that several parts of the species *Opuntia ficus-indica* (L.) Mill. have diuretic and antigotous effects (15), antinflammatory effects (16). Antiulcerous effects have been demonstrated in *Opuntia ficus-indica* (17). Moreover, antihyperglycemic and hypocholesterolemic effects have been attributed to the *Opuntia ficus-indica* (18, 19). Formulations with different proportions of cactus pear and quince pulp were studied for pH, acidity and vitamin C content; none of the sensory characteristics showed significant differences during 90 days of storage demonstrating the value of the fruit juice (20).

In Turkey, efforts are currently under way to develop the cactus pear production and to increase its introduction into various common foods. It is located wildly in the Mediterranean Region in the country with wide phenotypic characteristics. However there is no report on Turkish cactus pear about how much variation exists among different cactus pear genotypes. Therefore we report an evaluation of physico-chemical characteristics of 25 selected promising cactus pear genotypes from eastern Mediterranean region in Turkey.

MATERIALS AND METHODS

Chemicals

The all chemicals used were purchased from Sigma & Aldrich company and were of analytical grade.

Plant materials

Twenty five promising cactus pear accessions from eastern Mediterranean region in Turkey were used. These accessions had apparently high yield and free of pest and disease characteristics. Approximately 5 kg per accession of cactus pear fruits were harvested from trees when 30 to 70 % of full color development in 2007. The fruits selected according to uniformity of shape and color and then transported to laboratory for analysis. Samples divided into two groups and first groups of fruits used for fruit weight and dimensions, ascorbic acid, beta carotene, acidity, pH and soluble solid content (SSC) analysis. The other group was dried and was ground to a fine powder with a mortar and pestle, and kept at room temperature prior to extraction. The dried samples were packed into new plastic bags and stored in a dessicator for a maximum of 3 days until antioxidant activity and total phenolic analysis.

The sample weighing about 100 g was extracted in a soxhlet with methanol (MeOH) at 60 °C for 6 h. The extract was then filtered and concentrated in vacuum at 45 °C. Finally, the extracts were then lyophilized and kept in the dark at 4 °C until tested.

Fruit weight was measured by using a digital balance with a sensitivity of 0.001 g (Scaltec SPB31). Linear dimensions, length and width of fruits were measured by using a digital caliper gauge with a sensitivity of 0.01 mm. External and internal color of cactus pear fruits was measured on the cheek area of 25 fruit with a Minolta Chroma Meter CR-400 having a measuring area of 8 mm in diameter for readings of small samples without cut-off (Minolta-Konica, Japan). Since the fruit has varying color, a place representing the developed color of the fruit was selected. L^* (lightness), a^* (green to red) and b^* (blue to yellow) values were measured (21). For the oluble solid contents (SSC), pH and acidity determinations, the samples were homogenized and samples were taken from this mixture. SSCs were determined by extracting and mixing one drops of juice from the each fruit into a digital refractometer (Atago) at 20 °C. pH was determined by potentiometric measurement at 20 °C with a pH meter. The acidity was determined by titration with 0.1 N NaOH to pH 8.1, expressing citric acid (%).

Total carotenoids were determined by a modification of the procedures described by Kuti (11). Approximately 2 g of cactus pear tissue were homogenized with a Waring blender and extracted with 10 ml of hexane/acetone/ethanol (50:25:25, v/v) before being centrifuged for 5 min at 6500 rpm at 5 °C. The top layer of hexane, containing the color, was recovered and transferred to a 50-ml volumetric flask. The volume of recovered hexane was adjusted to 50 ml with hexane. Total carotenoid determination was carried out on an aliquot of hexane extract by measuring absorbance at 450 nm in a UV1208 spectrophotometer (Shimadzu, Japan). Finally, total carotenoids were calculated using an extinction coefficient of β-carotene, E1% = 2505 (23).

Vitamin C content (reduced ascorbic acid) was analyzed by a modification of the procedures described by Pearson (24). 10 g of fruit was squeezed to obtain juice. A 10 mL aliquot sample was placed in 100 mL volumetric flask and brought to volume with 0.4 mL oxalic acid solution. Samples were immediately filtered through Whatman #4 paper. Vitamin C was quantified spectrophotometrically using a UV1208 spectrophotometer (Shimadzu, Japan). The spectrophotometer was adjusted to zero using 3 mL of oxalic acid solution at 520 nm. The absorbance of DCIP dye (2.045 mL) plus oxalic acid solution (0.955 mL) was read after exactly 15 sec. This value was noted as L1, which represents absorbance of DCIP dye. Then, the instrument was again adjusted to zero using the sample extract (0.273 mL) plus oxalic acid solution (2.727 mL). The absorbance of the oxalic acid solution (0.682 mL) plus the sample extract (0.273 mL) plus DCIP dye (2.045 mL) was recorded at the end of 15 sec as the L2 value, which represents decrease in absorbance of DCIP dye due its reaction with ascorbic acid. L1 and L2 values for each standard were obtained by the same procedure as the samples. Absorbance values of L1-L2 versus concentration of standard ascorbic acid solutions were plotted to construct a standard curve of ascorbic acid. The concentration of vitamin C in the samples was calculated from the least square equation of the standard curve and expressed as mg ascorbic acid per 100 g fresh weight (FW).

Total phenolics in the methanol extracts were determined colorimetrically using Folin-Ciocalteu reagent as described by Slinkard and Singleton (25). Gallic acid was used as a standard and results were expressed as mg gallic acid equivalents (GAE) per g dry weight (DW) basis.

Total antioxidant capacity of samples was determined by hydrogen atom transfer reactions (β-carotene bleaching assay) assay. In β-carotene bleaching assay, antioxidant capacity is determined by measuring the inhibition of the volatile organic compounds and the conjugated diene hydroperoxides arising from linoleic acid oxidation (26). Antioxidant capacities of the samples were compared with those of synthetic antioxidant butylated hydroxyanisole (BHA) and the blank.

For each quantitative trait measured the means and the standard deviations were calculated using the TABULATE procedure of SAS (27). Correlation analyses were conducted using CORR procedure.

RESULTS AND DISCUSSION

We report here a first evaluation of physico-chemical characteristics of cactus pear accessions grown in Turkey. Considerable differences in all physico-chemical properties were evident among the 25 cactus pear accessions within the species, *Opuntia ficus-indica* (Table 1). As coefficient of variation (C. V.) indicated fruit size variables were

Table 1. Mean and standard deviations of fruit size characteristics for cactus pear accessions sampled from eastern Mediterranean region of Turkey.

Accession	Fruit weight (g)	Fruit width (mm)	Fruit length (mm)	Fruit index	Skin width (mm)	Seed weight (g)
1	118.07 ± 18.38	52.69 ± 4.03	74.41 ± 3.79	0.71 ± 0.08	2.62 ± 0.34	2.12 ± 0.04
2	82.99 ± 2.93	47.44 ± 0.59	67.79 ± 10.54	0.71 ± 0.13	3.30 ± 0.27	1.38 ± 0.07
3	68.55 ± 0.81	44.42 ± 0.85	67.5 ± 1.00	0.66 ± 0.02	3.26 ± 0.61	1.60 ± 0.11
4	70.51 ± 3.65	45.96 ± 1.59	64.62 ± 2.06	0.71 ± 0.04	3.41 ± 0.77	1.15 ± 0.04
5	108.14 ± 2.66	51.07 ± 0.64	73.16 ± 3.45	0.70 ± 0.04	2.17 ± 0.88	1.84 ± 0.06
6	73.99 ± 4.61	44.82 ± 1.14	68.25 ± 2.66	0.66 ± 0.01	2.97 ± 0.10	1.41 ± 0.13
7	77.27 ± 4.15	51.79 ± 6.22	59.31 ± 2.37	0.88 ± 0.14	2.71 ± 0.75	1.55 ± 0.05
8	79.89 ± 10.10	47.89 ± 0.56	67.19 ± 3.95	0.71 ± 0.04	3.44 ± 0.35	1.18 ± 0.02
9	82.79 ± 9.37	49.62 ± 1.51	59.88 ± 0.82	0.83 ± 0.03	4.47 ± 0.51	1.60 ± 0.16
10	80.84 ± 6.86	47.09 ± 4.56	65.39 ± 1.50	0.72 ± 0.08	2.97 ± 0.23	1.80 ± 0.16
11	62.46 ± 4.43	42.03 ± 1.31	70.35 ± 3.37	0.60 ± 0.01	2.80 ± 0.37	1.79 ± 0.15
12	94.89 ± 3.56	49.94 ± 1.32	71.81 ± 0.23	0.70 ± 0.02	2.77 ± 0.49	1.58 ± 0.03
13	107.94 ± 15.43	51.65 ± 1.48	74.97 ± 2.83	0.69 ± 0.04	3.57 ± 0.65	1.24 ± 0.04
14	48.70 ± 4.71	40.49 ± 1.21	53.26 ± 1.59	0.76 ± 0.04	2.01 ± 0.08	1.94 ± 0.08
15	99.66 ± 18.54	50.02 ± 4.10	65.56 ± 3.45	0.77 ± 0.09	3.81 ± 0.55	1.76 ± 0.14
16	102.42 ± 13.58	51.49 ± 1.57	69.46 ± 9.48	0.75 ± 0.09	3.16 ± 0.31	1.65 ± 0.05
17	61.72 ± 9.83	43.68 ± 3.94	71.87 ± 7.71	0.61 ± 0.05	4.71 ± 1.05	1.55 ± 0.05
18	50.97 ± 7.48	40.71 ± 0.65	56.75 ± 2.36	0.72 ± 0.02	1.88 ± 0.57	1.16 ± 0.08
19	65.34 ± 10.80	45.02 ± 1.08	55.52 ± 0.88	0.81 ± 0.03	3.13 ± 0.23	1.20 ± 0.10
20	52.00 ± 3.10	39.65 ± 0.69	54.91 ± 1.05	0.72 ± 0.01	1.77 ± 0.20	1.79 ± 0.13
21	83.21 ± 4.41	47.24 ± 1.37	64.35 ± 2.24	0.73 ± 0.01	2.82 ± 0.69	1.87 ± 0.07
22	100.71 ± 11.64	51.70 ± 1.76	64.70 ± 1.37	0.80 ± 0.02	3.51 ± 0.53	1.74 ± 0.09
23	59.00 ± 1.27	42.96 ± 0.80	61.56 ± 2.21	0.70 ± 0.02	2.21 ± 0.08	2.05 ± 0.06
24	59.73 ± 4.28	43.58 ± 4.01	58.35 ± 0.90	0.75 ± 0.01	2.17 ± 0.52	1.24 ± 0.04
25	56.98 ± 5.32	44.05 ± 2.28	58.38 ± 1.71	0.75 ± 0.02	2.66 ± 1.05	2.04 ± 0.18
Mean	77.95 ± 31.01	46.68 ± 4.40	64.77 ± 7.08	0.73 ± 0.08	2.97 ± 0.86	1.61 ± 0.31
C.V. (%)	27	9	11	11	29	19

considerable varied among the accession tested (range from 9 (fruit width) to 29 (skin width)). Average fruit weight values of cactus pear accessions ranged from 48.70 g (C14) to 118.07 g (C1) with an average of 77.95 g. Fruit width and length were found between 39.65–52.69 mm and 53.2–74.97 mm, respectively indicating great variability among accessions.

Previously fruit weight, width and length of cactus pear accessions depending on origin and cultivar were reported between 86–160 g (28, 29, 30, 31, 32); 48.10–60.00 mm and 63.27–111.00 mm, respectively (29, 32). It could be argued that the differences in fruit weight and dimensions are due to used cultivars/ accessions, diverse environments.

Seed weight of accessions (100 seeds / g) was the highest in accession C1 as 2.12 g whereas was the lowest in accession C4 as 1.15 g (Table 1). Mondragon and Perez (30) reported an average value of 5.2 g seeds per fruit indicating higher value than our results. Presence of seeds in cactus pear fruits is the major deterrent to first time consumers. Therefore developing cultivars with fewer, smaller and softer seeds should be taken in account (31). In cactus pear breeding, one of the most important objectives is to combine of outstanding sugar content and low seed weight per fruit (29).

Several fruit characteristics of the accessions were presented in Table 2. Although the means of the pH were similar for the accessions (C.V. = 4%) other traits varied considerably. Indeed, the variation in beta carotene was extremely high (C.V. = 72%). The SSC of accessions is very high (average 12.24%). The highest SSC content was observed in C19 (14.20%), followed by C10 (14.00%) and C9 (14.00%). The lowest SSC was recorded in C2 as 8.80%. The SSC content of cactus pear accessions was recorded between 10.5 and 14.6% (29, 31, 33, 34). The acidity of the accessions was very low and pH is very high. Acidity and pH of cactus pear accessions were between 0.12–0.33% and 5.25–6.10, respectively. Cactus pear fruits are characterized as a low acid food (pH >4.5). The acidity was lower than the other fruits such as pear (0.3%), orange (0.8%), apple (0.9%), peach (0.9%), strawberry (0.9%), pineapple (1.1%), raspberry (1.8%), plum (2.2%) and apricot (2.4) (35). Acidity and pH in cactus pear were reported between 0.08–1.23% (34) and 5.0–6.5 (29, 31, 33, 34). Our fruit weight, SSC, pH and acidity results are in good agreement with above literature. Many factors affect the fruit weight, SSC, pH and acidity in fruit species including cultivar/ genotype, altitude, environmental conditions (36).

The ascorbic acid is present in considerable amount (18.04–37.31 mg / 100 g FW) and beta carotene ranged

Table 2. Mean and standard deviations of fruit characteristics for cactus pear accessions sampled from eastern Mediterranean region of Turkey.

Accession	Soluble solids (%)	pH	Acidity	Beta carotene (µg /g)	Vitamin C (mg /100 g)	Antioxidant activity (%)	Total phenolics (mg GAE/g DW)
1	12.80 ± 0.10	5.88 ± 0.19	0.14 ± 0.01	14.75 ± 0.99	18.04 ± 2.42	71.9 ± 3.5	38.5 ± 3.5
2	8.80 ± 0.10	5.47 ± 0.06	0.17 ± 0.01	8.74 ± 0.56	24.94 ± 0.34	67.5 ± 3.6	43.0 ± 2.3
3	10.20 ± 0.20	5.45 ± 0.04	0.17 ± 0.01	19.32 ± 0.98	28.98 ± 0.51	55.9 ± 4.1	19.4 ± 0.5
4	9.00 ± 0.10	5.60 ± 0.05	0.16 ± 0.01	4.92 ± 0.76	24.89 ± 1.07	55.8 ± 3.6	21.2 ± 0.6
5	12.40 ± 0.20	5.87 ± 0.03	0.19 ± 0.00	25.13 ± 1.16	33.71 ± 1.48	45.5 ± 5.2	23.0 ± 1.8
6	13.60 ± 0.10	5.82 ± 0.05	0.15 ± 0.01	16.87 ± 0.82	34.10 ± 0.45	57.4 ± 1.6	40.3 ± 1.5
7	12.80 ± 0.20	6.09 ± 0.02	0.13 ± 0.01	3.41 ± 0.21	33.28 ± 1.49	55.0 ± 1.96	24.4 ± 1.0
8	9.00 ± 0.10	5.82 ± 0.05	0.18 ± 0.00	3.43 ± 0.21	21.05 ± 0.59	70.2 ± 4.4	23.0 ± 1.8
9	14.00 ± 0.20	5.97 ± 0.04	0.24 ± 0.01	6.43 ± 0.21	34.07 ± 1.65	63.7 ± 2.8	43.9 ± 1.0
10	14.00 ± 0.20	5.93 ± 0.05	0.14 ± 0.01	8.96 ± 2.44	35.15 ± 0.34	65.3 ± 1.1	40.3 ± 2.3
11	12.80 ± 0.20	5.53 ± 0.08	0.22 ± 0.01	4.64 ± 0.41	26.67 ± 1.48	67.0 ± 1.5	32.1 ± 1.8
12	10.40 ± 0.20	5.89 ± 0.08	0.14 ± 0.00	4.92 ± 0.10	25.59 ± 1.37	65.7 ± 1.6	39.4 ± 1.3
13	12.40 ± 0.20	6.05 ± 0.03	0.20 ± 0.01	9.47 ± 0.99	37.31 ± 1.54	63.3 ± 0.9	35.7 ± 1.4
14	13.00 ± 0.05	5.47 ± 0.02	0.23 ± 0.01	3.41 ± 0.21	29.33 ± 1.78	70.2 ± 2.7	19.4 ± 2.0
15	13.00 ± 0.20	5.96 ± 0.05	0.12 ± 0.00	8.96 ± 0.87	32.09 ± 1.04	76.6 ± 1.3	31.2 ± 1.7
16	13.20 ± 0.20	6.02 ± 0.04	0.24 ± 0.01	7.96 ± 0.49	37.12 ± 0.17	62.3 ± 3.3	19.4 ± 2.2
17	13.20 ± 0.20	5.79 ± 0.04	0.29 ± 0.01	3.92 ± 0.45	31.40 ± 2.71	70.4 ± 4.0	36.6 ± 1.4
18	13.80 ± 0.20	5.25 ± 0.04	0.33 ± 0.01	4.16 ± 0.21	29.14 ± 1.46	73.9 ± 5.3	49.4 ± 2.9
19	14.20 ± 0.10	5.78 ± 0.06	0.18 ± 0.01	5.67 ± 0.49	31.5 ± 0.61	64.1 ± 3.7	32.1 ± 3.1
20	13.80 ± 0.20	5.85 ± 0.10	0.21 ± 0.01	5.67 ± 0.39	33.96 ± 1.63	53.7 ± 1.1	23.9 ± 1.8
21	13.40 ± 0.20	6.04 ± 0.04	0.17 ± 0.01	5.67 ± 0.30	23.62 ± 0.74	65.9 ± 1.3	30.3 ± 2.5
22	13.00 ± 0.20	5.75 ± 0.03	0.20 ± 0.00	5.67 ± 0.41	28.84 ± 0.75	66.8 ± 0.9	34.8 ± 0.4
23	12.80 ± 0.20	6.10 ± 0.00	0.18 ± 0.01	5.64 ± 0.30	27.46 ± 1.49	76.8 ± 1.7	47.6 ± 1.7
24	10.20 ± 0.10	5.87 ± 0.03	0.14 ± 0.01	3.40 ± 0.15	31.50 ± 2.18	67.9 ± 1.5	26.6 ± 1.6
25	10.20 ± 0.10	5.70 ± 0.10	0.19 ± 0.01	2.64 ± 0.12	22.24 ± 1.29	54.3 ± 2.2	40.3 ± 1.5
Mean	12.24 ± 1.71	5.8 ± 0.23	0.19 ± 0.05	7.75 ± 5.56	29.44 ± 5.16	64.3 ± 7.8	32.6 ± 9.3
C.V. (%)	14	4	26	72	18	12.1	28.4

from 2.64 to 25.13 (µg / g), respectively (Table 3). Generally, fruits of all cactus pear accessions had higher ascorbic acid content than beta carotene. The results on ascorbic acid content in cactus pears agree with previously reported values (17.1–29.2 mg / 100 g (14, 22, 34). Ascorbic acid is an important nutrient antioxidant (37). Our ascorbic acid results also suggesting that cactus pear fruits had considerably higher ascorbic acid than the average ascorbic acid contents in some common fruits, such as plum (3 mg / 100 g FW), pear (4 mg / 100 g FW), apple (6 mg / 100 g FW) and banana (20 mg / 100 g FW) (35). As carotenoids, beta carotene was widely distributed among colored fruits and vegetables and contributes to both the appearance and attractiveness of fruit as well as additional nutritional value in the form of dietary antioxidants (37). The deep orange or yellow color of the fruits (apricots, mangoes, means it is rich in beta carotene. Beta carotene is a precursor to vitamin A and is changed in the body to vitamin A. Vitamin A is needed for healthy eyes and skin. Epidemiological studies have shown that high intakes of carotenoid-rich fruits and vegetables and high blood levels of beta carotene are associated with decreased incidence of some cancers because its antioxidant properties and helping eliminate free radicals from body (38).

Total phenolic contents and antioxidant activities of 25 accessions of cactus pear fruits were also shown in Table 2. The accession C18 had the highest total phenolic content (49.4 mg GAE per g DW) followed by C23 (47.6 mg GAE per g DW) and C9 (43.9 mg GAE per g DW), respectively. The overall average total phenolic content was 28.4 mg GAE per g DW (Table 2). Our findings on cactus pear fruit phenolic content provide opportunities to improve cactus pear fruit quality and nutritive value. The total antioxidant activity among the cactus pear accessions range from 45.5% to 76.8% was in determined by β-Carotene Bleaching assay. The antioxidant activity of synthetic antioxidant, butylated hydroxyanisole (BHA) was 77.41%. Our data are clearly suggesting that antioxidant activities were significantly different among the accessions of cactus pear accessions. A difference in antioxidant activity was also observed among cultivars belongs to apple between 14.7 and 40.7% (39). The average antioxidant activity of accessions (64.3%) were higher than some common fruits such as apple (25.7%), quince (60.3%) and pear (14.0%) (39).

Internal and external fruit color variables were also presented in Table 3. The highest variation in among the accessions for the color measurements were in external and internal a values (C.V. = 57 and 97%, respectively).

Table 3. Mean and standard deviations of fruit color measurements for cactus pear accessions sampled from eastern Mediterranean region of Turkey.

	External			Internal		
Accession	L	a	b	L	a	b
C1	57.7 ± 3.5	5.0 ± 0.7	40.1 ± 2.0	53.3 ± 4.9	5.5 ± 2.5	55.6 ± 3.1
C2	58.9 ± 2.9	1.9 ± 1.2	36.9 ± 2.2	46.1 ± 0.5	6.8 ± 1.5	44.9 ± 3.0
C3	52.1 ± 1.0	15.8 ± 0.8	33.6 ± 2.5	39.8 ± 1.6	14.1 ± 1.7	40.4 ± 1.1
C4	54.9 ± 0.6	6.9 ± 1.3	33.2 ± 1.2	33.3 ± 1.0	3.8 ± 0.2	31.0 ± 1.7
C5	47.5 ± 0.8	20.1 ± 0.3	31.7 ± 3.3	41.3 ± 2.5	9.8 ± 2.5	40.0 ± 5.0
C6	60.3 ± 0.3	1.8 ± 1.2	41.8 ± 1.3	51.8 ± 3.6	0.8 ± 0.7	53.4 ± 3.5
C7	50.6 ± 2.4	15.3 ± 1.6	28.9 ± 0.3	45.5 ± 0.7	8.3 ± 1.0	53.9 ± 3.0
C8	62.0 ± 2.4	2.2 ± 2.3	37.1 ± 0.6	43.2 ± 7.1	8.3 ± 2.8	46.0 ± 11.0
C9	51.4 ± 3.0	9.3 ± 9.3	24.8 ± 1.5	35.2 ± 1.1	8.3 ± 1.6	41.0 ± 6.8
C10	56.9 ± 3.1	10.9 ± 1.7	28.5 ± 1.3	37.1 ± 0.9	0.7 ± 0.4	36.5 ± 0.6
C11	61.8 ± 2.0	1.1 ± 1.0	38.2 ± 0.2	55.6 ± 2.1	-3.3 ± 0.2	48.2 ± 4.8
C12	61.2 ± 0.8	2.0 ± 0.1	37.4 ± 0.3	51.2 ± 0.0	-1.6 ± 1.1	46.6 ± 1.0
C13	44.9 ± 3.8	13.3 ± 4.0	26.7 ± 3.0	48.6 ± 1.0	8.6 ± 0.9	58.2 ± 0.1
C14	61.4 ± 2.5	4.5 ± 2.1	33.8 ± 1.1	51.1 ± 3.3	-0.2 ± 1.7	54.9 ± 1.4
C15	52.3 ± 3.5	12.3 ± 5.2	29.0 ± 3.1	51.1 ± 2.5	4.4 ± 1.2	56.9 ± 1.7
C16	47.3 ± 1.2	14.8 ± 1.8	28.1 ± 2.1	44.2 ± 0.6	13 ± 1.3	53.3 ± 0.8
C17	53.6 ± 0.9	8.5 ± 3.0	30.4 ± 2.1	46.2 ± 0.6	8.8 ± 2.5	53.8 ± 2.1
C18	57.1 ± 2.5	6.8 ± 2.6	35.1 ± 1.3	57.1 ± 1.7	-1.4 ± 0.7	56.8 ± 0.5
C19	51.4 ± 1.2	7.3 ± 2.7	27.7 ± 1.7	44.5 ± 0.2	9.1 ± 1.7	47.3 ± 3.9
C20	52.2 ± 0.4	8.9 ± 0.5	33.5 ± 1.1	55.2 ± 1.7	6.8 ± 0.2	64.2 ± 2.5
C21	54.5 ± 2.3	8.5 ± 1.6	33.8 ± 1.8	47.5 ± 1.3	-2.5 ± 0.3	46.1 ± 2.6
C22	51.5 ± 1.3	12.2 ± 0.4	29.2 ± 2.8	36.7 ± 4.3	-1.8 ± 0.9	29.6 ± 0.2
C23	51.2 ± 1.6	10.5 ± 1.6	30.8 ± 1.3	47.1 ± 1.8	12.7 ± 1.0	55.8 ± 2.8
C24	56.3 ± 0.4	9.7 ± 0.2	33.3 ± 0.8	49.1 ± 1.6	7.4 ± 2.3	55.9 ± 0.7
C25	52.4 ± 3.1	14.2 ± 1.8	34.5 ± 2.5	47.7 ± 0.1	12.7 ± 0.4	56.7 ± 0.4
Mean	54.5 ± 8.8	9.0 ± 5.1	32.7 ± 4.3	46.4 ± 6.5	5.6 ± 5.4	49.1 ± 8.8
C.V. (%)	9	57	13	14	96	18

Table 4. Correlation coefficient and relevant P values for the fruit color, antioxidant activity and total phenolics of cactus pear accession selected from eastern Mediterranean region of Turkey.

Variable	E/L	E/a	E/b	I/L	I/a	I/b	AA
Fruit external color a (E/a)	-0.86						
	0.000						
Fruit external color b (E/b)	0.75	-0.64					
	0.000	0.001					
Fruit internal color L (I/L)	0.34	-0.38	0.51				
	0.100	0.059	0.009				
Fruit internal color a (I/a)	-0.59	0.55	-0.35	-0.27			
	0.002	0.005	0.088	0.192			
Fruit internal color b (I/b)	-0.04	-0.06	0.14	0.81	0.21		
	0.850	0.785	0.495	0.000	0.318		
Antioxidant activity (AA)	0.36	-0.45	0.03	0.31	-0.28	0.22	
	0.076	0.024	0.874	0.132	0.173	0.295	
Total phenols (TP)	0.14	-0.28	0.08	0.20	-0.19	0.10	0.43
	0.510	0.179	0.713	0.346	0.356	0.620	0.034

Correlation coefficients between antioxidant activity and total phenolic contents and the different cactus pear fruit color measurements were presented in Table 4. The antioxidant activity is poorly correlated with total phenolic content in cactus pear fruits thus suggesting that other components, contribute more significantly to the total antioxidant capacity. Previously, USENIK *et al.* (40) reported that antioxidant activity of sweet cherries is not related to phenolic content.

CONCLUSION

This investigation shows the potential value of cactus pear fruits as a good source of natural antioxidants and that consumption of cactus pear fruit or its products may contribute substantial amounts of antioxidants to the diet. The potential value of wild growing cactus pear was previously reported from Mediterranean region of Turkey (41, 42); however, Beta carotene, Vitamin C, antioxidant activity and total phenolics were reported as a first time in this report. Based on the available data in this study and the phytochemical contents of cactus pear fruits, there is a high likelihood that cactus pear fruits may provide the types of nutritional and health benefit associated with consumption of fruits and vegetables in general. In addition, the *Opuntia ficus-indica* accessions presented significant differences in all the parameters. Individual accessions which combine higher antioxidant activity, beta carotene, fruit weight and vitamin C may be important to bring them commercial production. However no single accession has high sugar, low seed weight, high antioxidant activity and high total phenolic and vitamin C content, these accessions still represent good genetic resources for further hybridization and research. Its nutritional use should be encouraged in arid and semi arid areas where each nutritional resource is vital.

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