Some Physical Fruit Properties of Cactus Pear (*Opuntia* spp) That Grow Wild in the Eastern Mediterranean Region of Turkey♦

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ABSTRACT

Cactus pears (*Opuntia* spp) that grow wild were collected from five locations in the southeastern coast of the Mediterranean region of Turkey. The location affected the fruit and seed characteristics significantly. Cactus-pear samples collected from Bozön and Çiftlikköy locations showed better fruit and seed properties compared to those collected from the other locations. Correlation parameters among fruit quality were significant and high. The aborted-seed weight and number were more correlated with fruit properties than that of viable seeds. The weights of both fruit and pulp were positively affected with increase in seed content. The multivariate analysis also showed similar results to ANOVA and correlation tests.

Keywords: Cactus pear, physical characteristics, fruit, seed, Mediterranean, Turkey

INTRODUCTION

The cactus pear (*Opuntia* spp) belongs to the Cactaceae family and is native to arid and semiarid regions. The fruit is a many-seeded berry with a pleasant taste. The cactus pear, a good source of nutrient and vitamins (Sawaya et al., 1983a; Barbera et al., 1992), is mainly consumed fresh and, in some countries, is processed into food products such as jams, fruit juice, alcoholic beverages, additives, etc. (Sawaya et.al., 1983b). Furthermore, the cactus pear is also considered as a potential alternative crop for dry regions due to its ability to withstand prolonged drought (Russel and Felker, 1987; Potgieter, 1995).

Studies showed that the fruit size and shape are affected by the seed number and weight (Barbera et al., 1994; Bukovac and Nakagawa, 1968; Barbera et al., 1995). The relationship between fruit size and seed content varies with several factors, such as genotype and fruit position within the canopy (Grant and Ryugo, 1984; Lawes et al., 1990). Prickly pear fruits contain totally 100 to 300 seeds (Barbera and Inglese, 1993; Barbera et al., 1994). The seeds of the fruit constitute about 10% to 15% of the pulp and are discarded.

The cactus pear is cultivated and grown commercially in countries such as Mexico, the United States, Italy, and Israel. On the other hand, this cactus is categorized as an underutilized crop in several other Mediterranean countries, including Turkey. The cactus pear grows wild in regions comprising high humidity, as are the Mediterranean and Aegean regions in Turkey.

To the best of our knowledge, there are no commercial plantations and no definite varieties of the cactus pear in Turkey. It is not cultivated as a regular commercial crop. The cacti are naturalized and grow in brushy areas either as individual plants or as groups as well as around homes. The majority of the existing cactus-pear plants are thorny and produce edible fruits with an orange-yellow color. Only the seedy pulp

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is consumed fresh locally and, traditionally, fruits are sold in the streets by the people who peel the pericarp of fruits in the presence of the consumer. Discarded pericarp with its prickled peel comprises 48% of the fruit and has a high level of pigment (Aksay et al., 1998; Coşkuner et al., 2000; Turker et al., 2001). No attempts on breeding studies and commercialization practices have been known so far in Turkey; cactus pear (*Opuntia ficus-indica* L.) still remains a wild species (Aksoy, 1995).

The objective of this study was to investigate fruit and seed properties of the cactus pear collected from five different locations in the eastern coast of the Mediterranean region of Turkey.

MATERIALS AND METHODS

The cactus pears were collected from wild populations of *Opuntia* sp. located in southeastern coast of Mediterranean region of Turkey at Adana (37°00′12″N, 35°15′48″E), Bozön (36°45′24″N, 34°30′00″E), Çiftlikköy (36°45′48″N, 34°30′06″E), Silifke (36°20′24″N, 33°55′24″E) and Tarsus (36°55′00″N, 34°50′48″E). Approximately 150 fruits were collected from each location at the end of August. For each location, 25 samples were selected randomly from the 150 fruits. The whole fruit weight (FW), core weight (CW), fruit length (FL) and fruit diameter (FD) of samples were measured immediately after harvest.

The fruit diameter and length were measured using calipers. The fruits were washed and the prickles and glochides on the peel surface were removed under running tap water by rubbing. After the free water drained from the fruits, their weight was recorded. Fruits were cut longitudinally, the flesh and thick peel were separated, and the weights of these fractions were recorded. Seeds were washed under running water several times on a screen (700 micron) to separate the seeds from the pulp, then drained. They were dried at ambient temperature and weighed. The dried seeds were sorted as viable and aborted. The seeds were weighed as total seed dry weight (TSDW), viable-seed dry weight (VSDW) and aborted-seed dry weight (ASDW) and counted as total seed number (TSN), viable-seed number (VSN) and aborted-seed number (ASN). The pulp weight (PW) was calculated by subtracting the FW from wet-seed weight and skin weight.

The data obtained were evaluated by analysis of variance (ANOVA) using the STATISTICA Package Program (Statsoft, 1995). The principal-component analysis (PCA) was applied to the pooled data to establish the relationship among the characteristics of the fruit and to detect the significant factors responsible for variations.

RESULTS

The physical-quality characteristics of cactus pear investigated in this study are given in Table I. The fruit properties differed significantly among locations (Table 1). The samples from the Bozön location comprised higher fruit diameter and length together with high fruit, core, and pulp weights compared to those collected from the other locations. Furthermore, Bozön samples possessed the highest fruit weight (102 g). The fruits from the other locations (Adana, Çiftlikköy, Tarsus, and Silifke) were statistically of the same weight, with Adana samples comprising the lowest fruit weight (76.7 g). The same trend detected for the fruit weights also was observed for the core weights of the cactus-pear samples. The mean values of the pulp weights of the different locations ranged from 70.46 g to 96.71 g, with the Bozön fruit samples having highest pulp weight.

There were significant differences among locations concerning the seed properties of the fruits. Although the fruits collected from Bozön and Çiftlikköy had the highest fruit weights, they had low values for dry-

seed weight, viable dry-seed weight, viable-seed number. In contrast, fruits from this region had high aborted-dry-seed weight and high aborted-seed numbers. The total dry-seed weights of the samples showed small variations among the locations ranging from 2.1 g to 2.7 g., resulting in two groups of locations. The group comprising Tarsus and Adana showed somewhat higher values as far as the total dry seed weight was concerned (Table 2). The viable-seed weights showed higher variations among locations, with Adana and Tarsus samples comprising higher values. Nonetheless, aborted-seed weight of the fruits from different locations was quite close to each other. The total-seed number of the fruits varied from 227 to 270 among locations. Viable-seed numbers ranged from 78 to 131. The number of aborted seeds ranged from 96 to 172. Adana and Tarsus samples contained more viable seeds than aborted seeds. Silifke samples contained equal numbers of aborted and viable seeds, while fruit from Bozön and Çiftlikköy contained fewer viable seeds than aborted seeds (Table 2).

The correlation coefficients were determined among each of the fruit and seed characteristics (Table 3). The fruit weight was significantly and positively correlated with the pulp weight, core weight, total seed number, aborted-seed number, and aborted-seed weight. As expected, the pulp weight showed the same trend as evaluated for fruit weight. No significant relationships were found between the three fruit characteristics (FW, PW, and CW) and total seed weight, viable-seed weight, viable-seed number and viable/aborted-seed ratio. The total seed weight was correlated to the viable-seed number, viable-seed weight, aborted-seed weight, and total seed number. The viable-seed number did not show any relationship to the aborted-seed number and weight.

On the other hand, viable-seed number was significantly correlated with the total seed number and viable/aborted-seed ratio. Contrary to the viable-seed results, the aborted-seed number and weight were only slightly correlated with the fruit parameters. Furthermore, the viable seeds showed a high positive correlation with the total seed number and a high negative correlation to the viable/aborted-seed ratio. The total seed number showed positive correlations with other parameters, except the viable/aborted-seed ratio. The highest correlation coefficient was found between the fruit weight and the pulp weight, as expected ($r=0.93$).

Principal component analysis (PCA), a useful technique in exploratory data analysis, has been used in food research with different objectives (Acquistucci, 1996; Frau et al., 1997; Molina-Cano et al., 1997; Boccorh et al., 1998; Oscarsson et al., 1998). In this study, PCA was used to explain the variability of the original data as possible with as few of these principal components as possible. Eighty-four percent of the variation in the cactus pear fruit and seed properties was explained by the first three principal components (PCs), 45% by PC1, 27% by PC2, and 2% by PC3, respectively (Table 4). The data dimensions were reduced from 12 quality parameters to 3 principal components with 16% loss of variation. The results of the PCs are presented in Figures 1 and 2. There is a joint increase of fruit weight (FW), pulp weight (PW), core weight (CW), fruit diameter (FD), total seed number (TSN), aborted-seed weight (ASW) and number (ASN), and fruit length (FL) in axis 1, toward the positive direction. The fruit weight and pulp weight are strongly correlated with each other and both are correlated with the core weight, fruit diameter and length, aborted-seed weight and number. Toward the negative direction, the viable/aborted-seed ratio was significantly negative correlated with the aborted-seed number.

The V/A ratio is positively correlated with the viable-seed dry weight (VSDW) and number (VSN) and total seed weight (TSW) in axis 2 (Figure 1). Thus, viable-seed properties of cactus pear decrease toward the negative direction on PC axis 2.

The ASN is positively correlated with the ASDW and TSN in axis 3. On the other hand, the ASN is negatively but less strongly correlated, although ASN is positively correlated in axis 1, with PW, FD, FW, and CW in axis 3. This indicated that a rise in seed content of fruit slightly decreases pulp yield of cactus pear (Figure 2).

DISCUSSION

The statistical results showed that the cactus pear size and weight are affected by the location in which the cactus grows, which is in accordance with previous studies (Bukovac and Nakagawa, 1968; Barbera et al., 1994). Although, the length of fruits from each location did not differ much, the fruit diameter differed significantly among locations. Depending on the fruit characteristics, such as dimensions and weight, two groups of locations appeared. Bozön and Çiftlikköy, which are closely located to each other near the sea coast and have the same climatic conditions, belonged to one group. These two locations have much higher humidity compared to the other locations of the second group.

The results showed that, the fruit weight of the wild fruit was slightly affected by the aborted-seed weight and number, as well as the total seed number. On the other hand, the viable-seed to aborted-seed ratio did not show an effect on fruit quality in terms of size. These findings were lower than that reported by Barbera et al. (1994). This difference in results might be due to the use of cultivated varieties by these researchers.

As reported by Barbera et al. (1994), the viable-seed number/aborted-seed number (V/A) ratio was not dependent on the total seed number. The principal-components analysis showed that the cactus pear with high fruit diameter and low viable-seed number/aborted-seed number will give a parallel rise in ASN, CW, PW, FW, and TSN of the fruit. Thus, the fruit quality increases toward the positive direction.

The cactus pear grows wild and is not yet cultivated in Turkey. Such data might give a starting point for breeding studies.

REFERENCES

Acquistucci, R. 1996. The maillard reaction in pasta: preliminary classification by multivariate techniques. Lebensm. Wiss. u. Technol. 29:626-631.

Aksay, S., Coşkuner, Y., Karababa, E. and Ekiz, H.I. 1998. Physical, chemical and technological properties of prickly pear (*Opuntia* spp.) fruits. Gida Mühendisliği Kongre ve Sergisi Abstr Book, pp 281-289.

Aksoy, U. 1995. Present Status and Future Prospects of Underutilized Fruit Production in Turkey. In: Proceedings of the first meeting of the CHIEAM Cooperative Working Group on Underutilized Fruit Crops in the Mediterranean Region (Edited by Llácer. G, Aksoy, U and Mars, M.) Zaragoza (Spain) 9-10 November 1994, pp 97-107.

Barbera, G. and Inglese, P. 1993. La coltura del ficodindia. Calderini Edagricole. Bologna, Italy. 189 p.

Barbera, G., Carimi, F. and Inglese, P. 1992. Physical, morphological and chemical changes during fruit development and ripening in three cultivars of prickly pear, *Opuntia ficus-indica* (L.) Miller. J. Hortic. Sci., 67, (3):307-312.

Barbera, G., Inglese, P. and La Mantia, T. 1994. Influence of seed content on the some characteristics of the fruit of cactus pear, (*Opuntia ficus-indica* Mill.). Scientia Hort., 58:161-165.

Barbera, G., Inglese, P. and Pimienta-Barrios, E. 1995. Agro-ecology and Uses of Cactus Pear. FAO Plant Production and Protection Paper No 132. Food and Agriculture Organization of the United Nations, Rome, p 216.

Boccorh, R.K., Paterson, A. and Piggot, J.R. 1998. Factors influencing quantities of sugars and organic acids in blackcurrant concentrates. Z. Lebensm Unters Forsch A 206:273-278.

Bukovac, M.J. and Nagakawa, S. 1968. Gibberellin induced asymmetric growth of apple fruits. Hortscience, 3:172-174.

Coşkuner, Y., Turker, N., Ekiz, H.I., Aksay, S. and Karababa, E. 2000. Effect of pH and temperature on the thermostability of prickly pear (*Opuntia ficus-indica*) yellow-orange pigments. Nahrung 44:263-265.

Frau, M., Simal, S., Femenia, A. and Rosello, C. 1997. Application of principal component analysis to chemical characteristics of Mahon cheese. Z. Lebensm Unters Forsch A 205:429-432.

Grant, J.A and Ryugo, K. 1984. Influence of within canopy shading on fruit size, shoot growth, and return bloom kiwifruit. J. Am. Soc. Hortic. Sci., 109:799-802.

Lawes, G.S., Wooley, D.J. and Lai, R. 1990. Seeds and other factors affecting fruit size in kiwifruit. Acta Hortic., 282:153-156.

Molina-Cano, J.L., Francesch, M., Perez-Vendrell, A.M., Ramo, T., Voltas, J. and Brufau, J. 1997. Genetic and environmental variation in malting and feed quality of barley. J Cereal Science, 25:37-47.

Oscarsson, M., Andersson, R., Aman, P., Olofsson, S. and Jonsson, A. 1998. Effects of cultivar, nitrogen fertilization rate, and environment on yield and grain quality of barley. J Sci. Food. Agric., 78:359-366.

Potgieter, J. 1995. The cultivation of spineless cactus pear (*Opuntia ficus-indica*) Guideleines for small farmers. ITSC Information Bulletin, pp. 28-32.

Russel, C.E. and Felker, P. 1987. The prickly pears (*Opuntia* spp., Cactaceae): A source of human and animal food in semiarid regions. Economic Botany, 41 (3):443-445.

Statsoft 1995. Statistica for Windows, Release 5.0 Statsoft Inc. Tulsa, OK,USA.

Sawaya, W.N., Khalil, J.K. and Al-Mohammad, M.M. 1983a. Nutritive value of prickly pear seeds, *Opuntia ficus-indica*. Qual. Plant. Plants Foods Hum. Nutr., 33:91-97.

Sawaya, W.N., Khatchadourian, H.A., Safi, W.M. and Al-Mohammad, H.M. 1983b. Chemical characterization of prickly pear pulp *Opuntia ficus-indica* and the manufacturing of prickly pear jam. J. Food Technol. 18:183-197.

Turker N., Coşkuner Y., Ekiz H.I., Aksay S. and Karababa E. 2001. The effect of fermentation on the thermostability of the yellow-orange pigments extracted from cactus pear (*Opuntia ficus-indica*). Eur Food Res Technol A 212:213–216.

Table 1. Fruit Properties of Cactus Pear Samples in Five Locations

	FD (cm)	FL (cm)	FW (g)	CW (g)	PW (g)
Adana	4.6 c†	6.7 ab	76.7 b	40.7 b	35.5 c
Bozön	5.2 a	7.0 a	102.0 a	55.1 a	50.9 a
Çiftlikköy	4.9 b	6.6 b	85.8 b	47.9 b	42.3 b
Silifke	4.5 c	7.1 a	77.7 b	40.5 b	35.9 c
Tarsus	4.5 c	6.8 ab	81.6 b	44.3 b	38.1 bc

†Means within a column followed by the same letter are not significantly different at the 0.05 level.
FD: Fruit diameter (cm), FL: Fruit length (cm), FW: Fruit weight (g), CW: Core weight (g), PW: Pulp weight (g).

Table 2. Seed Properties of Cactus Pear Samples in Five Locations

	DSW (g)	**VSDW (g)**	**ASDW (g)**	**VSN (n)**	**ASN (n)**	**TSN (n)**	**VSDW/ ASDW**
Adana	2.6 a†	2.0 a	0.6 bc	131 a	96 c	227 c	3.33 a
Bozön	2.2 b	1.4 c	0.8 a	98 b	172 a	270 a	1.75 c
Çiftlikköy	2.1 b	1.4 c	0.8 a	78 b	172 a	251 b	1.75 c
Silifke	2.2 b	1.7 bc	0.6 bc	124 a	124 b	248 b	2.83 b
Tarsus	2.7 a	2.0 a	0.7 ab	123 a	114 bc	237 c	2.86 b

†Means within a column followed by the same letter are not significantly different at the 0.05 level.
DSW: Dry-seed weight (g), VSDW: Viable-seed dry weight (g), ASDW: Aborted-seed dry weight (g), VSN: Viable-seed number (n), ASN: Aborted-seed number (n), TSN: Total seed number.

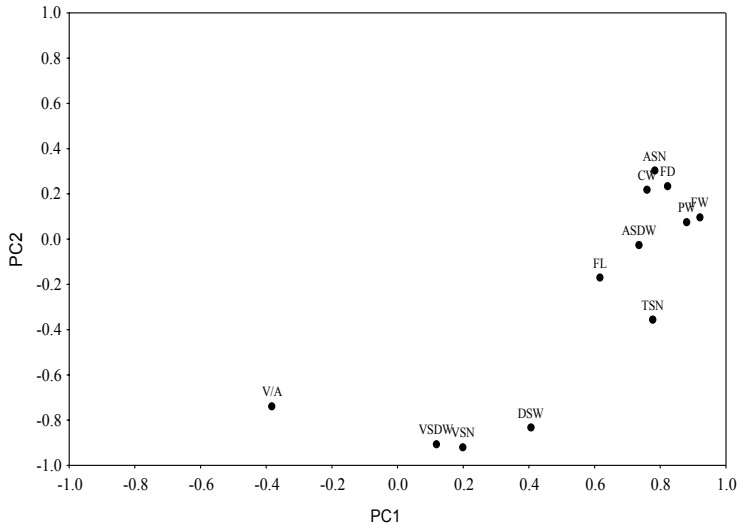
Table 3. Correlation Matrix of Fruit and Seed Properties†

	FL	**FW**	**CW**	**PW**	**DSW**	**VSDW**	**ASDW**	**TSN**	**VSN**	**ASN**	**V/A**
FD	0.34	**0.86**	**0.81**	**0.83**	0.13	-0.08	**0.50**	**0.43**	-0.06	**0.57**	-0.35
FL		**0.60**	**0.50**	**0.49**	0.24	0.14	0.26	**0.47**	0.31	0.32	0.01
FW			**0.92**	**0.93**	0.24	0.02	**0.52**	**0.54**	0.10	**0.57**	-0.27
CW				**0.99**	0.38	0.15	**0.59**	**0.60**	0.18	**0.58**	-0.25
PW					0.27	0.06	**0.54**	**0.54**	0.09	**0.58**	-0.29
DSW						**0.83**	**0.52**	**0.60**	**0.78**	0.11	0.36
VSDW							0.16	0.36	**0.77**	-0.18	**0.55**
ASDW								**0.62**	0.06	**0.71**	**-0.46**
TSN									**0.57**	**0.75**	-0.19
VSN										-0.11	**0.61**
ASN											**-0.72**

† n=125; FD: Fruit diameter (cm), FL: Fruit length (cm), FW: Fruit weight (g), CW: Core weight (g), PW: Pulp weight (g), DSW: Dry-seed weight (g), VSDW: Viable-seed dry weight (g), ASDW: Aborted-seed dry weight (g), TSN: Total seed number, VSN Viable-seed number (n), ASN: Aborted-seed number (n), PP: Pulp percentage (%).
Bold-type indicates that correlation coefficients are significant at the 0.05 level.

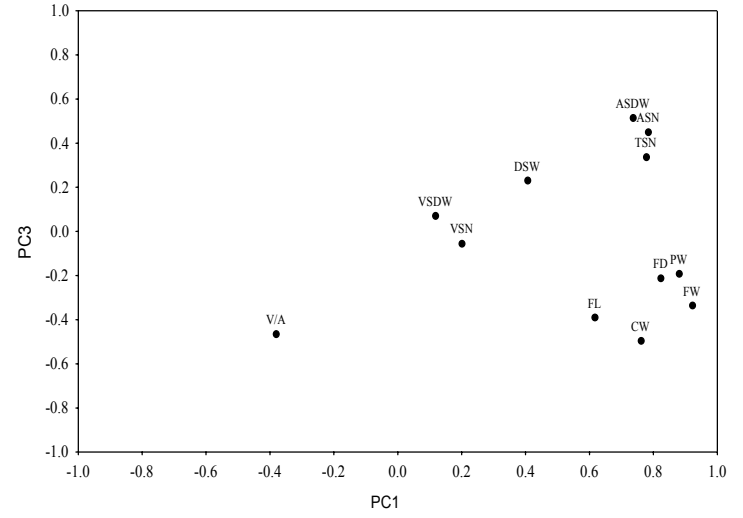
Table 4. Principal Component Analysis; Characteristics of the Selected Component

Component	Eigenvalue (k)	Percent of Variation	Cumulative Percent
1	5.38	45	45
2	3.27	27	72
3	1.44	12	84



FD: Fruit diameter (cm), FL: Fruit length (cm), FW: Fruit weight (g), CW: Core weight (g), PW: Pulp weight (g), DSW: Dry-seed weight (g), VSDW: Viable-seed dry weight (g), ASDW: Aborted-seed dry weight (g), VSN: Viable-seed number (n), ASN: Aborted-seed number (n), PP: Pulp percentage (%).

Figure 1. Principal Component Analysis (PCA). Representation of the Fruit and Seed Quality Variables as a Function of Both the First (PC1) and Second (PC2) Principal Components



FD: Fruit diameter (cm), FL: Fruit length (cm), FW: Fruit weight (g), CW: Core weight (g), PW: Pulp weight (g) DSW: Dry-seed weight (g), VSDW: Viable-seed dry weight (g), ASDW: Aborted-seed dry weight (g) VSN: Viable-seed number (n), ASN: Aborted-seed number (n), PP: Pulp percentage (%).

Figure 2. Principal Component Analysis (PCA). Representation of the Fruit and Seed Quality Variables as a Function of Both the First (PC1) and Third (PC3) Principal Components