Changes in Physical Properties and Chemical Composition of Cactus Pear (*Opuntia ficus-indica*) During Maturation♦

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ABSTRACT

The physical and chemical changes of cactus pear grown wild in the Bozön-Mersin (Turkey) area during the period of ripening were investigated. The cactus pear fruits were collected weekly for 15 weeks starting at the end of June 2000. The cactus pear collected reached full maturity 98 to 112 days after flowering and showed a sigmoidal growth pattern. The pulp to whole-fruit ratio at full maturity was 0.45 to 0.50 g pulp/g whole fruit and the total-soluble-solids to total-titratability ratio was 75. The increase in the development of fruit color coincided within the period of fast growth.

Key Words: cactus pear (*Opuntia ficus-indica*), maturation, physicochemical composition

INTRODUCTION

Cactus pear (*Opuntia* spp) is in the Cactaceae family and is native to arid and semiarid regions. The fruit is a berry with a thick peel enclosing a delicately flavored very seedy pulp. Because cactus pear can withstand prolonged drought, it is considered as a potential alternative crop for drier regions (Nobel et al. 1987, Kuti 1992, Barbera et al. 1995, Mizrahi et al. 1997). The juicy ripe fruits are consumed fresh or processed into juices, jams, etc.; the young tender cladodes are also used as fresh or cooked vegetable (Barbera et al. 1992; Nobel et al. 1987; Joubert, 1993). Moreover, cactus pear fruit containing betalain pigments is a good potential for the use as a natural food colorant. This fruit contains the red-violet betacyanins in addition to the yellow betaxanthins (Merin et al. 1987; Forni et al. 1992; Coskuner et al. 2000; Turker et. al. 2001).

Studies concerning the growth and post-harvest physiology of cactus pear fruits have increased in recent years due to their nutritional value and economic potential. Extensive researches have been carried out in countries such as Mexico, Chile, and Italy where cactus pear is cultivated for commercial use (Retamal et al. 1987; Rodriguez-Felix and Ochoa, 1998; Sepulveda, 1998; Barbera et al. 1994; Mizrahi et al. 1997).
In this research, conducted as a part of a research project concerning natural food-colorant production from cactus pear, the period of fruit maturation and, thereby, estimating maximum pigment concentration

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time of cactus pear grown wild in the Mediterranean region of Turkey were studied. For this purpose, the physical and chemical changes during the ripening period were monitored. Knowledge of this relationship is essential for establishing harvest maturity indices and suitable post-harvest handling procedures for cactus pear as well as for determining the period of highest betalain concentration.

MATERIALS AND METHODS

Study Site Description

The yellow-orange cactus pear (*O. ficus-indica*) fruits used in this research grow wild in Bozön-Mersin (Turkey). Mersin is situated at Mediterranean coast of South Anatolia having geographic coordinates of 34°30′00″ east, 36°48′20″ north and 150 m above sea level. Summer in Mersin is hot and very humid while winter is temperate and humid with heavy rains achieving 580 mm annual rainfall. It was reported that the highest rainfall was 125 mm in December and the lowest was below 20 mm from June to August based on the data of 30 years mean climatological rainfall in Mersin (Özsoy and Saydam, 2000).

Fruit Collection and Preparation

The fruits were collected weekly for 15 weeks, starting at the end of June 2000. The whole cactus pear samples were obtained from Bozön-Mersin area with 10 randomly selected samples per week. The collected fruits were immediately washed under tap water and then drained on tissue paper before physical measurements. The whole fruit after removing the seeds was homogenized in a Waring blender for chemical analyses. The results are given as the average of 10 samples.

Fruit Physical Measurements

The following measurements were carried out on the collected fruits: (a) fruit diameter and length (polar diameter) (Somet-Inox calipers); (b) fruit volume by flotation; (c) whole fruit, pulp and peel weights (Chyo, Japan); (d) wet weight of seeds.

Fruit growth was recorded in terms of length, width, weight and volume.

Chemical Analyses

The amount of total sugar in the homogenized fruit samples was determined by the phenol-sulfuric acid method with glucose as a standard (Rao and Pattabiraman, 1989). The pigment concentration was followed by absorbance measurements of the extracted juice at 476 nm and 538 nm using a spectrophotometer (Shimadzu UV-Visible 160A, Japan) according to Coskuner et al. (2000). The dry matter content of the fruit sample was determined by drying at 105°C to constant weight in an oven (Electro-mag, Germany). The total ash, total titratable acidity and Na, K, Fe, Ca, and Mg levels (with a flame atomic absorption spectrophotometer, Shimadzu, Japan) of the cactus pear samples were determined according to ,. methods (AOAC, 1990).

RESULTS AND DISCUSSION

Cactus pear sampling started 49 days after flowering (DAF), the time when pigmentation was initiated (Figure 1). Changes in physical properties and chemical composition occurring during maturation were followed for 15 weeks of sampling period.

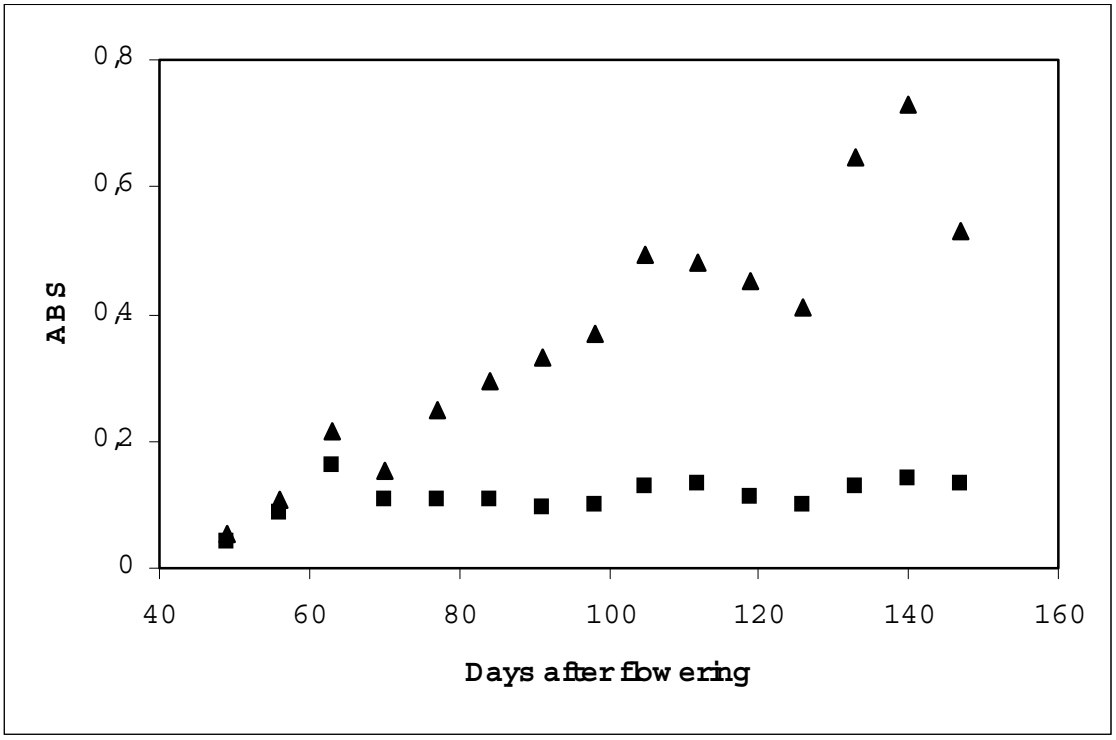

Figure 1. Color Development During Maturation of Cactus Pear (▲ 476 nm, ■ 538 nm)

Cactus pear fruits are 5 cm to 10 cm in length and 4 cm to 8 cm in width. Above 30% to 45% of the fruit is composed of a thick pericarp (peel) and the remainder is a juicy pulp comprising many hard seeds. Seeds comprise 5% to 10% of the pulp weight (Kuti, 1992; Barbera et al. 1994; Redhead, 1990; Cantwell, 1991). The percentage of seeds changed from 2.19 to 5.59 per whole fruit and from 4.32 to 10.51 per pulp for different clones of Opuntia grown in Argentina and the United States (Felker et al. 2002). The fruit weighs about 80 g to 120 g and comprises 85% water (Weiss et al. 1993; Sawaya and Khan, 1982). The natural pH of the cactus pear is 5.4 to 5.75 (Sawaya et al. 1983; Coskuner et al. 2000). The amount of total titratable acid varies from 0.15% to 0.25%. The amount of the total sugar content of the fruit varies from 6% to 14% and the total soluble solid content is 13% to 14%. The fruit sugar is composed of 53% glucose and the remainder is fructose. Sucrose, on the other hand, is found only in very low amounts (Sawaya et al. 1983; Saenz HC, 1995; Cantwell et al. 1992; Gurrieri et al. 2000). The level of invertase activity was observed to be related to the sucrose content of the fruits (Kuti and Galloway, 1994). Research concerning the mineral content of the cactus pear, however, is scarce. 27.6 mg Ca, 27.7 mg Mg, 0.8 mg Na, 161 mg K, 15.4 mg P, and 1.5 mg Fe have been found in 100 g of fruit pulp with 0.44% ash content (Sawaya et al. 1983; Barbera et al. 1995; Potriger, 1995). Gurrieri et al. (2000) reported 1.7 ppm to 2.9 ppm Mn^{2+}, 0.3-0.4 ppm Zn^{2+} and 0.6-1.2 ppm Fe^{2+} for yellow and white cultivars of Sicilian cactus pear.

A stage of reduced growth was observed between 49 and 63 DAF. The fruit continued to grow until harvest maturity showing a sigmoidal growth (Figure 2).

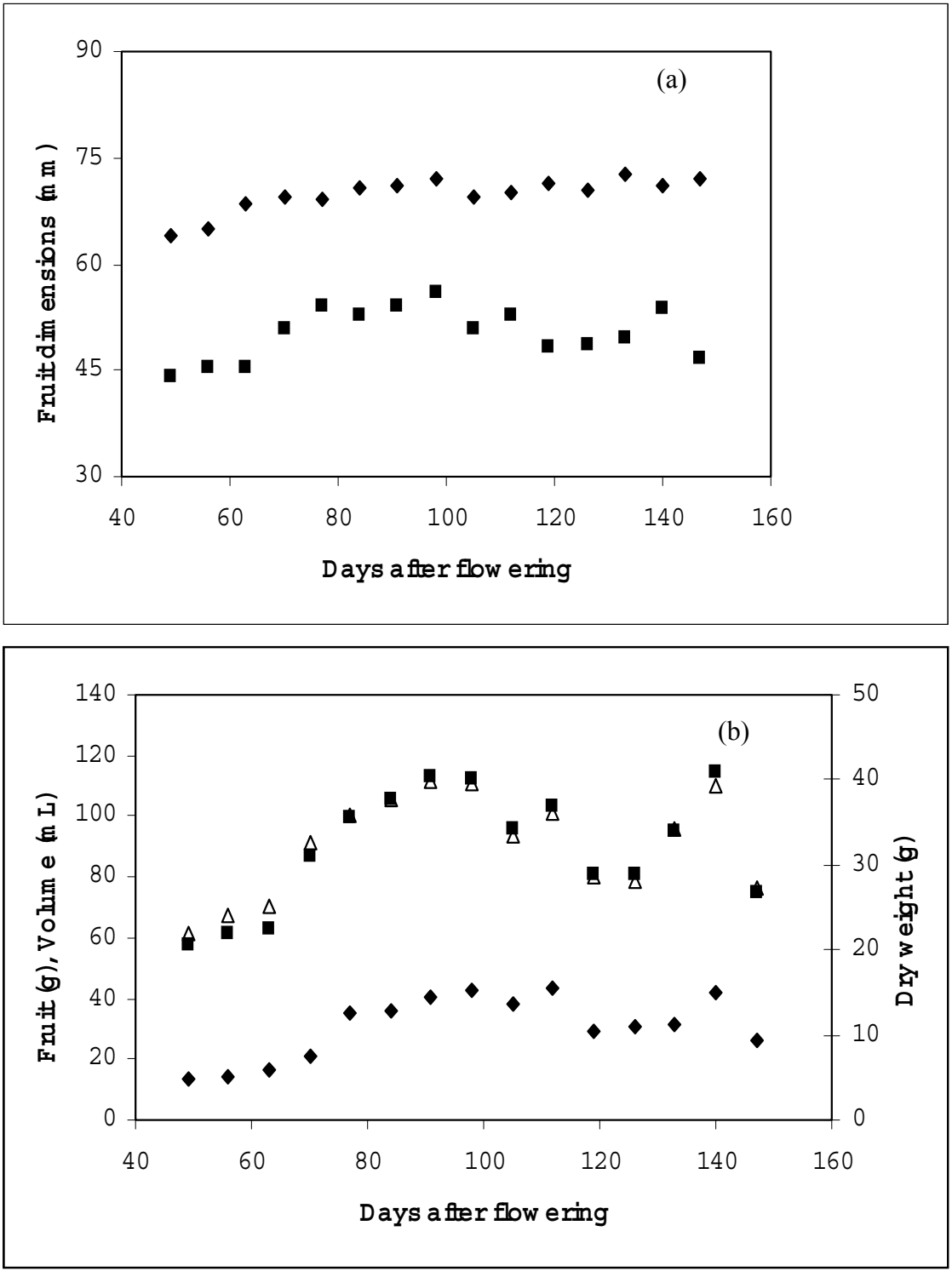

Figure 2. Changes in Terms of: (a) ■ Fruit Diameter, ◆ Fruit Length; (b) ■ Whole Fruit Weight, Δ Fruit Volume, and ◆ Total Dry Weight During Maturation of Cactus Pear

The cactus fruits belonging to Opuntia species have a sigmoidal growth curve, whereas the growth rate and maturation time change with the type of species and culture (Kuti, 1992; Barbera et al. 1992; Lakshminarayana et al. 1979; Nerd et al. 1999). Generally, rapid growth is observed between 20 and 30 DAF, which then enters a reduced-growth-rate stage. The fruit continues to grow until harvest maturity, showing a significantly faster growth between 40 and 80 DAF (Barbera et al. 1992). As the fruits enter the fast-growth period, changes both in chemical composition and in physical structure start simultaneously. The fast chemical and physical changes observed during this growth period cease toward fruit maturity. The chemical composition and dry weight of the fruit follows the same trend with ripening. (Cantwell 1991; Saenz 1995; Barbera et al. 1995; Lakshminarayana et al. 1979; D'Hallewin and Mulas 1997). During the period of rapid increase in fruit weight, the pulp weight increased simultaneously, whereas peel weight decreased during 63 to 77 DAF. The fruit pulp-to-peel ratio increased during the rapid-growth period. Meanwhile, the wet seed weight increased slightly to 0.141 until 70 DAF, then decreased to 0.065 g/g fruit, where it remained constant. Furthermore, the number of seeds initially increased to 5.44 per g fruit, then decreased and remained more or less constant at 2.96 per g fruit (Figure 3). The seedy pulp of cactus pear is used for human consumption. For this reason, it is important to determine the period when the pulp reached a maximum. The pulp to whole-fruit ratio might be a suitable ratio of maturity index in this respect. This ratio increased rapidly and reached a plateau 77 DAF at an average value of 0.45 to 0.50 g pulp/g whole fruit (Figure 4). According to the literature, as the fruit reaches harvest maturity, the pulp reaches around 60% of the whole fruit (Kuti, 1992; Cantwell, 1991; Barbera et al. 1992).

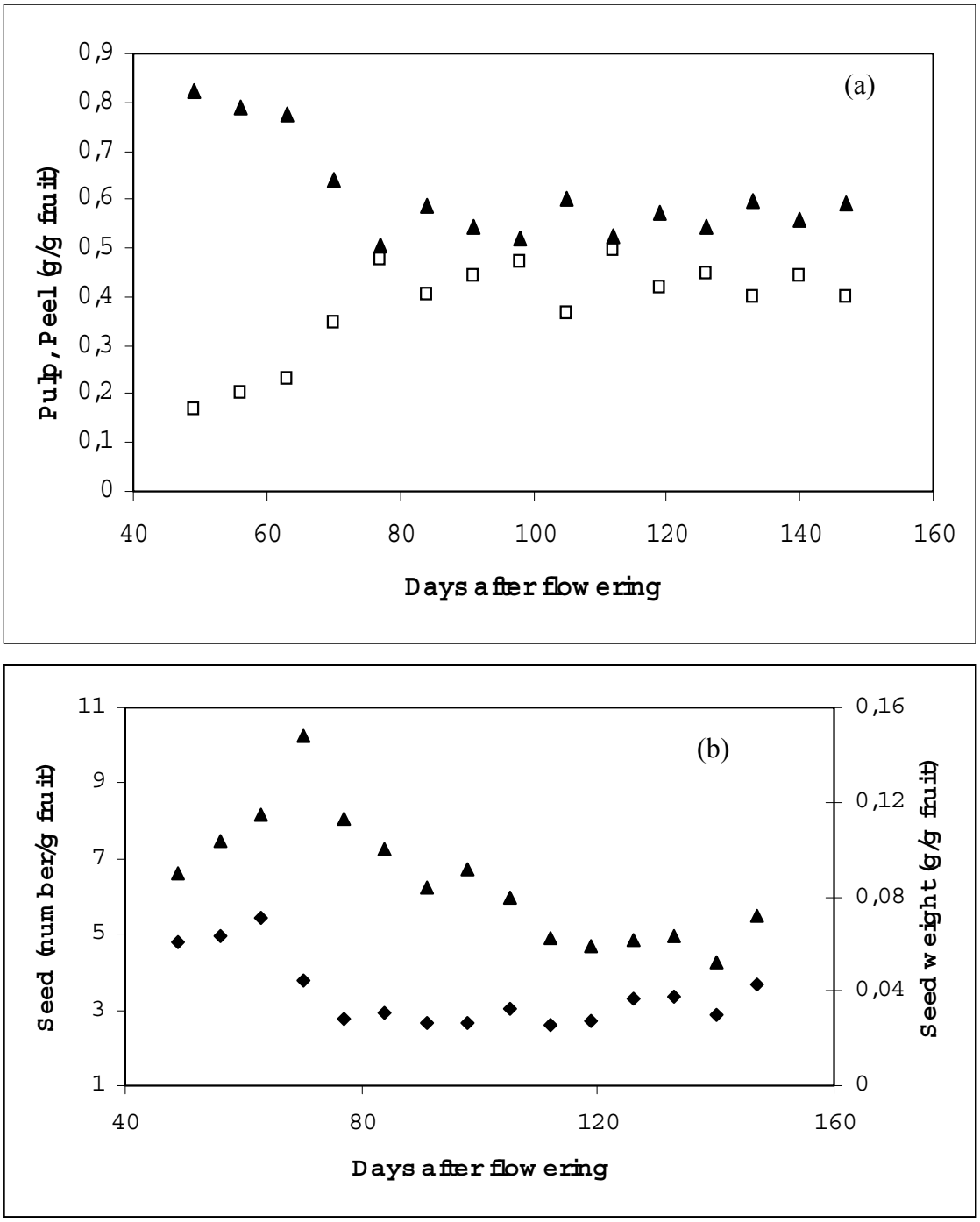

Figure 3. Changes in Terms of: (a) □ Pulp Weight, ▲ Peel Weight;
(b) ◆ Number of Seeds, ▲ Wet Seed Weight, During Maturation of Cactus Pear

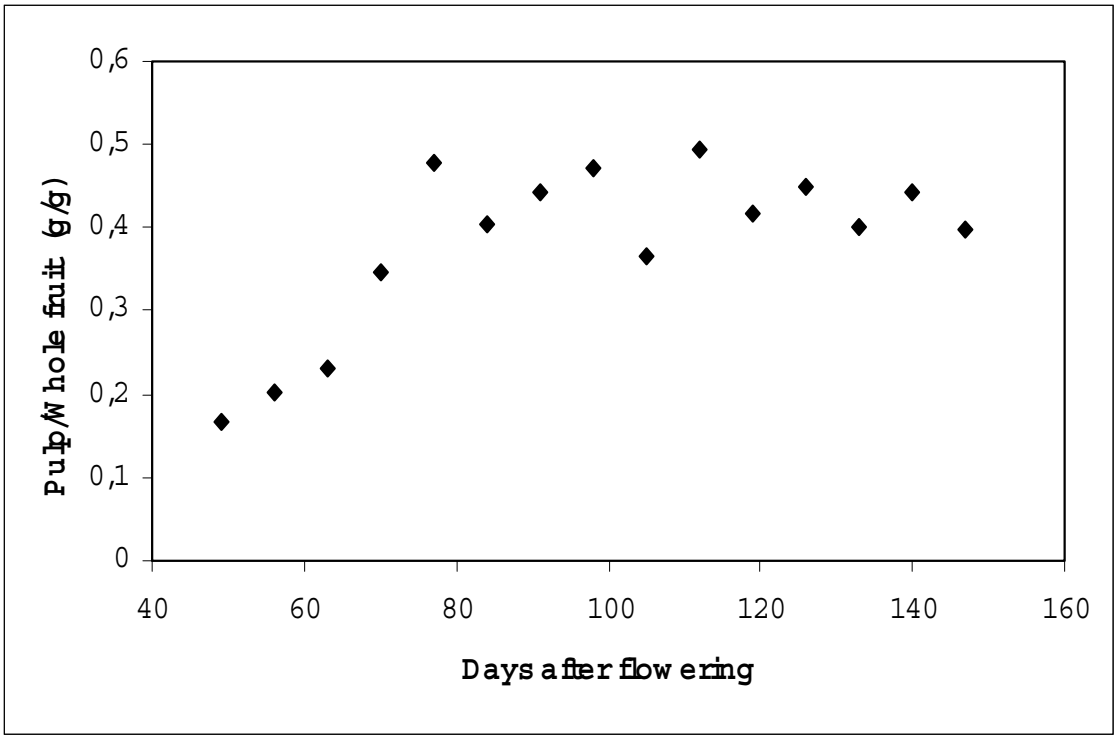

Figure 4. Change in Pulp to Whole-Fruit Ratio of Cactus Pear During Maturation

The total soluble solids and total sugar content increased simultaneously with the increase of fruit weight 63 DAF. The total soluble solids content, initially at 4.5°Brix, showed a sigmoidal increase reaching a value of 14.42°Brix 91 DAF. Thereafter, a decrease in total soluble solids was observed. The total sugar content showed a similar trend, but remained constant 84 DAF reaching a value of 8.5%. The total sugar content remained constant while some decrease in the total soluble solid content was observed after full maturity (Figure 5). The total titratable acidity (TTA) reached a maximum of 0.88% 70 DAF and then continually decreased to 0.162%. On the other hand, the pH value increased to pH 5.5 until 98 DAF and, thereafter remained constant. The evaluation of the ratio of total soluble solids to total titratable acidity throughout fruit development showed that this ratio remained constant at 9 until 63 DAF, subsequently increased rapidly to 63 to 78 until 98 DAF, and then remained more or less constant at 75°Brix/%TTA (Figure 6). The amount of ash of the fruit increased until 63 DAF, afterwards decreased to 0.958% at 84 DAF, and finally remained constant at this value. Among the minerals measured, except Na, the amounts of Fe, Mg, K, and Ca began decreasing 63 DAF (Figure 7). As total soluble solids and total sugar increase, the total titratable acidity, the amounts of minerals and ash decrease during maturation of the cactus fruits (Redhead, 1990; D'Hallewin and Mulas, 1997; Nerd et al. 1999). The same trend was also observed in cactus pear samples.

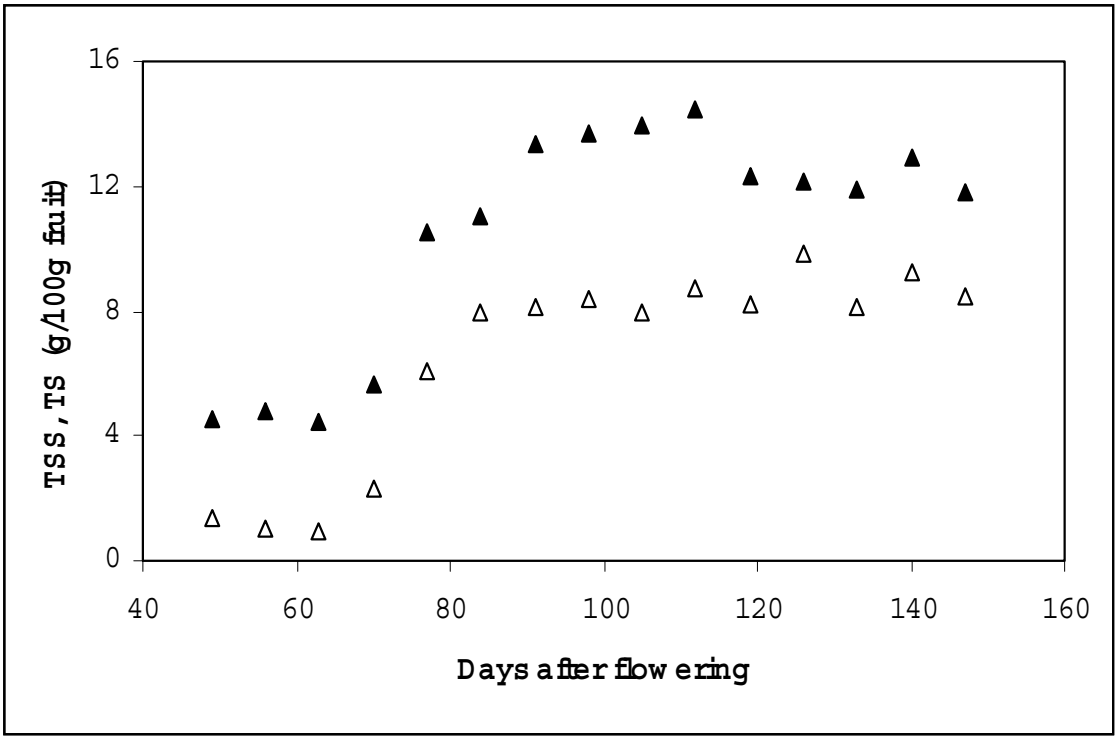

Figure 5. Changes in Total Soluble Solids and Total Sugar Amount
During Maturation of Cactus Pear (Δ Total Sugar, ▲ Total Soluble Solids)

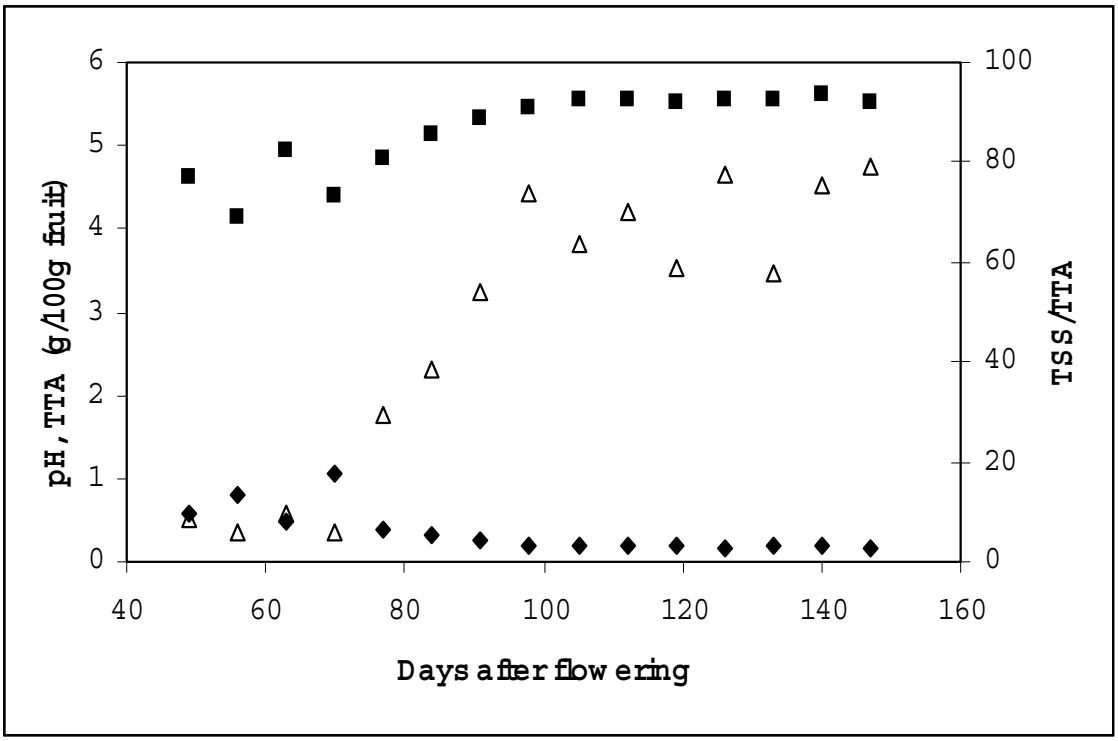

Figure 6. Changes in ■ pH Value, ◆ Total Titratable Acidity
and Δ Total Soluble Solids/Total Titratable Acidity Ratio
During Maturation of Cactus Pear

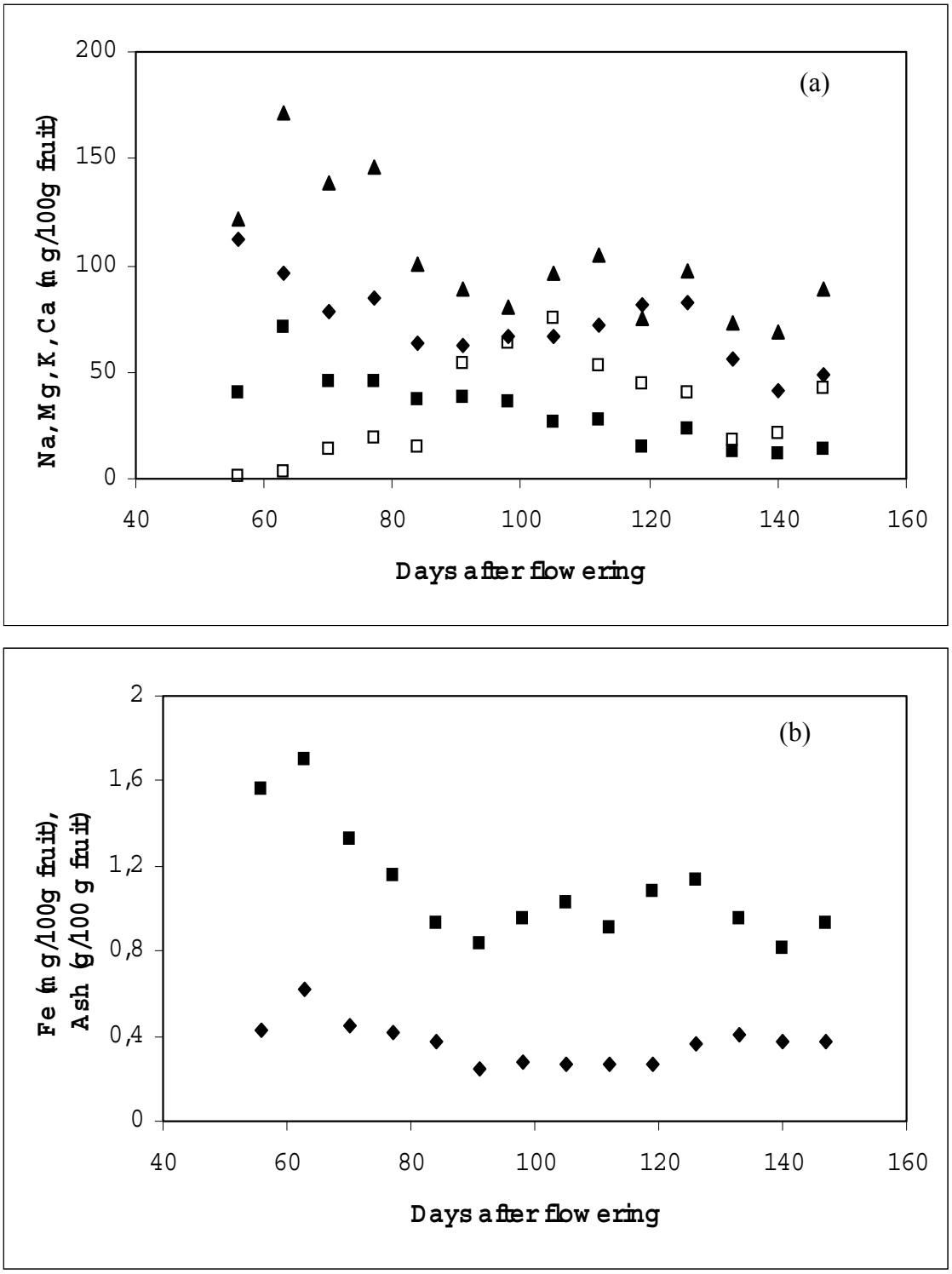

Figure 7. Changes in the Amounts of: (a) ▲ K, ◆ Ca, □ Na and ■ Mg; (b) ◆ Fe and ■ Ash Contents During Maturation of Cactus Pear

Taking all these data into account, it can be concluded that the cactus pear collected from Bozön-Mersin area reaches full maturity 98 to 112 days after flowering. This result is in accordance with the literature (Barbera et al. 1992; Kuti 1992; Lakshminarayana et al. 1979; Nerd 1999). After reaching full maturity, physical losses occurred. The fruit started to soften and spoil after full maturity was reached, which may lead to fruit material loss.

Fruit ripening is related to the initiation and the development of pigmentation of the fruit (Kuti, 1992; Cantwell, 1991; Barbera et al. 1992). It was reported that the chemical changes and taste coincided during ripening (Nerd et al. 1999). Comparing fruit growth data and chemical changes with the increase in the development of fruit color showed that they coincided within the period of fast growth. The betalain content of the fruit increased rapidly until 112 DAF and then, after a short lag time, increased further until 126 DAF. Nevertheless, because the fruit after full maturity quickly starts to soften and spoil, handling of fruit for food colorant production becomes difficult. For this reason, harvesting the fruit as soon as it reaches full maturity and then processing for food colorant production seems to be the best alternative.

CONCLUSION

The cactus pears of Bozön-Mersin reached full maturity between 98 and 112 DAF. The ratio of pulp to peel and total soluble solids to total titratable acidity reached a maximum at maturity and remained constant afterwards at 0.45 to 50 and 75, respectively. These can be used to assess the maturation period of the cactus pears grown at Bozön-Mersin. Because this study was conducted as a part of a research project of production of a natural food colorant, it was also considered to estimate the time when maximum betalain concentration was achieved, which coincided with the period of full maturity. In this respect, following directly the development of the betalain pigment can also give a clue to the degree of maturity of the cactus-pear fruits.

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