JCHR (2018) 8(2), 147-156

Journal of Chemical Health Risks

www.jchr.org

ORIGINAL ARTICLE

Effects of Harvesting Stages and Storage Temperatures on Pigment Contents in Fresh Fig of Four Iranian Cultivars

Hamid Zare[*1], Masoumeh Marzoughi Sotoudeh[2]

[1] *Fig Research Station, Fars Agricultural and Natural Resources Research and Training Center, AREEO, Estahban, Iran*

[2] *Deptartment of Horticultural Science, Islamic Azad University, Shiraz Branch, Shiraz, Iran*

(Received: 4March 2018 Accepted: 22 July 2018)

KEYWORDS

Fig cultivars;
Harvesting stages;
Pigments

ABSTRACT: Investigating of pigments changing trend in different stages of fruit maturity is essential for utilizing from nutritional value of pigments in fresh fruit consumption, unfortunately not known for Iranian fresh figs until now. In order to achieve this goal, this experiment was conducted in a factorial experiment based on a complete randomized design with three replications in Estahban Fig Research Station, Estahban, Iran in 2017. The first factor was fig cultivar in four levels (Sabz, Siah, Matti, and Shahanjir), and the second factor was fruit harvesting stage at three levels (before maturity, maturity and after maturity), and the third factor was the storage temperature at two levels (4 and 22 degrees Celsius). The levels of chlorophyll a and b, total chlorophyll, carotenoids and anthocyanin in fresh fruits of fig cultivars at different harvesting stages and storage temperatures were measured. The results showed an increasing trend in some pigments such as chlorophyll b, total chlorophyll, and carotenoids during the development of fig fruit maturation. The highest amount of tested pigments in this experiment was in Siah cultivar, which indicates the higher nutritional value of these fruits for fresh consumption. The majority of pigments content increase in harvested fruit after maturity. Therefore, in order to use the nutritional value of pigments in fresh figs, figs be harvested and used for fresh consumption after maturity.

INTRODUCTION

Fig is one of the most important horticultural crops, cultivated by human since many years ago [1]. As, in most parts of Iran, it is found in commercial orchards or individual plant. Fresh and dry fig is rich in phenolic compounds including proanthocyanin compared with tea known as the richest of phenolic compounds [2]. This fruit is the main source of fiber, potassium, calcium, iron and free sodium. Additionally, high amount of anthocyanin, carotenoid, vitamin, free fat and amino acid can be found in fig fruit [3]. Different fig species showed various phenotypes. For example, black skin figs revealed high level of polyphenols, anthocyanin, flavonoid, and antioxidant [4]. Noticeably, color changes of fig fruit are due to chlorophyll degradation and simultaneous synthesis of special pigments including anthocyanin and carotenoid.

Carotenoids are the most commonly used pigmentation group in nature as they are produced in yellow to red in the most of fruits. In addition, the quantity and quality of carotenoids are different in vegetables and fruits as vegetables showed a defined quality pattern, in which lutein, violaxanthin, and neoxanthin are the part of their carotenoids. On the other hand, fruits come with complex

*Corresponding author: hamidzare777@gmail.com (H. Zare)

carotenoid as the most changes occurred commonly in both profile pigmentations and their concentration during fruit ripening with the higher difference in fruit skin than its pulp. However, there are many differences in the concentration of pigments in the stage of commercial ripening between species and cultivars. Accordingly, such differences ate affected by environmental conditions and horticultural practice [5].

The content of anthocyanin was different among three genotypes namely Gol-bahar, Ghremez-Galin, Rezvan during four different stages of fruit development in Gorgan-Iran. For example, the black fruit of Gol-bahar genotype showed an increasing trend in the content of anthocyanin during developmental stage. However, downward change in Ghremez-Galin and Rezvan genotypes was found in the last stages of fruit development. Interestingly, antioxidant, phenol and flavonoid contents decreased in all genotypes [6]. The process of fig fruit ripening and color changes from green to black, white and bluish stimulated within eight days in the late period II of its development, and at the stage, the fruits reached to their maximum diameter. Levels of carotene, lutein, violaxanthin, and neoxanthin were similar to chlorophyll as the rate of carotene and lutein degradation was initially greater than those of the xanthophyll pigments. Degradation rates of the various carotenoids were comparable 4 to 8 d after treatment. β-carotene, the most important fig pigment, was rapidly degraded. After completing catabolism of β -carotene, the maximum rate of chlorophyll destruction was reached. As β -carotene is supposed to have a protective function, degradation of chlorophyll and xanthophylls could be made by photooxidative processes. However, no significant changes were found in anthocyanin accumulation [7].

Chlorophyll pigment can be served in a series of biological properties, such as antioxidant, antimutagenic activities, and modulation of xenobiotic metabolizing enzyme activity [8, 9]. The role of chlorophyll in human health including reducing risk of colon cancer is investigated by scientific research and its presence in the food product such as not fully-ripe fruit can enhance its nutritional value. Moreover, chlorophyll acts as an important role in reducing free radical such as DPPH (1,1-Diphenyl 1-2-picrylhydrazyl) [10].

Carotenoids act as pre-cursor of vitamin A in human and play important role in protection of human population against some diseases and cancers [11-13]. Anthocyanins are well-known for the rich antioxidant compounds in which their content increased at the late stage of fruit ripening [14].

The impact of maturity, storage temperature and storage duration on pigment contents and sensory quality of fruit play a key role in consumer acceptance that they are willing to pay more for the best fruit quality [15]. Numerous studies reported physicochemical changes occurred during developmental and harvesting stages in some fruits including kiwifruit [16], sweet cherry [17], nectarine [15] and raspberry [18].

Storage temperature modified fruit quality. Cold storage induced anthocyanin's accumulation in red-orange and strawberries [19, 20]. Anthocyanin changes depended on storage temperature and strawberry cultivar [21]. Anthocyanin content in strawberry increased, more rapidly at 10°C than at 3°C in the white tip maturity stage, but declined in red ripe maturity stage during the storage [22].

Generally, harvesting stages affect the quality of the product [23]. During different harvesting stages, the carotenoid content of fruit can be changed [24].

Due to the importance of pigments role, the aim of this study was to assess the content of some pigments (anthocyanin's, chlorophyll and carotenoid) and also the effects of harvesting stages and storage temperatures on pigments content in four commercial Iranian fig cultivars including Sabz, Siah, Shah-Anjir, and Matti.

MATERIALS AND METHODS

We investigated the effects of harvesting stage and storage temperature on pigments contents of four fresh fig cultivars in Estahban Fig Research Station, Estahban, Iran in 2017. Three commercial Iranian fig cultivars were harvested (Sabz, Siah, Shah-Anjir, and Matti) at three stages of fruit physiological maturations: Stage 1: before maturation, stage II: maturation and Stage III: after maturation from

Estahban Fig Research Station and placed at special pockets. Harvested samples were free from contamination, health, and uniform. Having been harvested, fig cultivars were kept at two temperatures (4 ±1 °C and 22±2 °C). Samples were evaluated after 14 d to determine the effect of those treatments on the fruit pigments. The following characters were determined.

Anthocyanin determination

Fruit tissue, 0.1 gr, was homogenized in 3 ml HCL in Methanol (1:99). The homogenate was centrifuged at 15000 ×gr for 10 min and kept at dark place overnight. Anthocyanin contents were determined spectrophotometrically (Spectronic Genesys5) at the wavelength of 550 nm [25]. Anthocyanin concentration calculated using the extinction coefficient (ε = 3300 (cm/mol)).

Chlorophyll and carotenoid analysis

Chlorophyll and carotenoid determinations were conducted according to the methods of Arnon (1949). Chlorophyll contents were determined spectrophotometrically (Spectronic Genesys 5) at the wavelength of 645 and 663 nm for chlorophyll a, b and total and 470 nm for carotenoid [26]. Chlorophyll and carotenoid concentrations calculated by below equations:

$$C_a\ (mg/g) = [12.7\times A_{663} - 2.69\times A_{645}]\ \times V/1000\times W$$
(Chlorophyll a)

$$C_b\ (mg/g) = [22.9\times A_{645} - 4.86\times A_{663}]\ \times V/1000\times W$$
(Chlorophyll b)

$$C_{a+b}\ (mg/g) = [8.02\times A_{663} + 20.20\times A_{645}]\ \times V/1000\times W$$
(Chlorophyll)

$$Carotenoids = 100(A_{470}) - 3.27(mg\ chl._a) - 104(mg\ chl._b)/22$$
(a+b)

Statistical analysis

The experiment design was factorial based on a complete randomized design with three replications. Analysis of variance was performed using the SAS software and means were compared by Duncan's Multiple Range Test (DMRT). Differences between means at 5% ($P<0.05$) level were considered as significant.

RESULTS AND DISCUSSION

Chlorophyll a content

The content of chlorophyll a was at the highest level before maturation. In fig, chlorophyll a degradation occurred rapidly which was in accordance with the study conducted on pear fruit [27]. Rapid chlorophyll degradation was due to either a great peroxidase enzyme activity or a high sensitivity of its pigment to the stress condition [28, 29]. Additionally, the final catabolite of other chlorophylls contributed to chlorophyll a degradation [30]. Fig fruits harvested at the final stage of fruit maturation obtained the lowest concentration of this pigment (0.18 mg/g FW) (Table 1). No significant association was found between stages of fruit harvesting and storage temperature (Table 2). Another result of the present study is that chlorophyll a content was highly common in the Siah cultivar (0.32 mg/g FW) (Table 3) at both storage temperatures (Table 4). The lowest content of such pigment was found in Matti cultivar at 4 and 22°C and Shah-Anjir cultivar at 22 °C. Moreover, Siah cultivar harvested at the beginning of maturation had the highest chlorophyll a content (0.4 mg/g FW). However, this cultivar did not show any significant difference at the maturation stage in chlorophyll a content. Minimum chlorophyll a content was related to the Matti and Shah-Anjir cultivars harvested after maturation (Table 5). Siah cultivar harvested after maturation and stored at 4 and 22 °C reached the lowest chlorophyll a concentration (Table 6).

Table 1. Effects of harvesting stage on Chlorophyll a, b, and total; Carotenoid and Anthocyanin contents of fresh figs

harvesting stages	Chlorophyll a(mg.g^{-1})	Chlorophyll b(mg.g^{-1})	Total Chlorophyll (mg.g^{-1})	Carotenoid (mg.g-1)	Anthocyanin (µM.g-1)
Before ripening	0.25 a	0.17 b	0.43 b	47.8 b	0.36 a
Ripening	0.18 b	0.14 b	0.33 b	50.0 b	0.10 b
After ripening	0.20 ab	0.41 a	0.62 a	96.7 a	0.14 ab

*Means with the same letters in each column are not significantly different using Duncan test at $P< 0.01$

Table 2. Interaction effects of storage temperature and harvesting stage on Chlorophyll a, b, and Total; Carotenoid and Anthocyanin contents of fresh fig fruit.

Treatment		Chlorophyll a (mg.g^{-1})	Chlorophyll b(mg.g^{-1})	Total Chlorophyll (mg.g^{-1})	Carotenoid (mg.g^{-1})	Anthocyanin (µM.g-1)
storage temperature (°C)	harvesting stages					
4	Before ripening	0.26a	0.19b	0.46ab	49.39b	0.36a
4	ripening	0.19 a	0.13b	0.32b	50.79b	0.11b
4	After ripening	0.19 a	0.42a	0.61a	94.21a	0.14b
22	Before ripening	0.26 a	0.17b	0.44ab	49.50b	0.36a
22	ripening	0.19 a	0.15b	0.34b	50.57b	0.11b
22	After ripening	0.19 a	0.35ab	0.52ab	95.61a	0.14b

*Means with the same letters in each column are not significantly different using Duncan test at $P<0.01$

Table 3. Effects of fig cultivars on Chlorophyll a, b, and Total; Carotenoid and Anthocyanin contents of fresh fig fruit.

Fig cultivars	Chlorophyll a (mg.g^{-1})	Chlorophyll b (mg.g^{-1})	Total Chlorophyll (mg.g^{-1})	Carotenoid (mg.g^{-1})	Anthocyanin (µM.g-1)
Sabz	0.18b	0.12c	0.3b	48.6b	0.13b
Shah-Anjir	0.19b	0.15bc	0.34b	37.5b	0.07b
Siah	0.32a	0.43a	0.76a	88.6a	0.46a
Matti	0.15b	0.26b	0.41b	84.7 a	0.14b

* Means with the same letters in each column are not significantly different using Duncan test at $P<0.01$

Table 4. Interaction effects of fig cultivars and storage temperature on Chlorophyll a, b, and Total; Carotenoid and Anthocyanin contents of fresh fig fruit.

Treatment		Chlorophyll a (mg.g^{-1})	Chlorophyll b (mg.g^{-1})	Total Chlorophyll (mg g^{-1})	Carotenoid (mg.g^{-1})	Anthocyanin (µM.g-1)
Fig cultivars	Storage Temperature (°C)					
Sabz	4	0.19ab	0.10c	0.29b	47.20ab	013
Sabz	22	0.19ab	0.10c	0.29b	50.08ab	0.13
Shah-Anjir	4	0.19ab	0.19bc	0.38b	37.83b	0.07
Shah-Anjir	22	0.16b	0.10c	0.26b	37.45b	0.07
Siah	4	0.32a	0.45a	0.78a	89.16a	0.46
Siah	22	0.32a	0.45a	0.78a	89.28a	0.46
Matti	4	0.15b	0.26b	0.41b	85.00a	0.14
Matti	22	0.15b	0.26b	0.42b	84.11a	0.14

*Means with the same letters in each column are not significantly different using Duncan test at $P<0.01$.

Table 5. Interaction effects of fig cultivars and harvesting stages on Chlorophyll a, b, and Total Chlorophyll, Carotenoid and Anthocyanin contents of fresh fig fruit.

Treatment		Chlorophyll a ($mg.g^{-1}$)	Chlorophyll b ($mg.g^{-1}$)	Total Chlorophyll ($mg.g^{-1}$)	Carotenoid ($mg.g^{-1}$)	Anthocyanin (μM.g-1)
Fig cultivars	**Harvesting stages**					
Sabz	Before ripening	0.19bcd	0.13c	0.32de	49.82b	0.15b
Sabz	ripening	0.19bcd	0.10c	0.25de	40.79b	0.13b
Sabz	After ripening	0.15cd	0.15c	0.34de	55.20b	0.13b
Shah-Anjir	Before ripening	0.24bc	0.16c	0.41de	32.81b	0.05b
Shah-Anjir	ripening	0.22 bc	0.12c	0.34de	43.29b	0.03b
Shah-Anjir	After ripening	0.10 d	0.18c	0.28de	36.41b	0.13b
Siah	Before ripening	0.40a	0.29c	0.70a	62.29b	1.12a
Siah	ripening	0.30 ab	0.24c	0.51cd	59.61b	1.01a
Siah	After ripening	0.27 bc	0.78a	0.90a	143.91a	1.01a
Matti	Before ripening	0.22bc	0.11c	0.28de	46.30b	0.12b
Matti	ripening	0.22 bc	0.13c	0.20e	56.48b	0.19b
Matti	After ripening	0.07d	0.53b	0.76b	151.42a	0.12b

*Means with the same letters in each column are not significantly different using Duncan test at $P < 0.01$.

Table 6. Interaction effects of figs, harvesting stages and storage temperature on Chlorophyll a, b, and total Chlorophyll contents of fresh figs

Treatments			Chlorophyll a ($mg.g^{-1}$)	Chlorophyll b ($mg.g^{-1}$)	Total Chlorophyll ($mg.g^{-1}$)
Fig Cultivar	**storage temperature (°C)**	**harvesting stage**			
Sabz	4	Before ripening	0.249a-c	0.135bc	0.381b-d
Shah-Anjir	4	Before ripening	0.249a-c	0.166bc	0.415b-d
Siah	4	Before ripening	0.406a	0.355bc	0.760ab
Matti	4	Before ripening	0.174a-c	0.115c	0.289b-d
Sabz	4	Ripening	0.200a-c	0.075c	0.275b-d
Shah-Anjir	4	Ripening	0.224a-c	0.120c	0.345b-d
Siah	4	Ripening	0.273ab	0.214bc	0.487b-d
Matti	4	Ripening	0.228a-c	0.135bc	0.208cd
Sabz	4	After ripening	0.131bc	0.082c	0.241cd
Shah-Anjir	4	After ripening	0.104bc	0.302bc	0.406b-d
Siah	4	After ripening	0.305ab	0.784a	1.090a
Matti	4	After ripening	0.0732c	0.532a	0.760ab
Sabz	22	Before ripening	0.249a-c	0.132bc	0.381b-d
Shah-Anjir	22	Before ripening	0.249a-c	0.166bc	0.415b-d
Siah	22	Before ripening	0.406a	0.289bc	0.690a-c
Matti	22	Before ripening	0.174a-c	0.119c	0.293b-d
Sabz	22	Ripening	0.200a-c	0.075c	0.275b-d
Shah-Anjir	22	Ripening	0.224a-c	0.120c	0.345b-d
Siah	22	Ripening	0.273ab	0.294bc	0.567bc
Matti	22	Ripening	0.228a-c	0.135bc	0.208cd
Sabz	22	After ripening	0.131bc	0.82c	0.214cd
Shah-Anjir	22	After ripening	0.007c	0.013c	0.021d
Siah	22	After ripening	0.305ab	0.784a	1.090a
Matti	22	After ripening	0.073c	0.784a	0.760ab

*Means with the same letters in each column are not significantly different using Duncan test at $P<0.01$.

Oxidative chlorophyll degradation due to the integrity reduction and cell wall decomposition during maturation and ripening caused hydrogen peroxide production as this compound reacted with vitamin C and phenolic compound led to reducing the antioxidant activity at these stages [31]. Noticeably, green color of plants depends on type of photosynthetic reactions. In this regard, chlorophyll was the most important pigment of the green plants. In the normal state of chloroplasts, the chlorophyll degradation enzyme is linked to the internal membrane and does not have access to the chlorophyll bonded to the thylakoids, but during the maturity and senescence process, the chloroplast integrity is lost and the two compounds are in direct contact, which ultimately leads to the decomposition of chlorophyll [14] and color changes from green to yellow, red and purple [32]. Commercial maturation of some cultivars of pear fruit is associated with the chlorophyll content of peels and these changes were defined as a practical index during developmental stages [27]. In line with our results, a study on the olive fruit reported the photosynthesis activity, chlorophyll and carotenoid concentrations of fruit reduced during ripening [33].

Chlorophyll b content

Fig fruits harvested after maturation were at the highest level of chlorophyll b. The pigment degradation did not occur during fruit maturation. The chlorophyll b of fig fruits was tolerated to stress condition and enzyme degradation of chlorophyll. Accordingly, chlorophylls in addition to different chemical structures had a various toleration against environmental and stress conditions [32]. Regarding Table 1 fresh fig fruits harvested at the other stages of fruit, maturations reached the lowest chlorophyll b content. On the other hand, fig fruits harvested before maturation and stored at 4 and 22 °C increased chlorophyll b content. However, those fig fruits harvested at other stages of fruit maturation and stored at both temperatures did not show any significant difference. In addition, the highest and lowest chlorophyll b content was observed in Siah and Sabz cultivars, respectively (Table 3). Siah cultivar kept at 4 and 22°C obtained the highest of this pigment. However, Sabz cultivar stored at 4 and 22 °C and Shah- Anjir kept at 22°C had the minimum content of chlorophyll b (Table 4). Siah cultivar harvested after maturation and stored at 4 and 22°C obtained maximum chlorophyll b content (Table 5). The lowest of this pigment observed in Sabz cultivar harvested at maturation and stored at 4 and 22°C. A downward change in pigment content was also found in Shah-Anjir harvested at the stage of maturation (Table 6). The results of the present study showed that rather than chlorophyll a content, chlorophyll b was more common in figs harvested after maturation; however, at two other stages of fig maturation, the content of chlorophyll a was higher than another pigment. This result is supported by the study conducted on strawberry fruits, which reported that the chlorophyll b degradation had a slower trend than the chlorophyll a degradation [29].

Total chlorophyll content

Fig fruits harvested after maturation increased total chlorophyll content, but fig fruits harvest at the other stages showed the lowest content of total chlorophyll (Table 1). Fruits harvested after maturation with the storage temperature of 4 °C had the highest content (Table 2). Total chlorophyll content enhanced in Siah cultivar stored at 4 and 22°C and harvested after maturation (Table 3, 4, 5, 6). Moreover, Matti cultivar had the lowest content of this pigment at maturation stage (Table 5). Nectarine (cv Red Gold) harvested at the last stage of fruit development obtained the highest chlorophyll a, b and total, which was in accordance with the results of the present study [34].

Carotenoid content

The highest carotenoid content belonged to the fig fruits harvested after maturation (Table 1). Fig fruits harvested after maturation and stored at 4 and 22°C obtained the maximum content of carotenoid (Table 2). Siah and Matti cultivars harvested after maturation and stored at 4 and 22°C increased the carotenoid content (Table 3, 4, 5 and 7). Carotenoid content was increased on Acerola fruit which harvested after ripening stage [24]. The enhancement of carotenoid after harvest may result from carotenoid biosynthesis during maturation [24] and carotenoid development even in low temperature [35]. Carotenoids of 'Maradol' papaya were influenced by postharvest storage temperature which was in line with our study [36]. The content of carotenoid decreased along with the photosynthetic activity during fruit ripening [37]. Carotenoids led to fruit color changes from yellow to red. Noticeably, they act a key role in human population health (precursor of vitamin A). Since carotenoids are accounted for the antioxidant compound and with the highest activity, they are capable of preventing free radical formations and as a result, they protect the body against diseases [11-13].

Anthocyanin content

Fresh fig fruits harvested before maturation obtained the highest content of anthocyanin (0.36 μM.g^{-1}) (Table 1), whilst storage temperature of fig fruit was not significant. Siah cultivar stored at 4 and 22 °C had the highest level of pigment (Table 3, 4). The highest level of pigment was observed in Siah cultivar harvested at all the stages of fruit maturation (Table 5). Additionally, Siah cultivar harvested at maturation stage and stored at both temperatures reached the highest content. However, the lowest content of pigment was found in Sabz and Shah-Anjir cultivars harvested before maturation (with both storage temperatures) (Table 7).

Table 7. Interaction effects of fig cultivars, harvesting stages and storage temperature on Carotenoid and Anthocyanin contents of fresh figs

Treatments			Carotenoid	Anthocyanin
Fig cultivars	**Storage temperature (°C)**	**Harvesting stage**		
Sabz	4	Before ripening	56.16b	0.07b
Shah-Anjir	4	Before ripening	32.81b	0.05b
Siah	4	Before ripening	62.29b	1.10a
Matti	4	Before ripening	46.30b	0.12ab
Sabz	4	Ripening	42.96b	0.13ab
Shah-Anjir	4	Ripening	44.33b	0.03b
Siah	4	Ripening	59.42b	1011a
Matti	4	Ripening	56.48b	0.19ab
Sabz	4	After ripening	42.50b	0.13ab
Shah-Anjir	4	After ripening	36.35b	0.13ab
Siah	4	After ripening	145.78a	0.15ab
Matti	4	After ripening	152.22a	0.12ab
Sabz	22	Before ripening	56.82b	0.07b
Shah-Anjir	22	Before ripening	32.81b	0.05b
Siah	22	Before ripening	62.07b	1.10a
Matti	22	Before ripening	46.30b	0.12ab
Sabz	22	Ripening	42.94b	0.13ab
Shah-Anjir	22	Ripening	42.83b	0.03b
Siah	22	Ripening	59.99b	1.11a
Matti	22	Ripening	56.48b	0.19ab
Sabz	22	After ripening	50.48b	0.13ab
Shah-Anjir	22	After ripening	36.62b	0.13ab
Siah	22	After ripening	145.78a	0.15ab
Matti	22	After ripening	149.55a	0.12ab

*Means with the same letters in each column are not significantly different using Duncan test at *P*<0.01.

In fact, anthocyanin compounds have a high capacity of free radical scavenger in human body and play important roles in human population health. Indeed, anthocyanin compounds reduce the risk of coronary heart diseases (CADs), and different types of cancers [38]. Anthocyanin content in plants is affected by environmental factors and harvest stage [39]. Generally, antioxidant capacity and fruit quality had the stable trend during storage stage. In albedo of blood oranges, the long storage time had a few effects on the quality of fruit, due to the anthocyanin synthesis and phenolic compounds compared with Thompson oranges [40]. Among different types of fig cultivars, anthocyanin changes showed a various trend during fruit ripening [6]. Indeed, changes in anthocyanin accumulation were found during growth season because of genetics, climate, growing season and horticultural practices [41]. At the beginning of fruit pigment synthesis (anthocyanin), the upward changes were associated with an increase in soluble sugar [34], and later synthesis of this pigment was found in decrease of that sugar [42]. Moreover, color change in pomegranate cultivar is contributed to a decrease in total acidity and an increase in sugar. Anthocyanin pigments are affected by the structural fluctuation, which is reversible with acidity changes [43, 44]. Anthocyanin content in blood orange was enhanced at 6 °C during storage and at the end of that period, the highest content was determined [45]. An increase in anthocyanin content during fig fruit maturation can depend on activation of the enzymes involved in phenylpropanoid metabolisms such as phenylalanine ammonialyase (PAL), chalcone synthase (CHS), dihydroflavonol 4-reductase (DFR), and UDP-glucose flavonoid glucosyltransferase (UFGT) [20, 45].

CONCLUSIONS

Fresh fig fruits showed an upward change in chlorophyll b, total chlorophyll and carotenoid during fruit maturation. Siah cultivar reached the highest level of pigment content with highest nutritional value in this regard. Since the greatest contents of carotenoid, chlorophyll b, and total chlorophyll were associated with fruits harvested after maturation, fresh figs have the most nutritional value with harvesting in stage of after-ripening and also, suitable for eating.

ACKNOWLEDGEMENTS

We gratefully thank all of our collaborators at Estahban Fig Research Station, and Fars Agricultural and Natural Resources Research and Training Center.

Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

1. Aksoy U., 1998. Why figs? An old taste and a new perspective. Acta Hortic. 480, 25-26.

2. Vinson J.A., Hao Y., Su X., Zubik L., 1998. Phenol antioxidant quantity and quality in foods: vegetables. J. Agric Food Chem. 46(9), 3630-3634.

3. Stover E., Aradhya M., Ferguson L., Crisosto C.H., 2007. The fig: overview of an ancient fruit. HortScience. 42(5), 1083-1087.

4. Solomon A., Golubowicz S., Yablowicz Z., Grossman S., Bergman M., Gottlieb H.E., Altman A., Kerem Z., Flaishman M.A., 2006. Antioxidant activities and anthocyanin content of fresh fruits of common fig (*Ficus carica* L.). J Agric Food Chem. 54(20), 7717-7723.

5. Perkins-Veazie P., Collins J.K., Pair S.D., Roberts W., 2001. Lycopene content differs among red-fleshed watermelon cultivars. J. Sci Food Agric. 81(10), 983-987.

6. Kikha Z., Saifi I., Varasteh F., Qassim-Nejad A., 2015. Comparison of morphological and phytochemical traits of spring and summer products of three genotypes of figs in Golestan province- Iran. Environmental Plant Physiology. 10, 62-72.

7. Puech A.A., Rebeiz C.A., Crane J.C., 1976. Pigment changes associated with application of ethephon ((2-chloroethyl) phosphonic acid) to fig (*Ficus carica* L.) fruits. Plant Physiol. 57(4), 504-509.

8. Delgado-Pelayo R., Gallardo-Guerrero L., Hornero-Méndez D., 2014. Chlorophyll and carotenoid pigments in

the peel and flesh of commercial apple fruit varieties. Food Res Int. 65, 272-281.

9. Ferruzzi M.G., Blakeslee J., 2007. Digestion, absorption, and cancer preventative activity of dietary chlorophyll derivatives. Nutr Res. 27(1), 1-12.

10. Sgherri C., Pérez-López U., Pinzino C., 2015. Antioxidant properties of food products containing lycopene are increased by the presence of chlorophyll. Lycopene: Food Sources, Potential Role in Human Health and Antioxidant Effects Edited by bailey JR. New York: Nova Science Publishers, inc, 39-90.

11. Krinsky N.I., Johnson E.J., 2005. Carotenoid actions and their relation to health and disease. Mol Aspects Med. 26(6), 459-516.

12. Taylor M., Ramsay G., 2005. Carotenoid biosynthesis in plant storage organs: recent advances and prospects for improving plant food quality. Physiol Plant. 124(2), 143-151.

13. Voutilainen S., Nurmi T., Mursu J., Rissanen T.H., 2006. Carotenoids and cardiovascular health–. Am J Clin Nutr. 83(6), 1265-1271.

14. Wang S.Y., Lin H.S., 2000. Antioxidant activity in fruits and leaves of blackberry, raspberry, and strawberry varies with cultivar and developmental stage. J Agric Food Chem. 48(2), 140-146.

15. Echeverría G., Cantín C., Ortiz A., López M., Lara I., Graell J., 2015. The impact of maturity, storage temperature and storage duration on sensory quality and consumer satisfaction of 'Big Top®'nectarines. Sci Hortic (Amsterdam). 190, 179-186.

16. Tavarini S., Degl'Innocenti E., Remorini D., Massai R., Guidi L., 2008. Antioxidant capacity, ascorbic acid, total phenols and carotenoids changes during harvest and after storage of Hayward kiwifruit. Food Chem. 107(1), 282-288.

17. Serrano M.a., Díaz-Mula H.M., Zapata P.J., Castillo S., Guillén F.N., Martínez-Romero D., Valverde J.M., Valero D., 2009. Maturity stage at harvest determines the fruit quality and antioxidant potential after storage of sweet cherry cultivars. J Agric Food Chem. 57(8), 3240-3246.

18. Stavang J.A., Freitag S., Foito A., Verrall S., Heide O.M., Stewart D., Sønsteby A., 2015. Raspberry fruit quality changes during ripening and storage as assessed by colour, sensory evaluation and chemical analyses. Sci Hortic (Amsterdam). 195, 216-225.

19. Kalt W., Forney C.F., Martin A., Prior R.L., 1999. Antioxidant capacity, vitamin C, phenolics, and anthocyanins after fresh storage of small fruits. J Agric Food Chem. 47(11), 4638-4644.

20. Lo Piero A. R., Puglisi I., Rapisarda P., Petrone G., 2005. Anthocyanins accumulation and related gene expression in red orange fruit induced by low temperature storage. J Agric Food Chem. 53(23), 9083-9088.

21. Cordenunsi B., Nascimento J.D., Lajolo F., 2003. Physico-chemical changes related to quality of five strawberry fruit cultivars during cool-storage. Food Chem. 83(2), 167-173.

22. Shin Y., Ryu J.A., Liu R.H., Nock J.F., Watkins C.B., 2008. Harvest maturity, storage temperature and relative humidity affect fruit quality, antioxidant contents and activity, and inhibition of cell proliferation of strawberry fruit. Postharvest Biol Technol. 49(2), 201-209.

23. Clark R., Menary R., 1979. The importance of harvest date and plant density on the yield and quality of Tasmanian peppermint [Mentha piperita] oil. J Am Soc Hortic Sci. 104, 702-706.

24. Lima V.L., Mélo E.A., Maciel M.I.S., Prazeres F.G., Musser R.S., Lima D.E., 2005. Total phenolic and carotenoid contents in acerola genotypes harvested at three ripening stages. Food Chem. 90(4), 565-568.

25. Wagner G.J., 1979. Content and vacuole/extravacuole distribution of neutral sugars, free amino acids, and anthocyanin in protoplasts. Plant Physiol. 64(1), 88-93.

26. Arnon D.I., 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. Plant Physiol. 24(1), 1-15.

27. Doleh L., Hassanpour Asil M.A., Abdollahi H., 2010. Effective factors determining the commercial maturity of fruit in different pears. Iranian Horticultural Science. 41(2), 189-196.

28. Ding B., Shi G., Xu Y., Hu J., Xu Q., 2007. Physiological responses of Alternanthera philoxeroides (Mart.) Griseb leaves to cadmium stress. Environ Pollut. 147(3), 800-803.

29. Martínez G.A., Civello P.M., Chaves A.R., Añón M.A.C., 2001. Characterization of peroxidase-mediated chlorophyll bleaching in strawberry fruit. Phytochemistry. 58(3), 379-387.

30. Costa M.L., Civello P.M., Chaves A.R., Martínez G.A., 2005. Effect of ethephon and 6-benzylaminopurine on chlorophyll degrading enzymes and a peroxidase-linked chlorophyll bleaching during post-harvest senescence of broccoli (Brassica oleracea L.) at 20 C. Postharvest Biol Technol. 35(2), 191-199.

31. Serrano M., Martinez-Romero D., Guillen F., Castillo S., Valero D., 2006. Maintenance of broccoli quality and functional properties during cold storage as affected by modified atmosphere packaging. Postharvest Biol Technol. 39(1), 61-68.

32. Koca N., Karadeniz F., Burdurlu H.S., 2007. Effect of pH on chlorophyll degradation and colour loss in blanched green peas. Food Chem. 100(2), 609-615.

33. Salvador M., Aranda F., Fregapane G., 2001. Influence of fruit ripening on 'Cornicabra'virgin olive oil quality A study of four successive crop seasons. Food Chem. 73(1), 45-53.

34. Mashayekhi K., Sadeghi H., Akbarpur V., Atashi S., Qasemi Y., Mousavi Zadeh S.J., 2014. Changes in Carbohydrates of leaf and fruits of peach cv. Redgold during the growing season in Kerman weather conditions. Journal of Horticultural Science. 28(1), 1-9.

35. Ding C.K., Chachin K., Hamauzu Y., Ueda Y., Imahori Y., 1998. Effects of storage temperatures on physiology and quality of loquat fruit. Postharvest Biol Technol. 14(3), 309-315.

36. Rivera Pastrana D.M., Yahia E.M., González Aguilar G.A., 2010. Phenolic and carotenoid profiles of papaya fruit (*Carica papaya* L.) and their contents under low temperature storage. J Sci Food Agric. 90(14), 2358-2365.

37. Roca M., Mínguez-Mosquera M.I., 2001. Changes in chloroplast pigments of olive varieties during fruit ripening. J Agric Food Chem. 49(2), 832-839.

38. Chandrasekhar J., Madhusudhan M., Raghavarao K., 2012. Extraction of anthocyanins from red cabbage and purification using adsorption. Food and bioproducts processing. 90(4), 615-623.

39. Arvanitoyannis I., Mavromatis A., 2009. Banana cultivars, cultivation practices, and physicochemical properties. Crit Rev Food Sci Nutr. 49(2), 113-135.

40. Shoja A., Ghasem Nejad M., Mortazavi N., 2011. Changes in antioxidant capacity and quality after harvest of Thomson and blood orange juice during storage. Journal of Horticultural Science. 25(2), 147-155.

41. Bureau S., Renard C.M., Reich M., Ginies C., Audergon J.M., 2009. Change in anthocyanin concentrations in red apricot fruits during ripening. LWT-Food Sci Technol. 42(1), 372-377.

42. Nergiz C., Engez Y., 2000. Compositional variation of olive fruit during ripening. Food Chem. 69(1), 55-59.

43. Cabrita L., Fossen T., Andersen Ø.M., 2000. Colour and stability of the six common anthocyanidin 3-glucosides in aqueous solutions. Food Chem. 68(1), 101-107.

44. Kulkarni A.P., Aradhya S.M., 2005. Chemical changes and antioxidant activity in pomegranate arils during fruit development. Food Chem. 93(2), 319-324.

45. Rapisarda P., Bianco M.L., Pannuzzo P., Timpanaro N., 2008. Effect of cold storage on vitamin C, phenolics and antioxidant activity of five orange genotypes [*Citrus sinensis* (L.) Osbeck]. Postharvest Biol Technol. 49(3), 348-354.