Phytochemical Attributes of Some Dried Fig (*Ficus carica* L.) Fruit Cultivars Grown in Iran

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Summary

In the present study, total phenolic, total flavonoids, total anthocyanins, total antioxidant capacity, total soluble solids, colour parameters (such as L*, a*, b*, C*, and H°) and phenolic compounds, including catechin, total catechin, quercetin-3-glucoside, total quercetin, and chlorogenic acid of nine dried fig fruit cultivars in Fars province, Iran, were studied since only limited information on that topic is available in the literature. Results showed that the total phenolic content in 'Khafrak' cultivar was significantly higher than other examined cultivars. Regarding to the values of total antioxidant capacity, there were no statistically significant differences among the majority of cultivars except between 'Khafrak' and 'Rowno'. Except for 'Khafrak' and 'Rowno', TF content in 'Sigoto' was significantly higher than the other examined cultivars. Anthocyanin content in all cultivars was negligible and it was not detected in some cultivars. Based on colorimetric results, the lightest skin color was observed in 'Shahanjir', while the darker color was in 'Seyah'. Significant differences were determined among the cultivars with respect to the distribution of phenolic compounds. Catechin and total quercetin contents in 'Matti' were significantly higher than the other examined cultivars. Results suggest that chlorogenic acid played a trifling role in determination of antioxidant capacity of the fruits. In addition, the cluster analysis based on Euclidean distance with Unweighted pair-group method using arithmetic average (UPGMA) method separated the cultivars into three main groups.

Key words

dried fig; phenolic compounds; antioxidants; flavonoids

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Received: November 2, 2016 | Accepted: February 20, 2017

ACKNOWLEDGEMENTS
The authors would like to thank the research section of the University of Guilan for their help..

Introduction

Fig, a deciduous tree belonging to the Moraceae family, is an important fruit worldwide for dry and fresh consumption. It is one of the first fruit trees that has been cultivated by humans, and mentioned in the holy Quran, Christian bible, and the Hebrew (Flaishman et al., 2008a). Dried figs are a superior source of vitamins, amino acids, minerals, crude fibers (5.8%, w/w), and phenolic compounds (Chang et al., 2016; Flaishman et al., 2008; Solomon et al., 2006; Veberic et al., 2008). On a weight basis, dried figs contain one of the highest concentrations of polyphenols among the commonly consumed foods and beverages (Kamiloglu and Capanoglu, 2013; Vinson, 1999; Vinson et al., 2005). The amount of total phenolic content in dried fruits (mg GAE/g) has been reported in accordance with prunes > raisins > figs > dates (Chang et al., 2016). Dried figs are an excellent source of flavonoids and polyphenols including gallic acid, syringicacid, (-)-epicatechin, and rutin (Kadam et al., 2011; Vinson, 1999). Phenolic compounds occur in all fruits as a diverse group of secondary metabolites (Kamiloglu and Capanoglu, 2015; Oliveira et al., 2009). Fig is naturally rich in many health benefiting phyto-nutrients, antioxidants, and vitamins (Debib et al., 2014; Solomon et al., 2006). Phenolic substances are important constituents of fruit quality because of their sensory properties (flavor and colour) (Serrano et al., 2010; Vermerris and Nicholson, 2006). Moreover, polyphenols inhibit lipid auto-oxidation by acting as radical scavengers, and consequently are important antioxidants that protect the body against reactive oxygen species (ROS) (du Toit et al., 2001; Navarro et al., 2006; Silva et al., 2004). Flavonoids are a large family of polyphenolic compounds synthesized by plants. The flavones and catechins are the most powerful flavonoids for protecting the body against the propagation of the oxidative chains (Tapas et al., 2008). Altogether, these polyphenolic compounds in dried figs help scavenging harmful oxygen derived from free radicals of body cells, and thereby, protect us from cancers, diabetes, cardiovascular problems, degenerative diseases, and infections (Chang et al., 2016; Debib et al., 2014; Jasmine et al., 2015; Li et al., 2013; Tomás-Barberán and Andres-Lacueva, 2012). Selected fig cultivars in this study are potentially valuable gene pools that could be used for breeding of cultivars with enhanced health properties. Despite the importance of polyphenolics and their potential antioxidant activities, unfortunately, up to date, data on antioxidant properties and phenolic compounds from Iranian dried fig fruits are scarce. Therefore, the aim of this study was to characterize some of the antioxidant properties and phenolic compounds in 9 selected fig cultivars from the Fars province of Iran. Total phenolic, total flavonoids, total anthocyanins, total antioxidant capacity, total soluble solids, colour parameters, and phenolic compounds of these fig cultivars were determined.

Material and methods

Plant material and fruit extraction

Dried fig fruits were collected during 2012 in Fars province, which is located in the south-west of Iran. The examined cultivars were the following: 'Sigoto', 'Khafrak', 'Rowno', 'Shahanjir', 'Atabaki', 'Kashki', 'Matti', 'Manbili', and 'Seyah'. Fruits were harvested at their fully mature stage. For the phytochemical analyses 20 g of fig fruits from each treatment were homogenized in a blender at room temperature. All samples were screened for their total anthocyanins, total phenolic contents, total flavonoids, phenolic compounds (catechin, total catechin, quercetin-3-glucoside, total quercetin, and chlorogenic acid), and total antioxidant capacity following a single extraction procedure. For this procedure, 2 g aliquots of each homogenate were transferred to polypropylene tubes and extracted with 4 mL of extraction buffer containing methanol and acetic acid (85:15 v/v) for 24 h at room temperature. The upper solution was centrifuged at 10000 rpm, and the supernatant fluid was decanted (Bakhshi and Arakawa, 2006).

Total phenolic (TP)

Total phenolic (TP) were analyzed spectrophotometrically using the modified Folin–Ciocalteu colorimetric method with some modifications as described by Singleton et al. (1999). Values of TP were estimated by comparing the absorbance of each sample with a standard response curve generated using gallic acid. Results are expressed as mg gallic acid equivalents (GAE) on a dry weight (DW) basis (mg GAE 100 g^{-1} DW). Data are reported as means ± SE for three replications.

Total flavonoids (TF)

The total flavonoids (TF) content was determined colorimetrically as described previously by Du et al. (2009) at 506 nm. The flavonoid content was determined by a (+)-catechin standard curve and expressed as mean of milligrams of (+)-catechin equivalent (CE) per 100 g of DW of fruit. Data are reported as means ± SE for three replications.

Total anthocyanins (TA)

Modified pH differential method of Zhishen et al. (1999) was used for assessment of total anthocyanins (TA). Absorbance was measured at 520 and 700 nm and expressed as milligrams of cyanidin-3-glucoside (molar extinction coefficient of 26900 $L{*}m^{-1}{*}mol^{-1}$ and molecular weight of 449.2) per 100 g of DW of fruit. The difference in absorbance of the anthocyanins solutions between these two pH values permits an accurate and rapid determination of TA content in the sample matrix. Data are reported as means ± SE for three replications.

Total Antioxidant capacity (TAC) determined by DPPH

DPPH (1, 1-diphenyl-2-picrylhydrazyl) is a well-known radical and a trap (scavenger) for other radicals. The ability to scavenge DPPH free radicals was determined based on the method of Du et al. (2009) with minor modifications. Briefly, 50 µL of different Fig extracts were added to 950 µL of a 6.25×10^{-5} M solution of DPPH in methanol. A control sample containing the same volume of solvent in place of extract was used to measure the maximum DPPH absorbance. After the reaction was allowed to take place in the dark for 30 min, the absorbance at 517 nm was recorded to determine the concentration of remaining DPPH. The percentage of DPPH, which was scavenged (% DPPHsc), was calculated using:

$$\% \text{ DPPHsc} = [(\text{Acont} - \text{Asamp}) / \text{Acont}] \times 100$$

where Acont is the absorbance of the control, and Asamp is the absorbance of the sample. Data are reported as means ± SE for three replications.

HPLC analysis of phenolic compounds

Phenolic compounds were analyzed by high-performance liquid chromatography (HPLC) as described by Bakhshi and Arakawa (2006). Fifty microliters of the filtered sample (0.45 µm pore size membrane filter) were injected in HPLC (Waters, 1525, Milford, USA) equipped with a UV-Visible detector (Waters Dual λ Absorbance 2487), C18 column: Waters Symmetry C18 5µm 4.6×150 mm (Waters, Dublin, Ireland), at 280, 320 and 350 nm. The phenolic compounds were identified by comparing their UV spectra and retention times with those of the corresponding standards and by the spiking of samples with the appropriate standard. Catechin and chlorogenic acid standards purchased from Sigma-Aldrich (Canada Ltd) and quercetin 3-galactoside from extrasynthase, France. All samples were analyzed in triplicate.

Fruit skin colour

Fruit skin colour was measured using a colorimeter (Chroma Meter CR-400, Minolta, Japan). Colour parameters were expressed as tristimulus colourimetric measurements, that is, L*, a*, b*, C, and H°. Lower L* values indicate darkness, and higher L* values indicate lightness. Negative a* values indicate green colour, and positive a* values indicate red colour. Positive b* values indicate a more yellow colour, and negative b* values indicate blue colour. The chroma (C) value, calculated as $[C = (a^{*2} + b^{*2})^{1/2}]$, indicates colour intensity or saturation. Hue angle, a parameter that has been shown to be effective in predicting visual colour appearance, was calculated using the formula $[H = \tan^{-1}(b^*/a^*)]$, where 0° or 360° = red-purple, 90° = yellow, 180° = green, and 270° = blue.

Total soluble solids (TSS)

Percentage of TSS was determined by a digital refractometer (CETI-Belgium) at 20°C. Tests were carried out for three replications.

Statistical analysis

The results obtained were expressed as means ± SE (standard error). Analysis of variance was performed by GLM procedures (SAS 9.1 for Windows). Significant differences were calculated according to Duncan's multiple range tests. The p value < 0.05 was considered statistically significant. Correlation coefficients and their levels of significance were calculated using PROC CORR. Similarity matrix based on Euclidean distance was constructed from phytochemical data. It was used for the cluster analysis and construction of dendrogram through Unweighted pair-group method using arithmetic average (UPGMA), performed by the PAST (Version 1.97) software package. The cophenetic correlation coefficient was calculated to check the fitness of the cluster.

Results and discussion

Antioxidant properties (TP, TF, TA, and TAC), TSS, and skin colour of dried figs

Evaluated cultivars exhibited great diversity in levels of TP, TF, and TAC (Table 1). The amount of TP ranged from 1120 to 2681.8 mg GAE 100 g^{-1} DW, with an average of 1785 mg GAE 100 g^{-1} DW; the amount of TF ranged from 685.4 to 1171 mg GAE100 g^{-1} DW, with an average of 908.1 mg CE 100 g^{-1} DW; the amount of TA ranged from 0.8 to 4.44 mg Cyd-3-glu 100 g^{-1} DW. The amount of TAC ranged from 37.7 to 70.2 DPPH %, with an average of 57.07 DPPH %; the amount of TSS ranged from 60 to 84.8 °Brix, with an average of 68.62 °Brix (Table 1). The TP content in 'Khafrak' cultivar was significantly higher than the other examined cultivars (2681.8 mg GAE 100 g^{-1} DW). Regarding to the values of total antioxidant capacity, there were no statistically significant differences among the majority of cultivars except between 'Khafrak' and 'Rowno'. The lowest TP and TAC contents were found in the 'Rowno' cultivar (1120 mg GAE 100 g^{-1} DW and 37.7 DPPH %). Except for 'Khafrak' and 'Rowno', TF content in 'Sigoto' was significantly higher than the other examined cultivars. The highest and lowest amount of TF belonged to 'Sigoto' and 'Seyah'cultivars, respectively (1171 and 685.4 mg CE 100 g^{-1} DW). Although 'Seyah' contained the lowest content of TF, there was no significant difference among 'Seyah', 'Manbili', 'Matti', and 'Kashki'. Çalişkan and Aytekin Polat (2011) during their investigations on some fig cultivars belonged to the Smyrna, Common, and San Pedro groups reported that the amount of total phenol in their fruit ranged from 28.6 to 211.9 mg GAE 100 g^{-1} FW. Kamiloglu and Capanoglu (2015) reported that the TP contents of two Turkish dried fig varieties of Sarilop and Bursa Siyahi were 193 and 417 mg GAE/100 g DW, respectively. In our study, the results belonging to the total flavonoids obtained from Iranian dried figs were quite higher than those of other studies on dried fig cultivars (Bey and Louaileche, 2015; Debib et al., 2014; Hoxha et al., 2015; Kamiloglu and Capanoglu,

Table 1. Antioxidant properties of different Iranian dried figs

Cultivar	Total flavonoid (mg CE/100 g DW)	Total phenolic (mg GAE/100 g DW)	TSS (°Brix)	Total antioxidant capacity (DPPH %)	Total anthocyanin (mg Cyd-3-glu/100 g DW)
'Sigoto'	1171 ± 106a	1807.5 ± 12cd	61.8 ± 4.9b	61.37 ± 2.3ab	3.26 ± 0.56a
'Khafrak'	1160 ± 23a	2681.8 ± 72a	60.0 ± 7.5b	70.02 ± 1.5a	nd
'Rowno'	1058.7 ± 4ab	1120 ± 22.4f	64.6 ± 3.5b	37.70 ± 1.8c	nd
'Shahanjir'	975.4 ± 92b	1944.3 ± 57bc	73.4 ± 2.3ab	50.13 ± 8.8bc	nd
'Atabaki'	937.3 ± 26b	1662.7 ± 36d	68.4 ± 3.3b	64.24 ± 1.3ab	nd
'Kashki'	765.4 ± 54c	2121.2 ± 193b	67.2 ± 0.91b	65.39 ± 4.1ab	0.8b ± 0.37bc
'Matti'	724.3 ± 10.2c	1409.0 ± 48e	67.2 ± 4.8b	54.06 ± 9.6ab	4.44 ± 0.07a
'Manbili'	695.4 ± 36c	1582.5d ± 110e	70.2 ± 3b	53.48 ± 1.8b	4.1 ± 0.92a
'Seyah'	685.4 ± 34c	1735.9 ± 52cd	84.8 ± 6.8a	57.27 ± 2ab	1.33 ± 0.31b

Mean in each column followed by the same letters are not significantly different at P < 0.05 according to Duncan's multiple range test. Data expressed as means ± SE

Table 2. Colour parameters of different Iranian dried figs

Cultivar	L*	a*	b*	C	H°
'Sigoto'	66.94 ± 3.4ab	10.91 ± 1.2bc	45.70 ± 0.14bc	46.98 ± 0.44cd	76.57 ± 2.2a
'Khafrak'	68.07 ± 4.6ab	9.07 ± 1.0bc	87.52 ± 1.2a	87.99 ± 1.2a	84.09 ± 1.4a
'Rowno'	69.93 ± 4.8a	7.15 ± 1.5c	54.58 ± 0.16ab	55.09 ± 0.28bc	82.16 ± 2.5a
'Shahanjir'	72.07 ± 3.8a	7.67 ± 1.3c	61.04 ± 0.61ab	61.52 ± 0.9ab	82.84 ± 1.8a
'Atabaki'	54.50 ± 7.6b	18.34 ± 1.8a	35.99 ± 5.6c	40.39 ± 3.4d	63 ± 11.5bc
'Kashki'	61.44 ± 6.02ab	13.01 ± 1.6ab	40.15 ± 4.0c	42.24 ± 2.8d	71.94 ± 7.0ab
'Matti'	66.74 ± 3.05ab	10.67 ± 1.0bc	83.98 ± 1.4a	84.66 ± 1.2a	82.76 ± 1.8a
'Manbili'	65.39 ± 2.06ab	9.63 ± 0.6bc	86.55 ± 1.1a	87.08 ± 1.1a	83.65 ± 1.1a
'Seyah'	33.23 ± 1.3c	15.93 ±1.9ab	19.53 ± 1.7d	25.21 ± 2.5e	50.79 ± 1.9c

Mean in each column followed by the same letters are not significantly different at $P < 0.05$ according to Duncan's multiple range test. Data expressed as means ± SE; L*, a*, b*, C, and H° are color parameters: lightness/darkness, red/green, blue/yellow, chroma, and hue angle, respectively.

2015). Differences in total phenolic and flavonoids in figs may be attributed to differences in the region of cultivation and the type of cultivar used (Hoxha et al., 2015).

The evaluated cultivars had a low amount of TA, and the highest amount of it belonged to 'Matti' cultivar (4.44 mg Cyd-3-glu 100 g^{-1} DW) (Table 1). Moreover, TA was not detected in some cultivars including 'Khafrak', 'Rowno', 'Shahanjir' and 'Atabaki'. The TA contents were significantly higher in 'Matti', 'manbili' and 'Sigoto' than the other cultivars. Our results were in parallel with Hoxha et al. (2015) who showed a great diversity in TA contents of Albanian dried fig (0-5.32 mg Cyd-3-glu/100 g DW). Also, Solomon et al. (2006) during their investigation on some fig varieties showed that anthocyanins were not detected in 'Kadota' and 'Burnswick' varieties. For better understanding of the existence of anthocyanin in fig cultivars, the measurement of ceyanidin-3-glucoside, ceyanidin-3-rutinoside, and cyanidin-3-rhamnoglucoside with HPLC analyses are needed. Differences in anthocyanin contents of the studied cultivars may result from differential expression of genes encoding anthocyanin production in fruits.

TSS contents of our study (dried figs) were much higher than those of other studies on Common fig fruit cultivars (Vallejo et al., 2012). These cultivars (dried figs) have a high amount of TSS. 'Seyah' cultivar, which is characterized by dark black fruit skin, contained the highest amount of TSS (84.8 °Brix) among the tested cultivars. There were no significant differences between 'Shahanjir' and 'Seyha', but TSS content in 'Seyah' was significantly higher as compared to that in dried figs. No much differences among the majority of cultivars with respect to the levels of TSS revealed that the most studied dried figs had similar TSS and this parameter was not much variable in Iranian dried figs. The lowest TSS content was found in 'Khafrak', which had the highest amount of TP and TAC.

Although purple, yellow, and dark colours were observed among the examined cultivars, the light and yellow colours were observed among the majority of them (Table 2). L^* value was significantly lower in 'Seyah' than the other cultivars. Values of L*= 72.07 and hue angles of (H°) = 82.84 were found for 'Shahanjir', indicating a light color, whereas the dark colour of 'Seyah' was characterized by values of L*= 33.23 and H° = 50.79. In general, 'Seyah' fruits appeared to be darker than the other cultivars. 'khafrak', 'Manbili', and 'Matti' fruits showed higher colour intensity (higher C values) than other cultivars. The value of C in 'Seyah' was significantly lower than the other examined cultivars. 'Atabaki' cultivar had the highest b^* value (18.34), indicating red-purple color. However, 'Shahanjir' fruits appeared to be much brighter (Higher L^* values) and more vivid (higher C) than the other examined cultivar (Table 2). The skin thickness in all tested cultivars was not considerable and probably played it a trifling role in composing of phenolic compounds and antioxidant properties, whereas the fruit pulp had the uttermost share in antioxidant properties. Results indicated that 'Khafrak' with high amount of TF had the lowest amount of TSS. Also, 'Seyah' with the highest amount of TSS had the lowest amount of TF (Table 1). So we can conclude that in some of these figs the fruits containing higher amounts of TF have lower amounts of TSS, and as TSS increases, the colour of fruit skin will decrease. 'Sigoto', with light skin colour, had the highest amount of TF. Also, 'Khafrak' cultivar contained the highest amount of TP and TAC had a light colour. So, our results indicated in some cultivars of dried fig the fruits with highest amount of phenolic substances and antioxidant capacity have light skin colour. This is presumably for the fact that these cultivars have the much thin skin layer, and the majority amount of phenolic compounds and antioxidant constituent substances assemble in their pulp. Therefore, the dark or red colour of the skin does not imply the existence of high phenolic compounds and antioxidant properties in the fruits. Since the skin has a thin thickness, the fruit pulp is the one which determines the amount of phenolic compounds and antioxidant properties. Çalişkan and Aytekin Polat (2011) and Solomon et al. (2006) during their investigations on some fig cultivars belonged to the Common group reported that the fig cultivars with green or yellow skin colour had the least amount of TP, TA and TAC, and figs with dark blue or red colours have the highest amount of TP, TA and TAC. Also, our results are in contrast with Debib et al. (2013) and Bey and Louaileche (2015) who found that the dark dried fig contains a higher content of phenolics than the green and yellow ones.

Phenolic compounds

The results of phenolic compounds assays showed that the amount of catechin ranged from 1.25 to 4.77 mg 100 g^{-1} DW, with an average of 2.62 mg 100 g^{-1} DW; the amount of total catechin ranged from 4.34 to 14.51 mg 100 g^{-1} DW, with an average of 7.52 mg 100 g^{-1} DW; the amount of quercetin-3-glucoside ranged from 0.12 to 1.27 mg 100 g^{-1} DW, with an average of 0.47 mg 100 g^{-1} DW; the amount of total quercetin ranged from 3.06

Table 3. Total and individual phenolic compounds of Iranian dried figs (mg/100 g DW).

Cultivar	Catechin	Total catechin	Quercetin-3-glucoside	Total quercetin	Chlorogenic acid
'Sigoto'	3.57 ± 0.003b	8.39 ± 0.006c	0.33 ± 0.003b	5.51 ± 0.003bcd	0.23 ± 0.001d
'Khafrak'	1.41 ± 0.003cd	5.36 ± 0.006d	0.34 ± 0b	4.07 ± 0.006cd	0.25 ± 0.003c
'Rowno'	1.73 ± 0.006cd	5.27 ± 00.003d	0.30 ± 0.003b	5.83 ± 0.003bcd	0.55 ± 0.001a
'Shahanjir'	1.36 ± 0.003d	4.34 ± 0.006d	1.27 ± 0.54a	3.06 ± 0.003d	0.22 ± 0.002e
'Atabaki'	3.057 ± 0.33b	14.51 ± 1.6a	0.34 ± 0.01b	11.37 ± 3.07b	0.063 ± 0.001h
'Kashki'	1.25 ± 0.25d	3.40 ± 0.83d	0.12 ± 0.03b	1.36 ± 0.93d	0.25 ± 0.004c
'Matti'	4.77 ± 0.34a	9.41 ± 0.06c	0.94 ± 0.03a	35.18 ± 0.003a	0.38 ± 0.001b
'Manbili'	1.26 ± 0.09d	5.25 ± 0.93d	0.35 ± 0.02b	10.35 ± 1.35bc	0.19 ± 0.002f
'Seyah'	1.95 ± 0.003c	11.49 ± 0.006b	0.26 ± 0.003b	7.24 ± 0.003bcd	0.15 ± 0.001g

Mean in each column followed by the same letters are not significantly different at $P < 0.05$ according to Duncan's multiple range test. Data expressed as means ± SE.

to 35.18 mg 100 g^{-1} DW, with an average of 9.33 mg 100 g^{-1} DW; the amount of chlorogenic acid ranged from 0.063 to 0.55 mg 100 g^{-1} DW, with an average of 0.25 mg 100 g^{-1} DW (Table 3). Catechin and total quercetin contents in 'Matti' were significantly higher than the other examined cultivars. There were no significant differences among 'Kashki', 'Shahanjir', 'Rowno', 'Khafrak', 'Sigoto', and 'Seyah' with respect to distribution of total quercetin. The amount of total catechin in 'Atabaki' was significantly higher compared to that in dried figs. Although 'Kashki' had the lowest amount of catechin and total catechin among the tested cultivars, there were no significant differences among 'Kashki', 'Shahanjir', 'Rowno', and 'Khafrak'. Quercetin-3-glucoside levels were significantly higher in 'Shahanjir' and 'Matti' than that in the other cultivars, while there were no significant differences among the other cultivars. There were statistically significant differences among all cultivars with respect to the contents of chlorogenic acid and its level in 'Rowno' was markedly higher than that in other examined cultivars. Although 'Rowno' had the highest amount of chlorogenic acid, the lowest amounts of TP and TAC were found in it. Therefore, it seems that chlorogenic acid played a trifling role in determination of antioxidant capacity of the fruits. There are no reports about amounts of total catechin and total quercetin in dried fig fruits in the literature. Vallejo et al. (2012) during their investigations on some fig cultivars belonged to the dried figs reported that the amount of quercetin-3-glucoside in their fruit ranged from 0.7 to 2.5 mg 100 g^{-1} DW, which was higher than the amount of quercetin-3-glucoside in our fig samples. Kamiloglu and Capanoglu (2015) reported that the catechin contents of two Turkish dried fig varieties of 'Sarilop' and 'Bursa Siyahi' were 1.5 and 2.5 mg/100 g DW, which were lower than catechin in some our fig cultivars including 'Matti', 'Sigoto' and 'Atabaki'. On the other hand, the amount of chlorogenic acid in our fig fruit cultivars was lower than 'Sarilop' and 'Bursa Siyahi' varieties. Significant differences were determined among the cultivars with respect to the distribution of phenolic compounds. These differences are possibly attributed to cultivar-specific characteristics, cultural practices, as well as climate and soil characteristics.

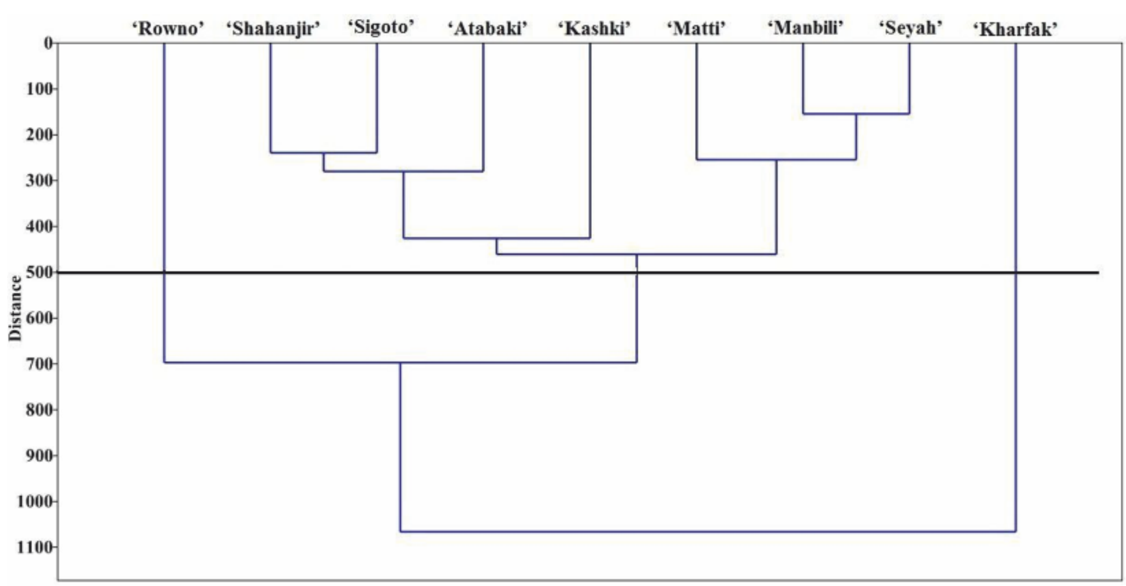

Figure 1. UPGMA dendrogram of phytochemical data based on Euclidean distance in 9 Iranian dried fig cultivars.

Cluster analysis

Cluster analysis was performed to develop a UPGMA dendrogram based on phytochemical data. Dried fig cultivars were divided into three main groups based on the values of the Euclidean distance. Groups 1 to 3 consisted of 1, 7 and 1 cultivars, respectively (Fig. 1). The cophenetic correlation coefficient (r = 0.84) was calculated to evaluate the usefulness of the UPGMA method in clustering plant accessions. The similarity matrix based on Euclidean distance showed the lowest distance between 'Manbili' and 'Seyah' and the highest one between 'Rowno' and 'Khafrak'.

Conclusion

Selected fig cultivars in this study had ralatively high levels of TP (1120-2681.8 mg GAE/100 g DW), TF (685.4-1171 mg GAE/100 g DW), TSS (60-84.8 °Brix), and useful phenolic compounds. 'Shahanjir' fruits appeared to be much brighter and more vivid than the other examined cultivar. The TA contents were significantly higher in 'Matti', 'manbili' and 'Sigoto' than the other cultivars. Total catechin content in 'Atabaki' was significantly higher as compared to that in dried figs. Quercetin-3-glucoside levels were significantly higher in 'Shahanjir' and 'Matti' than that in the other cultivars. The cluster analysis showed the lowest distance between 'Manbili' and 'Seyah' and the highest one between 'Rowno' and 'Khafrak'. Overall, the present study shows that the dried figs have a high concentration of polyphenols and can be considered as a good source of natural antioxidants for use as functional food ingredients controlling diseases caused by oxidative stress. These results could also be considerable for the efficient use of these cultivars as breeding materials in advanced biotechnology studies or future traditional breeding.

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