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RESEARCH

The Phenolic Composition and Antioxidant Properties of Figs (*Ficus carica* L.) Grown in the Black Sea Region

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Abstract

This study compared the phenolic composition and antioxidant properties of three varieties of fig fruits (*Ficus carica* L) from the Eastern Black Sea region of Türkiye. Total polyphenol content (TPC), total flavonoid content (TFC), and phenolic compositions were analyzed in green, purple, and dark purple species. The mean TPC value was 42.10 ± 5.71 mg GAE/100 g FW, ranging from 35.98 to 47.30 mg GAE/100 g FW, and was highest in the dark purple species. The mean TFC value was 1.27 ± 0.93 mg QUE/100 FW g, ranging between 0.35 and 2.21 mg QUE/100 FW g, and was highest in the purple species. The samples' total antioxidant capacity was measured based on ferric reducing/antioxidant power (FRAP), the values ranging from 151.98 to 372.97 µmol $FeSO_4.7H_2O$/100 g FW, with an average value of 239.64 µmol $FeSO_4.7H_2O$/100 g FW, being highest in the dark purple species. The 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity of the fruits was expressed as SC_{50} (mg/mL), and the values ranged from 10.04 to 42.42 mg/mL, being highest in the purple species. The phenolic composition was analyzed using HPLC-PDA according to the method in which 25 phenolic standards were used. Chlorogenic acid and *t*-cinnamic acid were the most common phenolic compounds, with rutin, chrysin, apigenin, and luteolin being detected at different amounts. In conclusion, the purple species contained the highest flavonoid content, was rich in apigenin, luteolin, and chrysin, and possessed the highest DPPH radical scavenging activity.

Keywords Fig fruits · *Ficus carica* · Phenolic · Antioxidant

Introduction

Fruits are rich in bioactive compounds, including phenolics, which exhibit strong antioxidant activity. Consuming fruits and their phenolic-rich extracts reduces the risk of chronic disease. Understanding the phenolic composition and antioxidant activity of berries is crucial for the development of functional foods and nutraceuticals that promote human health [1, 2].

Figs are represented by the species *Ficus carica* from the genus *Ficus* of the family Moraceae and order Urticales. *Ficus carica*, consisting of 600 to 2000 different types, is primarily cultivated in hot and dry climates, such as those in the Middle East and Mediterranean region [3]. The most important fig species are Mission, Brown Türkiye, Kadota, Bursa siyahi, Sarilop, and Sarizeyek [4]. Türkiye is a major exporter of figs, which are grown mostly in the Black Sea, Marmara, Aegean, Mediterranean, Southeastern, and Central Anatolia regions. The country is home to two subspecies of *Ficus carica*, namely *F. carica* ssp. *carica* and *F. carica* ssp. *rupestris*. Figs are consumed fresh, dried, partially dried, or deep-frozen, and sun-drying accounts for 65% of fresh-weight production [5].

Figs have long been cultivated along the Mediterranean coast of Türkiye. However, with the exception of the areas of Bursa, Mersin (Mut), and Hatay, specialized orchards dedicated to fresh fig production are limited in the country. Nonetheless, the Black Sea region provides favorable conditions for fig cultivation. [6]. Uslu et al. (2022) identified fresh figs and one fig jam, selected from among 44 different types of figs grown in the Black Sea area, as promising genotypes based on the study objective [7]. Sezen et al. [8] found 50 wild fig accessions in Coruh Valley, a biodiversity hotspot with unique tree, leaf, and fruit features [8]. The figs from this region are known for their distinctive taste, texture,

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and aroma. Figs in the Black Sea region, figs are generally characterized by their small to medium size, tender and soft flesh, and sweet flavor. The Mediterranean diet, rich in natural antioxidants derived from vegetables and fruits such as figs and olives, has been associated with various health benefits, including the prevention of coronary heart disease and cancer [2]. Figs, both fresh and dried, are a significant component of the human diet due to their high levels of fiber, trace minerals, antioxidant polyphenols, proteins, sugars, and organic acids [4]. These antioxidant polyphenols, such as chlorogenic acid, quercetin, rutin, and epicatechin, are recognized for their antioxidant activity, which may reduce the risk of chronic diseases such as cardiovascular disease, cancer, and neurodegenerative disorders [9–12]. A previous study found that fig fruit extract possesses a high antioxidant capacity and immune-enhancing activities, scavenging radicals and increasing clearance rates in normal mice with water soluble polysaccharide. This suggests the potential for use as a functional food for preventing diseases caused by radical overproduction [13].

Limited data are available concerning the phenolic composition and antioxidant properties of figs grown in the Black Sea region, despite their widespread cultivation and use in traditional medicine [14]. While the Black Sea region's climate and soil conditions impact on crop growth and quality, investigating fig phenolic composition and antioxidant properties can reveal potential health benefits.

The purpose of this study was to investigate the phenolic composition and antioxidant properties of fig fruit grown in the Black Sea region of Türkiye. Understanding the specific phenolic compounds present in figs from this region, as well as their antioxidant activity, can provide valuable information in terms if the development of functional foods and nutraceuticals capable of improving human health.

Materials and Methods

Plant Materials

This study examined three local fig species (*Ficus carica* L.) from Trabzon, Türkiye, focusing on green, purple, and dark purple species. Ten fresh fruits were randomly collected from the north, south, east, and west sides of all trees during the peak harvest period for each fig species.

Fruit Extraction

The fresh fruits were first weighed and then completely crushed whole in a blender before being extracted with methanol. Specifically, 50 g of chopped fruit was mixed with 250 mL of 98% methanol and shaken for 24 h. After passing the mixture through Whatman No. 4 filter paper followed by Whatman No. 1 filter paper, the resulting extract was stored in a deep freeze (−18 °C) until needed.

Physico-Chemical Analysis

The total soluble solid content (TSS) was determined by measuring fresh fruit juice using a digital handheld refractometer, the result being displayed as a percentage value (Atago, Pr-32A, Japan). Titratable acidity (TA) in blender-shredded juice filtrate was measured following the methods of the Association of Official Analytical Chemists (Mettler–Toledo Inc., Columbus, OH, USA) using an automatic titrator [15, 16].

Total Phenolic Content

The Folin-Ciocalteu assay was used to assess the total phenolic content (TPC) of the methanolic fig extract [17]. A volume of 20 µL of the fig extract was mixed with 400 µL of 0.2 N Folin–Ciocalteu's reagent, and the resulting mixture was then diluted to 680 µL with distilled water. Next, 400 mL of Na_2CO_3 (7.5%) was added to the mixture, which was then incubated for an additional 2 h at room temperature. After a 4-minute incubation period, the absorbance of the mixture was measured at 760 nm using a Thermo Scientific Evolution TM 201 UV-VIS spectrophotometer from the USA. The TPC of the samples was determined as mg gallic acid equivalents (GAE) *per* 100 g FW sample. A standard curve of gallic acid standard was prepared in advance, ranging from 0.01 to 1.0 mg GAE/mL ($y = 4.4364x + 0.0335$, R^2:0.9983).

Total Flavonoid Content

A spectrophotometric test was used to determine the total flavonoid concentration (TFC) [18]. Briefly, to 25 µL of the extract were added 50 µL of 10% Al $(NO_3)_3$ and 50 µL of 1.0 M $NH_4.CH_3COO$. The mixture was then diluted to 3.0 mL with ethanol (99%) and incubated at 25 °C for 45 min. The absorbance was then measured at 415 nm. TFC was expressed as mg quercetin equivalent (QUE)/100 g FW sample using quercetin standards (from 0.031 to 0.5 mg QUE/g), with the line equation ($y = 5.30x + 0.044$, R^2:0,995).

Antioxidant Activities

The total antioxidant capacity of the methanolic extract was measured using the ferric reducing antioxidant power assay (FRAP) method [19]. Fresh FRAP reagent (ferric tripyridyltriazine (Fe-III-TPTZ)), $FeCl_3$, and acetate buffer solution in 40 mM HCl and 2.5 mL of 20 mM $FeCl_3.6H_2O$ solution were added to a test tube. Three milliliters of the

FRAP reagent and 100 µL of sample were then mixed and incubated for 4 min at 37 °C. The absorbance was then read at 595 nm. Different concentrations of $FeSO_4.7H_2O$ (from 1000 to 31.25 µmol/mL) were used to prepare the standard curve. The results were expressed as µmol $FeSO_4.7H_2O$ equivalents/100 g FW sample using the curve with the line equation ($y = 0.0006x + 0.0037$, R^2:0,997).

The free radical scavenging activity of the extract was measured using the method described by Molyneux [20]. Briefly, 750 µL of the extract was mixed with 750 µL of DPPH radical solution. This mixture was then kept in the dark for 45 minutes at 25 °C, and the absorbance was read at 517 nm. The result was calculated as SC_{50}, lower SC_{50} values indicating higher radical scavenging activity.

Analyses of Phenolic Compositions (HPLC-PDA)

The phenolic composition of the methanolic extract was determined using the reverse phase high-performance liquid chromatographic method (RP-HPLC) (Shimadzu Corporation LC 20AT, Japan) with PDA and 25 phenolic standards. The HPLC-PDA method was validated as described in our previous study [21]. A gradient program was applied with 70–30% acetonitrile-ultrapure water and 2% acetic acid-ultrapure water as the mobile phase. This analysis was performed at a flow rate of 20 ml, an oven temperature of 30 °C, and a flow rate of 1.0 mL/min. Liquid-liquid extraction was used to enrich the sample prior to HPLC-PDA analysis of the phenolic component. First, the methanolic extracts were evaporated (IKA-Werke, Staufen, Germany), and the residue was dissolved in distilled water at pH 2. The pH of the aqueous extracts was adjusted to 2 with diluted HCl. The organic phases were then combined after three extractions with diethyl ether and ethyl acetate. The organic phase was collected in a flask, and the solvent was evaporated. After the residue had been dissolved in methanol, it was passed through a 0.45 µm filter (RC membrane, 0.45 µm) and given to the device for phenolic analysis. The results were calculated as µg/100 g of sample.

Statistical Analysis

Three replicate experiments were conducted, and the resulting data were analyzed on SPSS version 20.0 software (SPSS Inc., Chicago, IL, USA). One-way ANOVA and Tukey's test were used to compare TPC, TFC, FRAP, and DPPH parameters among the different species.

Results and Discussions

Figus spp. are grown in many regions of Anatolia, where all four seasons are intensely experienced. The subspecies of these fruits, which have not to date been classified, have been categorized as either wild (*Ficus carica erinosyce*) or cultivated (*Ficus carica domestica*), although many species are found in Anatolia [6, 7, 22]. This study investigated three fig species from Trabzon, one of the Eastern Black Sea provinces of Türkiye (Fig. 1). The TSS and TA of the fig fruits ranged from 18.59 to 21.62% and 0.178 to 0.184%, respectively (Table 1). Comparable ranges of TSS (15-28%) and TA (0.09-1.04%) have been reported for fig cultivars from various parts of the world [15]. The interaction between TSS and TA, which is highly dependent on the maturity stage of fresh produce, determines the taste and flavor of any fresh product. The highest TSS:TA ratio value in the present study (126.94) was observed in purple fig fruits (Table 1).

Total Polyphenolic Content and Antioxidants Activity

This preliminary study compared the TPC and antioxidant properties of the three fig species grown in the region for the first time in the literature. Methanolic extracts were used instead of water because methanol has a lower polarity than water and is also a good solvent for several polyphenols present in fruits [23, 24]. The total phenolic and flavonoid contents and antioxidant results were expressed on a

Fig. 1 The green, purple and dark purple (*Ficus carica* L.) species used in the study

Table 1 Physico-chemical analysis of fig fruits

	Green	Purple	Dark purple
TSS (%)	20.76 ± 1.52[a]	21.62 ± 2.40[a]	18.59 ± 1.38[b]
TA (%)	0.184 ± 0.04[a]	0.178 ± 0.03[a]	0.181 ± 0.03[a]
TSS:TA	122.42 ± 41.51[a]	126.94 ± 30.92[a]	107.86 ± 27.80[a]

Different letters (a-b) in the same lines are significantly different at the 5% level ($p < 0.05$)

fresh weight (FW) basis (Table 2). The total amount of polyphenol substance varied between 35.98 and 47.30 mg GAE/100 g FW, with a mean value of 41.76 ± 5.07 mg GAE/100 g FW. The TPC values of all three genotypes differed, the highest value being observed in the dark purple species. A large screening study of Mediterranean region fig fruit species from the province of Hatay reported a mean TPC value of 61.80 ± 20.70 mg GAE/ 100 g FW, ranging widely from 28.60 to 211.90 mg GAE/100 g FW [25]. The TPC values in the present study are consistent with that research, and varied depending on the fig type. In a study conducted in the Mediterranean region and involving Algerian *Ficus carica* species, TPC values were reported in the range of 42 mg GAE/100 g FW to 58 mg GAE/100 g FW, similar to our own results [26]. In the present study, the highest TPC was observed in dark purple species and the lowest in the green species. The mean TFC in our samples was 1.26 ± 0.82 mg QUE/100 g FW, ranging between 0.35 and 2.21 mg QUE/100 g FW. The highest amount of TFC was found in the purple species, followed by the dark purple and green species. Polyphenols, found in various plants, are beneficial for health and are isolated from their matrices. Flavonoids, a subclass, exhibit antioxidant, anti-inflammatory, and antimicrobial activities [27]. The polyphenols of fig fruit consist of approximately 3% flavonoids, the remaining polyphenols consisting of phenolic acids, procyanidins, proanthocyanidins, anthocyanins, tannins, etc. [28]. Comparison of these three fig species in the literature has shown that the darker fruit contains higher levels of polyphenols, as well as flavonoids. Previous studies indicate that dark-skinned fruits contain more polyphenols [15, 29]. A study conducted of dried light-colored and dark-colored fig fruit reported that the total amount of phenolic substances as well as total antioxidant properties and individual phenolic compounds all vary depending on the extraction conditions. Those authors also described acid hydrolysis as an important criterion [30].

The antioxidant capacity of the three species of figs was tested using two different antioxidant assays, FRAP and DPPH radical scavenging tests. The FRAP test measures total antioxidant capacity by reducing ferric complexes in the presence of antioxidant substances. The FRAP values varied between 151.98 and 327.97 µmol $FeSO_4.7H_2O$/100 g FW, and the highest antioxidant capacity was found in the dark purple species. Studies have shown that dark-colored fig cultivars with high TPC are of high antioxidant value, similarly to other fig cultivars [4, 15, 26, 29].

The DPPH radical scavenging capacity test showed a negative correlation between the SC_{50} value and radical scavenging ability, with purple species exhibiting the highest ability. This may be due to different antioxidant mechanisms or polyphenol types in fruit extracts.

Phenolic Profiles

The amount and composition of polyphenols in fig fruit vary depending on the genetic characteristics of the fruit and the climatic conditions in the growing environment [29]. Interestingly, that study noted no exact relationship among the color of the species, polyphenol content, and antioxidant properties. Compared to the total amount of polyphenols in fig fruit and bee products, that are rich in polyphenols, it appears that 100 g of fresh figs contains similar amounts of polyphenol to 100 g of honey [31], but less than pollen [32] and propolis [33]. The phenolic composition of methanolic extracts in the present study was analyzed using HPLC-PDA, applying the validated chromatography technique previously utilized for phenolic compound analysis enriched through liquid-liquid extraction [21]. The resulting chromatograms, representing 25 phenolic compounds, are summarized in Fig. 2, with

Table 2 Total phenolic content, total flavonoid content, and antioxidant capacity of the fig fruits

	Green	Purple	Dark Purple	Mean values
Total phenolic contents (mg GAE/100 g FW)	35.98 ± 2.12[c]	42.02 ± 0.31[b]	47.30 ± 1.53[a]	41.76 ± 5.07
Total flavonoid Content (mg QUE/100 g FW)	0.35 ± 0.14[c]	2.21 ± 0.30[a]	1.24 ± 0.04[b]	1.26 ± 0.82
Total antioxidant Capacity (FRAP) (µmol $FeSO_4.7H_2O$/100 g FW)	151.98 ± 30.10[b]	193.97 ± 20.20[b]	372.97 ± 35.20[a]	239.64 ± 104.72
DPPH radical scavenging cavity (mg/mL)	42.42 ± 0.40[a]	10.04 ± 0.29[c]	35.56 ± 3.46[b]	29.34 ± 14.87

Different letters (a-c) in the same lines are significantly different at the 5% level ($p < 0.05$)

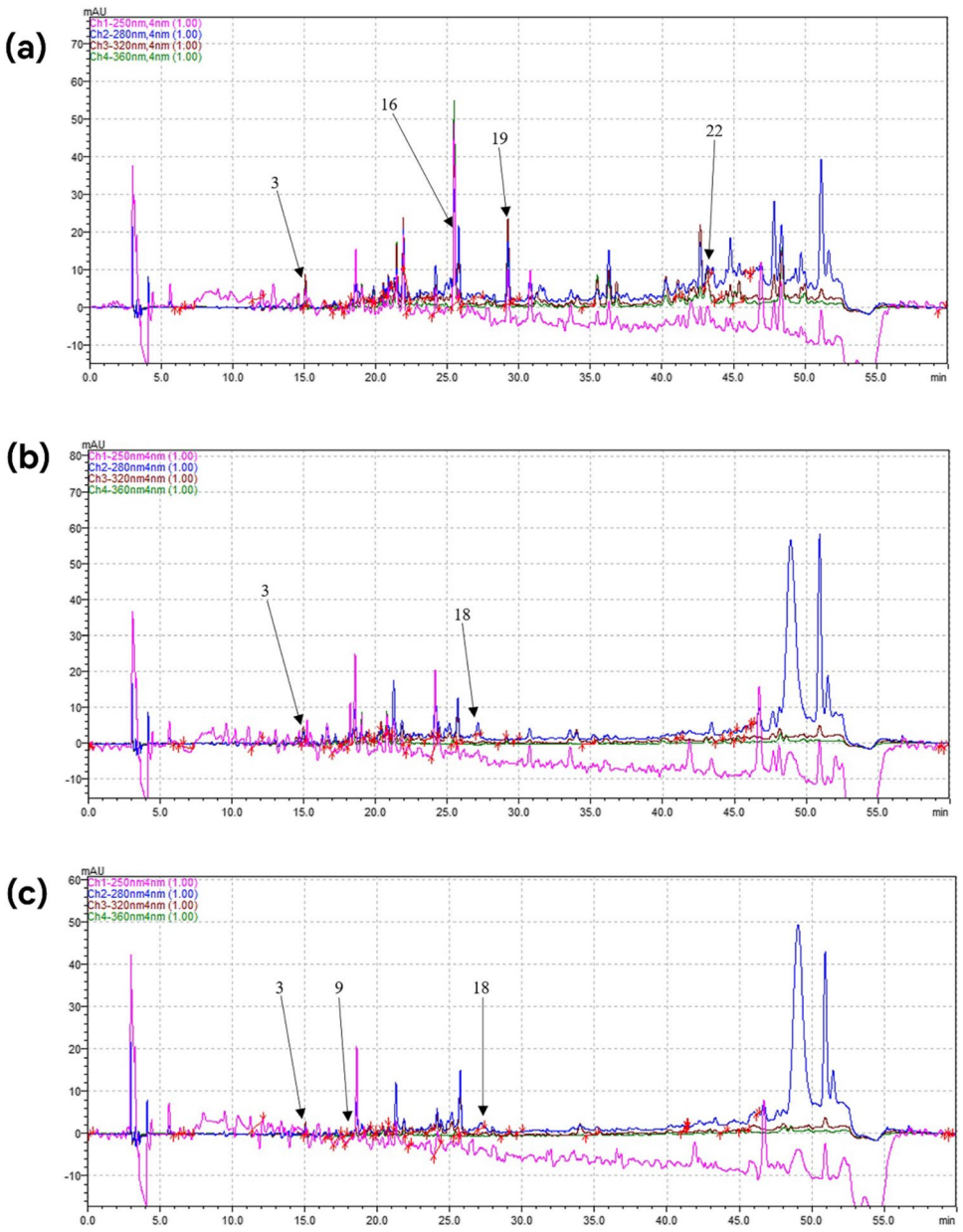

Fig. 2 HPLC-PDA chromatograms of the phenolic components in the fig samples(a-Purple; b-Green; c-Dark purple)(1) Gallic acid, (2) Protocatechuic acid, (3) Chlorogenic acid, (4) *p*-OH benzoic acid, (5) Epicatechin, (6) Caffeic acid, (7) Syringic Acid, (8) *m*-OH benzoic acid, (9) Rutin, (10) Ellagic acid, (11) *p*-Coumaric Acid, (12) Ferulic acid, (13) Myricetin, (14) Resveratrol, (15) Daidzein, (16) Luteolin, (17) Quercetin, (18) *t*-Cinnamic acid, (19) Apigenin, (20) Hesperetin, (21) Ramnetin, (22) Krisin, (23) Pinosembrin, (24) CAPE, (25) Curcumin

corresponding quantitative analysis values presented in Table 3. Additionally, more unidentified peaks were observed compared to the peaks defined according to the standard chromatogram. Chlorogenic acid and *t*-cinnamic acid were detected as major phenolic components in the green and dark purple species, whereas chrysin, apigenin and luteolin were detected only in the purple species. Studies have reported chlorogenic acid as the major phenolic component of the fig fruit [12], followed by rutin, luteolin and quercetin [28, 29]. Gallic acid, chlorogenic acid, syringic acid, catechin, epicatechin, and rutin were the polyphenols detected using HPLC-PDA in figs from Slovenia [12]. Anthocyanins are pigments that bestow color on fruits and vegetables and that are responsible for the color, appearance, and sensory properties of fig species [34]. In a study in which LC-UV-DAD/ESI- MS^n was applied to 18 fig varieties, chlorogenic acid was identified as the primary phenolic compound and cyanidin-3-rutinoside as the primary anthocyanin [28]. The findings of another study of dried fig species indicate the existence of diverse phenolic acids, including chlorogenic acid, protocatechuic acid, and vanillic acid. Additionally, flavonoids including luteolin, apigenin, and rutin in glycosides were detected in the fruit [35]. That study supports our findings. Chlorogenic acid, cinnamic acid, rutin, apigenin, and luteolin were the most common polyphenols in the local fig species compared to other fig species described in the literature, although gallic acid, coumaric acid, and ellagic acid were

Table 3 Phenolic composition of the Fig fruits by HPLC-PDA

Phenolic groups (µg/100 g FW)		Green	Purple	Dark purple
Phenolic acids	Hydroxybenzoic acids			
	p-OH Benzoic acid	–	–	–
	m-OH Benzoic acid	–	–	–
	Protocathequic acid	–	–	–
	Gallic acid	–	–	–
	Chlorogenic acid	213	–	249
	Syringic acid	–	–	–
	Ellagic acid	–	–	–
	Hydroxycinnamic acids			
	t-cinnamic acid	65	–	68
	Ferulic acid	–	–	–
	p-Coumaric acid	–	–	–
	Caffeic acid	–	–	–
	Caffeic acid phenethyl ester (CAPE)	–	–	–
Flavanoids	Flavonol			
	Rhamnetin	–	–	–
	Quercetin	–	–	–
	Rutin	–	32	215
	Myricetin	–	–	–
	Flavan-3-ols			
	Epicatechin	–	–	–
	Flavones			
	Chrysin	–	85	–
	Apigenin	–	368	–
	Luteolin	–	470	–
	Flavanones			
	Pinocembrin	–	–	–
	Hesperidin	–	–	–
	Other polyphenols			
	Curcumin	–	–	–

(–): not detected

not detected in the present study [15, 26, 28, 29]. The fact that these compounds were not identified in our study may be attributed to the limited sensitivity of HPLC in detecting compounds present in trace amounts in local species or to the inadequacy of the extraction technique employed.

Conclusion

This study investigated the phenolic composition and antioxidant properties of three local fig species from the Eastern Black Sea region of Türkiye. Significant differences were observed in amounts of total phenolic substances. Flavonoid and antioxidant properties also varied. The purple species contained the highest level of flavonoids and was richer in chrysin, apigenin, and luteolin. The fig fruit may potentially exhibit functional food and nutraceutical properties.

Author Contribution Çiğdem Bayrak: Formal analysis, writing the article; Ceren Birinci: HPLC studies; Mehmet Kemal: Formal analysis; Sevgi Kolaylı: Planning the study, writing and editing the article.

Data Availability Not applicable.

Declarations

Ethics Approval Not applicable.

Consent to Participate Not applicable.

Consent for Publication Not applicable.

Conflict of Interest The authors declare no conflict of interest.

References

1. del Río-Celestino M, Font R (2020) The health benefits of fruits and vegetables. Foods 9:369. https://doi.org/10.3390/foods9030369
2. Solomon A, Golubowicz S, Yablowicz Z et al (2006) Antioxidant activities and anthocyanin content of fresh fruits of common fig (*Ficus carica* L.). J Agric Food Chem 54:7717–7723. https://doi.org/10.1021/jf060497h
3. Crisosto H, Ferguson L, Bremer V et al (2011) Fig (*Ficus carica* L.). In: Yahia EM (ed) Postharvest biology and Technology of Tropical and Subtropical Fruits. Woodhead Publishing, pp 134–160e
4. Arvaniti OS, Samaras Y, Gatidou G et al (2019) Review on fresh and dried figs: chemical analysis and occurrence of phytochemical compounds, antioxidant capacity and health effects. Food Res Int 119:244–267. https://doi.org/10.1016/j.foodres.2019.01.055
5. Muminjanov H, Karagöz A (2018) Biodiversity of Turkey: contribution of genetic resources to sustainable agriculture and food systems. Food and Agriculture organization of the United Nations, Ankara
6. Çalışkan O, Polat A (2012) Morphological diversity among fig (*Ficus carica* L.) accessions sampled from the eastern Mediterranean region of Turkey. Turk J Agric For 36:179–193. https://doi.org/10.3906/tar-1102-33
7. Uslu NA, Özcan M, Aydin E (2022) Artvin, Giresun, Ordu illerinde Sofralık ve Reçellik İncir Seleksiyonu. Anadolu Tarım Bilimleri Dergisi 37:317–330. https://doi.org/10.7161/omuanajas.968849
8. Sezen I, Ercisli S, Gozlekci S (2014) Biodiversity of figs (*Ficus carica* L.) in Coruh valley of Turkey. Erwerbs-Obstbau 56:139–146. https://doi.org/10.1007/s10341-014-0222-6
9. Huang W-Y, Cai Y-Z, Zhang Y (2009) Natural phenolic compounds from medicinal herbs and dietary plants: potential use for Cancer prevention. Nutr Cancer 62:1–20. https://doi.org/10.1080/01635580903191585
10. Ramassamy C (2006) Emerging role of polyphenolic compounds in the treatment of neurodegenerative diseases: a review of their intracellular targets. Eur J Pharmacol 545:51–64. https://doi.org/10.1016/j.ejphar.2006.06.025
11. Rangel-Huerta OD, Pastor-Villaescusa B, Aguilera CM, Gil A (2015) A systematic review of the efficacy of bioactive compounds in cardiovascular disease: phenolic compounds. Nutrients 7:5177–5216. https://doi.org/10.3390/nu7075177
12. Veberic R, Colaric M, Stampar F (2008) Phenolic acids and flavonoids of fig fruit (*Ficus carica* L.) in the northern Mediterranean region. Food Chem 106:153–157. https://doi.org/10.1016/j.foodchem.2007.05.061

13. Yang X, Yu W, Ou Z et al (2009) Antioxidant and immunity activity of water extract and crude polysaccharide from *Ficus carica* L. Fruit. Plant Foods Hum Nutr 64:167–173. https://doi.org/10.1007/s11130-009-0120-5
14. Mawa S, Husain K, Jantan I (2013) *Ficus carica* L. (Moraceae): Phytochemistry, traditional uses and biological activities. Evid Based Complement Alternat Med 2013:1–8. https://doi.org/10.1155/2013/974256
15. Ercisli S, Tosun M, Karlidag H et al (2012) Color and antioxidant characteristics of some fresh fig (*Ficus carica* L.) genotypes from northeastern Turkey. Plant Foods Hum Nutr 67:271–276. https://doi.org/10.1007/s11130-012-0292-2
16. Trad M, Gaaliche B, Renard CMGC, Mars M (2013) Inter- and intra-tree variability in quality of figs. Influence of altitude, leaf area and fruit position in the canopy. Sci Hortic 162:49–54. https://doi.org/10.1016/j.scienta.2013.07.032
17. Kemal M, Esertaş ÜZÜ, Kanbur ED et al (2023) Characterization of the black cumin (*Nigella sativa* L.) honey from Türkiye. Food. Bioscience 53:102760. https://doi.org/10.1016/j.fbio.2023.102760
18. Fukumoto LR, Mazza G (2000) Assessing antioxidant and Prooxidant activities of phenolic compounds. J Agric Food Chem 48:3597–3604. https://doi.org/10.1021/jf000220w
19. Benzie IFF, Strain JJ (1996) The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. Anal Biochem 239:70–76. https://doi.org/10.1006/abio.1996.0292
20. Molyneux P (2004) The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. Songklanakarin J Sci Technol 26:211–219
21. Kara Y, Can Z, Kolaylı S (2022) Applicability of phenolic profile analysis method developed with RP-HPLC-PDA to some bee product. Braz Arch Biol Technol 65:e22210384. https://doi.org/10.1590/1678-4324-2022210384
22. Soni N, Mehta S, Satpathy G, Gupta RK (2014) Estimation of nutritional, phytochemical, antioxidant and antibacterial activity of dried fig (*Ficus carica*). J Pharmacogn Phytochem 3:158–165
23. Ganesan P, Kumar CS, Bhaskar N (2008) Antioxidant properties of methanol extract and its solvent fractions obtained from selected Indian red seaweeds. Bioresour Technol 99:2717–2723. https://doi.org/10.1016/j.biortech.2007.07.005
24. Purnamasari R, Winarni D, Permanasari AA et al (2019) Anticancer activity of methanol extract of *Ficus carica* leaves and fruits against proliferation, apoptosis, and necrosis in Huh7it cells. Cancer Inform 18:1176935119842576. https://doi.org/10.1177/1176935119842576
25. Çalişkan O, Aytekin Polat A (2011) Phytochemical and antioxidant properties of selected fig (*Ficus carica* L.) accessions from the eastern Mediterranean region of Turkey. Sci Hortic 128:473–478. https://doi.org/10.1016/j.scienta.2011.02.023
26. Mahmoudi S, Khali M, Benkhaled A et al (2016) Phenolic and flavonoid contents, antioxidant and antimicrobial activities of leaf extracts from ten Algerian *Ficus carica* L. varieties. Asian Pac J Trop Biomed 6:239–245. https://doi.org/10.1016/j.apjtb.2015.12.010
27. Panche AN, Diwan AD, Chandra SR (2016) Flavonoids: an overview. J Nutritional Sci 5:e47. https://doi.org/10.1017/jns.2016.41
28. Vallejo F, Marín JG, Tomás-Barberán FA (2012) Phenolic compound content of fresh and dried figs (*Ficus carica* L.). Food Chem 130:485–492. https://doi.org/10.1016/j.foodchem.2011.07.032
29. Kamiloglu S, Capanoglu E (2015) Polyphenol content in figs (*Ficus carica* L.): effect of sun-drying. Int J Food Prop 18:521–535. https://doi.org/10.1080/10942912.2013.833522
30. Bey MB, Louaileche H, Zemouri S (2013) Optimization of phenolic compound recovery and antioxidant activity of light and dark dried fig (*Ficus carica* L.) varieties. Food Sci Biotechnol 22:1613–1619. https://doi.org/10.1007/s10068-013-0258-7
31. Saral Ö (2023) An investigation into chestnut honeys from Artvin Province in Turkiye: their physicochemical properties, phenolic profiles and antioxidant activities. Chem Biodivers e202201162. https://doi.org/10.1002/cbdv.202201162
32. Gercek YC, Celik S, Bayram S (2022) Screening of plant pollen sources, polyphenolic compounds, fatty acids and antioxidant/antimicrobial activity from bee pollen. Molecules 27:117. https://doi.org/10.3390/molecules27010117
33. Can Z, Kara Y, Kolayli S, Çakmak I (2023) Antioxidant activity and phenolic composition of propolis from Marmara region, Turkey, J Apicultural Res 1–7. https://doi.org/10.1080/00218839.2022.2157582
34. Wallace TC, Giusti MM (2015) Anthocyanins. Adv Nutr 6:620–622. https://doi.org/10.3945/an.115.009233
35. Russo F, Caporaso N, Paduano A, Sacchi R (2014) Phenolic compounds in fresh and dried figs from Cilento (Italy), by considering Breba crop and full crop, in comparison to Turkish and Greek dried figs. J Food Sci 79:C1278–C1284. https://doi.org/10.1111/1750-3841.12505