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Research Article

Sugar Composition and Biochemical Properties of Fig Seed Obtained from Abbas Variety

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ABSTRACT
This study used seeds obtained from the Abbas fig variety grown in Kahramanmaraş region. Abbas figs were crushed and their seeds were extracted. After drying, the moisture, ash, and fat content of Abbas fig seeds were determined as 5.78%, 3.88%, and 23.37%, respectively. Abbas fig seeds exhibited a total phenolic content of 533.66 mg GAE/kg DW and a DPPH antioxidant activity of 2.25 µmol TE/g DW. Oil extracted from seeds was examined for its fatty acid composition, free fatty acid concentration and peroxide value. Linolenic (40.44%), linoleic (28.40%) and oleic (16.16%) acids were the major fatty acids in the oil of Abbas fig seed, respectively. The sugar profile of fig seeds was analyzed by HPLC. Sucrose was the primary sugar in Abbas fig seeds, followed by raffinose, stachyose, glucose, and fructose. To the best of our knowledge, this is the first comprehensive analysis focusing on the sugar composition of Abbas fig seeds.
Keywords: Abbas fig seed, sugar composition, oligosaccharides, fatty acid

Abbas Çeşidi İncir Çekirdeğinin Şeker Bileşimi ve Biyokimyasal Özellikleri

ÖZ
Bu çalışmada, Kahramanmaraş bölgesinde yetişen Abbas incir çeşidinden elde edilen çekirdekler kullanılmıştır. Abbas incirleri ezilerek çekirdekleri ayrılmıştır. Kurutulduktan sonra, Abbas incir çekirdeklerinin nem, kül ve yağ içerikleri sırasıyla %5.78, %3.88 ve %23.37 olarak belirlenmiştir. Abbas incir çekirdekleri, 533.66 mg GAE/kg Kuru Ağırlık (KA) toplam fenolik içeriği ve 2.25 µmol TE/g KA DPPH antioksidan aktivitesi sergilemiştir. Çekirdeklerden ekstrakte edilen yağın yağ asidi bileşimi, serbest yağ asidi konsantrasyonu ve peroksit değeri incelenmiştir. Abbas incir çekirdeği yağındaki ana yağ asitleri sırasıyla linolenik (%40.44), linoleik (%28.40) ve oleik (%16.16) asitler olmuştur. İncir çekirdeklerinin şeker profili HPLC ile analiz edilmiştir. Abbas incir çekirdeklerinde birincil şeker sakkaroz olup, bunu rafinoz, stakiyoz, glikoz ve fruktoz takip etmiştir. Bildiğimiz kadarıyla, bu çalışma Abbas incir çekirdeklerinin şeker bileşimine odaklanan ilk kapsamlı araştırmadır.
Anahtar Kelimeler: Abbas incir çekirdeği, şeker bileşimi, oligosakkaritler, yağ asidi

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Introduction

Ficus carica, widely recognized as the fig, is a popular fruit enjoyed globally in both its fresh and dried forms. Most of the world's edible figs are cultivated in areas characterized by mild winters and scorching, arid summers, such as Türkiye, Morocco, Egypt, Spain, Greece, California, Italy, and Brazil (Baygeldi et al., 2021). Türkiye has long been the world's major producer of figs, producing 350,000 tons in 2022 (or about 27.86% of the world's production) (Güney et al., 2022; TUİK, 2022). Turkey has a wide variety of regionally adapted fig cultivars, indigenous varieties, and untamed forms that display substantial phenotypic variability, including different colors, size, shapes, and flavors. Extensive breeding studies have been conducted on edible fig germplasm. The 'Abbas' fig variety, a cultivated local genotype in Kahramanmaraş Province, was selected and further characterized and it received geographical indication registration in 2019 (Gündeşli, 2020).

Extensive breeding studies have been conducted on edible fig germplasm and Abbas' fig variety was selected among diverse genotypes in Kahramanmaraş Province between 2017 and 2019 (Gündeşli, 2020). This new cultivar has been widely planted in Kahramanmaras, Türkiye.

Owing to the substantial generation of by-products such as peels, seeds, and leftover flesh at different stages of the processing cycle, the waste utilization of the fruit processing industries has emerged as one of the most challenging issues in the world (Kodagoda & Marapana, 2017). Commonly, low-quality figs, a significant source of fermentable sugar, are used to make ethyl alcohol. During the ethyl alcohol-producing process, fig seeds are discarded separately (Bölek, 2021). Considering the circular economy approach, the usage of fig waste products in the food industry is crucial. So far, the literature has suggested the utilization of discarded fig seeds for the creation of innovative functional extracts. For instance, Bölek (2021) investigated the impact of incorporating waste fig seed powder as a novel component in biscuit formulation. The results revealed a substantial enhancement in the total phenolic content and antioxidant activity of the biscuits due to the inclusion of fig seed powder. Similarly, Gül and Ulutürk (2019) established that the incorporation of fig seed flour in cookie production led to improvements in dietary fiber, protein, and mineral content, without any adverse effects on their technological attributes or sensory acceptability. Takma et al. (2021) enriched gluten-free cupcakes with varying proportions of fig seed pomace flour, which was derived from cold-pressing. The cupcakes with fig seed pomace flour had a glycemic index lower than 55, which can be classified as low glycemic food according to the 2-hour *in vitro* digestion. Tufan et al. (2023), investigated the impact of incorporating fig seed into quail diets as a feed supplement, focusing on growth performance, carcass traits, and antioxidant capacity. The findings suggest that including fig seed at levels between 0.50% and 1.00% in the diet may positively influence growth metrics, carcass quality, and selected blood parameters.

Numerous studies have investigated the high contents of α-linolenic and linoleic acids and the antioxidant properties of fig seed oil, recently making it a candidate for functional food incorporation (Baykara et al., 2021; Hssaini et al., 2020; Nakilcioğlu Taş, 2019). In a recent study, fig seed oil was encapsulated into nanostructured lipid carriers to protect it from oxidation by Erdoğan and Gökçe (2021). It was found that encapsulation significantly enhanced the formulation's stability, which included substantial amounts of gamma-tocopherol and unsaturated linoleic acid extracted from fig seed oil. Baykara et al., (2021) reported that adding fig seed oil, either by itself or in combination with different extracts, to chitosan-based food packaging could help extend the shelf life of food by preventing spoilage for several days.

Considering the recent rise in the utilization and consumption of fig seeds and their relatively limited research attention compared to other fig components, this study aimed to provide an

overview of sugar composition, general chemical composition, and bioactivity, as well as the fatty acid composition of fig seeds from the Abbas variety in Türkiye. To date, the sugar composition of fig seeds has not been examined. The present study could provide insights into the relative proportions of different sugars present in fig seeds, helping to elucidate their nutritional value and to explore sustainable applications for underutilized byproducts.

Material and Methods

Abbas fig seed sample

This study used the Abbas fig (*Ficus carica* L.) variety grown in the Kahramanmaraş region in Türkiye. Figs were considered fully ripened when they were easily separated from the twig. They were picked randomly from a few trees at different positions in 2019, at the beginning of August. Fig seeds were extracted after chopping the fresh fruits in a water bath. The seeds were washed several times with water and allowed to dry at room temperature for one week. All materials were kept at 4°C before analyses. Before extraction, fig seeds were crushed with a coffee grinder (Fakir, Roxy, Türkiye) to homogenize them.

Determination of general composition, total phenolic content and antioxidant activity

The moisture, oil content, and ash levels of the samples were determined following the procedures outlined in Eker et al. (2022). To determine moisture content (%), samples were heated in a drying oven (Jeio Tech, ON-O2G, Korea) at 105 ± 1 °C until a constant mass was achieved. Oil content (%) was determined by extracting the samples with *n*-hexane using a Soxhlet extractor (Behr, E4, Germany). For ash content determination, approximately 1 g of the blended sample was placed in a high-temperature oven (SNOL, 8,2/1100, Lithuania) and heated until it turned into gray ash, a process that took approximately 5-6 hours at temperatures between 550 °C and 600 °C. Antioxidant components from fig seeds were extracted using a maceration extraction method. The extraction was conducted using 50% (*v/v*) aqueous ethanol that was previously reported as one of the effective solvent mixtures to extract fig seed (Nakilcioğlu-Taş & Ötleş, 2021). A solid/liquid ratio of 1:20 (*w/v*) was used to extract the sample. After that, the mixture was agitated on a magnetic stirrer (Isotex, SH-4, Türkiye) for 60 minutes at room temperature. Following extraction, the mixture was centrifuged at 6500 rpm for 15 minutes at 4 °C using a centrifuge (Hettich, Mikro 220R, Germany), and subsequently filtered through filter paper. The total phenolic content was determined using the Folin–Ciocalteu method, as described by Singleton and Rossi (1965). The total phenolic content was calculated as milligrams of gallic acid equivalent (GAE) per gram of fig seeds. Antioxidant activity was evaluated using a commonly employed radical scavenging assay as DPPH. DPPH assay was carried out using the method cited by Tanriseven et al. (2020). The antioxidant activity was calculated as milligrams of trolox equivalent (TE) per gram of fig seeds. All substances were expressed as dry weight basis. All analyses were performed in triplicate.

Sugar analysis

The sugar profile of fig seeds was determined using a Thermo Dionex Ultimate 3000 HPLC system, which was equipped with a gradient pump, an autosampler, and a refractive index detector (Shodex RI-101). Separation was carried out on a HyperREZ XP carbohydrate column (Ca^{2+} Counter-ion, 8 µm, 8% cross linkage). For sample extraction, 100 mg of homogenized fig seed was mixed with 15 ml of 80% ethanol and incubated in a water bath at 50 °C for 30 minutes. After incubation, the mixture was centrifuged at 3836 × g for 15 minutes. This extraction step was repeated once, and both supernatants were pooled. The combined extract was concentrated at 40 °C using a rotary evaporator (Stuart, RE300DB, UK) connected to a vacuum pump (N810FT). The concentrate was then brought up to 5 ml with distilled water, vortexed, and filtered through a 0.22 µm syringe filter. A standard solution consisting of glucose, fructose, sucrose, raffinose,

and stachyose (Sigma Chemical) was used for calibration. Sugar concentrations were quantified using the calibration curves of these standards and expressed as a percentage of the fig seed's dry weight, taking into account all dilution factors (Basha, 1992).

Fatty acid analyses

Fig seed oil was extracted using a Soxhlet apparatus with n-hexane as the solvent. The extracted oil was then used to determine free fatty acid content, peroxide value, and fatty acid profile following the methodology of Eker et al. (2022). For the fatty acid composition analysis, the oil samples were esterified employing the cold methylation technique described by (Liu et al., 2018). Gas chromatography (Thermo Fisher, Trace GC Ultra) equipped with a flame ionization detector (GC-FID) and a DBWAX capillary column (30 m × 0.25 mm id × 0.250 µm) was employed. The injector and detector temperatures were set at 250 °C and 280 °C, respectively. The initial oven temperature was 50 °C (1 min.), then raised to 200 °C at a rate of 25 °C/min., and finally increased to 230 °C at a rate of 3 °C/min. A 1 µl injection volume (split ratio: 1/50) was used. Peaks were identified by comparing their retention times with a FAME mix solution (Sigma–Aldrich). The results were expressed as percentage area.

Results and Discussion

General composition, total phenolic content and antioxidant activity

The chemical composition, total phenolic and antioxidant properties of fig seeds were analyzed and are presented in Table 1. The table provides insights into the key components of fig seeds and their potential health-related attributes. The oil content of fig seeds was found as 23.37 ± 5.60%, indicating a notable presence of dietary oil. This could contribute to the overall nutritional value of fig seeds and their potential as a source of healthy fatty acids. The present result on Abbas fig oil was in accordance with the published data (23.06-23.67%) reported by Nakilcioglu (2019) for Sarilop varieties from Turkey. The moisture content of fig seeds was 5.78 ± 0.07% indicating a relatively low moisture content for these seeds. This could contribute to their shelf stability and suitability for various culinary and processing applications (Nakilcioğlu Taş, 2019). The ash content of fig seeds was determined as 3.88 ± 0.03%. The ash measurement often indicates the presence of essential minerals, which contribute to their nutritional profile.

Fig seeds exhibited a substantial total phenolic content of 533.66 ± 4.94 mg GAE/kg seed DW. Our TPC finding is consistent with the previous study that reported TPC of fig seeds varied between 447 mg GAE/kg dry matter when extracted with 100% acetone and 714 mg GAE/kg dry matter using 50% (*v/v*) aqueous methanol (Nakilcioğlu-Taş & Ötleş, 2021). In their investigation, the researchers explored how six distinct solvents affected the polyphenolic content and antioxidant potential of fig seed extracts. Aqueous ethanol solution was selected as the extraction solvent due to its low toxicity and the widespread availability of both water and ethanol, which are commonly employed for extracting natural antioxidants. In addition, our TPC finding was also comparable with those obtained from 50% ethanol mixture by (Nakilcioğlu-Taş & Ötleş, 2021). In a study, it was determined that TPC of fresh fig was between 1988.1-3076.4 mg GAE/kg DM (Nakilcioğlu & Hışıl, 2013). Our results diverge notably from the observations of TPC values of fresh fig. The chemical differences between fresh fruit and seeds could be attributed to the diverse roles of these plant tissues.

Antioxidant activity was measured by the DPPH assay and reported as µmol Trolox equivalents (TE) per gram of dry seed weight. Fig seeds demonstrated a DPPH radical scavenging capacity of 2.25 ± 0.09 µmol TE/g DW. Nakilcioğlu-Taş & Ötleş (2021) reported fig seed antioxidant activity with 41.6% DPPH inhibition and 8504 mg $FeSO_4$/kg DM FRAP values. While direct quantitative comparison is limited by the differing units of measurement, both studies consistently indicate that fig seeds possess notable antioxidant properties. These findings are consistent with

Bölek. (2021) and Konuk Takma et al. (2021), who reported that increasing the substitution ratio of fig seed powder in biscuits and fig seed pomace flour in gluten-free cupcakes led to significant enhancements in antioxidant activity and TPC. Consistent with the literature, our results demonstrate that fig seed can be considered a potential ingredient for various food products.

Table 1. Some biochemical properties of Abbas fig (*Ficus carica* L.*)* seeds

Substance	Value
Fat (%)	23.37 ± 5.60
Moisture (%)	5.78 ± 0.07
Ash (%)	3.88 ± 0.03
Total phenolic content (mg GAE/kg seed DW)	533.66 ± 4.94
DPPH (µmol TE/g seed DW)	2.25 ± 0.09

Sugar composition of fig seed

Table 2 shows the sugar composition of fig seeds. The chromatogram obtained by HPLC analysis is given in Figure 1. The results confirmed that sucrose (1.11 g/100 g DW) was found major sugar, followed by stachyose (0.22 g/100 g DW), raffinose (0.10 g/100 g DW), fructose (0.08 g/100 g DW) and glucose (0.05 g/100 g DW) in fig seeds. There is currently limited information available regarding the specific carbohydrate composition of fig seeds. In previous studies, the glucose content of fresh fig was found major sugar and ranged from 2.50-15.89 g/100 g, while the fructose content was reported between 1.92-11.90 g/100 g (Aljane et al., 2007; Çalişkan & Aytekin Polat, 2011; Melgarejo et al., 2003; Slatnar et al., 2011). The amount of sucrose was reported as a trace in certain accessions, and in some cases, it was not determined (Çalişkan & Aytekin Polat, 2011). Veberic & Mikulic-Petkovsek et al. (2015) analyzed individual sugars of different parts of dried fig (whole fruit, peel, pulp and leaf). The authors noted that glucose and fructose were detected in all parts of the fruit, whereas sucrose was present exclusively in figs (15.57 to 32.84 g/kg DW) and pulp (6.60 to 26.1 g/kg DW). In the following literature, the sugar composition can vary depending on the different parts of the fig and cultivar. However, in general, fig seeds obtained from the present study seem to have a relatively low sugar content and diverse profile compared to the fresh or dried parts of fig fruit.

Raffinose and stachyose, classified as oligosaccharides, are simple sugars composed of a sucrose molecule linked to α-D-glucopyranosyl units via α-1,6-galactosidic bonds. These compounds are thought to provide energy to the developing plant embryo during seed germination and help protect the embryo from dehydration throughout maturation (Elango et al., 2022; Hill, 2003). Raffinose and stachyose are common in the seeds of many plants, especially those in the legume family, such as the chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), soybean (*Glycine max)* or in plant structures adapted for storage, such as roots, tubers, and certain types of leaves (Elango et al., 2022). They are also reported as sugar components in other fruit seeds of cucurbits (Handley et al., 2022), muskmelon (Chrost & Schmitz, 1997) and hemp (*Cannabis sativa* L.) (Crescente et al., 2018). Oligosaccharides, being non-digestible carbohydrates, serve multiple physiological functions, including regulating blood sugar evels, providing minimal calories, promoting dental health, improving gut health, relieving diarrhea, and enhancing mineral absorption (Qiang et al., 2009). Konuk Takma et al., (2021) reported a reduced glycemic index of cupcakes formulated with fig seed pomace flour. Our findings are in line with those reported by Konuk Takma et al., (2021).

Table 2. Sugar composition of Abbas fig (*Ficus carica* L.) seeds

Component	g/100 g DW
Stachyose	0.22 ± 0.03
Raffinose	0.10 ± 0.01

Sucrose	1.11	±	0.09
Glucose	0.05	±	0.07
Fructose	0.08	±	0.09

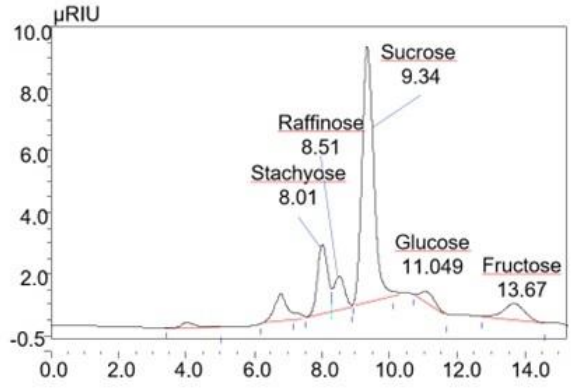

Figure 1. HPLC chromatogram of sugar compounds obtained from Abbas fig (*Ficus carica* L.) seeds

Fatty acid composition and physicochemical quality

Table 3 summarizes the chromatographic profiles of the fatty acids determined in fig seed oil and lists the presence of the 6 detected fatty acids. The primary fatty acids present in these seed oils are linolenic acid (C18:3), linoleic acid (C18:2), and oleic acid (C18:1). Among the saturated fatty acids, palmitic acid (C16:0) is predominant, followed by stearic acid (C18:0). Abbas fig seed oil exhibited a high proportion of total unsaturated fatty acids (TUFA), averaging 85.00%. This comprised mono-unsaturated fatty acids (MUFA, C18:1) and poly-unsaturated fatty acids (PUFA, C18:3 and C18:2), which accounted for average values of 16.16% and 68.84%, respectively (Table 1). Overall, these results agree with those reported on fig seeds from different varieties by Taş et al. (2019) and Baygeldi et al. 2021. The acidity and peroxide value of fig seed oil were determined as 1.15 g/100 g and 18.05 meq O_2/kg. Common legal limits for fatty acidity and peroxide value in edible oils often fall within the range of 0.1-3.0 g/100g and 0.5 to 20.0 meq O_2/kg, respectively, depending on the type of oil and regional regulations. However, according to Duman and Yazıcı (2018), the maximum free fatty acidity and peroxide value of edible oil should not exceed 0.6% and 10 meq O_2/kg. The results show that fig seed oil has a higher free fatty acidity and peroxide value which are contradictory to what we would expect. Higher values obtained from fresh fig seed could be attributed to heat exposure during the Soxhlet extraction process.

Table 3. Fatty acid compositions (%) and physicochemical quality of Abbas fig (*Ficus carica* L.) seeds oil

Parameter	**Mean**
Fatty acids (%)	
Myristic acid	0.90 ± 0.64
Palmitic acid (C16:0)	8.45 ± 0.40
Stearic acid (C18:0)	3.83 ± 0.15
Oleic acid (C18:1)	16.16 ± 0.57
Linoleic acid (C18:2)	28.40 ± 0.65
Linolenic acid (C18:3)	40.44 ± 1.31
MUFA	16.16
PUFA	68.84
TUFA	85.0
TSFA	13.18
Physicochemical quality	
Fatty acidity (g/100g)	1.15 ± 0.07
Peroxide value (meq O_2/kg)	18.05 ± 0.30

MUFA: Monounsaturated fatty acids, PUFA: Polyunsaturated fatty acids, TUFA: Total unsaturated fatty acids, TSFA: Total saturated fatty acids

Conclusion

The analysis of Abbas variety fig seeds from Türkiye unveiled key compositional attributes, including a notable 23.37% oil content, low moisture content at 5.78%, and an ash content of 3.88%, indicating the presence of essential minerals. Besides, it presented significant phenolic content and antioxidant activity. It was found that Abbas fig seed oil is a rich source of linolenic acid (40.44%), linoleic acid (28.40%) and oleic acid (16.16%). This investigation provides the initial

comprehensive characterization of sugar components within fig seeds. The results showed that the predominant sugar of fig seed was sucrose, followed by stachyose, raffinose, fructose, and glucose. Stachyose and raffinose content, both non-digestible carbohydrates underscore the potential of fig seeds as a valuable dietary component with potential health benefits. Understanding the sugar composition of fig seeds is crucial because it has implications for their potential use in various food applications. Future studies could delve deeper into the sugar metabolism of fig seeds. Understanding how these sugars are synthesized and metabolized, and their impact on human health can pave the way for the advancement of functional food items and strategies for dietary improvement.

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