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RESEARCH ARTICLE

Biochemical, bioactive content and antioxidant activity of 18 unnamed jujube ecotype fruits from Aegean region in Türkiye

Halil Ibrahim Sagbas

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Abstract Jujube was introduced to Türkiye 200 years ago and currently, it grows in many regions under diverse agroclimatic conditions. More recently there were an increasing attention to this fruit. Both grafted and seed propagated jujube trees are found in the country and grafted ones bear bigger fruits. The present study describes biochemical, bioactive, and antioxidant characteristics of 18 unnamed seed propagated jujube ecotypes sampled from Afyonkarahisar province in Türkiye. During the full maturation stage fruit samples were obtained from ecotypes and soluble solid content (SSC), total antioxidant capacity, total phenolic content, individual sugars and organic acids were determined in fresh flesh of fruits. Total antioxidant capacity was determined by DPPH (2,2-diphenyl-1-picrylhydrazyl) and FRAP (Ferric Reducing Antioxidant Power) assays. Results showed that there was a great variability among ecotypes on most of the searched parameters. SSC were in range of 14.50–23.50%. Total antioxidant capacity ranged between 79.72 and 84.89% in DPPH assay and 13.82–30.14 µmol TE/g fresh weight base in FRAP assay, respectively. Total phenolic content of ecotypes was from 293 to 992 mg gallic acid equivalent (GAE) per 100 g fresh weight base (FW). Predominant sugar of all samples were fructose and glucose, which varied between 4.86 and 13.82% and 3.35–9.15%, respectively. The main organic acids were malic acid and followed by citric acid for all 18 jujube ecotypes. Malic and citric acid content ranged between 0.38 and 4.64% and 0.35–1.23%, respectively. These results indicated the richness of jujube genetic resources in Türkiye and the ecotypes JJ04 and JJ09 were identified as superior based on their phytochemicals content. This finding is important for breeding and also for the pharmaceutical perspective of jujube.

Keywords Bioactive content · Composition · Diversity · Fruit · Functional food · Jujube

H. I. Sagbas (✉)
Department of Horticulture, Fethiye Faculty of Agriculture, Mugla Sitki Kocman University, Mugla 48000, Turkey
e-mail: hibrahimsagbas@gmail.com

Introduction

The horticultural plant biodiversity, which expresses the sustainability of natural life, is based on the diversity of species, cultivars, ecotypes, accessions (Del Rio-Celestino and Font 2020; Delialioglu et al. 2022). More recently horticultural plants including fruits, vegetables, grapes and ornamentals gained more interest by consumers due to their human health promoting substances (Del Rio-Celestino and Font 2020; Cosme et al. 2022). Among fruit species are an excellent source of minerals and essential vitamins, and some fruits are very high in fiber. They also contain bioactive components that have a positive effect on human health such as antioxidants, including flavonoids, organic acids, specific sugars, carotenoids etc. (Volpe 2019; Nyanchoka et al. 2021; Mottaleb et al. 2023).

Jujube began to be cultivated in certain regions in Türkiye around 200 years ago. It can be an alternative to warm temperate climates. The plant relatively new crop in the country showing great potential to be a profitable and sustainable industry. They can be used as fresh, dried or processed. The fruit's drought and salinity tolerance and multiple uses indicate great potential for many areas of Türkiye and indicate economic value (Ikinci et al. 2022).

The origin of jujube (*Ziziphus jujuba* Mill.) is southeast Asia including China and the most familiar species for fruit production are *Z. jujuba* and *Z. mauritiana* (Sun et al. 2011). There are between 700 (Gao et al. 2013) and 800 (Yao 2012) different cultivars of *Ziziphus* spp. in China. The majority of their fruits are used as dried. China meets 90% of the world's jujube production, followed by South Korea, Iran, Morocco, Greece, and Spain, respectively (Sheng and Shen 2011; Li et al. 2023;). Value-added food products can be obtained such as confectionery, compote, bread, soup, cake, snack, paste, tea, sweetener, pickles, jam, syrup, and alcoholic beverage (*brodo di giuggiole*) by applying certain processes to these dried fruits (Krska and Mishra 2009; Choi et al. 2011). China exports 4,700 tons of dry jujube annually and generates 5 million dollars income (Capocasa et al. 2008; Koley et al. 2016; Wojdylo et al. 2016).

Türkiye is an agricultural country where four seasons are experienced, surrounded by seas on three sides, and subtropical and temperate climate fruit species can be grown (Capocasa et al. 2008). While there are many different cultivars belonging to different species of jujube around the world there are two different ecotypes of *Z. jujube* in Türkiye, namely small and large fruit jujube (Ikinci et al. 2022). According to TUIK (Turkish Statistical Institute) data, Türkiye has produced 2,248 tons of jujube on an area of 292 hectares in 2022 (Anonymous 2023).

Jujube, which has been widely used in Chinese folk medicine for more than 4,000 years (Shahrajabian et al. 2020), is known as an edible medicinal fruit (Liu et al. 2021). It is known to be safer and healthier than standard herbal remedies. Jujube contains a wide variety of bioactive components such as vitamin C, phenolics, flavonoids, triterpenic acids and polysaccharides (Bai et al. 2016). The World Health Organization (WHO) has been recommending fruit and vegetable consumption for a balanced and healthy diet for years. With the effect of this situation, there has been an increased interest in research on the determination of bioactive components in fruits that benefit human health in recent years (Urun et al. 2021). Phenolic compounds have a wide spectrum of biochemical activities such as antimutagenic, antioxidant and anticarcinogenic properties. Consumption of plants, which are strong antioxidant sources, suppresses ROS (reactive oxygen species) in the human body. In addition, this situation protects the body against many diseases such as cancer, endothelium (a cardiovascular disease), cataracts and emphysema (Skrovankova et al. 2022; Unal and Okatan 2023). Previous pharmacological research emphasized that jujube has very important anti-inflammatory and antioxidant effects (Lam et al. 2016; Ji et al. 2017; Rajaei et al. 2021). Sugar content in fruit is one of the most important quality parameters for consumers and it provides objective data to breeders (Attar et al. 2022). Organic acids and soluble sugars are the most abundant compounds in ripe fruit. These are important parameters that determine the flavor and aroma of the fruit (Gundogdu et al. 2021). The most abundant organic acids in jujube were malic acid, citric acid and succinic acid (Wojdylo et al. 2016; Cosmulescu et al. 2018), while the most abundant sugars were glucose, fructose and sucrose (Tepe 2020).

Genetic diversity in ecotypes helps plant breeders to reach the elite ecotype by utilizing genetic resources. It is known that Türkiye is among the countries where wild forms of jujube wildly found (Akbolat et al. 2022). There is a large natural population of jujube in the vicinity of the study region and it was also stated in another study that this genetic diversity should be evaluated (Yildirim et al. 2015).

Thus, the aim of this study is to evaluate the biochemical, bioactive and antioxidant diversity of the fruits of jujube ecotypes, which are not widely cultivated in Türkiye, and are not widely known by the Turkish people.

Materials and methods

Plant material

The material of this study consisted of 18 seed propagated jujube ecotypes, selected from different villages and town centers within the borders of Dinar district of Afyonkarahisar province (Fig. 1). Dinar is a district that located in the inner Aegean region of Türkiye, with mild continental climate conditions and an average altitude of 900 m from sea level. Each ecotype is unique represented by one plant in this study because in nature all ecotypes propagated naturally by seeds and we have found only one plant per ecotype.

Although water-soluble vitamins, total antioxidant capacity and total phenolic content of jujube fruits decrease with ripening, the amount of sugar increases with ripening (Guo et al. 2015; Tepe 2020). Jujube is a climacteric fruit specie. Considering these conditions during the harvest phase, the fruit samples were collected at the veraison phase (half red). The visual of tree, shoot, flower, small fruit and harvested fruit belonging to JJ02 ecotype is presented in Fig. 2.

Fig. 1 Sampling location (Afyonkarahisar province in red color)

Sampling and Extracts Preparation

Ecotypes were given the code "JJ" as an abbreviation of the name jujube tree and 18 ecotypes are numbered from 1 to 18. For example, JJ01-JJ02-JJ03 etc. Harvest dates of fruit samples were between 20 September 2021 and 26 September 2022. Then, the samples were transported to the laboratory by being carried in the cold chain on the same day. The analyzes were carried out on fruits sampled per plant per ecotype with 3 replications including 10 fruits in each replication. After the flesh of the fruits in each replication was separated from their endocarps by hand, they were homogenized using a fruit extractor. Some of this homogenized material was stored at -80 °C for use in sugar and organic acid determinations. The rest of the sample was used for extraction (70v/30v; methanol/water) to use it both for total antioxidant capacity and total phenol analysis. All analyses were done on 3 replications.

Total antioxidant capacity

The total antioxidant capacity determination was carried out using two different assays (DPPH [2,2-diphenyl-1-picrylhydrazyl] and FRAP [Ferric Reducing Antioxidant Power]).

DDPH assay was performed according to the method presented by Attar et al. (2022). Firstly, an ethanolic DPPH solution was prepared at a concentration of 0.06 µM. 1950 µL volume of DPPH was added

Fig. 2 Image of tree, shoot, flower, small fruit and ripe fruit of JJ02 ecotype

to 50 µL jujube extract. Afterward, this mixture was stirred for 60 s and incubated at 25 °C for half an hour in a dark media. The free radical scavenging activity of jujube extracts was measured using Multiscan GO microplate spectrophotometer (Thermo Fisher Scientific, Finland). The device was tuned to a wavelength of 515 nm and measurements were made at 5-minute intervals. The solvent was used as blank. Finally, the RSA value was calculated using the equation below and the values were expressed as a percentage.

$$\text{DPPH}(\%) = \left[(\text{CA} - \text{SA}) / \text{CA}\right] * 100$$

CA: Control absorbances.

SA: Sample absorbances.

The FRAP assay was performed according to the method presented by Skrovankova et al. (2022). Firstly, The FRAP solution was prepared. The contents of the solution are as follows: 25 mL of 300 mM acetate buffer (pH 3.6), 2.5 mL of 10 mM 2,4,6-tripyridyl-s-triazine (TPTZ) in 40 mM HCl solution (100 mL), and 2.5 mL of 20 mM ferric chloride ($FeCl_3.6H_2O$). The methanol extract was then filtered using filtration paper, and 1 mL of the extract was mixed with 1.5 mL of freshly prepared FRAP solution. Then, absorbance values were measured at 515 nm wavelength using Multiscan GO microplate spectrophotometer (Thermo Fisher Scientific, Finland). Finally, the measurement values results were expressed against standard Trolox (TE, 6-hydroxy-2,5,7,8- tetramethylchromane-2-carboxylic acid) in Trolox equivalents, µmol TE/g FW.

Total phenolic content

Total phenolic content was measured spectrophotometrically using the Folin–Ciocalteu reagent and modifying the method described by Spanos and Wrolstad (1990). First of all, 70% methanol was prepared and 9 ml of methanol was added to 1 ml of fruit extract. After the mixture was centrifuged at 5500 rpm for 10 min, 50 µl of supernatant was mixed with 250 µL of Folin-Ciocalteu reagent. Then, 750 µl of 20% (w/v) sodium carbonate (Na_2CO_3) was added to this mixture. The final mixture was incubated at 25 °C for half an hour. After this stage, absorbance values were measured at 760 nm wavelength using a UV/VIS spectrophotometer (Thermo Fisher Scientific, Finland). Total polyphenolic amounts were calculated using gallic acid (GA) standards with known concentrations and a daily calibration curve. Result values were recorded as mg GAE (gallic acid equavalent)/100 g fresh weight (FW) of jujube flesh.

Sugar content

Sugar analysis in jujube samples held at -80 °C by being homogenized was carried out using HPLC device (Shimadzu LC 20 A VP, Japan) with UV detector (Shimadzu SPD 20 A VP, Kyoto, Japan) according to the method presented by Crisosto (1997). The sucrose, glucose, fructose and xylose content of the samples were determined using the standards with a concentration of 15–2500 ppm. Before starting the analysis, the homogenized fruit samples were thawed and were reached to room temperature. 1 g of fruit sample was added to 4 mL of ultrapure water. The mixture was held in an ultrasonic water bath at 80 °C for 15 min and then it was centrifuged at 5500 rpm for 15 min. Thereafter, this was filtered by using Whatman filters (nylon syringe, 0.45 µm, 13 mm diameter). Coregel-87 C (7.8 * 300 mm) HPLC column was used in the analysis. Separations were performed at 70 °C at a flow rate of 0,6 mL/m. Elution was isocratic with ultrapure water. Individual sugars were calculated based on their standards and expressed in % of fresh weight (FW).

Organic acid analysis

Organic acid analysis was performed according to the protocol presented by Urun et al. (2021). In this analysis, D-malic, succinic, citric, tartaric, and L-ascorbic acid contents of the samples were determined by using HPLC device (Shimadzu LC 20 A VP, Japan) with UV detector (Shimadzu SPD 20 A VP, Kyoto, Japan). 87 H (5 µm, 300 mm * 7.8 mm [I.D.], Transgenomic) was chosen as the column. The operating conditions of the device are as follows: Column temperature was at 40 °C, flow rate was 0,8 mL/min, injection volume was 20 µL, and detection wavelength was 210 nm. 0.05 mM H_2SO_4 (sulphuric acid) was used as the solvent. For this, the temperature of the samples, which were kept at -80 °C, was reached to 25 °C. One ml of sample was shaken with 4 mL of 3% metaphosphoric acid. The mixture was held in an ultrasonic water bath at 80 °C for 15 min and then, it centrifuged at 5500 rpm for 15 min. Subsequently, the mixture was filtered using Whatman filters (nylon syringe, 0.45 µm, 13 mm diameter) and the solutions were injected into the device. The identified organic acids were evaluated according to the calibration curve of the relevant standard, and the result values are presented as mg/100 g fresh weight base.

Solid soluble content (SSC)

Most of the solid soluble content in jujube fruits is total sugar. The components that contribute the most to the SSC are glucose (20%), fructose (20%) and sucrose (10%) (Li et al. 2007). SSC contents of fruit samples were determined by Yilmaz et al. (2009), and the results are presented as percentages.

Statistical analysis

All fruit analyzes were performed in three replications. The results were evaluated using SPSS software (Release 15.0; SPSS Inc., Chicago, IL, USA). Analysis of variance was performed to observe the differences. Finally, coefficient of variation values were calculated in this software.

Results and discussion

Total phenol and antioxidant capacity

According to results of DPPH assay, the highest antioxidant activity of the ecotypes was found in JJ04 with 84.89%, followed by JJ16 with 84.30%, while the lowest DPPH value was observed in JJ14 with 79.72%. The highest FRAP value was 30.14 µmol TE/g FW in JJ09, while the lowest FRAP value was 13.82 µmol TE/g FW in JJ14 ecotype (Table 1).

Total phenolic content was quite variable among ecotypes, and it was obtained between 293.19 mg GAE/100 g FW (JJ18) and 992.48 mg GAE/100 g FW (JJ09).

Tepe (2020), investigated the total antioxidant capacity determination of the harvested jujube fruits using the DPPH assay and the total phenolic content of the antioxidant capacity of the ecotypes was 0.381 mmol TE/g dry weight (DW), and the total phenol content was 4030.62 mg GAE/100 g DW. Kou et al. (2015), determined the antioxidant capacity of 15 jujube cultivars using the DPPH and FRAP method, and they also analyzed the total phenolic content. Accordingly, antioxidant capacity was determined as between 1.046 and 1.908 mM TE/100 g FW by DPPH assay and 224.62-406.18 mg ascorbic acid equivalents (AAE)/100 g FW by FRAP assay, and total phenolics were 55.8–252.0 mg GAE/100 g FW. They indicated genotypic differences for all these parameters which in agreement with our results. In another study, ten promising jujube accessions were analyzed for antioxidant capacity (DPPH assay) and total phenolic content. The DPPH values of accessions were in range of 1.35–3.81 mmol TE/100 g FW, and total phenolic contents were 276–542 mg GAE/100 g FW (Gao et al. 2012a), which indicate similarities with our findings. Gao et al. (2011) conducted antioxidant capacity and total phenolics analysis in 5 jujube cultivars. Accordingly, the antioxidant capacities

Table 1 Total antioxidant capacity and total phenol content in fruits of jujube ecotypes

Ecotype	DPPH (%)	FRAP (µmol TE/g FW)	Total Phenol content (mg GAE/100 g FW)
JJ01	82.72	15.05	578.63
JJ02	83.67	14.63	574.98
JJ03	80.23	14.91	803.50
JJ04	84.89	14.81	451.14
JJ05	83.95	14.83	940.23
JJ06	81.19	14.79	572.32
JJ07	80.11	29.28	830.74
JJ08	83.59	14.54	580.64
JJ09	82.93	30.14	992.48
JJ10	80.28	14.90	723.48
JJ11	80.26	14.57	888.18
JJ12	83.77	14.95	787.68
JJ13	82.25	14.82	736.63
JJ14	79.72	13.82	444.54
JJ15	82.26	14.98	967.27
JJ16	84.30	14.87	855.82
JJ17	83.95	29.40	644.73
JJ18	81.73	14.70	293.19
Minimum	79.72	13.82	293.19
Maximum	84.89	30.14	992.48
Mean	82.32	17.22	703.68
Coefficient of variation (%)	2.0	33.1	28.2

of the fruits were found to be 2681–5632 μmol TE/100 g FW and the total phenolics as 428–600 mg GAE/100 g FW. In Romania, the total antioxidant capacity and total phenolic content of the fruits of two jujube cultivars were examined by Cosmulescu et al. (2018). The antioxidant capacity was 1266–1267 mg AAE/100 g and the total phenolics were found to be 557–682 mg GAE/100 g FW. Yilmaz (2019) found that the free radical scavenging activity was 0.58 μmol TE/L DW in fully ripe jujube fruits in Türkiye, and it was 2.74 μmol TE/L DW in unripe fruits in the analysis performed with the DPPH assay. In addition, according to the results of the same study, the total phenolic content was 1163 mg GAE/L. Gao et al. (2012b) determined the antioxidant activity and total phenolics in a jujube cultivar named 'Muzao' using ABTS assay. Total phenolic content of fresh fruits was determined as 2196 mg GAE/100 g DW and antioxidant capacity was 7.2 mmol TE/100 g DW. When considering above research it is clear that antioxidant capacity and total phenolic content of jujube cultivars/ecotypes dependence and the results indicate similarities for both parameters with our results.

Solid soluble content (SSC)

The importance of SSC in food is immense. SSC is among the quality parameters of fruits and vegetables and, it often plays an important role in determining the harvest date. SSC value increases with the ripening process (Cangi et al. 2011). In addition in some previous research, it has been stated that SSC increases with different cultivation techniques applied to the plant (a balanced irrigation and fertilization program, thinning of fruits, better lighting of fruits by pruning) (Todorov and Georgiev 1986; Parker et al. 2015).

In the present study, SSC values were found to be relatively higher than previous research. It was determined that the JJ06 ecotype had the highest SSC (24.35%), followed by the JJ02 ecotype (23.50%). The jujube ecotypes with the lowest SSC were JJ15 with 14.50% and JJ16 with 15.70%, respectively. In addition, the mean SSC value was found to be 19.52%.

Ye et al. (2022) conducted a study to observe the effect of different organic fertilizers on jujube composition. Total soluble solids of no fertilizer medium, organic fertilizer from soybean compost, decomposed sheep manure and biogas fertilizer were 15.45%, 18.48%, 16.63% and 17.05%, respectively. Gao et al. (2011) found the SSC of jujube fruits to be 14.9–18.8% in their study. Koley et al. (2016) reported that SSC to be 10–19% in their study. They conducted on 12 cultivars (*Ziziphus mauritiana* cv.) belonging to another specie of jujube. Previous research showed that cultivars or ecotypes belongs to different horticultural plants shows great differences for biochemical content including SSC (Urun et al. 2021; Topcu 2022).

This study revealed that from a practical perspective, selection of jujube ecotypes with high phytochemical content under the same environmental conditions is an important strategy that will benefit jujube breeding. More generally, further research on ecotype-driven recruitment should build on our findings and be implemented in research ideally involving larger sample sizes.

Sugar and organic acid components

Sugar compounds are phytochemicals that determine the sweetness of fruits, increase the presence of sensory interactions between sweetness and flavor perceptions, and make up the majority of solid soluble content (SSC) (Sun et al. 2011; Saint-Eve et al. 2014). For all observed 18 ecotypes, the dominant sugar components were fructose and glucose, respectively, while the dominant organic acid components were malic acid and citric acid. Fructose was quite variable among ecotypes, and the fructose in flesh was the highest in JJ02 ecotype with 13.82% and followed by JJ06 with 9.68%, while the lowest fructose was found in JJ07 ecotype with 4.86%. Glucose was between 3.35% (JJ02) and 9.15% (JJ01) among the ecotypes. Sucrose and xylose were found minor sugar components in jujube fruit. The concentration of sucrose was highest in JJ03 with 3.10% and followed by JJ14 with 2.55%, while the concentration of sucrose was the lowest in JJ05 with 0.18% and followed by JJ16 with 0.33%. Xylose was the sugar component with the lowest concentration, and it varied between 0.07% (JJ05 ecotype) and 0.41% (JJ08 ecotype) (Table 2).

Organic acid profile of a fruit is one of the most important factors determining the quality (Zhang et al. 2010). Thus, the biochemical contents of fruits and vegetables are among the popular topics of researchers. Malic acid content was quite variable among the ecotypes. The lowest and highest malic

Table 2 Sugar components and solid soluble contents of jujube ecotypes

Ecotype	Fructose %	Glucose %	Sucrose %	Xylose %	SSC %
JJ01	9.30	9.15	1.05	0.17	22.05
JJ02	13.82	3.35	1.56	0.35	23.50
JJ03	6.39	5.86	3.10	0.13	19.95
JJ04	7.68	7.31	0.38	0.12	19.50
JJ05	6.60	6.07	0.18	0.07	17.30
JJ06	9.68	8.30	2.33	0.27	24.35
JJ07	4.86	4.90	2.10	0.12	17.70
JJ08	9.22	7.52	2.39	0.41	22.80
JJ09	6.84	6.51	1.16	0.13	18.90
JJ10	6.25	6.14	0.80	0.12	17.30
JJ11	7.12	6.43	1.42	0.09	19.30
JJ12	9.40	5.36	1.13	0.31	19.30
JJ13	8.45	7.64	1.21	0.16	20.80
JJ14	4.94	4.41	2.55	0.10	16.30
JJ15	5.74	5.14	0.51	0.11	14.50
JJ16	5.84	5.58	0.33	0.14	15.70
JJ17	7.95	7.71	2.32	0.14	21.30
JJ18	7.44	6.77	0.37	0.23	20.80
Minimum	4.86	3.35	0.18	0.07	14.50
Maximum	13.82	9.15	3.10	0.41	24.35
Mean	7.64	6.34	1.38	0.18	19.52
Coefficient of variation (%)	28.2	22.9	64.7	61.9	14.0

acid values were observed from JJ14 ecotype (0.38%) and JJ07 ecotype (4.64%), respectively (Table 3). Citric acid was between 0.35% (JJ14 ecotype) and 1.23% (JJ02 ecotype). The concentration of succinic acid was the lowest in JJ04 and JJ16 with 0.11%, while the concentration of succin-ic acid was the highest in JJ02 with 0.55%. The concentration of tartaric acid varied between 0.04% (JJ13 ecotype) and 0.26% (JJ06 ecotype).

Gao et al. (2012b) used jujube fruits and found that the sugar components were as follows: Glucose was 274.5 mg/100 g DW, fructose was 1648.0 mg/100 g DW and sucrose was 37.1 mg/100 g DW. In the same study, the organic acid components were as follows: Malic acid was 206.7 mg/100 g DW, citric acid was 198.9 mg/100 g DW and succinic acid was 14.8 mg/100 g DW. In a study (Cosmulescu et al. 2018), examining the biochemical content of jujube fruits malic acid was 106.1-305.6 mg/L, lactic acid was 48.1-163.9 mg/L, oxalic acid was 45.3–92.3 mg/L and tartaric acid was 23.2–35.6 mg/L. Gao et al. (2012a) showed that glucose was 1156.7-2727.4 mg/100 g FW, sucrose was 557.3–2801 mg/100 g FW, fructose was 294-730.3 mg/100 g FW, and rhamnose was 0-105.1 mg/100 g FW in jujube fruits. Also organic acid components were followed as: Malic acid was 294-740.3 mg/100 g FW, citric acid was 39.4-196.6 mg/100 g FW, succinic acid was 0-177.9 mg/100 g FW. In addition, Fu et al. (2021) reported that the total sugar amount of jujube fruits harvested at different maturity stages was not related to maturity. According to the results of the research, glucose was found between 84.9 and 211.7 mg/g, fructose 109-201.9 mg/g and sucrose 102.8-440.9 mg/g, respectively. The organic acids detected in the same study were as follows: Malic acid 162.23–266.9 mg/100 g, and citric acid 149.1-296.73 mg/100 g.

This study indicates similarities with the results of some researchers, and it also shows differences with the results of some researchers. These differences may be due to various factors such as the plant species examined in the biochemical content of fruit

Table 3 Organic acid components of the jujube ecotypes

Ecotype	Malic acid %	Citric acid %	Succinic acid %	Tartaric acid %
JJ01	1.01	0.60	0.33	0.11
JJ02	2.15	1.23	0.55	0.24
JJ03	0.99	0.90	0.17	0.15
JJ04	0.77	0.80	0.11	0.07
JJ05	0.79	0.58	0.21	0.07
JJ06	1.82	1.21	0.39	0.26
JJ07	4.64	0.60	0.17	0.13
JJ08	1.77	1.05	0.46	0.17e
JJ09	0.96	0.74	0.17	0.11
JJ10	0.54	0.36	0.15	0.12
JJ11	0.59	0.56	0.22	0.06
JJ12	0.80	0.75	0.23	0.11
JJ13	0.90	0.48	0.17	0.04
JJ14	0.38	0.35	0.12	0.07
JJ15	0.49	0.58	0.19	0.20
JJ16	0.44	0.49	0.11	0.07
JJ17	0.81	0.57	0.18	0.10
JJ18	1.45	0.99	0.46	0.22
Minimum	0.38	0.35	0.11	0.04
Maximum	4.64	1.23	0.55	0.26
Mean	1.18	0.71	0.24	0.13
Coefficient of variation (%)	84.4	37.5	55.1	51.5

species, ecotype, agricultural practices, maturity level of the fruit at harvest, post-harvest storage, climatic conditions to which the plant is exposed, and geographical location. (Kostic et al. 2013; Ozkan et al. 2018; Keles 2020; Cavusoglu et al. 2021; Korkmaz et al. 2022).

Conclusion

Results showed that JJ04 and JJ09 ecotypes can be accepted as functional foods with the highest antioxidant capacity and total phenol content. JJ02 and JJ06 are ecotypes with high sugar contents and SSC with delicious fruit for consumers for table consumption, and they also have the potential to be value-added food as dried fruit. Jujube, which is also considered as a medicinal edible fruit, but not particularly well-known by western countries, has not been evaluated widely academically and commercially in Türkiye until today. Nowadays, the importance of a healthy and well-balanced diet continues to rise increasingly. It has been frequently stated in previous research that this fruit contains high bioactive components. The value of a fruit species that can be an alternative to temperate climate fruit species is priceless such as jujube. The fact that it is both a table and an industrial product reveals the high potential of the market value of jujube. As a result, this research and similar research to be done in the future will contribute to the breeding of jujube. It would also be useful to genetically compare the morphological differences of these ecotypes in addition to investigating their biochemical differences.

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Data Availability The data used in the manuscript can be provided by the author upon request.

Declarations

Conflict of interest The author declares no conflicts of interest.

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