BIOLOGICA NYSSANA
15 (2) December 2024: 69-74
DOI: 10.5281/zenodo.13902146

Biochemical contents of some jujube genotypes

Original Article

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Received: *August 20, 2024*
Revised: *September 20, 2024*
Accepted: *September 23, 2024*

Abstract:

This study aimed to evaluate the biochemical content of 15 jujube genotypes with superior characteristics from the Denizli/Çivril region over a two-year period. Significant differences were found among the genotypes regarding their biochemical properties. Genotypes 10, 11, and 13 consistently exhibited higher total phenolic content compared to the others in both years. Additionally, genotypes 10, 2, and 11 showed higher total flavonoid content than the other genotypes. Genotypes 2, 10, and 1 demonstrated greater total antioxidant content, while genotypes 10, 2, and 11 had elevated vitamin C levels. Overall, genotypes 10, 11, and 2 consistently exhibited higher biochemical values compared to the others across both years.

Key words:
Ziziphus jujuba, total antioxidant, total phenolic content, total flavonoid content, vitamin C

Apstrakt:

Biohemijski sastav nekih genotipova jujube

Ova studija je imala za cilj da proceni biohemijski sadržaj 15 genotipova urme sa superiornim karakteristikama iz oblasti Denizli/Čivril tokom dvogodišnjeg perioda. Uočene su značajne razlike među genotipovima u pogledu njihovih biohemijskih svojstava. Genotipovi 10, 11 i 13 dosledno su pokazivali viši ukupni sadržaj fenola u poređenju sa ostalim genotipovima tokom obe godine. Takođe, genotipovi 10, 2 i 11 imali su veći ukupni sadržaj flavonoida u odnosu na druge genotipove. Genotipovi 2, 10 i 1 su pokazali viši ukupni antioksidativni sadržaj, dok su genotipovi 10, 2 i 11 imali povećan nivo vitamina C. Generalno, genotipovi 10, 11 i 2 su dosledno pokazivali veće biohemijske vrednosti u poređenju sa ostalim genotipovima tokom obe godine.

Ključne reči:
Ziziphus jujuba, ukupni antioksidansi, ukupni saržaj fenola, ukupni sadržaj flavonoida, vitamin C

Introduction

Jujube is one of the oldest known fruit species cultivated for over 5,000 years, especially in China and India. Therefore, its use for medical and food purposes has become widespread (Mengjun, 2003; Yildirim et al., 2015; San et al., 2016). Jujube makes a significant contribution to human nutrition due to its rich nutrient and phytochemical profile. It is particularly abundant in vitamins, organic acids, sugars, minerals, polyphenols, amino acids, carbohydrates, oleic acid, and linoleic acid (San & Yildirim, 2010; Jat et al., 2013; San et al., 2016; Wojdyło et al., 2016; Gündoğmuş & Taşçı, 2017; Liu et al., 2021). Tepe et al. (2022) stated that jujube fruit has a high phenolic content. They also emphasized that jujube extracts can have a natural antioxidant effect due to their high phenolic content. The antioxidant, anti-inflammatory, anti-obesity, hepatoprotective, antidiabetic, antimicrobial, and anticancer properties of these components have been reported to have protective effects on human health (San & Yildirim, 2010; Ji et al., 2017; Gowd et al., 2020; Feng et al., 2021; Kahraman et al., 2022; Hançer et al., 2023; Aoudeh et al., 2024; Pepe et al., 2024; Yıldırım et al., 2024). In addition, according to the World Health Organization, an adult can meet the daily requirement of vitamins C and B from a single jujube fruit (Jat et al., 2013). In addition to its effects on human health, its high adaptability, long and economic life, various consumption methods, and ease of cultivation have made it an increasingly popular fruit worldwide (Mengjun, 2003). In Türkiye, the jujube planting area has increased by 512% and the production quantity by 1,072% in the last 10 years. China meets more than 90% of the world's jujube production (Jat et al., 2013), and today it produces approximately 8 million t in a 2 million ha area (Liu et al., 2021). As natural habitats in Türkiye, the Coruh Valley Basin, Demirci District of Manisa, and Çivril District of Denizli are among the leading regions where jujube cultivation is widespread (Yasa, 2016). This study aimed to determine the biochemical contents of different 15 jujube genotypes with superior fruit characteristics in the Denizli/Çivril region.

Materials

This study was conducted in an orchard with 15-year-old jujube (*Ziziphus jujuba* Mill.) trees planted on seedlings at a spacing of 7 × 3.5 m in the Çivril district of Denizli province. The research area is situated at an altitude of 915 m, at coordinates of 38°14′ North, and 29°59′ East. Fruits were harvested at least 50% of the outer skin colour turned from green to golden yellow (Hussain et al., 2021). The fresh fruits were harvested on September 12, 2021, for the first year, and the second year's harvest was on September 5, 2022. Fifty fruit samples were collected from each jujube genotype in 2021 and 2022, representing the tree from four different directions. Fruits were placed in perforated bags, transported to the laboratory and analyses were conducted immediately.

Methods

Determination of total phenolic content

The total phenolic content was determined using the Folin-Ciocalteu method as described by Singleton & Rossi (1965). Homogenized fruit pulp was subjected to extraction in tubes for 1 h using a solution of acetone, water, and acetic acid (70:29.5:0.5). Accordingly, the samples were mixed with 0.1 ml of extract with di-ionized water and 0.1 ml (2N) Folin-Ciocalteu indicator and kept at room temperature for 6 min. Then 0.5 ml of 20% sodium carbonate solution was added and incubated at room temperature for 30 min for color development. After color development, the absorbance values of the samples were read in a spectrophotometer at 760 nm wavelength (Model T60U, PG Instruments, and USA).

Determination of total flavonoid content

The total flavonoid content was determined according to the method described by Kim et al. (2003). First, 1 ml of each sample was mixed with 0.3 ml of 5% sodium nitrite ($NaNO_2$) solution and incubated for 5 min. Then, 0.3 ml of 10% aluminium chloride ($AlCl_3$) solution was added and incubated for an additional 6 min. Afterwards, 2 ml of 1 M sodium hydroxide (NaOH) was added, and the mixture was allowed to stand for 2 min. Subsequently, 4 ml of distilled water was added, and thoroughly mixed, and the absorbance values of the samples were read at 510 nm wavelength.

Determination of total antioxidant

The total antioxidant capacity was determined using the method reported by Kumaran & Karunakaran (2006) employing 1,1-diphenyl-2-picrylhydrazyl (DPPH). First, 2 g of each sample were grounded and incubated in 20 ml of 80% methanol at -20 °C for 2 h. Then, the mixture was centrifuged at 2,000 rpm for 5 min, and the supernatant was collected for analysis. Following this step, 2 ml of 0.1 mM DPPH dissolved in methanol was added to 100 µL of the supernatant. After 30 min of incubation, the absorbance was measured at 517 nm wavelength.

Determination of Vitamin C

The vitamin C content in the fruits was determined according to Namdar (2005). Fruit juice was obtained from a portion of each sample, and the vitamin C content was determined by titrimetric method. Specifically, 10 ml of fruit juice was mixed with 50 ml of meta-phosphoric acid solution and filtered. Then, 10 ml of the filtrate was titrated with a dye solution. The obtained values were used to calculate the vitamin C content according to the formula provided by the researcher.

Statistical Analysis

The data obtained in the study were subjected to the analysis of variance using the Minitab software package. Tukey's multiple comparison test was used to determine significant differences among the genotypes.

Results and discussion

The results of the biochemical measurements of the genotypes in 2021 are presented in **Tab. 1**. Significant differences were observed among the genotypes only in terms of total phenolic content ($p \leq 0.05$). Statistically significant differences were not found among the genotypes in other characteristics.

In the study, the highest total phenolic content was obtained in genotype 10 with 3.131 mg GAE 100 g^{-1}. This was followed by genotype 11 with 2.445 mg GAE 100 g^{-1} and genotype 13 with 2.362 mg GAE 100 g^{-1}, respectively. The lowest total phenolic content was found in genotype 5 with 0.669 mg GAE 100 g^{-1}. The highest total flavonoid content was obtained in genotype 10 with 0.885 mg CE 100 g^{-1}. This was followed by genotype 2 with 0.884 mg CE 100 g^{-1} and genotype 11 with 0.738 mg CE 100 g^{-1}, respectively. The lowest total flavonoid content

Table 1. Biochemical contents of the genotypes in 2021

The genotypes	Total phenolic content (mg GAE 100 g^{-1})*	Total flavonoid content (mg CE 100 g^{-1})	Total antioxidant (mmol TE g^{-1})	Vitamin C (mg 100 g^{-1})
1	1.091±0.36 ^{de}	0.645±0.33	0.713±0.28	174.30±89.70
2	1.337±0.60 ^{cde}	0.884±0.40	0.855±0.37	238.90±19.00
3	1.852±0.09 ^{bcd}	0.685±0.04	0.634±0.06	185.05±12.67
4	1.233±0.02 ^{cde}	0.718±0.16	0.693±0.20	194.10±44.10
5	0.669±0.10 ^{e}	0.521±0.07	0.484±0.04	140.90±21.10
6	1.378±0.24 ^{cde}	0.515±0.09	0.451±0.08	139.30±26.00
7	1.584±0.12 ^{bcde}	0.509±0.08	0.415±0.09	137.60±23.40
8	2.105±0.43 ^{bc}	0.577±0.04	0.488±0.04	155.90±11.05
9	1.302±0.46 ^{cde}	0.737±0.05	0.681±0.08	199.18±15.01
10	3.131±0.05 ^{a}	0.885±0.22	0.786±0.22	239.10±60.60
11	2.445±0.59 ^{ab}	0.738±0.11	0.621±0.12	199.50±31.00
12	2.157±0.06 ^{bc}	0.663±0.10	0.560±0.11	179.30±27.20
13	2.362±0.35 ^{ab}	0.704±0.20	0.637±0.13	190.30±54.50
14	2.131±0.07 ^{bc}	0.565±0.06	0.447±0.05	152.67±17.15
15	1.784±0.24 ^{bcd}	0.704±0.04	0.569±0.01	190.19±12.94

* the difference between means indicated by different letters is significant at the p≤0.05 level

was found in genotype 7 with 0.509 mg CE 100 g^{-1}. In the study, the highest total antioxidant content was determined in genotype 2 with 0.855 mmol TE g^{-1}. This was followed by genotype 10 with 0.786 mmol TE g^{-1} and genotype 1 with 0.713 mmol TE g^{-1}, respectively. The lowest total antioxidant content was found in genotype 7 with 0.415 mmol TE g^{-1}. The highest vitamin C content was obtained in genotype 10 with 239.10 mg 100 g^{-1}. This was followed by genotype 2 with 238.90 mg 100 g^{-1} and genotype 11 with 199.50 mg 100 g^{-1}, respectively. The lowest vitamin C content was found in genotype 7 with 137.60 mg 100 g^{-1}.

The biochemical measurements of the genotypes in 2022 are presented in **Tab. 2**. Similar to the findings in 2021, statistically significant differences were observed among the genotypes only in terms of total phenolic content ($p \le 0.05$). No statistically significant differences were found among the genotypes in other characteristics.

The highest total phenolic content was obtained in genotype 10 with 3.914 mg GAE 100 g^{-1}. This was followed by genotype 11 with 3.057 mg GAE 100 g^{-1} and genotype 13 with 2.953 mg GAE 100 g^{-1}. The lowest total phenolic content was found in genotype 5 with 0.837 mg GAE 100 g^{-1}. The highest total flavonoid content was achieved in genotype 10 with 1.266 mg CE 100 g^{-1}, followed by genotype 2 with 1.264 mg CE 100 g^{-1}, and genotype 11 with 1.055 mg CE 100 g^{-1}. The lowest total flavonoid content was observed in genotype 7 with 0.728 mg CE 100 g^{-1}. In terms of total antioxidant content, the highest value was recorded in genotype 2 with 1.719 mmol TE g^{-1}, followed by genotype 10 with 1.580 mmol TE g^{-1}, and genotype 1 with 1.434 mmol TE g^{-1}. The lowest total antioxidant content was detected in genotype 7 with 0.836 mmol TE g^{-1}. The highest vitamin C content was obtained in genotype 10 with 342.00 mg 100 g^{-1}, followed by genotype 2 with 341.60 mg 100 g^{-1}, and genotype 11 with 285.30 mg 100 g^{-1}. The lowest vitamin C content was found in genotype 7 with 196.70 mg 100 g^{-1}.

Li et al. (2007) reported varying levels of vitamin C content ranging from 192 mg/100 g to 359 mg 100 g^{-1} and total phenolic content ranging from 5.18 mg GAE g^{-1} to 8.53 mg GAE g^{-1} in five Chinese jujube varieties. They indicated that both nutrient and biochemical contents varied among different varieties. San et al. (2009) reported vitamin C contents ranging from 271.30 mg 100 g^{-1} to 366.00 mg 100 g^{-1} in some promising jujube genotypes, suggesting their safe use in human nutrition. San et al. (2016) stated that jujube fruits are rich in vitamin C and phenolic compounds, with vitamin C content varying from 32 mg 100 g^{-1} to 375 mg 100 g^{-1} across varieties. Gao et al. (2011) reported vitamin C contents ranging from 77.20 mg 100 g^{-1} to 102.3 mg 100 g^{-1}, total phenolic content ranging

Table 2. Biochemical characteristics of the genotypes in 2022

The genotypes	Total phenolic content (mg GAE 100 g^{-1})*	Total flavonoid content (mg CE 100 g^{-1})	Total antioxidant (mmol TE g^{-1})	Vitamin C (mg 100 g^{-1})
1	1.364±0.44 ^{de}	0.923±0.47	1.434±0.57	249.30±12.40
2	1.671±0.75 ^{cde}	1.264±0.57	1.719±0.74	341.60±15.70
3	2.315±0.12 ^{bcd}	0.979±0.06	1.275±0.13	264.70±18.10
4	1.541±0.02 ^{cde}	1.028±0.23	1.392±0.40	277.60±63.10
5	0.837±0.13 ^{e}	0.745±0.11	0.974±0.08	201.50±30.30
6	1.722±0.30 ^{cde}	0.737±0.13	0.907±0.17	199.30±37.10
7	1.980±0.16 ^{bcde}	0.728±0.12	0.836±0.18	196.70±33.50
8	2.631±0.53 ^{bc}	0.825±0.05	0.981±0.01	222.98±15.89
9	1.627±0.57 ^{cde}	1.054±0.07	1.370±0.17	284.80±21.40
10	3.914±0.06 ^{a}	1.266±0.32	1.580±0.45	342.00±86.60
11	3.057±0.74 ^{ab}	1.055±0.16	1.248±0.24	285.30±44.30
12	2.696±0.08 ^{bc}	0.949±0.14	1.126±0.23	256.40±38.90
13	2.953±0.44 ^{ab}	1.007±0.28	1.281±0.27	272.20± 77.90
14	2.664±0.09 ^{bc}	0.808±0.09	0.899±0.11	218.40±24.60
15	2.229±0.30 ^{bcd}	1.006±0.06	1.144±0.03	272.00±18.50

* the difference between means indicated by different letters is significant at the p≤0.05 level

from 428.50 mg GAE 100 g^{-1} to 600.40 mg GAE 100 g^{-1}, and total flavonoid content ranging from 159.30 mg rutin eq. 100 g^{-1} to 230.30 mg rutin eq. 100 g^{-1}. Chen et al. (2018) reported vitamin C contents ranging from 162.50 mg 100 g^{-1} to 244.57 mg 100 g^{-1} and total flavonoid contents ranging from 41.21 mg g^{-1} to 62.72 mg g^{-1} across different jujube varieties. Wojdyło et al. (2016) indicated total phenolic content ranging from 1442 mg 100 g^{-1} to 3432 mg 100 g^{-1} and vitamin C content ranging from 387 mg 100 g^{-1} to 555 mg 100 g^{-1}. The researchers attributed these variations among varieties to genetic differences. Ivanišová et al. (2017) determined total flavonoid content ranging from 1.49 to 11.57 g QE g^{-1}, suggesting that variation in fruit properties stems from genetic diversity. Reche et al. (2019) reported vitamin C contents of 0.49 g 100 g^{-1} for organically grown jujubes and 0.50 g 100 g^{-1} for conventionally grown jujubes, total phenolic contents of 452.2 mg GAE 100 g^{-1} for organically grown jujubes and 433.7 mg GAE 100 g^{-1} for conventionally grown jujubes, and total flavonoid contents of 83.10 mg eq. rutin 100 g^{-1} for organically grown jujubes and 111.30 mg eq. rutin 100 g^{-1} for conventionally grown jujubes. Tepe & Ekinci (2021) examined the effect of different drying temperatures on total phenolic and antioxidant content in jujube fruits. The researchers reported that the total phenolic and antioxidant content of fresh jujube fruits were 911.4±47.32 mg GAE 100 g-1 DW and 0.214±0.001 mmol TE g-1 DW. They found that phenolic and antioxidant contents in fruits decreased with the increase in drying temperature. Riaz et al. (2021) determined the total phenolic contents of jujube fruits to be on average 284.6 mg GAE 100 g^{-1} and total flavonoid contents to be on average 98.7 mg QE 100 g^{-1}. Our research findings showed similarities with previous studies in some values while deviating in others. The reasons for these discrepancies include the wide variation in physical, chemical, and functional properties among jujube varieties cultivated worldwide, as well as the influence of ecological factors, variety/genotype characteristics, genetic traits, and storage and cultural-care conditions on jujube fruit quality (Gao et al., 2011; Gündüz & Saraçoğlu, 2014; Almansa et al., 2016; Abdel-Sattar et al., 2024). In fact, cultural practices can be so influential that fruits obtained from regularly irrigated trees exhibit higher vitamin C content compared to those from trees subjected to limited irrigation (Cui et al., 2008).

Conclusion

In conclusion, jujube is an excellent natural antioxidant source due to its high content of vitamin C and total phenolic compounds. It is believed that the information obtained in this study will increase consumers' interest in jujube fruits. The research results have revealed the significant influence of the genotype on bioactive compounds. In terms of biochemical contents, genotypes 10, 11, and 2 consistently stood out with the highest values in both years, while genotype 7 consistently exhibited the lowest values. Promising genotypes with high biochemical contents are expected to play a significant role in a variety of breeding programs.

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