Scientific Papers. Series B, Horticulture. Vol. LXVII, No. 1, 2023
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

CHEMICAL ANALYSIS OF SOME LOCAL AND CULTIVATED JUJUBE GENOTYPES (*ZIZIPHUS JUJUBA* MILL.) FROM DOBROGEA REGION

Ioan STOLI, Florin STĂNICĂ

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, District 1, Bucharest, Romania

Corresponding author email: stoli.ioan@gmail.com

Abstract

The cultivation of Chinese jujube can be traced back 7,000 years to the Neolithic era, making it one of the oldest cultivated fruit plants in the world. In Romania, Chinese jujube can be found in nature, semi-spontaneously, in Jurilovca and Mahmudia in Tulcea County and Ostrov in Constanța County. This paper describes the genotypes of Chinese jujube (Ziziphus jujuba Mill.) found in the Dobrogea region, specifically in Jurilovca, Mahmudia, Bugeac, and Ostrov. The study focuses on the chemical analysis and mineral composition of seven local jujube genotypes from Dobrogea and five Chinese cultivars. In the analyzed jujubes, sugar content varied between 15.91% to 31.07%; dry matter varied between 19.50% and 39.00%; total polyphenols varied between 390 to 1,020 mg gallic acid/100 g, calcium varied between 6.29 and 47.95 mg/100 g.

***Key words**: Chinese jujube, polyphenols, sugar content, mineral composition.*

INTRODUCTION

Ziziphus jujuba Mill., also known as jujube in English or Zao in Chinese, originates from the middle and lower regions of the Yellow River, the "mother river" of the Chinese people. Its fruits are often confused with Indian jujube (*Ziziphus mauritiana*), but these are two different species.

The *Ziziphus jujuba* tree produces flowers in early summer (June-July), and the fruits ripen gradually in autumn (September-October). The fruits can be consumed fresh, dried, or processed into juices, wines, syrups, preserves, candies, and vinegar.

Jujube stands out with its unique composition, encompassing 23 types of amino acids rarely present in other fruits. This diversity contributes to its reputation as a traditional and functional Chinese food renowned for its numerous health benefits. The primary minerals in jujube include phosphorus, potassium, calcium, and manganese. Notably, sodium, zinc, copper, and iron are also present (Shahrajabian, 2019).

The cultivation of Chinese jujube can be traced back 7,000 years to the Neolithic era, making it one of the oldest cultivated fruit plants in the world. During the Han Dynasty, approximately 2,000 years ago, the cultivation of Chinese jujube spread throughout the entire region of Northern and Southern China (Liu, 2020).

In Romania, Chinese jujube can be found in nature, semi-spontaneously, in the localities of Jurilovca, Mahmudia in Tulcea County, and Ostrov in Constanța County. It is believed that they reached our country through the Silk Road and routes near ancient Greek, Roman, and Byzantine cities, such as the Argamum Fortress (Jurilovca, Tulcea County), Enisala Fortress (a fortress overlooking the Razim and Babadag lakes today), Salsovia Fortress (Mahmudia, Tulcea County), and Vicina Fortress (located on Păcuiul lui Soare Island, also known as the sunken fortress in the Ostrov area, Constanța County) (Stănică, 2019).

MATERIALS AND METHODS

The study was conducted by analyzing the fruits of seven wild jujube genotypes identified in Tulcea and Constanța County, namely the Jurilovca, Mahmudia, Bugeac, and Ostrov genotypes, and on five jujube cultivars, namely Taigu Ban, Hu Ping, Xuan Cheng Jiang Zao, Jun Zao, and Hongan.

The cultivars of Chinese jujube were analyzed to compare wild jujube genotypes for a better understanding.
This study aims to present several biochemical characteristics of the fruits, such as sugar content (%), soluble dry matter (%), acidity (citric acid%/100 g), total polyphenols (mg gallic acid/100 g), and antioxidant capacity (mg Trolox/100 g). Additionally, the mineral content, including lead (µg/kg), cadmium (µg/kg), chromium (µg/kg), copper (mg/kg), zinc (mg/kg), manganese (mg/kg), iron (mg/kg), sodium (mg/100 g), potassium (mg/100g), calcium (mg/100 g), and magnesium (mg/100 g), were also analyzed.

RESULTS AND DISCUSSIONS

The presented data shows that sugar levels varied significantly among the samples of Chinese jujube fruits, with values ranging from 15.91% to 31.07%.
The Jurilovca III 1, Ostrov, and Jurilovca I 1 genotype exhibit the highest sugar levels, 31.07%, 29.90%, and 26.40%, respectively, while the Hu Ping, Jun Zao, and Hongan varieties had the lowest sugar levels, 15.91%, 16.35%, and 17.45% (Table 1, Figure 1).
The presented data in Figure 2 refers to the acidity level expressed as citric acid (%) measured in different samples of Chinese jujube fruits. Acidity is an essential characteristic of fruits and can influence their taste and quality.
Acidity levels vary significantly among genotypes, ranging from 0.26% to 1.05%.

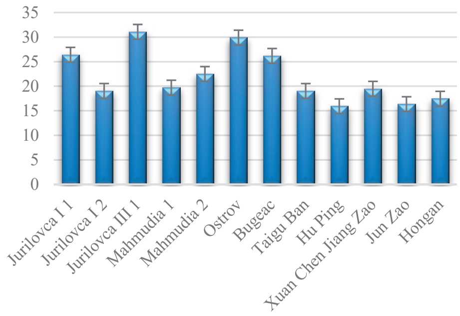

Figure 1. Sugar content (%)

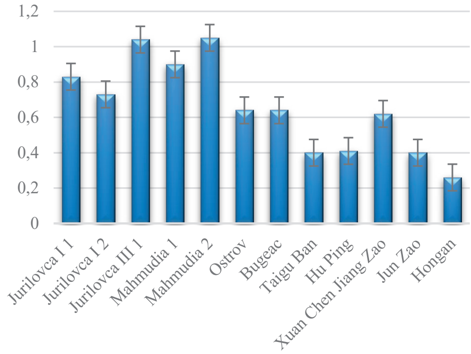

Figure 2. Acidity (citric acid %/100 g)

The Mahmudia 2, Jurilovca III 1, and Mahmudia 1 genotypes exhibit the highest acidity levels, 1.05%, 1.04%, and 0.90%. At the same time, the fruits of the Hongan, Taigu Ban, and Jun Zao varieties have the lowest acidity levels, 0.26%, 0.40%, and 0.40%, respectively (Table 1.)

Table 1. Biochemical analyses

Genotype	Sugar content (%)	Acidity (citric acid %/ 100 g)	Soluble dry matter (%)	Total polyphenols (mg gallic acid/ 100 g)	Antioxidant capacity (mg Trolox/100 g)
Jurilovca I 1	**26.4**	**0.83**	25.50	**690**	**375.0**
Jurilovca I 2	19.04	**0.73**	24.75	**750**	**382.5**
Jurilovca III 1	**31.07**	**1.04**	**27.00**	**780**	**405.0**
Mahmudia 1	19.71	**0.9**	21.75	**720**	**397.5**
Mahmudia 2	**22.49**	**1.05**	**30.00**	**1020**	**442.5**
Ostrov	**29.9**	0.64	**39.00**	510	232.5
Bugeac	**26.17**	0.64	**34.5**	**690**	**315.0**
Taigu Ban	19.03	0.40	21.00	420	142.5
Hu Ping	15.91	0.41	19.50	390	120.0
Xuan Chen Jiang Zao	19.48	0.62	19.50	540	270.0
Jun Zao	16.35	0.40	21.00	480	202.5
Hongan	17.45	0.26	24.00	450	240.0

.

Dry matter content (%) measured in different fruit genotypes is presented in Figure 3, being an indicator of fruit quality.

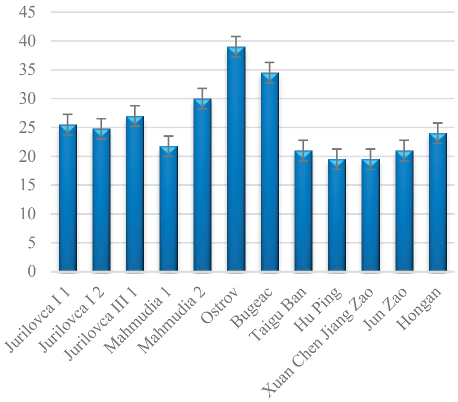

Figure 3. Dry matter (%)

The dry matter levels varied significantly among genotypes, ranging from 19.5% to 39%. The Ostrov, Bugeac, and Mahmudia 2 genotypes exhibit the highest levels of soluble dry matter, 39.00%, 34.50%, and 30.00%. At the same time, the fruits of the analyzed cultivars Hu Ping, Xuan Chen Jiang Zao, and Jun Zao had the lowest levels for dry matter, 19.50%, 19.50%, and 21.00%.

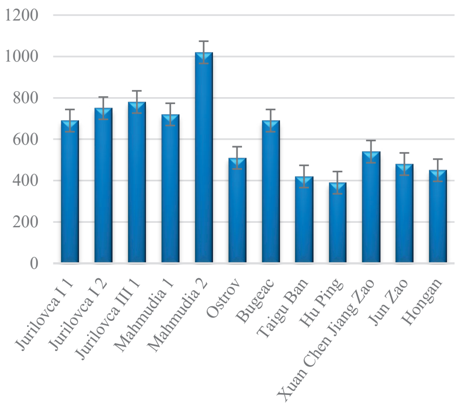

Figure 4. Total polyphenols (mg gallic acid/100 g)

Polyphenols are organic compounds found in plants and are considered beneficial for health as they can help prevent chronic diseases such as cardiovascular diseases and cancer. In general, foods that contain high levels of polyphenols are considered healthy, and consuming them can benefit health.

Total polyphenol levels varied significantly among samples of Chinese jujube fruits, ranging from 390 to 1,020 mg gallic acid/ 100 g. Mahmudia 2, Jurilovca III 1, and Jurilovca I 2 exhibit the highest levels of total polyphenols, with values of 1,020 mg gallic acid/100 g, 780 mg gallic acid/100 g, and 750 mg gallic acid/100 g, respectively. At the same time, the fruits of the analyzed cultivars Hu Ping, Taigu Ban, and Hongan had the lowest levels of total polyphenols, with values of 390 mg gallic acid/100 g, 420 mg gallic acid/100 g, and 450 mg gallic acid/100 g, respectively (Table 1., Figure 4).

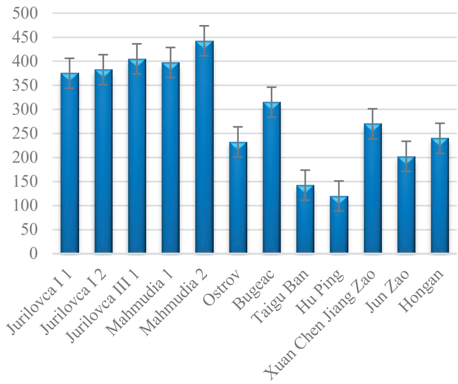

Figure 5. Antioxidant capacity (mg Trolox/100 g)

Antioxidant capacity refers to the ability of a substance to neutralize or prevent cellular damage caused by free radicals and other reactive oxygen species. Antioxidants can be found in various foods, including fruits and vegetables, and help protect cells and tissues from oxidative stress and the adverse effects of aging and chronic diseases.

According to the presented data, antioxidant capacity measured by the DPPH method varied significantly among genotypes, with values ranging from 120 to 442.5 mg Trolox/100 g. Mahmudia 2, Jurilovca III 1, and Mahmudia 1 genotypes exhibited the highest antioxidant capacities with values of 442.50 mg Trolox/ 100 g, 405 mg Trolox/100 g, and 397.50 mg Trolox/100 g, while the fruit samples of the Chinese jujube cultivars Hu Ping, Taigu Ban, and Jun Zao had the lowest antioxidant capacity values of 120 mg Trolox/100g, 142.50 mg Trolox/100 g, and 202.50 mg Trolox/100 g, respectively (Table 1., Figure 5).

Table 2. Mineral contain of Chinese jujube fruits

Genotype	Pb µg/kg	Cd µg/kg	Cr µg/kg	Cu mg/kg	Zn mg/kg	Mn mg/kg	Fe mg/kg	Na mg/100 g	K mg/100 g	Ca mg/100 g	Mg mg/100 g
Jurilovca I 1	7.88	<1	164.18	0.9	2.9	**2.89**	**1.28**	22.61	42.09	**38.95**	**10.99**
Jurilovca I 2	13.53	<1	137.96	0.99	1.96	2.51	0.38	22.95	**51.99**	**37.51**	**11.06**
Jurilovca III 1	16.8	<1	**242**	**1.98**	**3.85**	**3.77**	0.7	26.08	**53.61**	**47.95**	**11.9**
Mahmudia 1	**49.86**	**3.87**	102.2	0.76	2.59	**4.06**	0.13	25.42	**55.16**	**34.66**	**11.56**
Mahmudia 2	9.21	<1	63.4	1.47	**3.72**	**4.03**	0.39	26.78	51.06	**36.3**	**11.94**
Ostrov	**45.43**	**3.66**	<1	1.54	2.21	2.48	0.22	26.41	**52.54**	14.44	9.46
Bugeac	8.9	<1	**543.6**	0.6	2.48	**3.39**	0.2	19.51	47.87	**25.09**	**10.68**
Taigu Ban	**26.73**	2.17	130.39	**1.89**	**6.28**	2.04	**1.24**	**32.02**	**53.6**	9.44	8.21
Hu Ping	17.68	1.89	63.46	**3.14**	1.39	1.93	0.5	**33.18**	49.43	6.29	7.78
Xuan Chen Jiang Zao	20.77	2.58	112.38	1.49	2.79	1.52	0.49	24.55	**54.07**	9.57	8.78
Jun Zao	17.37	2.3	<1	**1.97**	2.93	2.24	**1.42**	**32.39**	**51.88**	8.33	7.85
Hongan	**40**	2.2	**188.6**	**1.86**	2.28	2.08	**1.89**	**30.35**	49.79	9.97	8.47

The highest lead content was recorded on Mahmudia 1 and Ostrov genotypes with values of 49.86 µg/kg and 45.43 µg/kg. In contrast, in the Chinese jujube varieties, the highest values were found in the Taigu Ban variety, with a weight of 26.73 µg/kg, and the Xuan Chen Jiang Zao variety, with a value of 20.77 µg/kg. According to Commission Regulation (EC) No. 1881/2006 on maximum levels for specific contaminants in food products, the permissible limit for lead content in fruits is 0.1 mg/kg, equivalent to 100 µg/kg (Table 2).

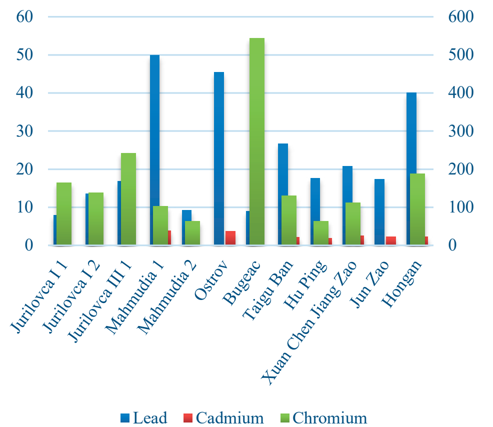

Figure 6. Content of lead, cadmium, and chromium (µg/kg) from jujube fruits

Cadmium is another heavy metal that can be toxic to the human body and can be found in some fruits and vegetables, especially those grown in contaminated soils or exposed to other sources of pollution such as water or air. Generally, fruits with thicker skins, such as bananas, oranges, and grapefruits, tend to have lower cadmium content than fruits with thinner skins, such as apples or grapes. In our case, the highest values were recorded in the fruits of Mahmudia 1 and Ostrov genotypes, with values of 3.87 µg/kg and 3.66 µg/kg. In the Chinese jujube varieties, the highest values were found in the fruits of Xuan Chen Jiang Zao and Jun Zao varieties, with values of 2.58 µg/kg and 2.30 µg/kg, respectively (Figure 6). According to Commission Regulation (EC) No. 1881/2006 on maximum levels for specific contaminants in food products, the permissible limit for cadmium content in fruits is 0.05 mg/kg, equivalent to 50 µg/kg. Chromium is an essential trace element for the human body and can be found in many foods, including fruits and vegetables. However, excessive consumption of chromium can be toxic to the body. In our case, the highest values in *Ziziphus jujube* genotypes were recorded in the Bugeac and Jurilovca III 1 genotypes, with 543.64 µg/kg values and 242.0 µg/kg values. On the Chinese jujube varieties, the highest values were found in Hongan and Taigu Ban varieties, with values of 188.59 μg/kg and 130.39 μg/kg (Table 2.).

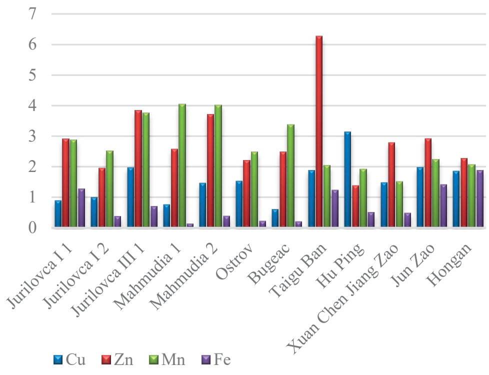

Figure 7. Content of Cu, Zn, Mn and Fe from jujube fruits (mg/kg)

Copper is an essential mineral for human health, involved in various physiological processes such as red blood cell formation and energy production. However, excessive copper consumption can be toxic and adversely affect health. In this case, the highest values recorded in Chinese jujube genotypes were found in the Jurilovca III 1 and Ostrov genotypes, with values of 1.98 mg/kg and 1.54 mg/kg, respectively. In the analyzed Chinese jujube varieties, the highest values were found in the Hu Ping and Jun Zao varieties, with values of 3.14 mg/kg and 1.97 mg/kg (Table 2, Figure 7).

Zinc is an essential mineral for human health and can be found in many foods, including some fruits. Zinc plays a vital role in the functioning of the immune system, wound healing, and average growth and development of the body. In this case, the highest zinc content was recorded in the Jurilovca III 1 and Mahmudia 2 genotypes, with values of 3.85 mg/kg and 3.72 mg/kg, respectively. In the analyzed Chinese jujube varieties, the highest values were found in the Taigu Ban and Jun Zao varieties, with values of 6.2 mg/kg and 2.93 mg/kg (Table 2, Figure 7).

Manganese is an essential mineral for the human body and is necessary for the normal functioning of many enzymes and metabolic processes. Manganese can be found in many foods, including fruits such as bananas, berries, and pineapple. In this case, the highest content recorded in Chinese jujube genotypes was found in the Mahmudia 1 and Mahmudia 2 genotypes, with values of 4.06 mg/kg and 4.03 mg/kg, respectively. In the analyzed Chinese jujube varieties, the highest values were identified in the Jun Zao and Hongan varieties, with values of 2.24 mg/kg and 2.08 mg/kg (Table 2, Figure 7).

Iron is an essential mineral for the human body and is necessary for producing hemoglobin in the blood, which carries oxygen to the cells. Iron can be found in many foods, including some fruits such as plums, figs, and raisins. The highest iron content in our case was recorded in the Jurilovca I 1 and Jurilovca III 1 genotypes, with values of 1.28 mg/kg and 0.70 mg/kg, respectively. In the analyzed jujube varieties, the highest values were found in the Hongan and Jun Zao varieties, with values of 1.89 mg/kg and 1.42 mg/kg (Table 2, Figure 7).

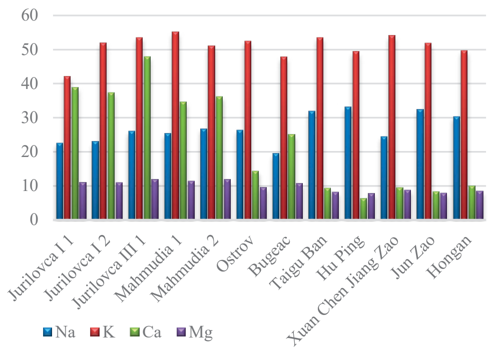

Figure 8. Content of Na, K, Ca and Mg from jujube fruits (mg/kg)

The genotypes with the lowest sodium content were Bugeac, Jurilovca I 1, and Jurilovca I 2, with values of 19.51, 22.61, and 22.95 mg/100g, respectively. On the other hand, the analyzed varieties, Hu Ping, Jun Zao, and Taigu Ban, had higher sodium content with values of 33.18, 32.39, and 32.02 mg/100 g, respectively (Table 2, Figure 8). Generally, the sodium levels in these genotypes varied significantly, which can be important when selecting or choosing between different Chinese jujube varieties based on their sodium content. High sodium content may be associated with specific health issues like hypertension.

A significant variation in potassium content can be observed among genotypes, ranging from 42.09 mg/100 g to 55.16 mg/100 g. The highest potassium levels were found in the genotypes Mahmudia 1, Jurilovca III 1, and Ostrov, with 55.16, 53.61, and 52.54 mg/100g values. In contrast, the lowest levels were recorded in Jurilovca I 1, Bugeac, and the Hu Ping variety, with 42.09, 47.87, and 49.43 mg/100 g values, respectively (Table 2, Figure 8).

Calcium is an essential mineral for the human body, involved in various physiological functions such as maintaining bone and teeth health, nerve impulse transmission, muscle contraction, and blood clotting. A calcium-rich diet can reduce the risk of osteoporosis and bone fractures in advanced age.

The calcium content in these genotypes varied significantly, ranging from 6.29 mg/100 g to 47.95 mg/100 g. Genotypes with the highest calcium values were Jurilovca III 1, Jurilovca I 1, and Jurilovca I 2, with values of 47.95, 38.95, and 37.51 mg/100 g, respectively. On the other hand, the lowest values were recorded in the Hu Ping, Jun Zao, and Taigu Ban cultivars, with values of 6.29, 8.33, and 9.44 mg/100 g, respectively (Table 2, Figure 8).

Magnesium is an essential mineral for health, involved in several critical metabolic processes such as protein and DNA synthesis, nervous and muscular system function, and blood glucose regulation. Additionally, magnesium plays a crucial role in maintaining bone and heart health.

It can be observed that all genotypes had a magnesium content of around 10 g/100 g. However, there is a slight variation among genotypes, with the highest values found in the genotypes Mahmudia 2, Jurilovca III 1, and Mahmudia 1, with values of 11.94, 11.90, and 11.56 g/100 g, respectively. Meanwhile, the lowest values were present in the Hu Ping, Jun Zao, and Taigu Ban varieties, with values of 7.78, 7.85, and 8.21 g/100 g, respectively (Table 2, Figure 8).

CONCLUSIONS

The analysis of the biochemical composition of Chinese jujube fruits revealed their significant abundance in sugar content, dry matter, polyphenols, and antioxidant capacity. Among the studied genotypes, Jurilovca III 1 showed higher values than most genotypes, with Mahmudia 2 following closely.

As for mineral content, among the studied genotypes again, Jurilovca III 1 showed higher values for more minerals than others, followed by Mahmudia 1 this time.

All fruits from the wild genotypes, except for Ostrov, present higher potassium, calcium, and magnesium values than those of the analyzed varieties.

ACKNOWLEDGEMENTS

This research was supported by the project "PRO INVENT," Contract no.62487/03.06.2022 POCU/993/6/13 - cod SMIS: 153299 financed by The Human Capital Operational Programme 2014-2020 (POCU), Romania.

REFERENCES

Liu, J.J. & Zhao, X. & Liu, Z.G. & Wang, L.X. & Stănică, Florin & Zhao, Z.H. & Liu, M.J. & Wang, L.L. (2020). Advances in research on main antioxidant active components of jujube. *Acta Horticulturae.* 283-292. 10.17660/ActaHortic.2020.1287.36.

Liu, M., Wang, J., Wang, L. et al. (2020). The historical and current research progress on jujube - a superfruit for the future. *Hortic Res*, **7**, 119. https://doi.org/10.1038/s41438-020-00346-5

Miklavčič Višnjevec A., Baruca Arbeiter A., Hladnik M. (2019). An Integrated Characterization of Jujube (*Ziziphus jujuba* Mill.) Grown in the North Adriatic Region. *Food Technol Biotechnol*, 57(1):17-28. DOI:10.17113/ftb.57.01.19.5910

Shahrajabian, M. Hesam & Khoshkharam, Mehdi & Zandi, Peiman & Sun, Wenli & Cheng, Qi & Cheng, Qi. (2019). Jujube, a super-fruit in traditional Chinese medicine, heading for modern pharmacological science. *Journal of Medicinal Plants Studies*, 7. 173-178.

Stănică F. (2016). *Chinese Dates (Jujubes):* A New Promising Fruit Plant for Romania, In book: *Chinese Dates a traditional functional food*. Liu D, Ye X, Jiang Y. (Eds) CRC Press. Taylor & Francis Group. ISBN: 978-1-4987-0358-1. pp 387 (pp. 363-373) DOI: 10.1201/b20025-24.

Stănică F., (2019). Twenty Years of Jujube (*Ziziphus Jujuba* Mill.) Research in Romania. *Scientific Papers. Series B, Horticulture*, *Vol. LXIII* (2), Print ISSN 2285-5653, 17-24.

Yan, M., Wang, Y., Watharkar, R.B. et al. (2022). Physicochemical and antioxidant activity of fruit harvested from eight jujube (*Ziziphus jujuba* Mill.)

cultivars at different development stages. *Sci Rep,* 12, 2272. https://doi.org/10.1038/s41598-022 06313-5

Wojdyło A., Carbonell-Barrachina ÁA, Legua P, Hernández F. (2016). Phenolic composition, ascorbic acid content, and antioxidant capacity of Spanish jujube (*Ziziphus jujube* Mill.) fruits. *Food Chem.*, 2016 Jun 15, 201:307-14. doi:10.1016/j.foodchem.2016.01.090. Epub PMID: 26868581.