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BIOCHEMISTRY OF JUJUBE FRUIT (*ZIZIPHUS JUJUBA* MILL.) FROM ANALYSES TO COMPOUNDS (REVIEW)

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Abstract

Jujube (Ziziphus jujuba Mill.) is one of the most appreciated species in China with a long hystory in the Eastern Asia. Consumers prefer to eat the jujube fruit fresh due to its sensory qualities, but also of its rich nutritional properties. Studies have shown that the most advantageous nutritional characteristics of jujube fruit were its content of soluble sugars, 2-3 times more than other fruits, vitamin C with 100 times more than other fruits, vitamin B, acid triterpenoid, proline, polysaccharides, flavonoids, iron, potassium, calcium, and zinc. Jujube fruits contain a large amount of soluble dry matter that can exceed 30% when the total carbohydrate content exceeds 27%. Fruit acidity can vary between 0.3-1.0%. However, in the post-harvest period, ethylene can have adverse effects on fruits, such as senescence, rapid loss of quality, nutrients, and increased chances of attack by pathogens. For a longer consumption period, these fruits should be kept in a controlled atmosphere. This sudy aims to present a review focused on the biochemistry of jujube highlighted through researches.

Key words: *nutritional value, vitamin C, post-harvest period.*

INTRODUCTION

Jujube (*Ziziphus jujuba* Mill.) is one of the world's oldest cultivated fruit trees and the most important species in the large cosmopolitan family Rhamnaceae in terms of its economic, ecological, and social importance.
The consumers prefer both fresh and dry fruits as food or for pharmaceutical products, given the high number of nutrients, and amino acids (Xue et al., 2009; Choi et al., 2011).
Due to its biochemical composition, jujube fruit is also used as food, food additives, and flavoring (Li et al., 2006).
Ziziphus jujuba fruit shape varies from round, oval to elliptical. The fruit size ranges from that of a cherry to that of a plum (Markovski et al., 2015).
The epidermis of the fruit is thin, lustrous, and reddish-brown to chocolate in color (Soliman et al., 2013). The hue of the fruit clearly indicates the fruit's maturity.
Fruits with more than 50% dark brown colour are the best suited to consumption, regarding taste and juiciness.
The organoleptic characteristics are ordinary at full maturity, when the fruit is fully pigmented, but the fruits are more suitable for drying (Chen et al., 2015).
Total soluble content and total acidity can be used to determine the maturity stage (Yao, 2013).
The main soluble sugars in the fruit are fructose, glucose, and sucrose, which improve the sweet taste of the fruit (Pereek, 2013). Lignin, cellulose, and hemicellulose were mentioned in many studies as the primary dietary fibers contained in the fruit, with an essential role in food digestion. (Gao et al., 2013; Chen et al. 2018).
The vitamin C, flavonoids, carotenoids, and saponin content, which has antioxidative, anti-cancer, and anti-diabetes properties (Choi et al., 2012) recommend the fruit.
Its contents of sugar, vitamin B, cyclic nucleotide, proline, triterpene acids, potassium, iron, and zinc, were studied by Hu (2011) and Liu & Whang (2009).
Sugar, vitamin C, and cyclic adenosine monophosphate (cAMP) concentration was approximately 2, 100, and 1000 times that of apples. Polysaccharides, flavonoids, alkaloids, polyphenols, and pigments were also abundant in the fruit (Liu & Whang, 2019).

Dried jujube had carbohidrates 630-763% compared to fresh fruits, 23-32%, and sour jujube, 74.8%. In the fresh jujube vitam C was between 200-800 mg/100 g in the fresh fruit and 12-29 mg/100 g in the dried one. Protein content varied between 2.9-6.3% in the dried fruits comparted to 1.2% in the fresh jujube. Ca (mg/100 g) had values between 14 (fresh), 20-63 (dried), and 270 (sour jujube). The phosphor content was of 23 mg/100 g in the fresh jujube, 55-75 mg/100 g in the dried, and 59 mg/100 g in the sour jujube. This biochemical profile highlighted the high medicinal fruit quality.

The species of the genus *Ziziphus* entail 43 terpenoids, 31 saponins, 165 alkaloids, 151 flavonoids, and 40 other miscellaneous compounds (Ahmad et al. 2017; Ji et al., 2017). Terpenoids are abundant in the plants of the genus *Ziziphus*. To far, about 43 triterpenes have been isolated from the fruits, flowers, leaves, and seeds of *Z. celata*, *Z. spina Christi*, *Z. mauritiana*, *Z. jujuba*, *Z. lotus*, and other plants, with numerous triterpenes exhibiting potential biological properties (Ros et al., 2000; Ahmad et al., 2017). Furthermore, saponins, which are sugar conjugates of triterpenes, were found throughout the genus *Ziziphus*. Most plant species relate these compounds with defense functions. Saponins have several functional (emulsification, solubilization, foaming, sweetness, bitterness) and biological properties that have the potential to be used in a variety of applications, including food, cosmetics, and pharmaceutical industries, as well as soil bioremediation (Ji et al., 2017). There were approximately 31 saponins found in the roots, leaves, fruits, and seeds of *Z. mauritiana*, *Z. joazeiro*, *Z. jujuba*, *Z. spina christi*, and other plants. (Bozicevic et al., 2017; Dubey et al., 2019).

The food value of jujube is high, mainly due to the high soluble solids content exceeding the value of 30%, being an natural source as swetener.

The fruit's acidity varies between 0.3 and 1.0%. Depending on the cultivar, it has a very high content of ascorbic acid (vitamin C), with values of 330-880 mg/100 g fresh weight. The content of vitamin P exceeds 1000 mg/100 g fresh weight (Ciocârlan, 2000).

Like in other species, the cultivar deaply influence the biochemical profile of the fruit.

Due to its flavor, crispness, and juiciness, Dongzao is one of the most popular jujube cultivat worldwide. The jujube for export is harvested between August and October, with September being the best harvesting month (Morley-Brunker, 2010). Because of the limited shelf life of the Dongzao cultivar, the market supply is relatively short.

Several approaches have been tried to extend the shelf life of this cultivar. Zong et al. (2005), for example, investigated the influence of a controlled environment. Their findings revealed that the regulated environment preserves the integrity of the fruit membrane and resistance to browning and fermentation, hence extending the fruit's shelf life. However, this preservation mode is expensive, increasing the product's cost and making it less competitive.

Another technique is to harvest and store the fruit sooner, at the white ripening stage. Although this process is affordable, the influence on the nutritional quality of the fruit is uncertain. As a result, it is critical to understand the effect of development stages on the nutritional quality of jujube fruit in order to determine the optimal time at which the fruit can be harvested to preserve its nutritious value. The research presented the nutritional composition and quality of the jujube Dongzao depending on the maturity stages. The results revealed that the maturity stage had a substantial effect on the nutritious contents of the fruit. The majority of essential elements generated in the fruit grew until the full-red stage, and those that fell from the white maturity stage to the full-red stage exhibited just a minor decrease at the semi-red stage. All the carbohydrates increased significantly and gradually from white to full-red stage in the jujube fruit. Sucrose increased by 106% from white to full-red, whereas glucose, fructose, L-rhamnose, mannose, galactose, and maltose grew by 56%, 48%, 39%, 64%, 65%, and 160%, respectively. Overall, these results showed an accumulation of soluble sugars, mostly sucrose, mannose, and galactose, over the fruit maturity stages Accordingly, semi-red maturity seems to be the most appropriate stage for harvesting the jujube fruit to preserve its bioactive compounds (Zhang et al., 2020).

At the Faculty of Horticulture from Bucharest, 10 genotypes were studied: R1P2, R1P7,

R1P10 (Hu Ping Zao*), R2P7, R3P2, R3P3 (crack resistant), R3P4 (Hu Ping Zao*), R3P6, R3P10 (Taigu), and Dong Zao. Two clones of Hu Ping Zao (R2P8 and R3P4) and one genotype R3P8 were analyzed in dehydrated form (*clones of different origins), verifying whether or not this preservation method influences the quality parameters of the fruit.
Fresh fruits were harvested from the beginning of September until October. After morphological measurements, fruits were stored at 2-3°C and 90-95% relative humidity. Part of them was dehydrated using an Excalibur dehydrator for 20 hours at 45°C. The genotypes recorded a fruit weight between 5.89 g (R3P1 selection) to 28.57 g (Cheng TuoZao). Most of the analyzed genotypes had a solid soluble content higher than 30% Brix. Fruit content in minerals varied between 0.16% and 3.38%, with an average of 1.78%. The ascorbic acid content varied between 110.0 mg/100 g fw and 1020.0 mg/100 g fw (R1P11 selection), averaging 306.1 mg/100 g fw. Fruit acidity, expressed as malic acid, varied from 0.16% to 0.82% with an average of 0.36% (Stănică, 2000; Stănică & Vasile, 2008; Dicianu et al., 2017). The polyphenol content changed during fruit ripening. Thus, the highest polyphenols content was found in the fruit at the beginning of its formation and decreased with its maturation, all this time protecting against pathogens and pests (Wang et al., 2016; Shi et al., 2018).
Rahman et al. (2018) noted that 51.99-71.75% of the jujube is edible, with the edible part containing 4.43-6.01% protein, 82.35-89.63% carbohydrates, 45.64-88.97 mg/100g ascorbic acid, 0.48-0.63% lipids, 132.16-196.58 mg/100 g phenolics and 101.17-132.04 mg/100 g flavonoids in its dry matter (Hendek Ertop & Atasoy, 2018; Višnjevec et al., 2019).
Li et al. (2007) and Sunil (2013) described the composition of various jujube cultivars (Jinsixiaozao, Yazao, Jianzao, Junzao, Sanbianhong). Total phenols, minerals, and vitamins were determined in their experiment for the fruits of these cultivars; significant variation was found for water (17.38-22.52%), carbohydrate (80.86-85.63%), proteins (4.75%-6.86%), lipids (0.37-1.02%), soluble fibre (0.57-2.79%), insoluble fibre (5.24-7.18%), reducing sugar (57.61-77.93%), and ash (2.26-3.01%) (Pereek, 2013). Glucose and fructose were identied as major soluble sugars in all five cultivars, while rhamnose, sorbitol and sucrose were also present in lower amounts.

TRADITIONAL MEDICINAL USES AND POTENTIAL HEALTH BENEFITS OF JUJUBE

Jujube *(Zisiphus jujuba)* has been used as a traditional Chinese medicinal plant for many years for its various and numerous health benefits, including anti-inflammatory (Yu et al., 2012), anti-cancer (Plastina et al., 2012), gastro-intestinal protective (Huang et al., 2008), anti-oxidant (Cheng et al., 2012), anti-insomnia and neuro-protective properties (Yoo et al., 2010).

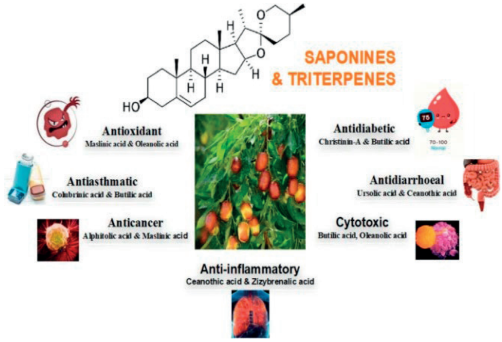

Figure 1. Main biological activities of triterpenes and saponins isolated from the genus *Ziziphus* (source: Sakna, 2022)

According to the modern medicine industry, jujube fruits and seeds are still utilized in Chinese and Korean traditional medicine and are said to relieve stress (Mill Goetz, 2009; Chen et al., 2017; Shahrajabian et al., 2020; Lu Y. et al., 2021). Among other health benefits, jujube lowers blood glucose and lipid levels and significantly lowers triglyceride, LDL, and cholesterol levels (Hemmati et al., 2015). Reche et al. (2019) observed 11 fatty acid compounds in four jujube cultivars, including, myristoleic acid, myristic acid, palmitic acid, cis-palmitoleic acid, trans-palmitoleic acid, stearic acid, oleic acid, 11-octadecenoic acid, linoleic acid, elaidic acid, and linolenic acid. Capric acid (C10:0), myristoleic acid (C14:1n5), lauric acid (C12:0), palmitic acid (C16:0), oleic acid (C18:1n9c), palmitic acid (C16:1n7), and linoleic acid (C18:2n6c) were found in four ripening phases of jujube fruit by

Song et al. (2019). Fatty acids are essential nutrients, some of which must be ingested through food to maintain health. The variety and content of fatty acids in jujube fruit could satisfy people's need for nourishment.

CONCLUSIONS

Jujube are sweet and nutritious, and have been used as dietary supplements since ancient times. For more than a thousand years, jujube has been used in China as a traditional herbal medicine for calming the mind. Modern scientific research has shown that the bioactive chemicals in jujube have anticancer, hepatoprotective, neuroprotective, antioxidant, anty-inflamatory and antiviral properties, as well as other health benefits such as enhancing immune function. Caution should be exercised when attempting to infer associations between the nutritional content and health functions of jujube. This is because the variety, ripening stage, storage and processing conditions of the fruit will affect its nutritional value and eventually lead to the increase or loss of some active functions.

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