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JUJUBE PROCESSING: METHODS, PRODUCTS AND NUTRACEUTICAL VALUE

Elena Gabriela STAN[1], Lavinia Mihaela ILIESCU[1, 2], Florin STĂNICĂ[1, 2]

[1]Faculty of Horticulture, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, 011464, Bucharest, Romania
[2]Research Center for Studies of Food Quality and Agricultural Products, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, 011464, Bucharest, Romania

Corresponding author email: iliescu_lavinia@yahoo.com

Abstract

Chinese jujube (Ziziphus jujuba Mill.) is the most important species of Rhamnaceae family and one of the oldest cultivated fruit trees in the world. In Romania, it was introduced for the first time in Dobrogea region, some 2000 years ago. The first cultivated varieties were introduced in 1997 at the Faculty of Horticulture, in Bucharest and nowadays the first commercial orchards are planted. This review aims to highlight the nutritional importance of jujube fruit and its high potential for the development of new and valuable food products. Moreover, jujube can be incorporated into different food formulations to improve their nutraceutical quality. A huge number of products can be obtained from fresh and dried jujube fruits: juice, compote, tea and coffee, liqueur, wine, brandy, but also gems, fruit bars and cakes. Jujube fruits can be processed in different ways, dehydration being utilized for most of the varieties. Besides that, fruits can be transformed into non-alcoholic fermented beverages such as juices, tea, coffee, energy drinks, or distilled beverages.

Key words*: benefits, food products, jujube fruits, nutritional importance, Ziziphus jujuba Mill.*

INTRODUCTION

Chinese jujube (*Ziziphus jujuba* Mill.), also called Chinese date, is one of the oldest cultivated fruit trees in the world and is the most important species in the large cosmopolitan family *Rhamnaceae* in terms of its economic, ecological, and social importance. Its utilization and cultivation history can be traced back to the Neolithic age, 7000 years ago (Qu & Wang, 1993; Guo et al., 2010; Liu et al., 2020).

Chinese jujube is a new fruit species for Europe with a high potential to be planted on arid and semiarid areas on marginal, poor, and even salty soils. Being a multi-millennial fruit crop in China, jujube has high importance in the Chinese diet due to its complex nutraceutical properties.

Nearly 1,000 varieties and local genotypes are cultivated in China on over two million hectares on low input production systems.

In Romania, jujube populations were found in the Dobrogea region (Ciocârlan, 2000), between the Danube and the Black Sea in the neighbourhood of antique sites as Greek, Roman and Byzantine ruins at Ostrov, Jurilovca and Mahmudia.

Probably, those old civilizations had an important role in the introduction of this Asian plant to the area (Stănică, 2000; Stănică, 2009; Stănică et al., 2018).

The plant, nearly unknown, is named Dobrogea olive by the locals and the fruits are rarely used for eating. Only Ostrov type, a real *Ziziphus jujube* tree, has interesting fruit for fresh and dry consumption (Ciocârlan, 2000; Stănică, 2009; Stănică et al., 2018).

Even it was introduced in the Dobrogea region, some 2,000 years ago by the Greek and Roman colonists, jujube plants and fruits are nearly unknown, as it happens in other countries from the Mediterranean basin.

The first cultivated varieties were introduced at the Faculty of Horticulture in Bucharest from Shanxi Province, China, within a common research project in 1997 (Stănică, 2019).

A superfruit species for the future should simultaneously meet the diverse needs of growers, consumers, marketers, governments, and society.

Generally, growers prefer fruit trees that crop early, reach high and stable yields quickly, and have light pest pressure, easy management, low cultivation costs, and high economic benefits (Stănică, 2019).
Consumers like fruits that are delicious and nutritious and that appeal to appearance and status. Marketers prefer fruits that can be easily transported from production areas and have long shelf lives and large markets (Liu et al., 2020).
The government and society pay more attention to ecological friendliness, the efficient use of land resources, and the social and economic advantages for rural farmers in marginal regions. By meeting all these expectations, jujube deserves to be considered a super fruit for the future (Liu et al., 2020).
This review aims to highlight the nutritional importance of jujube fruit and its high potential for the development of new and valuable food products.

MATERIALS AND METHODS

1. Health benefits

Traditional medicinal uses and potential health benefits of jujube are found also in the modern medical industry.
The jujube leaf, which is the main by-product of jujube, has also been used in traditional Chinese medicine (TCM) for thousands of years to improve sleep, nourish the heart and soothe the nerves, and reduce haemorrhaging (Damiano et al., 2017).
Based on Iranian traditional medicine, local traditional healers (Hamedi et al., 2016) used powders of stem bark and leaves of jujube to cure wounds and oral wounds as aphthous. Hamedi et al. (2016) also discovered that fruits are widely used in Iranian folk medicine as antitussive, laxative agents, and blood pressure reducers.
Jujube has also been used in Chinese medicine (TCM) for many years for its various and numerous health benefits such as anti-inflammatory (Yu et al., 2012), anti-cancer (Plastina et al., 2012), gastrointestinal protective, anti-oxidant, anti-insomnia, and neuroprotective (Yoo et al., 2010).
In recent years, food scientists and nutrition specialists agree that jujube fruits, consumed daily, contribute to reducing risks of certain diseases, including cancer and cardio and cerebrovascular diseases (Liu et al., 2000).
Different parts of jujube can be used for curing different kinds of illness such as diabetes, diarrhea, skin infections, liver complaints, urinary disorders, obesity, fever, pharyngitis, bronchitis, anaemia, cancer, insomnia, and of course for blood purification and the gastrointestinal tract (Shahrajabian et al., 2019).

2. Nutritional value

Jujube is an interesting plant to prevent several diseases. Fruits are one of the major dietary sources of various antioxidant phytocompounds for humans.
Jujubes have a high nutritional value for the human health (Stănică, 2016; Stănică, 2019).
Taking all this into consideration, the jujube fruits were included in the category of new "super fruits" that should be introduced on large scale production in Romania but in Europe, also (Stănică, 2016; Dicianu et al., 2017; Liu et al., 2017; Zhao et al., 2017; Stănică, 2019; Stănică et al., 2020a).
The various antioxidants (polyphenol, ascorbic acid, carotenoids, and tocopherols) present in fruits contribute to these beneficial effects (Peschel et al., 2006).
These antioxidants prevent diseases by scavenging radicals or by suppressing the formation of free radicals by binding to metal ions, reducing hydrogen peroxide, and quenching superoxide and singlet oxygen (Guroo et al., 2017).
Jujube has a high nutritional value due to the presence of a large number of nutrients and phytochemicals, such as fibres, proteins, fat, carbohydrate, vitamins (ascorbic acid, thiamine, and riboflavin), phenolics, and minerals (Chen et al., 2019; Rashwan et al., 2020).
First of all, its dietary fibres (Li et al., 2007) and fructose (Gao et al., 2012) contents may contribute to regulating blood sugar levels by slowing digestion, with its fibres content also contributing to controlling calories intake by its satiating effect.
To a lesser extent, jujubes are a source of healthy, essential fatty acids because jujube fruit is rich in unsaturated fatty acids (68.54-72.44% of the total fat in jujube fruits). There are 33 fatty acids identified from the dried pulp of *Ziziphus jujuba* Mill. (Gusakova et al., 1999).

The chain length of those components was from 7 to 28 carbon atoms. Sixteen fatty acids, with a dominance of 16:1 (Guo et al., 2010) and 16:1, (Pawlowska et al., 2009) are partly responsible for the fragrance of the fruit.

Fatty acid profiles of the fruits were influenced by their developmental stage (Guil-Guerrero et al., 2004).

The predominant fatty acids in jujube selections were oleic, linoleic, palmitic, and palmitoleic acids (San & Yildirim, 2010).

Jujube fruits are rich in lipids, especially linoleic acid (omega-6), that the human body is not capable of producing (Simopoulos et al., 2008).

Great interest has developed for jujubes because of their high content of vitamin C, which makes them an important source of this vitamin for human nutrition.

Moreover, the jujube, although to a lesser extent, is a source of several other vitamins, such as thiamine, riboflavin, niacin, vitamin B6, and vitamin A (Chen et al., 2019).

In this part, we comprehensively discussed the jujube nutrients and phytochemicals that were divided into three categories: macronutrients, micronutrients, and bioactive compounds.

The content of macronutrients, micronutrients, and bioactive compounds in jujube fruits. (*Ziziphus jujuba* Mill.) (Rashwan et al., 2020) is present in Table 2.

2.1. Macronutrients

Generally, macronutrients are the main nutrients in the foods that we consume, such as proteins, fat, carbohydrate, fibres, and moisture. According to the National Research Council (1989), jujube is a rich source of macronutrients.

Chinese jujube contains eighteen kinds of amino acids including eight essential amino acids. In addition, protein, sugar, and fat content ranged from 3.3 ~ 4.0, 50.3 ~ 86.9, and 0.2 ~ 0.4 g/100 g DW (dry weight), respectively (Food & Board., 1989).

Sheng and his team (2002) found that the jujube Chinese winter fruit contained moisture 74.08%, soluble protein 0.307%, total sugar 18.46%, soluble solid 27.0%, and fibres 1.37%.

In contrast, a study on five Chinese jujube cultivars made by Li et al. (2007) reported that jujube contained carbohydrates ranged from 80.86 to 85.63%, reducing sugar 57.61-77.93 %, soluble fibres 0.57-2.79%, insoluble fibres 5.24-7.18%, protein 4.75-6.86%, lipid 0.37-1.02%, and moisture 17.38-22.52 % (Li et al., 2007).

Afterwards, Uddin and Hussain (2012) uncovered that the moisture, total solids, total soluble solids, total sugar, proteins, fat, and ash contents of jujube fruit were 83%, 17%, 8.1°Brix, 6%, 1.6%, 0.2%, and 0.7%, respectively.

Instead, a study on four Spanish jujubes by Hernández et al. (2016) unveiled that Spanish jujube contained moisture amount from 78.3 to 82.1%, TSS (total soluble solids) 14.6 to 18.4 °Brix, total sugars 10.8 to 19.2 g·100 mL^{-1}, protein 3.7 to 5.8%, and crude fibres 0.7 to 1.0 g·100 g^{-1} DW.

A recent study on three Chinese jujubes by Chen et al., uncovered that the moisture content, total dietary fibres, protein, and total sugar of jujube fruit were ranged from 64.31-76.50, 4.85-7.32, 1.87-3.97 g/100 g, and 28.68 to 31.7% (FW), accordingly (Chen et al., 2019).

These studies confirmed that jujube fruits have large amounts of macronutrients and the contents were varied depending on location, cultivars, and detection method (Rashwan et al., 2020).

2.2. Micronutrients

Micronutrients are important substances that are found in small amounts in food, often indicated as minerals and vitamins. Micronutrients are vital elements for healthy growth and development and disease prevention.

Previous studies indicated that jujube fruits were a rich source of micronutrients including vitamins, macroelements (N, K, Mg, Ca, P, etc.), and microelements (Fe, Mn, Cu, Zn, etc.) (Chen et al., 2019; Choi et al., 2016). Sheng's team (Sheng et al., 2002) reported that Chinese winter jujube fruit contained higher vitamin C, approximately 379.4 mg/100 g, which was about 80 to 100 times higher than that of apple.

On the other hand, they also found that jujube fruit contained a moderate amount of minerals, such as phosphorus, potassium, calcium, magnesium, iron, manganese, copper, zinc and sodium. In addition, Li et al. (2007) evaluated the range of micronutrients in five Chinese

jujube cultivars such as ascorbic acid (192-359 mg/100 g), thiamine (0.04-0.08 mg/100 g), and riboflavin (0.05-0.09 mg/100 g). According to their study, the range of minerals contents (mg/100 g FW) in jujube cultivars were as follows, potassium contents (79.2 to 458, phosphorus 59.3 to 110, calcium 45.6 to 118, manganese 24.6 to 51.2, iron 4.68 to 7.90, sodium 3.22 to 7.61, zinc 0.35 to 0.63, and copper 0.19 to 0.42 (Li et al., 2007; San et al., 2009).

Jujube fruit contained about 71.92% of the nitrogen-free extract, which contained calcium and potassium approximately 72.14 and 899.82 mg/100 g, respectively (Kim et al., 2011). In the case of four Spanish jujubes cultivars, the range of vitamin C content was found to be 0.41-0.64 (g 100 mL^{-1}), while the range of macroelements content such as potassium, calcium, magnesium, and sodium were 11.9-17.3, 0.23-0.72, 0.40-0.77, and 0.11-0.43 g kg^{-1} DW, respectively.

Furthermore, the range of microelements content such as iron, zinc, copper, and manganese were 10.2-17.1, 4.0-5.1, 0.5-1.2, and 0.2-2.9 mg kg^{-1} DW, accordingly (Hernández et al., 2016).

In two Korean jujubes cultivars, the vitamin C content ranged from 29 ~ 37.67 mg/100 g FW, and the minerals content such as calcium, phosphorus, and iron were ranged from 11.58 to 14.69, 32 to 29.83, and 0.3 mg/100 g FW, respectively (Choi et al., 2016). Analysis of vitamin C content in three Chinese jujube cultivars showed the significantly higher content ranged from 162.50 to 244.58 mg/100 g FW (Chen et al., 2019).

In summary, it is confirmed that jujube fruit is a potential source of micronutrients (Rashwan et al., 2020).

2.3. Bioactive compounds

Jujube is considered a great source of bioactive components, including polyphenols, triterpenic acids, polysaccharides, nucleosides, and nucleobases. Jujube is thus recognized as one of the rich sources of functional food (Wojdyło, et al., 2016). For example, in the pulp of jujube fruit, total phenolic ranged from 1.1 to 2.4 g/100 g DW, and flavonoids contents ranged from 0.7 to 1.8 g/100 g DW.

Furthermore, the jujube fruits contained several flavonoids compounds, such as procyanidin B2, epicatechin, quercetin – 3 – O – rutinoside, quercetin – 3 – O – galactoside, kaempferol glucosyl – rhamnoside (Choi et al., 2011).

Jujube contained a low amount of triterpenic acids, nucleosides, and nucleobases. A study by Guo et al. (2015) reported that the total triterpenic acids in six stages of growth of jujube fruit ranged from 166-6126 (μg/g of DW), whereas the total nucleosides and nucleobases contents ranged from 253-481 (μg/g of DW). In the case of fresh jujube, titratable acids content of three Chinese jujube cultivars ranged from 1.98 to 3.12% FW, cAMP ranged from 20.35 to 87.5 (μg/g FW), and total flavonoids ranged from 41.21 to 62.72 (mg/g FW) (Chen et al., 2019). On the other hand, the polysaccharide is one of the minor bioactive compounds of jujube fruit (Zhan et al., 2018). A recent study confirmed that the maximum crude polysaccharide yield obtained from jujube fruit was 7.9%.

According to their research, the main components of jujube polysaccharides were arabinose, galactose, glucose, mannose, rhamnose, and galacturonic acid (Liu et al., 2020; Rashwan et al., 2020).

Table 1. Nutritional value of fresh jujube fruit

Nutritional value per 100 g	
Energy	79 kcal
Carbohydrates, by difference	20.23 g
Fat	0.2 g
Protein	1.2 g
Ash	0.51 g
Water	77.86 g
Vitamins	
Vitamin A	2 μg
Thiamine (B1)	0.02 mg
Riboflavin (B2)	0.04 mg
Niacin (B3)	0.9 mg
Vitamin B6	0.081 mg
Vitamin C	69 mg
Minerals	
Calcium (Ca)	21 mg
Iron (Fe)	0.48 mg
Magnesium (Mg)	10 mg
Manganese (Mn)	0.084 mg
Phosphorus (P)	23 mg
Potassium (K)	250 mg
Sodium (Na)	3 mg
Zinc (Zn)	0.05 mg
Copper (Cu)	0.073 mg

Source: USDA, 2019

The nutritional value of fresh jujube fruit according to (USDA, 2019) is present in Table 1. This makes jujube a premier choice for anyone looking to live a healthier life or even simply bolster their immune system.

3. Processing

The common purpose of food processing is to avoid food spoilage during the storage period, which is caused by the development of bacteria, yeasts and fungi. It also makes the seasonal products available for a long period.

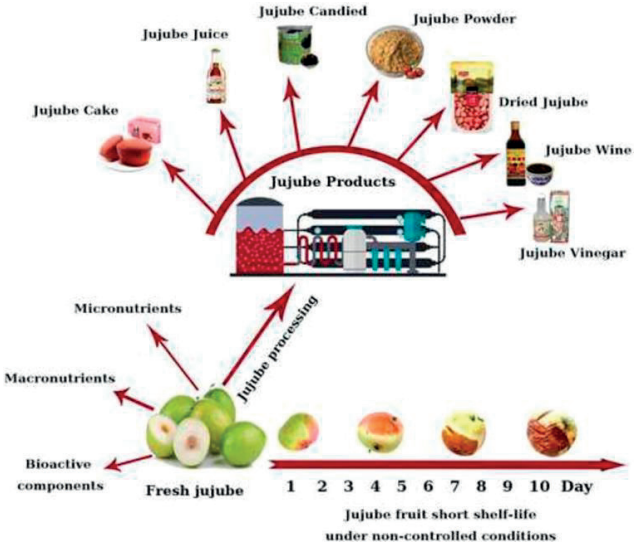
Suitable product processing allows maintenance of typical organoleptic and nutritional features of foods, which is also beneficial for human health (Krška & Mishra, 2009).

Normally, jujube fruit is harvested in autumn, and their postharvest shelf-life is very short (Stănică et al., 2020b). It can be stored for no more than ten days under non-controlled conditions (Zozio et al., 2014a).

Thus, it is very important to explore jujube processing and/or preservation strategies for extending its shelf-life.

Shin and co-authors studied the diverse processing methods for jujube fruits. They found that dried fruits, nectar, jam, fruit extracts, and powdered tea were the most promising processing methods. Evaluation of these products was conducted by sensory evaluation and chemical analysis (Shin et al., 1992).

Besides, Krška & Mishra (2009) studied the different ways of processing jujube fruits like cloying with honey, preservation in sweet-sour infusion vinegar, conservation in sweet infusions like compote and dry jujube fruits. Furthermore, another study investigated the processing and preservation of jujube fruits via developing various products formula such as jam, jelly, chutney and pickles (Rashwan et al., 2020; Uddin & Hussain, 2012). In Figure 1. processing possibilities of jujube can be observed.



Source: Rashwan et al., 2020

Figure 1. Processing possibilities of jujube fruit

3.1. Dried jujube

The drying technique is one of the most substantial methods for the preservation of foods, which has been used for a long time. Drying can assist in transportation and storage of jujube by providing some features such as lighter weight and smaller volume compared to fresh products.

In addition, it can prolong the product's shelf-life via minimizing and/or removing moisture-mediated deteriorative reactions.

Hence, it can prevent the growth and reproduction of the microorganisms that cause putrefaction (Brasiello et al., 2013).

Dried jujubes have a chewy texture and taste similar to dates. Besides, dried jujube products

(e.g. whole fruit, slices, jujube chips, and powder, etc.) are popular among consumers owing to great taste and high nutritional value (Hao et al., 2019; Wang et al., 2016; Wojdyło et al., 2016; Wojdyło et al., 2019).
In Figure 2, can be observed dried jujube in different forms.

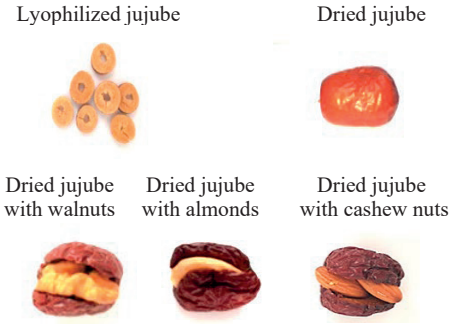


Figure 2. Dried jujube in different forms

3.2. Candied jujube

Candied fruit is known as crystallized fruit or glacé fruit, where the whole fruit or smaller pieces of fruit/peel are placed in heated sugar syrup, which absorbs the moisture from the fruit and eventually preserves it (Kuwabara, 1988). Candied jujube is a famous product in China. Haiying (2006) reported that candied jujube with nutritional value can meet more consumer's needs (Figure 3). Jujube with low-sugar syrup type can be prepared through substituting xylitol for sugar, where can be reduced saccharifierous quantity of the preserved fruit.

Figure 3. Candied jujube

3.3. Jujube jam, jelly and cakes

Jams are thick sweets prepared by the cooking of crushed or chopped fruits with enough amount of sugar, which tend to hold their shape but are less coherent than jelly (Rashwan et al., 2020).
Jelly is very similar to jam but is produced by boiling/cooking fruit juice with a large amount of sugar, with or without the addition of pectin and food acids depending on the pectin and acid content in the fruit (Zhao, 2012).
Jujube fruits have a large number of nutritional components especially polysaccharides that is considered as one of the bioactive compounds. Therefore, jujube jams and jelly are considered promising processed foods (Zhao et al., 2012).

Figure 4. Jujube cakes

3.4. Jujube fruit as a food additive

The jujube powder is used in many food product formulations (Najjaa et al., 2020). The ingredients added to food to enhance the nutritional value, improve the taste, maintaining the flavour and appearance of food, etc., are known as food additives. Recently, the application of food additives was of great importance in the food industries throughout the world.
However, there are increasing concerns about the harmful health effects (hazard) of synthetic food additives, including colourings, flavourings, and preservatives (Liu and Hill., 2015).
Therefore, the use of natural food additives is the better alternative to overcome the health risks of synthetic food additives. Jujube fruits are considered as one of the natural food ingredients, which is applied both in food and herbal medicinal (Rashwan et al., 2020) because of their good health benefits.
The powder of jujube (Figure 5) has a higher availability of phenolic compounds; possesses antioxidant, anticancer antimicrobial, and antianemia activity (Addo et al., 2019).

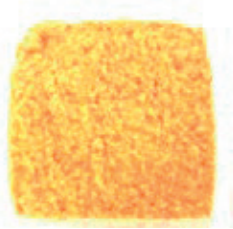


Figure 5. Jujube powder

For example, the addition of jujube extract to the bread dough showed an increased water absorption rate.
In addition, the dough development time, stability, and degree of the extension were decreased, while the degree of weakness, degree of resistance, and resistance/ extensibility were increased (Lee et al., 2005).

3.5. Jujube beverages

Any drinkable liquid prepared for human consumption except water is called a beverage. Recently, the consumption of fruit beverages has increased throughout the world due to the rich source of natural nutrients.
Like other fruits beverages, jujube beverages such as juice, tea, wine, and others, are also available in the market due to their rich source of bioactive compounds (Rashwan et al., 2020). China is one of the top jujube producers, which is about 90% of the total world production. Interestingly, the production amount of jujube in China has been increasing significantly from 4 to 15 million tons over the last 10 years (Guo et al., 2018).

3.6. Jujube juice

Jujube juice (Figure 6) contained a large number of bioactive components, is a rich source of vitamin C, and possesses antioxidant properties. (Vithlani et al., 2010).
Nowadays, jujube juice is consumed as a food ingredient and supplement due to potential sources of bioactive components (Rajauria & Tiwari., 2018; Zhang et al., 2012).
Jujube juice can be successfully combined with other fruits.

Figure 6. Jujube juice

3.7. Jujube wine

Jujube wine (Figure 7) is considered one of the important jujube fruit beverages. However, studies on wines production from jujube fruits are limited.
Based on the scientific study by Liu & Zhao, (2011), the optimum fermentation conditions for jujube wine were as follows: initial sugar (18%), pH value (4.0), fermentation temperature (24°C) and inoculum concentration of dry yeast *Saccharomyces cerevisiae* (0.3%) (Rashwan et al., 2020).

Figure 7. Jujube wine

3.8. Jujube brandy

VOCs (Volatile Organic Compounds) play an important role in brandy aroma, whereas the presence, absence, or different proportions of VOCs can be greatly influenced by processing methods (Rashwan et al., 2020). Fresh jujube brandy (Figure 8) is a popular alcoholic beverage that is produced by the distillation of fermented broth achieved via continuous fermentation of jujube fruits (Li et al., 2016).

Figure 8. Jujube brandy

This alcoholic beverage is characterized based on the presence of volatile organic compounds which are produced during the fermentation, distillation, and storage stages (Xia et al., 2020).

CONCLUSIONS

Jujube fruit is a dietary supplement with high contents of bioactive compounds such as dietary fibers, mineral, and natural antioxidant compounds. Nevertheless, fresh jujube has a short shelf-life. Thus, converting fresh jujube to processed products is the best way for preserving it for a long-time. Moreover, jujube can be incorporated into different food formulations to improve their nutraceutical quality. A huge number of products can be obtained from fresh and dried jujube fruits:

juice, compote, tea and coffee, liqueur, wine, brandy, but also gems, fruit bars and cakes. Jujube fruits can be processed in different ways, dehydration being utilized for most of the varieties. Besides that, fruits can be transformed into non-alcoholic fermented beverages such as juices, tea, coffee, energy drinks, or distilled beverages.

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