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A Review: The Physical, Nutritional, Bioactive Properties and Health Benefits of Jujube Fruit

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Abstract

Jujube (*Ziziphus jujuba* Mill.), which grows in tropical and sub-tropical regions of world and has been commercially cultivated in China for 4000 years. Jujube is a juicy and crispy fruit, resembling a large olive and tasting like an apple. Moreover, jujube has been used for treatment of several diseases in traditional Chinese medicine. Jujube has antioxidant, anticancer, hepatoprotective, anti-inflammatory, antimicrobial activities due to bioactive components such as phenolic compounds, saponins, polysaccharides and ascorbic acid. It is also a valuable fruit in terms of its nutrient content including carbohydrates, proteins, vitamins and minerals. In recent years, the tendency towards natural therapies has increased, due to increase in incidence of certain diseases and adverse effects of drugs used in the treatment of such diseases. Jujube could be considered as a natural therapeutic material because of bioactive and nutritional properties. The aim of present review is to introduce jujube fruit in terms of chemical composition, effects on health and bioactive properties.

Keywords: bioactive properties; health benefits; jujube; nutritional value

1. Introduction

Jujube (*Ziziphus jujuba* Mill.), belonging to *Rhamneceae* family, has been grown for 4000 years and has more than 700 cultivars in China [1]. The jujube is naturally spread in some regions of Russia, India, North Africa, Southern Europe, Middle East and Anatolia [2,3]. Jujube is called different names among cultures such as Chinese jujube, Tsao, Azufaifo, Chinese date, Dara, Unnab, Annap, and Hünnap [4,5].

China, the only exporter, produces 90% of jujube in the world [6,7]. In Turkey, statistical data has been compiled since 2013 by Turkey Statistical Institute. According to records, jujube production has increased from 142 tonnes in 2013, to 1760 tonnes in 2021 [8].

Jujube is a crispy and juicy fruit with a single hard stone, which resembles a large olive in size of approximately 4x6 cm, and tastes similar to an apple [9,10].

The color of jujube fruit changes from yellow to red-brown during maturation. Generally, jujube is consumed as fresh or dried fruit, but it also has a variety of consumption types such as tea, alcoholic beverages, pickles, jam, compote or candy in some cultures [11].

Jujube has been used in Traditional Chinese Medicine for thousands of years because of nutritional and bioactive properties [9, 12]. Recently, some researchers have indicated that jujube fruits are good source of vitamins (especially vitamin C) and minerals (calcium, iron and potassium as well as the content of carbohydrates, proteins and fatty acids [10,13,14]. The jujube, which is rich in phenolic compounds, has many bioactive properties such as antioxidant, anticancer, anti-inflammatory, hepatoprotective and sedative activities [9,15,16,17].

The purpose of the study is to review the jujube fruit in terms of physical features, nutritional values and bioactive properties.

2. Physical features

Jujube plant is a small deciduous tree with thorny branches and can reach 5-10 m height. Jujube has shiny-green leaves with 2-7 cm wide and 1-3 cm broad. Yellowish green, small flowers of jujube are 5 mm wide [18]. Also, there is one stone in the fruit [19]. Jujube fruits have ovoid and elongated shape like an olive. Jujube, a mild climate plant, can grow wild as well as cultivation for commercial purpose in garden. The growth rate of jujube trees is slower than other fruit trees.

The growing season of jujube is divided into 5 stages. Stage I is bud burst to leafing stage during early April-early May. Stage II is flowering to fruit set stage during mid-May-late June. Fruit formation stage is the third stage, and it occurs between late June-late July. During early August-early September, fruit maturation stage proceeds and then between October and March, dormancy stage continues [9].

Soil type does not have large effects on jujube growth because jujube trees are resistant to salinity and alkalinity. It is not necessary to provide large amount of water since jujube trees are better adapted to arid regions than other fruit trees [9]. Sandy, permeable, moist, and lime-rich soil with sufficient humus for jujube cultivation is more suitable [20]. Although jujube trees adapt to many climates, it needs summer heat for the formation of high-quality fruits.

3. Nutritional properties

Jujube fruit is a good source of vitamins, minerals, phenolic components, carbohydrates. Nutritional values and bioactive components of jujube depend on maturity stage and genotype [15].

Jujube contains approximately 85% carbohydrates, 57-77% reducing sugar, 0.57-2.79% soluble fibre, 5.24-7.18% insoluble fibre, 4.75-6.86% protein, 0.37-1.02% lipid, and 2.26-3.01% ash in dry weight [21]. In general, fructose, glucose and sucrose are the major sugars [22, 23]. Foods, which are rich in fructose, may be considered as potential food source for diabetic diets. So, jujube may be helpful for diabetics because of high fructose content [22]. Some researchers have indicated that sugar content and composition may differ based on cultivar, agro-climatic conditions and habitat [21]. Hernandez et al. [5] found that fructose, glucose, and sucrose levels of jujube ranged from 4.8 to 5.7 g/100 mL, 3 to 3.9 g/ 100 mL, 1.6 to 9.4 g/100 mL, respectively. Hernandez et al. [5] have indicated that the differences in the content of sugar depend on only cultivar because they grow at similar conditions. In another study, predominant sugars of jujube were defined as fructose, glucose, and sucrose. It was indicated that with the increasing maturity level, content of total sugar increased, then at the last stage of maturation, it decreased. Content of total sugar was determined as 817.42, 6061.23 and 4807.33 mg/100 g fresh weight at the first, fourth and last (sixth) stage of maturation, respectively. Additionally, it was reported that sucrose content increased with maturation despite of no sucrose content at initial stages [23].

There is limited information about protein and amino acid content of jujube. Amino acid profile of jujube at eight maturation stage was investigated by Choi et al. [24]. It was stated that protein content of jujube decreased from 42.1 to 4.6 g protein/100 g dry weight during maturation. Asparagine was reported to be major amino acid. Additionally, total free amino acids/protein (%) increased from 3.4 to 62.4 during maturation. Hernandez et al. [5] reported that protein content of jujube is ranged from 3.7% to 5.8% in dry weight and the usage of jujube in unbalanced plant-based diet might be helpful for remedy protein deficiency. Free amino acid composition of fresh, dried and stored jujube was showed by Pu et al. [25] The results demonstrated that fresh jujube contains approximately 26 g/kg free amino acid. The major amino acid was proline (17117.4 mg/kg), followed by threonine (3794.7 mg/kg) and serine (1151.4 mg/kg). Free amino acid content was stated to decrease as a result of Maillard reactions during drying [26].

Organic acids are indicators for fruit maturation, flavor, nutrition and acceptance of fruits [27]. Different types and amounts of organic acids in jujube were reported to be found depending on fruit's maturity stage, genotype, cultivation regions and climates [22,28]. According to the results of Gao et al. [22], while malic (294-740.3 mg/100 g fresh weight), citric (39.4-196.6 mg/100 g fresh weight) and succinic (0-177.9 mg/100 g fresh weight) acid were the organic acids in jujube cultivars. They have also indicated that the concentration of each organic acids differed dependent on cultivar. In a study, oxalic, tartaric, malic, lactic, and ascorbic acid were detected in jujube with different cultivar and maturity stage. Ascorbic (280.4-250.3 mg/L in white maturity; 312.9-319.2 mg/L in red maturity) and malic acid (106.1-130.7 mg/L in white maturity; 268.2-305.6 mg/L in red maturity) were reported to be major organic acids. They have stated that only oxalic acid content decreased with maturity from 92.3 to 45.3 mg/L, while the others reached maximum amount in the red maturity stage. This study has shown that maturity stage has important effect on organic acid content [15]. Although, Hernandez et al. [5] determined succinic acid (0.84-5.53 g/100 mL) as main organic acid, citric (0.30-0.77 g/100 mL), ascorbic (0.41-0.64 g/100 mL) and malic acid (0.21-0.31 g/100 mL) were reported to be detected in jujube fruits by other researchers. Some researchers have demonstrated that tartaric, malic, citric and succinic acid may exist in jujube fruits, but predominant organic acid was malic acid followed by tartaric acid.

At the different maturation stages, content of each organic acid was stated to be different [23]. Wu et al. [23] have also indicated that organic acids are the markers for fruit acceptability.

Li et al. [21] have reported that jujube has low lipid content (0.37-1.02%). Total lipid amount of fresh jujube fruits was observed between 0.06-0.1% by San and Yildirim [29]. They detected 19 different fatty acid and indicated that oleic (14.27-18.84%), linoleic (17.39-34.20%), palmitic (13.21-17.84%) and palmitoleic (7.27-18.86%) acid were predominant fatty acids in 4 jujube cultivars. These differences may result from jujube cultivars, chemical composition of jujube, geographical and climatic conditions.

Vitamins are essential micronutrients because they cannot be synthesized in human body. Therefore, it is a necessity to meet the need for vitamins with diet [30]. Vitamins have vital functions and lack of vitamins can cause various health problems [31]. Ascorbic acid (vitamin C), a water-soluble vitamin, has scavenging free radical activity and is a chelating and reducing agent [32]. Jujube is one of the richest fruits in terms of vitamin C [10]. Recommended nutrient intakes (RNIs) for vitamin C were stated that 45 mg/day for an adult man [33]. As recommended by FAO/WHO, one jujube fruit would meet the daily requirements for the complex vitamin C for an adult man [14]. In a study, ascorbic acid content of jujube was reported to be as 310.32 mg/100g fresh weight at the beginning of maturation and then decreased with maturation to 199.58 mg/100 g. It was indicated that ascorbic acid content of jujube is higher than most reported fruits as source of vitamin C such as kiwi, strawberry, lemon [23,34]. Cosmulescu et al. [15] have reported that ascorbic acid content of two different jujube cultivars were 280.4-250.3 mg/L at the white maturity stage, 321.9-319.2 mg/L at the red maturity stage. Most of studies indicate the highest ascorbic acid value at matured stage [35]. Wojdylo et al. [14] have stated that ascorbic acid content of four different jujube cultivars was ranged from 387 to 555 mg/100 g fresh weight. Gao et al. [22] have also indicated that hardness of fruit was significantly correlated with vitamin C content. Li et al. [21] have found that the amounts of other water-soluble vitamins were 0.04-0.09 mg/100 g for thiamine (B1), 0.05-0.09 mg/100 g for riboflavin (B2) and 192-359 mg/100 g for vitamin C. According to FAO, recommended daily riboflavin intake is 1.1 mg/day for female and 1.3 mg/day for male and recommended daily thiamin intake is 1.1 mg/day for female and 1.2 mg/day for male. Thus, one fresh jujube fruit wouldn't meet daily recommended intake.

Dietary minerals have great important roles in prevention of several diseases. Many researches show that jujube is one of the mineral-richest fruits. Hernandez et al. [5] determined four macro- (potassium, calcium, magnesium, sodium) and four micro-elements (iron, zinc, copper, manganese) in jujube. It was reported that potassium content of jujube was ranged from 11.9 to 17.3 g/kg dry weight as the highest mineral content [5]. Similarly, Wang et al. [36] have noticed the same result for potassium (13.1 g/kg). Calcium content of jujube was reported to be ranged from 0.23 to 0.72 g/kg and jujube might be considered as calcium source [36]. Jujube was found also rich in micro-elements such as iron (10.2-17.3 mg/kg dry weight), zinc (4.0-5.1 mg/kg dry weight), copper (0.5-1.2 mg/kg dry weight), manganese (0.2-2.9 mg/kg dry weight) by Hernandez et al. [5]. Li et al. [21] have stated that jujube is considered as rich fruit in terms of minerals and potassium (79.2-458 mg/100g fresh weight), calcium (45-118 mg/100g fresh weight), phosphor (59.3-110 mg/100 g fresh weight) and manganese (24.6-51.2 mg/100g fresh weight) have been defined as major minerals in the tested jujubes. İron (4.68-7.90 mg/100 g fresh weight), sodium (3.22-7.61 mg/100 g fresh weight), zinc (0.35-0.63 mg/100 g fresh weight) and copper (0.19-0.42 mg/100 g fresh weight) were also detected by Li et al. [21].

Phenolic content of fruits plays a key role with regard to improving sensory quality and resistance to some stress conditions [37,38]. Phenolic compounds also show bioactive properties such as antioxidant, anticancer, anti-inflammatory and antiallergic [39]. Ecological conditions, harvest and post-harvest conditions, maturity stage and process conditions of fruits have effects on the phenolics in terms of amount and quality [38]. In general, catechin, epicatechin and rutin are the main flavonoids; caffeic, gallic, chlorogenic and ferulic acid are the main phenolic acids of the jujube fruits [39,29,12,23,24]. Choi et al. [24] identified the flavonoids of jujube as epicatechin, procyanidin B2, kaempferol-glucosyl-rhamnoside, quercetin-3-galactoside, quercetin-3-robinobioside, quercetin-3-rutinoside. Phenolic content of jujube changes during maturation. It was observed that total flavonoid content of jujube decreased with maturity stage from 26.52 to 0.35 g/100 g dry weight [24]. Seven phenolic compounds (catechin, epicatechin, caffeic acid, ferulic acid, p-hydroxybenzoic acid, cholorogenic acid and rutin) were defined in jujube fruits by San and Yildirim [29]. San and Yildirim [29] have also indicated that predominant phenolic compounds of fruits were catechin (2.46-3.74 mg/100 g fresh weight) and rutin (0.88-3.60 mg/100 g fresh weight). Gao et al. [40] have reported that flavanoid content of different jujube cultivars were ranged from 159.3 to 230.3 mg rutin equivalent (RE)/ 100 g fresh weight. Phenolic content of jujube fruit (600.4 Gallic acid equivalent (GAE)/100 g fresh weight) have been reported to be higher than common fruits which are known for their high total phenolic contents such as cranberry (507 mg GAE/100 g fresh weight), red grape (182 mg GAE/100 g fresh weight), strawberry (147.8 mg GAE/100 g fresh weight) [40].

4. Bioactive Properties

4.1 Antioxidant properties

Antioxidants are defined as substances that greatly delay or inhibit the oxidation of materials that can easily be oxidized [41]. Antioxidant substances are divided into two groups as natural or synthetic. Natural antioxidants are extractable compounds which exist in plant and animal tissues or occur during the food processing such as fermentation and heat treatment. Important natural antioxidants include tocopherols, flavonoids, polyphenols, phenolic acids, vitamin C, carotenoids and selenium [42].

Jujube is a very rich fruit in terms of flavonoids and phenolic components. Gao et al. [22] have stated that jujube have more antioxidant activity (AA) than common antioxidative fruits such as pomegranate, guava and sweetsop. In their study trolox equivalent antioxidant capacity (TEAC), total phenolic (TPC) and total flavonoid content (TFC) of jujube fruits were ranged from 1.74 to 7.75 mmol Trolox equivalent (TE)/100 g fresh weight, 275.6 to 541.8 mg GAE/ 100 g fresh weight and 62 to 284.9 mg RE/100 g fresh weight, respectively. The authors have also indicated that higher AA was found in fruits which have higher antioxidant substances such as flavonoid and phenolic content and during the maturation, AA, TPC and TFC decreased [22].

Kou et al. [43] studied fifteen matured jujube cultivars in terms of bioactive compounds and AA. They have demonstrated that AA of jujube mainly depends on ascorbic acid, polyphenols and proanthocyanidins. In the study, AA of methanol extracts of jujube fruits was reported to be ranged from 1.04 to 1.91 mM TE/100 g fresh weight as DPPH values and 224.6 to 406.2 mg ascorbic acid equivalent (AAE)/100 g fresh weight as Ferric Reducing/Antioxidant Power (FRAP) values by Kou et al. [43].

Some researchers have investigated that jujube in the green maturity stage have higher DPPH scavenging activity, FRAP value and phenolic content than ripe jujube [44]. The DPPH radical scavenging activity and FRAP activity were found between 76.01-91.84% in green pulp and 0-85.11% in ripe pulp, respectively; 126.12 and 163.02 mmol FeSO4/g dry weight in green pulp and 0-148.18 mmol FeSO4/g dry weight in ripe pulp, respectively. Furthermore, a positive correlation between AA and TPC was reported by Siriamornpun et al. [44].

Cosmulescu et al. [15] have investigated those AA and bioactive compounds of two different jujube cultivars at four maturity stages from white to red maturity. During the maturation, TPC, TFC and AA were reported to be decreased from 1269.6-1643.4 to 475.3-529.5 to mg GAE/100 g, 34.6-48.5 to 19.9-26.7 mg QE/100 g, 1566.4-1661.4 to 1154.6-1164.7 mg AAE/100 g, respectively. They have indicated that TPC, TFC and AA decreased with maturity for two varieties and genotype has effect on amount and composition of bioactive compounds [15].

Four maturity stages of jujube fruits were analyzed in terms of antioxidant capacity and chemical components by Wang et al. [45] and pulp and peel of fruits were separately investigated. The results showed that peel of fruits have higher antioxidant capacity, total phenolic and flavonoid content than the pulp. At green maturity stage, all of these values were the highest level. However, these values significantly decreased during maturation [45]. Wu et al. [23] analyzed that the effect of maturation on some physicochemical properties and AA of jujube. It was stated that maturation levels were identified by red surface area percentage. This study showed that AA, total phenolic, total flavonoid and proanthocyanidin content decreased during the maturation. Epicatechin and cinnamic acid were reported to be found as the dominant phenolic compounds.

Choi et al. [24] determined AA of jujube by 4 methods; Folin Ciocalteu Reducing Capacity (F-C), DPPH Radical Scavenging Assay, ABTS Radical Scavenging Assay and Ferric Reducing/Antioxidant Power (FRAP) Assay. While F-C and FRAP assay were significantly correlated with each other (r=0.985), DPPH assay was weakly correlated with other methods (r=0.8). These AA methods have different principles such as FRAP and F-C assay detect only electron transfer antioxidants, ABST and DPPH detect electron transfer and hydrogen transfer antioxidants.[46] Therefore, differences between results of these methods may result from different precisions to a variety of antioxidative molecules. To explain the effect of AA in jujube, correlations between different compounds and antioxidant capacity results were calculated by Wojdylo et al. [14]. The results showed that content of ascorbic acid and polyphenolic compounds such as quercetin derivatives, polymeric procyanidins and flavonols related to antioxidant capacity (r>0.8). Zhang et al. [12] have investigated antioxidant capacities of the ethanolic extract of different tissues of jujube and it was noticed that flavonoid content of peel is higher than in the seed and pulp. Besides, antioxidant capacity was reported to be related to TPC and TFC in the study (r>0.98). In another study, AA and TPC of jujube pulp and peel were investigated by Xue et al. [47] The results of study showed that TPC and AA of jujube peel were found to be higher than pulp in three jujube cultivars. Xue et al. [47] have also reported that antioxidant capacity was measured by three different methods (DPPH, FRAP, TEAC) and all results of these three methods were highly correlated with each other.

There are studies on the relation between AA and peel color of Jujube. In literature, in this context, relation between antioxidant capacity and peel color of jujube was investigated by Xie et al. [48] It was reported that peel color may be an indicator for polyphenol content and antioxidant capacity. The L value represents lightness, and it indicates freshness of fruits [49]. Xie et al. [48] have reported that L values decreased from 87.24 to 58.77 during maturation. A value, which expresses redness, increased gradually from 0.53 to 17.03 during maturation. The b value, represent of yellowness, increased at the beginning of maturation, and then decreased. TPC of jujube peel decreased during maturation, while total flavonoid and proanthocyanidin content of jujube peel increased at first maturation stage and then decreased. It was indicated that higher L value is related to higher content of total phenolics, and it means that jujube would be at the first stage of maturation (unripe). The higher b value is related to higher content of flavonoids and proanthocyanidins which means jujube would be mid-mature. The higher a value related with higher content of total phenolics which means jujube would be fully mature.

4.2 Antimicrobial activity

In recent years, many microorganisms, which cause infections and contagious disease, have developed resistance against antibiotics because of antibiotics' misusage. For this reason, several researchers have indicated requirement of defining novel compounds having antibiotic effect [50]. Antimicrobial activity of fruits depends on cultivar and composition of fruit, species of target microorganism, processing and storage conditions. Proteins, lipids, pH, salts and temperature effect on antimicrobial activity of phenolic substances in fruits [51].

Özkan [52] have reported that jujube has antibacterial activity against gram positive bacterias. The highest antibacterial activity was identified against *Staphylococcus aureus* with 2 mg/mL (methanolic extract of jujube) minimum inhibitory concentration. Similarly, Abd-Alrahman et al. [53] and Ahmad and Beg [54] have stated that jujube extracts have antimicrobial effects on gram positive bacteria such as *S.aureus*. On the other hand, no or poor antimicrobial effects on gram negative bacteria such as *Escherichia coli* was reported by Abd-Alrahman et al. [53] and Ahmad and Beg [54].

4.3. Anticancer activity

It is known that Ziziphus species have been used for treatment several diseases such as diabetes, liver complaints, obesity, insomnia, and cancer in Traditional Chinese Medicine [1,9,64]. In cell culture studies, it was reported that *Ziziphus* extracts have anticancer activities on several tumor cell line [55]. It was stated that triterpenic acids were effective bioactive components on cancer [56]. Additionally, polysaccharides of jujube may show antitumor activity by different mechanisms such as inducing the apoptosis of tumor cells, prevention of oncogenesis and spread of tumor cells, improving immune response to tumors [57,58,59,60,7]. Choi et al. [24] have investigated some chemical properties, antioxidative and cancer cell inhibitory effects of jujube fruits at eight maturity level. Cancer cell inhibitory effect was determined by using MTT (3-(4,5-dimetiltiyazol2-yl)-2,5-difeniltetrazolyum-bromür) method. This method is based on measurement the color change of MTT test solution with the cell viability. MTT solution with yellow color is reduced by alive cells to formazan components with purple color, then the absorption is measured. In the study, two normal cell line and three carcinogenic cell line were treated with four doses of the jujube fruits at different maturity levels. Cervical cancer cells were dose-dependently inhibiting all maturity levels, in contrast with normal lung and lung cancer cells inhibition decreased with maturation. It was also noticed that cancer cell inhibition effects of jujube were related to flavonoid content and AA.

Anticancer activity of dried jujube fruit was investigated by Vahedi et al. [61] Jurkat leukemia cell line, HeLa epitheloid cervix and HEp-2 larynx carcinoma cell line was treated by water extract of dried jujube fruit. MTT results showed that jujube has dose-dependently cytotoxic effects on these cell lines [61]. Huang et al. [62] have demonstrated that jujube fruit extracts have anticancer activity in HepG2 hepatocellular carcinoma cell line by inducing apoptosis. In a study, the antiproliferative effects of different extracts obtained from jujube fruit on MCF7 and SKBR3 breast cancer cell lines were investigated. The highest antiproliferative activity was found in the fraction which is rich in triterpenic acid and protocatechuic acid [55]. Antiproliferative activity of deproteinized polysaccharides (DPP) of jujube fruits was evaluated by Hung et al. [63] DPP showed dose- and time-dependent antiproliferative activity against melanoma cells. Hoshyar et al. [64] have proved the in vitro anticancer activity of aqueous jujube extract against breast cell line. Additionally, in vivo experiments showed that due to decreasing the adverse effects of N-Methyl-N-Nitrosourea (NMU) carcinogenesis, jujube fruit could be helpful for treatment of breast cancer. They also indicated that this anticancer effect could be related to AA of jujube. In a study, it was demonstrated that aqueous extracts of two different varieties jujube have cytotoxic effect on leukemic cell line with 375 and 852 µg/mL IC_{50} (the half maximal inhibitory concentration) values [44].

4.4. Other health benefits

The liver has important role in the body because of functions in biotransformation and detoxification [65]. Therefore, protection of liver or curing liver injuries

with natural sources have been evaluated by many researchers [66]. The hepatoprotective effect of water extracted jujube was investigated and protocatechuic acid, vanilla acid, p-coumaric acid, catechol, p-hydroxybenzoic acid were indicated as the main phenolic compounds by Liu et al. [67] In vivo experiments in mice with alcohol-induced liver damage showed that oral administration of water extracted jujube decreased the level of total cholesterol and triglyceride, activities of serum hepatic AST (aspartate aminotransferase), ALT (alanine aminotransferase) and LDH (lactate dehydrogenase). Alcohol-induced liver damage cause to increasing of these parameters in the serum. Decreasing level of these parameters with oral administration of jujube indicated that jujube has therapeutic and protective effects against alcohol-induced liver damage. In another study, the researchers have shown that jujube fruits extracts have hepatoprotective effects in relation to modulate the oxidative stress in hepatic injury [68]. Selim et al. [69] have investigated effects of jujube and honey on the human hepatocarcinogenesis. The study run with 50 patients who have chronic hepatitis C. Patients were treated with 4 g jujube and 1 g honey three times per day for three months. Results showed that the treatment decreased the level of some parameters related to the disease such as ALT, AST, alkaline phosphatase (ALP), bilirubin. It may be considered the potential of using jujube for natural therapy against hepatocarcigonesis due to results of the study.

In Traditional Chinese Medicine, jujube has been used for some therapeutic purposes. Mostly encountered problems such as insomnia and anxiety have been treated with jujube [64,70]. Sedative and hypnotic effects of jujube have been associated with decreasing the monoaminergic system activity [71]. Jiang et al. [71] have indicated that most effective sedative and hypnotic functions of jujube were a result of existing saponins.
Another disease, which may be treated by jujube, is Alzheimer's Disease. Alzheimer's is memory loss caused by loss of cholinergic neurons of the nucleus basalis of Meynert (NBM) and cortical cholinergic deficiency [72]. Because jujube has activator effect on choline acetyltransferase due to oleamide content, jujube may be useful for therapy of Alzheimer's [73]. Rabiei et al. [72] have indicated that jujube has effects on memory repairing and restoring behavioral disorders produced by NBM lesion.

Nucleotide and flavonoids are specific bioactive components of jujube. For instance, cAMP (cyclic Adenosine Monophosphate) in jujube has important roles in several physiological processes such as neuroprotective effects, antimelancholic properties [74,75]. Additionally, some studies showed that jujube increased the cAMP level in plasma and hippocampus of animals [76]. cAMP has also an important role in gene expression, inhibition of cell proliferation, heart diseases, allergic diseases [77]. Kou et al. [43] found that the amount of cAMP in jujube ranged from 17.38 to 193.93 µg/g fresh weight.

5. Conclusion

Prevalence of many diseases such as cancer, diabetes, liver diseases, vitamin or mineral insufficiency has increased around the world. Medical treatments and drugs have some adverse effect. Therefore, interest in natural therapeutics has increased. Jujube is one of the richest fruits in nutritional and bioactive compounds. In the current paper, nutritional values and health benefits of jujube were reviewed. In the light of the previous researches,

a) The jujube fruit has high phenolic content. Jujube extracts may be used for natural antioxidant extracts because of high phenolic content.
b) The jujube is a rich source of ascorbic acid, strong antioxidant substance. Therefore, it may be beneficial to investigate usage potential of jujube as natural vitamin C supplement.
c) The knowledge of total phenolics, polysaccharides, triterpene acids, organic acids may be useful for understanding the bioactivity of jujube. Due to bioactive compounds, jujube fruits have a potential medicinal value.

Health benefits of jujube such as anticancer, antioxidant, antidiabetic and hepatoprotective activities have been indicated by previous researches. Further studies are needed to better understanding of curing potential of jujube.

Author's Contributions

Fadime Begüm Tepe: Drafted and wrote the manuscript
Raci Ekinci: Supervised the manuscript
Çetin Kadakal: Supervised the manuscript, checked the English grammar of the manuscript and edited.
Mustafa Nizam Nizamlıoğlu: Edited of the manuscript.

Ethics

There are no ethical issues after the publication of this manuscript.

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