

Nutritional composition of five cultivars of chinese jujube

Jin-Wei Li ^a, Liu-Ping Fan ^a, Shao-Dong Ding ^b, Xiao-Lin Ding ^{a,*}

^a School of Food Science and Technology, Southern Yangtze University, Wuxi 214036, Jiangsu Province, China

^b Center of Testing and Analysis, Southern Yangtze University, Wuxi 214036, China

Received 20 January 2006; received in revised form 18 August 2006; accepted 22 August 2006

Abstract

The proximate composition of five cultivars of Chinese jujube, along with mineral, vitamin and total phenolic contents were determined. Investigations showed that Chinese jujube contained 80.86–85.63% carbohydrate, 57.61–77.93% reducing sugar, 0.57–2.79% soluble fibre, 5.24–7.18% insoluble fibre, 4.75–6.86% protein, 0.37–1.02% lipid, 17.38–22.52% moisture and 2.26–3.01% ash. The soluble sugars of Chinese jujube included fructose, glucose, rhamnose, sorbitol and sucrose. Fructose and glucose were identified as the major sugars while sorbitol was present in much lesser amounts. Potassium, phosphorus, calcium and manganese were the major mineral constituents in Chinese jujube. Iron, sodium, zinc and copper were also detected in appreciable amounts. The contents of vitamin C, thiamine and riboflavin were found to be 192–359, 0.04–0.08 and 0.05–0.09 mg/100 g, respectively. Total phenolic contents ranged from 5.18 to 8.53 mg/g. No correlation between total phenolic contents and antioxidant capacities or antioxidant capacities and vitamin C contents of Chinese jujube was found.

© 2006 Elsevier Ltd. All rights reserved.

Keywords: Chinese jujube; Proximate composition; Soluble sugars; Minerals; Vitamin; Phenolic contents

1. Introduction

The jujube, which is mainly distributed in the subtropical and tropical regions of Asia and America, is a tree of the Rhamnaceae family. It is commonly used in folklore medicine for the curing of various diseases. Chinese jujube (*Zizyphus jujuba* Miller) is indigenous to China with a history of over 4000 years. It has been widely planted in reforested areas within the Yellow River valley, and chosen as a variety compatible with the present ecology and economy (Yan & Gao, 2002.). The fruit of Chinese jujube is a favoured and profitable fruit, and is much admired for its high nutritional value. It has been commonly used as a crude drug in traditional Chinese medicine for the purpose of analeptic, palliative, antiepileptic and also commonly used as food, food additive and flavourant for thousands of years. The Chinese share of the world jujube production is about 90% and its production has increased in the last

10 years due to the demands for food and pharmaceutical applications (Yan & Gao, 2002). A steady rise in consumer demand has been reflected by an expansion of Chinese production that was 1.1 million tonnes in 1997, reaching 1.4 million tonnes in 2001. Much of the annual Chinese jujube production has been consumed in fresh and dried forms, therefore, there have been numerous studies focused on the preservation and processing of Chinese jujube to enhance quality (Lu, Li, & Lu, 1992; Wan, Tian, & Qin, 2003; Wang, Li, & Dan, 2003). Other reports are mainly on characteristics of the shape and type of species. However, little information is available about the detailed chemical composition of Chinese jujube, which plays an important role in food processing and preservation.

Nowadays, five cultivars of Chinese jujube are commonly planted in China, including *Zizyphus jujuba* cv. *Jin-sixiaozao*, *Zizyphus jujuba* cv. *Jianzao*, *Zizyphus jujuba* cv. *Yazao*, *Zizyphus jujuba* cv. *Junzao* *Zizyphus jujuba* cv. *Sanbianhong*. In a previous paper, antioxidant activities of extracts from five cultivars of Chinese jujube were compared (Li, Ding, & Ding, 2005). In this study, the objective

* Corresponding author. Fax: +86 510 85807976.

E-mail address: lhw6688@hotmail.com (X.-L. Ding).

was to determine the detailed composition of five cultivars of Chinese jujube, including their proximate composition (total protein, total lipid, fibre and ash), soluble sugar, mineral, vitamin and total phenolic contents. The differences in nutritional composition of five cultivars of Chinese jujube were also compared.

2. Materials and methods

2.1. Materials

The five cultivars of Chinese jujube analyzed in this paper were collected from September to October of 2003 in Jinan of Shandong Province, China. They were air dried in the sun immediately after collection, and then botanically identified at the Research Institute of Jujube (Shandong, China). After drying, the five cultivars of Chinese jujube analyzed in this paper were stored at $-20\text{ }^{\circ}\text{C}$ until all assays were performed. All results represent averages of duplicate determinations and are expressed on a dry weigh basis.

2.2. Proximate composition analysis

Water content was determined by weight difference after drying of sample, following the official method of AOAC (1995). Lipid content was determined using a Soxhlet apparatus according to the procedure described by Huang (1989). Carbohydrate content was examined using phenol–sulphuric acid colorimetric method (Dubois, Gilles, Hamilton, Rebers, & Smith, 1956). Reducing sugar was determined by the method of desulphurization-titration (Huang, 1989). Insoluble and soluble fibre were measured according to the procedures described by Huang (1989). Protein content was calculated from the nitrogen content ($\%N \times 6.25$) analyzed by Kjeldahl method. Ash was measured according to the standard procedures (AOAC, 1995).

2.3. Soluble sugar extraction and analysis

All samples were sliced and the seeds were removed before comminuting. The finely powdered Chinese jujube was defatted by extraction for 4 h with a mixture of petroleum ether and chloroform (1:1, v/v) at room temperature according to the method described by Swamy, Ramakrishnaiah, Kurien, and Salimath (1991). Defatted Chinese jujube was first extracted twice with 80% ethanol, then by four times extraction with 70% ethanol. The ethanolic extracts were centrifuged and combined. The combined extracts were concentrated at $40\text{ }^{\circ}\text{C}$ under reduced pressure. The aqueous extracts obtained were de-proteinated with basic lead acetate, removing excess lead by addition of sodium oxalate crystals. Then, the sample was again extracted with ethanol (70%) and the ethanolic extracts were air dried. Sugar composition of the extracts was determined using a gas chromatograph (GC-14A, Shimadzu, Kyoto, Japan), in which oxime-trimethylsilyl derivatives was measured (Munshi, Vats, Dhillon, & Sukhija, 1990).

Trimethylsilylated (TMS) oximes of sugar extracts were prepared according to the method of Biermann and McGinnis (1989). The sample (50 mg) was dissolved in pyridine (2 ml). A 50 ml portion of the pyridine solution was transferred to a vial for pyridine stock solution containing 3% (w/w) hydroxylamine hydrochloride. The sample solution was kept at $70\text{ }^{\circ}\text{C}$ for 30 min. After cooling to room temperature, hexamethyldisilane (300 μl) and trimethylchlorosilane (200 μl) were added for silylation. The silylation was allowed to reach completion at room temperature for 30 min before analysis.

2.4. Mineral analysis

Potassium, calcium, magnesium, iron, sodium, zinc and copper were determined using atomic absorption spectrophotometer (Spectra-AA220, Varian Co., Palo Alto, CA, USA) after digestion in mixed acids (nitric acid:perchloric acid = 4:1). Phosphorus content was determined by the molybdenum-blue method in the wavelength of 660 nm according to the method described by Huang (1989). Selenium content was determined using the fluorometric method of Huang (1989).

2.5. Vitamin analysis

Thiamine and riboflavin were determined fluorometrically using a F96 spectrofluorometer (Shanghai Second Instrument Factory, Shanghai, China), following the AOAC (1995, methods). The content of vitamin C was measured by visual titration method of reduction of 2,6-dichlorophenol-indophenol dye (Huang, 1989).

2.6. Extraction and determination of amount of total phenolic compounds

The slices of Chinese jujube (10 g) were homogenized with homogenizer (Shanghai Second Instrument Factory, China) at 6000 rpm for 5 min with methanol–water (4:1, v/v) at room temperature. The ratio of the slices and solvent was 1:5 (w/v). The resulting slurries were extracted in a Soxhlet apparatus. The extracts were filtered under suction through Whatman No. 4 filter paper. The remaining very fine particles in the filtrate were centrifuged at 5680g for 15 min. The supernatants were collected and the solvent was evaporated in a rotary vacuum evaporator at $60\text{ }^{\circ}\text{C}$. The residues were refrigerated and freeze dried.

The amount of total phenolic compounds of Chinese jujube was determined according to the method described by Singleton, Orthofer, and Ramuela-Raventios (1999). Briefly, 0.1 ml of extraction solution was transferred to a volumetric flask and the volume was adjusted to 46 ml by addition of distilled water. Then 1 ml of Folin-Ciocalteu reagent was added to this mixture. After 3 min, 3 ml of sodium carbonate solution (20 g/L) were added to the volumetric flask. Subsequently, the mixture was shaken mechanically for 2 h at room temperature. The absorbance

was measured at 760 nm using a 751-UV-VIS spectrophotometer (Shanghai analytical Instrument Factory, Shanghai, China). The contents of total phenolic compounds of extracts from five cultivars of Chinese jujube were calculated using gallic acid as a standard.

2.7. Ferric-reducing antioxidant power analysis

The amount of total antioxidant capacity of Chinese jujube was carried out according to a modified method of FRAP described by Benzie and Szeto (1999).

2.8. Statistical analysis

All experiments were performed at least in duplicate, and analyses of all samples were run in triplicate and mean value repeated. Statistical analysis was done using the statistical analysis systems (SAS, version 8.1) software package. The results shown are presented as means of three determinations \pm SD (standard deviation). The results obtained were analyzed using one-way analysis of variance (ANOVA) for mean differences among five cultivars of Chinese jujube. p -values of <0.05 were considered to be statistically significant.

3. Results and discussion

3.1. Proximate composition

The results of the proximate chemical analysis of the five cultivars of Chinese jujube (*Zizyphus jujuba* cv. *Jinsixiaozao*, *Zizyphus jujuba* cv. *Jianzao*, *Zizyphus jujuba* cv. *Yazao*, *Zizyphus jujuba* cv. *Junzao*, *Zizyphus jujuba* cv. *Sanbianhong*) are shown in Table 1. The carbohydrate contents of the five cultivars of Chinese jujube were similar and ranged from 80.86 (*Zizyphus jujuba* cv. *Yazao*) to 85.63% (*Zizyphus jujuba* cv. *Sanbianhong*). No significant difference ($p > 0.05$) existed in the carbohydrate contents among the five cultivars of Chinese jujube. Reducing sugar contents of Chinese jujube studied varied from 57.61% to 77.93%.

The soluble fibre contents for five cultivars of Chinese jujube followed the order: *Zizyphus jujuba* cv. *Jinsixiaozao*

$>$ *Zizyphus jujuba* cv. *Jianzao* $>$ *Zizyphus jujuba* cv. *Yazao* $>$ *Zizyphus jujuba* cv. *Junzao* $>$ *Zizyphus jujuba* cv. *Sanbianhong* and were 2.79%, 1.51%, 1.46%, 1.07% and 0.57%, respectively. The soluble fibre contents of different Chinese jujube exhibited significant differences ($p < 0.05$) except for *Zizyphus jujuba* cv. *Jianzao* and *Zizyphus jujuba* cv. *Yazao*. The insoluble fibre contents of Chinese jujubes ranged from 5.24% to 7.18%. *Zizyphus jujuba* cv. *Jinsixiaozao* and *Zizyphus jujuba* cv. *Yazao* had higher insoluble fibre contents than those of the other three Chinese jujubes ($p < 0.05$).

The five cultivars of Chinese jujube had lower lipid contents and the values ranged from 0.37% to 1.02%. The lipid contents observed were lower than those of jujube reported by others (Danthu et al., 2002; Kwon et al., 1997). The lower lipid contents may be that some bound lipids were not extracted by ether (Ranhotra, Gelroth, & Vetter, 1996).

Protein contents of the five cultivars of Chinese jujube varied from 4.75% to 6.86% and ash contents varied from 2.26% to 3.01%. The cultivars appeared to significantly affect protein contents and ash contents ($p < 0.05$). The moisture contents of five cultivars of Chinese jujube ranged from 17.38% (*Zizyphus jujuba* cv. *Jianzao*) to 22.52% (*Zizyphus jujuba* cv. *Sanbianhong*).

3.2. Soluble sugars contents

The results of soluble sugars analysis are presented in Table 2. The soluble sugars identified in the five cultivars of Chinese jujube were fructose, glucose, rhamnose, sorbitol and sucrose. Fructose and glucose were identified as the major sugars while sorbitol was present in much lesser amounts. Other study has also shown that glucose and fructose were the main sugars present (Sakamura & Suga, 1987). The content of sucrose was found to be lower than the contents of fructose and glucose. Our result is in agreement with the findings of Beruter (1985). The explanation may be that sucrose, synthesized in the leaves, is hydrolyzed to glucose and fructose with the enzyme invertase when translocated to the flesh of the fruit, which is known to happen during ripening of fruits (DeVilliers, Meynhardt, & Debruyne, 1974).

Table 1
Chemical component of five cultivars of Chinese jujube (% of dry weight basis)

Component	<i>Zizyphus jujuba</i> cv.				
	<i>Jinsixiaozao</i>	<i>Yazao</i>	<i>Jianzao</i>	<i>Junzao</i>	<i>Sanbianhong</i>
Carbohydrate	81.62 \pm 3.12a	80.86 \pm 3.55a	84.85 \pm 1.83a	82.17 \pm 1.94a	85.63 \pm 0.96a
Reducing sugar	57.61 \pm 2.71c	60.24 \pm 2.56c	77.93 \pm 0.61a	58.73 \pm 1.13c	67.32 \pm 0.64b
Soluble fibre	2.79 \pm 0.24a	1.46 \pm 0.19b	1.51 \pm 0.11b	1.07 \pm 0.22c	0.57 \pm 0.03d
Insoluble fibre	6.11 \pm 0.30a	7.18 \pm 0.16a	5.24 \pm 0.13b	5.83 \pm 0.49b	5.56 \pm 0.28b
Lipid	0.37 \pm 0.01c	1.02 \pm 0.05a	0.39 \pm 0.02c	0.71 \pm 0.07b	0.65 \pm 0.03b
Protein	5.01 \pm 0.05d	6.86 \pm 0.02a	4.75 \pm 0.03e	6.43 \pm 0.02c	6.60 \pm 0.04b
Moisture	18.99 \pm 1.23ab	20.98 \pm 1.12ab	17.38 \pm 1.21b	21.09 \pm 1.39ab	22.52 \pm 1.43a
Ash	2.26 \pm 0.03e	2.78 \pm 0.05b	2.41 \pm 0.09d	3.01 \pm 0.06a	2.56 \pm 0.02c

Each value is expressed as means \pm standard deviation ($n = 3$). Means with different letters within a row are significantly different ($p < 0.05$) by Bonferroni t -test.

Table 2
Sugar contents of five cultivars of Chinese jujube (% of dry weight basis)

<i>Zizyphus jujuba</i> cv.	Fructose	Glucose	Rhamnose	Sorbitol	Sucrose
<i>Jinsixiaozao</i>	19.1 ± 0.15d	22.5 ± 0.41c	12.2 ± 0.24b	2.1 ± 0.19c	14.1 ± 0.15b
<i>Yazao</i>	18.6 ± 0.09d	26.3 ± 0.12b	12.5 ± 0.21b	0.3 ± 0.17d	11.5 ± 0.02c
<i>Jianzao</i>	42.9 ± 0.26a	19.2 ± 0.27d	14.1 ± 0.35a	1.9 ± 0.15c	0.21 ± 0.05d
<i>Junzao</i>	25.1 ± 0.11b	19.6 ± 0.09d	10.5 ± 0.12c	2.6 ± 0.09b	17.4 ± 0.12a
<i>Sanbianhong</i>	22.8 ± 0.24c	27.2 ± 0.31a	14.7 ± 0.14a	3.5 ± 0.21a	11.3 ± 0.21c

Each value is expressed as means ± standard deviation ($n = 3$). Means with different letters within a column are significantly different ($p < 0.05$) by Bonferroni t -test.

The content of fructose was 42.9% in *Zizyphus jujuba* cv. *Jianzao* and was the highest among Chinese jujube studied. This relatively high content of fructose makes *Zizyphus jujuba* cv. *Jianzao* useful for diabetics. Therefore, it can be said that the best cultivar for sugar quality is *Zizyphus jujuba* cv. *Jianzao*. The sugar content and composition in plants are known to differ greatly among cultivars according to their habitats. Samples used in this work were collected from the same area, therefore, our results can aid in the selection of cultivars for special food processing.

3.3. Mineral contents

The results of the analysis of the mineral contents of Chinese jujube are summarized in Table 3. The data indicated that potassium, phosphorus, calcium and manganese were the major mineral constituents in the five cultivars of Chinese jujube tested. Iron, sodium, zinc and copper were also detected in appreciable amounts. The nutritionally significant element selenium was not detected in any of the five cultivars of Chinese jujube examined.

Potassium was the predominant mineral in the five cultivars of Chinese jujube. The potassium contents ranged from 79.2 to 458 mg/100 g. The richest source of potassium in this study was *Zizyphus jujuba* cv. *Yazao*. From the statistical analysis, the potassium contents of five cultivars of Chinese jujube were significantly different ($p < 0.05$).

Regarding phosphorus contents the highest value was found in *Zizyphus jujuba* cv. *Jinsixiaozao* (110 mg/100 g) followed by *Zizyphus jujuba* cv. *Junzao* (105 mg/100 g), *Zizyphus jujuba* cv. *Sanbianhong* (79.7 mg/100 g) *Zizyphus*

jujuba cv. *Jianzao* (72.3 mg/100 g) and *Zizyphus jujuba* cv. *Yazao* (59.3 mg/100 g).

The calcium contents ranged from 45.6 to 118 mg/100 g. Calcium is one of the most preponderant minerals in Chinese jujube, which may also be helpful in lowering blood pressure. Several clinical and other studies have also shown calcium to be effective pressure lowering agents (Osborne et al., 1996; Zemel, 1997). Of course, the human bioavailability of the calcium in these calcium-rich plants is not known and could be compromised by the co-presence of natural components such as oxalates and phytates that can chelate calcium, rendering this critical divalent cation unavailable for absorption in the intestine. Thereby further research must be conducted to determine the contents of inhibitory components for some minerals analyzed.

The richest source of magnesium was *Zizyphus jujuba* cv. *Jianzao* (51.2 mg/100 g). Chinese jujube with the lowest magnesium content was *Zizyphus jujuba* cv. *Junzao* (24.6 mg/100 g). Magnesium is required by many enzymes, especially the sugar and protein kinase families of enzymes that catalyse ATP-dependent phosphorylation reactions.

The iron contents ranged from 4.68 to 7.90 mg/100 g. *Zizyphus jujuba* cv. *Yazao* and *Zizyphus jujuba* cv. *Junzao* were higher in iron. Statistical analysis showed the five cultivars of Chinese jujube were significantly different in their iron contents ($p < 0.05$). These iron contents presented here were higher than those reported in jujube in Senegal (Danthu et al., 2002).

The highest level of sodium was 7.61 mg/100 g (*Zizyphus jujuba* cv. *Yazao*) and the lowest 3.22 mg/100 g (*Zizyphus jujuba* cv. *Sanbianhong*). The sodium contents of

Table 3
Mineral contents of five cultivars of Chinese jujube (mg/100 g)

Minerals	<i>ZiZyphus jujuba</i> cv.				
	<i>Jinsixiaozao</i>	<i>Yazao</i>	<i>Jianzao</i>	<i>Junzao</i>	<i>Sanbianhong</i>
Potassium	79.2 ± 5.2a	458 ± 5.0e	375 ± 6.3d	201 ± 2.7b	244 ± 3.2c
Phosphorus	110 ± 2.3e	59.3 ± 1.5a	72.3 ± 2.7b	105 ± 1.8d	79.7 ± 1.4c
Calcium	65.2 ± 3.2b	91.0 ± 2.2d	45.6 ± 2.1a	118 ± 3.1e	76.9 ± 1.9c
Manganese	39.7 ± 4.1bc	36.5 ± 1.1b	51.2 ± 2.8d	24.6 ± 2.5a	42.1 ± 1.6c
Iron	4.68 ± 0.11a	6.93 ± 0.22d	6.42 ± 0.12c	7.90 ± 0.13e	6.01 ± 0.21b
Sodium	6.34 ± 0.31c	7.61 ± 0.28d	6.21 ± 0.24c	5.96 ± 0.23b	3.22 ± 0.11a
Zinc	0.55 ± 0.04d	0.63 ± 0.03c	0.47 ± 0.06b	0.42 ± 0.01b	0.35 ± 0.02a
Copper	0.26 ± 0.04b	0.27 ± 0.01b	0.42 ± 0.02c	0.31 ± 0.05b	0.19 ± 0.02a
Selenium	nd	nd	nd	nd	nd

Each value is expressed as means ± standard deviation ($n = 3$). Means with different letters within a row are significantly different ($p < 0.05$) by Bonferroni t -test.

different Chinese jujube exhibited significant differences ($p < 0.05$) except for *Zizyphus jujuba* cv. *Jinsixiaozao* and *Zizyphus jujuba* cv. *Jianzao*.

Zizyphus jujuba cv. *Jinsixiaozao* and *Zizyphus jujuba* cv. *Yazao* contained relatively high amounts of zinc (0.65 and 0.63 mg/100 g, respectively). Zinc is nutritionally essential for all organisms for several reasons, among them being its role in the immune system, the secretion of insulin (Chausmer, 1998), the release of vitamin A from liver stores (Hwang et al., 2002) and key enzymes such as superoxide dismutase (Boron et al., 1988; Hwang et al., 2002). As recommended by the Food and Nutrition Board, National Research Council (1989), its daily need is 16 mg.

The five cultivars of Chinese jujube contained relatively low amounts of copper (0.19–0.42 mg/100 g) that is important because it participates in numerous enzyme-catalysed oxidation–reduction reactions and processes, including certain components of the mitochondrial electron transport (Takahashi et al., 2002), and lysyl oxidase that is involved in collagen biosynthesis (Pereira, Gomes, & Teixeira, 2002).

In total, the mineral contents could be affected by climate, soil nutrient content, time of harvest and landraces used. It is noteworthy that minerals are important not only for human nutrition, but for plant nutrition as well. In addition, mineral-efficient varieties of plants are more drought resistant and require less irrigation (Bouis, 1996).

3.4. Vitamin contents

The vitamin contents of Chinese jujube are given in Table 4. According to the results, the amounts of thiamine (B1) and riboflavin (B2) were low in the five cultivars of Chinese jujube. Large amounts of vitamin C whose contents ranged from 192 to 359 mg/100 g were present. Therefore, it appears that Chinese jujube studied is a good source of vitamin C in the diet. On the average, a 20 g portion of Chinese jujube studied would provide about all of an adult's daily need of vitamin C recommended by Food and Nutrition Board, National Research Council (1989). As for vitamins, some plant components may inhibit vitamin absorption. However, their impact is often difficult to assess in the context of a total diet, particularly since some inhibitors such as fibre and phytates may also be effective health-promoting components.

3.5. Total phenolic contents

Total phenolic contents of Chinese jujube are given in Table 4. Among five cultivars of Chinese jujube tested, total phenolic contents decreased in the order of *Zizyphus jujuba* cv. *Yazao*, *Zizyphus jujuba* cv. *Jianzao*, *Zizyphus jujuba* cv. *Jinsixiaozao*, *Zizyphus jujuba* cv. *Junzao*, *Zizyphus jujuba* cv. *Sanbianhong*. Total phenolic contents of different Chinese jujube studied exhibited significant differences ($p < 0.05$) except for *Zizyphus jujuba* cv. *Jianzao* and *Zizyphus jujuba* cv. *Yazao*.

It has long been recognized that naturally occurring substances in fruits and vegetables have antioxidant activity. Among those substances, the phenolic compounds widely distributed in fruits and vegetables have the ability to scavenge free radicals, superoxide and hydroxyl radicals, by single-electron transfer. There is a consensus that the antioxidant capacity is directly correlated with phenolic compounds (Connor, Luby, Hancock, Berkheimer, & Hanson, 2002; Robards, Prenzler, Tucker, Swatsitang, & Glover, 1999; Yang, Lin, & Mau, 2002). However, Ismail, Marjan, and Foong (2004) reported no correlation between total phenolic contents and antioxidant capacities of extracts from five types of vegetables, nor were any relationships between antioxidant capacities and phenolic composition found in fruit berry, fruit wines (Heinonen, Meyer, & Frankel, 1998) or in plant extracts (Kahkonen et al., 1999). The previous study has also shown that antioxidant capacities of Chinese jujube followed the order: *Zizyphus jujuba* cv. *Jinsixiaozao* > *Zizyphus jujuba* cv. *Yazao* > *Zizyphus jujuba* cv. *Jianzao* > *Zizyphus jujuba* cv. *Junzao* > *Zizyphus jujuba* cv. *Sanbianhong* (Li et al., 2005). In this study, Pearson correlation analysis does not show any relationship between total phenolic contents and antioxidant capacities or antioxidant capacities and vitamin C contents of Chinese jujube ($p > 0.05$). For example, *Zizyphus jujuba* cv. *Jinsixiaozao* had lower total phenolic content, whereas its antioxidant capacity was a bit higher than those of *Zizyphus jujuba* cv. *Yazao* and *Zizyphus jujuba* cv. *Jianzao* that had higher total phenolic contents (Table 4). Therefore, phenolic compounds may contribute to the antioxidant capacity because of their ability to scavenge free radicals, superoxide and hydroxyl radicals. However, it is not the unique factor influencing the antioxidant capacity, there

Table 4
Vitamin, total phenolic contents and antioxidant capacity of five cultivars of Chinese jujube

<i>Zizyphus jujuba</i> cv.	Thiamine (mg/100 g)	Riboflavin (mg /100 g)	Vitamin C (mg/100 g)	Phenolic content GAE (mg/g)	Antioxidant capacity FRAP ^A (μmol/g)
<i>Jinsixiaozao</i>	0.05 ± 0.01c	0.07 ± 0.02b	359 ± 27b	7.42 ± 0.53c	1173 ± 112b
<i>Yazao</i>	0.04 ± 0.01c	0.07 ± 0.01b	192 ± 31c	8.53 ± 0.47b	1025 ± 125c
<i>Jianzao</i>	0.09 ± 0.01b	0.05 ± 0.01b	203 ± 19c	8.36 ± 0.33b	794 ± 52.1d
<i>Junzao</i>	0.06 ± 0.02bc	0.09 ± 0.02b	296 ± 38b	7.01 ± 0.42d	563 ± 74.3e
<i>Sanbianhong</i>	0.05 ± 0.01c	0.05 ± 0.01b	315 ± 24b	5.18 ± 0.29e	342 ± 45.8f

Expressed on dry weight basis. Each value is expressed as means ± standard deviation ($n = 3$).

Means with different letters b, c, d, e and f within a column are significantly different ($p < 0.05$) by Bonferroni *t*-test.

^A Taken from a previous paper written by Li et al., 2005.

are other phytochemicals such as vitamin C and pigments as well as the synergistic effects among them, which also contribute to the total antioxidant capacity. On the other hand, total phenolic contents, determined according to the Folin-Ciocalteu method, are not an absolute measurement of the amount of phenolic materials. Different type of phenolic compounds have different antioxidant capacities, which are dependent on their structure. Five cultivars of Chinese jujube possibly contain different types of phenolic compounds with different antioxidant capacities.

4. Conclusions

The present study reveals the difference in nutritional composition of five cultivars of Chinese jujube that may lead to their different applications. *Zizyphus jujuba* cv. *Jianzao*, owing to its high content of fructose, may be useful for diabetics. *Zizyphus jujuba* cv. *Yazao*, due to its abundance in total phenolic compounds, zinc and potassium, may contribute to reducing the risk of heart disease, cancer, arthritis, and aging process. *Zizyphus jujuba* cv. *Junzao*, with its high contents of vitamin and sucrose, is favorably consumed as fresh fruit. *Zizyphus jujuba* cv. *Jinsixiaozao* is rich in non-reducing sugar, and contains much less protein and ash than that of other cultivars; therefore it is a favorable material for polysaccharides extraction. In summary, Chinese jujube may be exploited for development of various functional foods.

Acknowledgements

The authors thank Shandong Research Institute of Jujube, China for supporting the research work. Thanks are given to Prof. GU Wen-Ying of Southern Yangtze University for beneficial discussion and WU Jian-Hua of Yuci Centre for Disease Control and prevention for mineral analysis.

References

- AOAC. (1995). *Official methods of analysis*. Washington, DC, USA: Association of official analytical chemists.
- Benzie, I. F. F., & Szeto, Y. T. (1999). Total antioxidant capacity of teas by the ferric reducing/antioxidant power assay. *Journal of Agricultural and Food Chemistry*, *47*, 633–636.
- Beruter, J. (1985). Sugar accumulation and changes in the activities of related enzymes during development of the apple fruit. *Journal of Plant Physiology*, *121*, 331–341.
- Biermann, C. J., & McGinnis, D. G. (1989). *Analysis of carbohydrates by GC and MS*. Boca Raton, FL: CRC Press.
- Boron, B., Hupert, J., Barch, D. H., Fox, C. C., Friedman, H., Layden, T. J., et al. (1988). Effect of zinc deficiency on hepatic enzymes regulating vitamin A status. *Journal of Nutrition*, *118*, 995–1001.
- Bouis, H. (1996). Enrichment of food staples through plant breeding: a new strategy for fighting micronutrient malnutrition. *Nutrition Reviews*, *54*, 131–137.
- Chausmer, A. B. (1998). Zinc, insulin and diabetes. *Journal of the American College of Nutrition*, *17*(2), 109–115.
- Connor, A. M., Luby, J. J., Hancock, J. F., Berkheimer, S., & Hanson, E. J. (2002). Changes in fruit antioxidant activity among blueberry cultivars during cold-temperature storage. *Journal of Agricultural and Food Chemistry*, *50*, 893–898.
- Danthu, P., Soloviev, P., Totte, A., Tine, E., Ayessou, N., Gaye, A., et al. (2002). Jujube trees in Senegal: a comparison between the organoleptic and physicochemical characteristics of the wild fruits and the introduced Gola variety. *Fruits*, *57*(3), 173–182.
- DeVilliers, O. T., Meynhardt, J. T., & Debruyn, J. A. (1974). The metabolism of sorbitol and sugars in Santa Rosa plums. *Agroplanta*, *6*, 51–54.
- Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*, *28*, 350–356.
- Food and Nutrition Board, National Research Council. (1989). *Recommended dietary allowances* (10th ed.). Washington, DC: National Academy Press.
- Heinonen, M., Meyer, A. S., & Frankel, E. N. (1998). Antioxidant activity of berry phenolics on human low-density-lipoprotein and liposome oxidation. *Journal of Agricultural and Food Chemistry*, *46*, 4107–4112.
- Huang, W. K. (1989). *Food testing and analysis*. China: Light Industry Press.
- Hwang, C. S., Rhie, G. E., Oh, J. H., Huh, W. K., Yim, H. S., & Kang, S. O. (2002). Copper- and zinc-containing superoxide dismutase (Cu/ZnSOD) is required for the protection of *Candida albicans* against oxidative stresses and the expression of its full virulence. *Microbiology*, *148*(11), 3705–3713.
- Ismail, A., Marjan, Z. M., & Foong, C. W. (2004). Total antioxidant activity and phenolic content in selected vegetables. *Food Chemistry*, *87*, 581–586.
- Kahkonen, M. P., Hopia, A. I., Vuorela, H. J., Rauha, J. P., Pihlaja, K., Kujala, T. S., et al. (1999). Antioxidant activity of plant extracts containing phenolic compounds. *Journal Agricultural and Food Chemistry*, *47*, 3954–3962.
- Kwon, Y. I., Jung, I. C., Kim, S. H., Kim, S. Y., Lee, J. S., & Lee, J. S. (1997). Changes in properties of pitted jujube during drying and extraction. *Agricultural Chemistry and Biotechnology*, *40*(1), 43–47.
- Li, J. W., Ding, S. D., & Ding, X. L. (2005). Comparison of antioxidant capacities of extracts from five cultivars of Chinese jujube. *Process Biochemistry*, *40*(11), 3607–3613.
- Lu, G. H., Li, C. J., & Lu, Z. S. (1992). Wound-induced respiration in thin slice of Chinese jujube fruit. *Journal of plant physiology*, *141*(1), 115–119.
- Munshi, S. K., Vats, S., Dhillon, K. S., & Sukhija, P. S. (1990). Lipid biosynthesis in seeds of Mustard (*Brassica juncea* L.) influenced by zinc and sulphur deficiency. *Physiologia Plantarum*, *80*, 102–108.
- Osborne, C. G., McTyre, R. B., Dudek, J., Roche, K. E., Scheuplein, R., Silverstein, B., et al. (1996). Evidence for the relationship of calcium to blood pressure. *Nutrition Reviews*, *54*, 365–381.
- Pereira, M. M., Gomes, C. M., & Teixeira, M. (2002). Plasticity of proton pathways in haem-copper oxygen reductases. *FEBS Letters*, *522*, 14–18.
- Ranhotra, G. S., Gelroth, J. A., & Vetter, J. L. (1996). Determination of fat in bakery products by three different techniques. *Cereal Foods World*, *41*, 620–622.
- Robards, K., Prenzler, P. D., Tucker, G., Swatsitang, P., & Glover, W. (1999). Phenolic compounds and their role in oxidative processes in fruits. *Food Chemistry*, *66*, 401–436.
- Sakamura, F., & Suga, T. (1987). Changes in chemical components of ripening oleaster fruits. *Phytochemistry*, *26*, 2481–2484.
- Singleton, V. L., Orthofer, R. M., & Ramuela-Raventios, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods in enzymology*, *299*, 152–178.
- Swamy, N. R., Ramakrishnaiah, N., Kurien, P. P., & Salimath, P. V. (1991). Studies on carbohydrates of red gram (*Cajanus cajan*) in relation to milling. *Journal of the Science of Food and Agriculture*, *57*, 379–390.
- Takahashi, Y., Kako, K., Kashwabara, S., Takehara, A., Inada, Y., Arai, H., et al. (2002). Mammalian copper chaperone cox17p has an essential role in activation of cytochrome C oxidase and embryonic development. *Molecular and Cell Biology*, *22*, 7614–7621.

- Wan, Y. K., Tian, S. P., & Qin, G. Z. (2003). Enhancement of biocontrol activity of yeasts by adding sodium bicarbonate or ammonium molybdate to control postharvest disease of jujube fruits. *Letters in Applied Microbiology*, 37(3), 249–253.
- Wang, J., Li, L. T., & Dan, Y. (2003). The correlation between freezing point and soluble solids of fruits. *Journal of Food Engineering*, 60(4), 481–484.
- Yan, Y. H., & Gao, Z. P. (2002). Industrialization of Chinese jujube. *Journal of Northwest Science and Technology University of Agriculture and Forestry*, 30(12), 95–98 (in Chinese).
- Yang, J. H., Lin, H. C., & Mau, J. L. (2002). Antioxidant properties of several commercial mushrooms. *Food Chemistry*, 77, 229–235.
- Zemel, M. B. (1997). Dietary pattern and hypertension: the DASH study. *Nutrition Reviews*, 55, 303–305.