Determination of selected physical and mechanical properties of Chinese jujube fruit and seed

Rui Li[1], Jun Peng[1], Shipeng Sun[1], Ahmad Al-Mallahi[2], Longsheng Fu[*1]

(1, College of Mechanical and Electronic Engineering, Northwest A&F University, Yangling 712100 China;
2, FUJI Project, Bosch Corporation, Tokyo 1508360 Japan)

Abstract: Some of physical characteristics and mechanical properties of two widely commercialized varieties of Chinese jujube (Zizyphus jujube cv. junzao and Zizyphus jujube cv. huizao) were studied at 62.2% and 35.4% w.b. for fruits and seeds of junzao and 70.3% and 25.2% w.b. for fruits and seeds of huizao. The results showed that fruits and seeds of junzao were larger in all the dimensions and heavier than that of huizao while the fruits of junzao were smaller in true density, bulk density and porosity than that of huizao. The aspect ratio and sphericity of both cultivars fruits were spherical and more likely to roll than slide. And all the physical parameters measured and calculated of both cultivars fruits and seeds were significant different to each other. The rupture force of junzao was higher than that of huizao at both orientations under compression. Greater rupture force and higher hardness were found at the horizontal orientation of both cultivars.

Keywords: Chinese jujube, junzao, huizao, physical characteristics, mechanical properties

Citation: LI, R., J. Peng, S.P. Sun, A. Al-Mallahi, and L.S. Fu. 2016. Determination of selected physical and mechanical properties of Chinese jujube fruit and seed. Agricultural Engineering International: CIGR Journal, 18(3):294-300.

1 Introduction

Chinese jujube (Ziziphus Jujuba Mill), commonly called red date is a deciduous fruit tree that blooms in early summer and ripens its fruit in autumn (Liu, 2000). It is grown in the temperate and subtropical areas of the Northern Hemisphere, especially the drier parts of north China (Lu et al., 2012). Because it is widely adapted, early bearing, long lived, easy to manage and has multiple uses and fits into long-term intercropping systems, Chinese jujube is becoming increasingly popular in many parts of China, especially in the dry northern parts (Liu, 2003). With appropriate cultivars, commercial cultivation of Chinese jujube can be carried out where the annual average temperature is 5.5℃ -22.0℃, annual rainfall is 87-2000 mm, and soil pH is 4.5-8.4. Chinese jujube is considered to be an ideal economic crop for arid and semiarid areas of the temperate zone where common fruit trees do not grow well (Liu, 2010). And the International Centre for Underutilized Crops in Southampton, U.K., has identified Chinese jujube as a crop with substantial growth potential (Choi et al., 2011). That's why it is also widely cultivated from southwest Europe to the Middle East, including India (Outlaw et al., 2002).

Chinese jujube fruits are rich in nutritive substances and have high medicinal value (Wu et al., 2016). Its pulp is eaten mostly fresh, but may be dried or processed into confectionary recipes in bread, cakes, compotes, and candy (Krska and Mishra, 2008). In addition to their food uses, Chinese jujubes have been used in many traditional medicines and have been shown to exhibit numerous health-promoting effects including antimicrobial and antiviral properties, reviewed in ref (Mahajan and Chopda, 2009). Its seeds are especially known for their sedative effect (Koetter et al., 2009). Chinese jujube seed flavonoids may in part contribute to this effect (Jiang et al., 2007). The fruits are nutritious, being high in flavonoids and vitamins C, B1, and B2. It may therefore be considered as a so-called functional food, having nutritional as well as medicinal uses (Huang et al., 2008).

Received date: 2016-03-16 **Accepted date:** 2016-07-29
***Corresponding author: Fu Longsheng,** College of Mechanical and Electronic Engineering, Northwest A&F University, China, Email: fulsh@nwsuaf.edu.cn

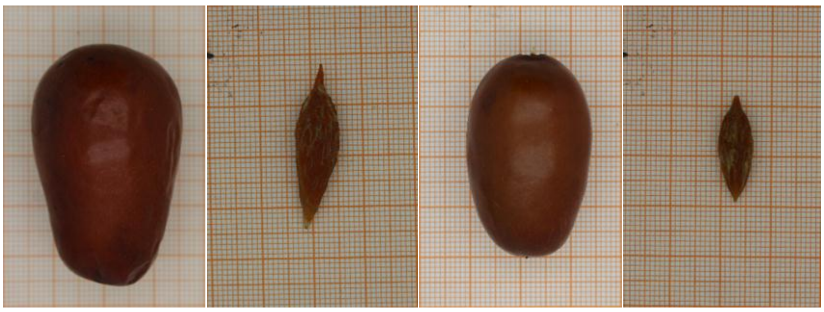
In the United States, Chinese jujube products are available at health food stores (Yao, 2013). Besides export of dried fruits, the majority of the Chinese jujube is produced and consumed locally (Choi et al., 2011). The market for fresh Chinese jujube is mostly restricted to producing regions for the following reasons: demand for fresh fruits, lack of awareness, lack of quality standards, lack of processing standards, and lack of market information systems and infrastructure (Yao, 2013). FAOstat does not maintain statistics on this crop.

Physical characteristics and mechanical properties of agricultural products are the most important parameters in design of harvesting, grading, transporting, processing and packaging systems (Fu et al., 2014; Rafiq et al., 2016). Among these physical characteristics, mass and volume are the most important in sizing systems(Fu et al., 2016). Other important parameters are width, length, thickness and seed sizes. Many studies have focused on the physical, mechanical and nutritional properties of fruits, such as orange or citrus (Kohno et al., 2011; Sharifi et al., 2007), peach (Li et al., 2014; Tabatabaekoloor, 2013), wild mango (Ehiem and Simonyan, 2012), hawthorn fruit (Moghadam and Kheiralipour, 2015), crabapple (Altuntas, 2015), and oak fruit (Tabar et al., 2012). While for other varieties of date fruits, some selected physical properties of *dairi* cultivar (Jahromi et al., 2008a) and *lasht* cultivar (Jahromi et al., 2008b) from Iran were reported. However, for the varieties of date fruits in China (named Chinese jujube), no detailed studies concerning the physical and mechanical properties of their fruit have been performed till now. Besides, seeds of Chinese jujube were extracted from fruits for medicine propose or processing in China. Therefore, the physical properties of seeds were also studied.

The aim of this study was to determine some selected physical and mechanical properties of fruit and seed of two widely commercialized varieties of Chinese jujube (*Zizyphus jujube* cv. *junzao* and *Zizyphus jujube* cv. *huizao*) to improve the design of some machines for its harvesting and processing. In order to achieve this objective, properties such as mass, volume, length, width, thickness, true density, geometric mean diameter, sphericity, aspect ratio, surface area, bulk density and porosity of fruit, and mass, length, width and thickness of seed were determined.

2 Material and methods

Two varieties of Chinese jujube, *Zizyphus jujube* cv. *junzao* (*junzao*) and *Zizyphus jujube* cv. *huizao (huizao) (as shown in Figure 1)*, used for this study were gathered from the National Engineering and Research Centre for Jujube which located in Shaanxi Province of China in October 28th, 2015. Hundred fruits of each variety were gathered, washed and labelled for easy identification, and kept at 25℃ in the laboratory. The moisture content of the two varieties determined by the vacuum oven drying method following the National Standard of China, GB5009.3-2010, which was issued by China State Bureau of Standards. They were found to be 62.2% and 70.3% w.b. for fruits of *junzao* and *huizao*, and 35.4% and 25.2% w.b. for seeds of *junzao* and *huizao*.



(a) (b) (c) (d)

Figure 1 Fruit (a) and seed (b) of *Zizyphus jujube* cv. *junzao* and fruit (c) and seed (d) of *Zizyphus jujube* cv. *huizao*.

2.1 Determination of physical properties

Linear dimensions, i.e. length, width and thickness were measured using digital Vernier reading to 0.01 mm. Mass of individual fruit was determined using an electronic balance (PTT-A1000, HuaZhi Scientific Instrument Co., Ltd. Fuzhou, China) with a sensitivity of 0.01 g. Fruit volumes were measured by the water displacement method. True density (g/cm^3) was then calculated by dividing the fruit mass with the fruit volume.

Bulk density was determined using the mass/volume relationship by filling an empty plastic container of predetermined volume (638.4 cm^3) and mass with fruits that were poured from the container, and weighed (Owolarafe et al., 2007; Vursavus et al., 2006). Porosity (packing factor) was calculated as the ratio of the differences in the fruit and bulk densities to the true density value and expressed in percentages (Owolarafe et al., 2007; Vursavus et al., 2006). The geometric mean diameter, sphericity, and surface areas of fruit were calculated by using the formula given by Kabas et al. (2006) and Jahromi et al. (2008a).

Seeds of Chinese jujube were extracted from fruits for medicine propose or processing. Therefore, only the mass and dimensions (length, width and thickness) of seeds were measured in this study for aiding development of seed removing machine.

The frequency distributions of the measured and calculated parameters above were given as skewedness and kurtosis and analysed using the Descriptive Statistics of the PASW Statistics 18 (SPSS Inc., an IBM Company, Chicago, Illinois, USA) which presented results in excess kurtosis (kurtosis-3).

2.2 Measurement of mechanical properties

Quasi-static compression tests were performed with an Electronic Universal Testing Machine equipped with a 5000 N compression load cell and integrator (DDL5, Changchun Research Institute for Mechanical Science Co., Ltd.). The measurement accuracy was 0.01 N. A 50 mm diameter flat circular plate was used to compress the fruit at a deformation speed of 10 mm/min until rupture occurred, as shown in Figure 2. Fruit compression tests were performed in two orientations viz., stem-calyx in horizontal and vertical directions. The mechanical properties of the jujube fruit were expressed in terms of the rupture force (the force necessary to penetrate the skin of the intact fruit) and hardness (resistance to deformation under load until the point of sudden fracture) which was calculated by ratio of the rupture force to deformation at the rupture point (Sirisomboon and Pornchaloempong, 2011). Figure 2 illustrated a typical force-deformation curve obtained from a plate compression test through parameter calculating formulae. The upward curve after the rupture point was caused by the hard seed in the fruit.

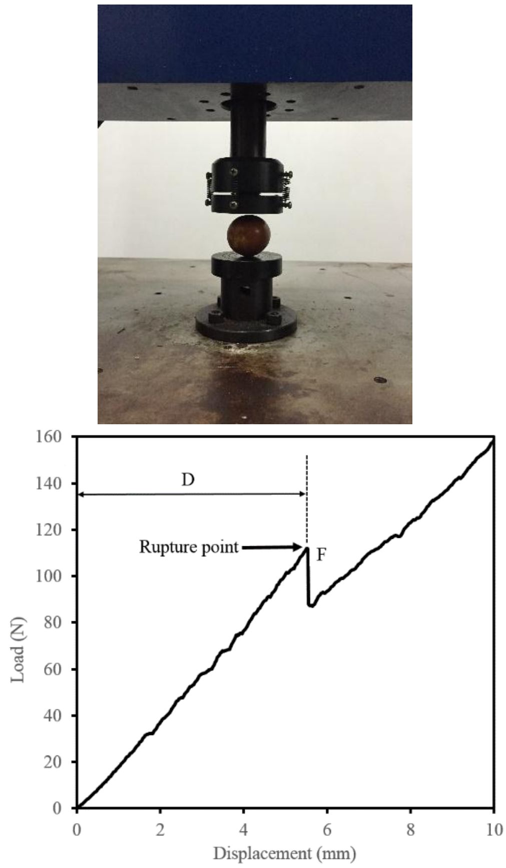


Figure 2 A typical force-deformation curve for jujube fruit under plate compression test (speed: 10 mm/min). Rupture force (N) = F; deformation at the rupture point (mm) = D; hardness (N/mm) = F/D.

3 Results and discussion

A summary for measured and calculated fruit physical properties of two varieties of Chinese jujube (*junzao* and *huizao*) is shown in Table 1. There were significant differences between all the fruit physical parameters measured and calculated of the two varieties.

Table 1 Summary for measured and calculated fruit physical properties of two varieties of Chinese jujube (*junzao* and *huizao*)

Parameter	Number of observations	*Junzao*	*Huizao*
Mass, g	100	14.90 (5.44)^a	8.50 (1.41)^b
Volume, cm^3	100	20.02 (5.82)^a	9.93 (1.55)^b
Length, mm	100	41.11 (4.15)^a	34.40 (2.35)^b
Width, mm	100	28.15 (2.92)^a	21.80 (1.43)^b
Thickness, mm	100	26.06 (3.09)^a	20.57 (1.67)^b
True density, g/cm^3	100	0.73 (0.08)^a	0.86 (0.09)^b
Geometric mean diameter, mm	100	31.11 (3.20)^a	19.67 (1.42)^b
Sphericity, %	100	75.78 (3.44)^a	57.18 (3.56)^b
Aspect ratio, %	100	68.60 (4.46)^a	63.49 (3.74)^b
Surface area, mm^2	100	3069.89 (648.40)^a	1221.49 (175.44)^b
Bulk density, g/cm^3	10	0.41 (0.01)^a	0.47 (0.01)^b
Porosity, %	10	43.40 (1.14)^a	45.80 (1.48)^b

Note: Standard deviation values in the parentheses.

$^{a\text{-}b}$ Letters indicate the statistical difference in rows ($p \leq 0.05$).

The *junzao* fruit mean length, width and thickness were found to be 41.11 mm, 28.15 mm, and 26.06 mm, respectively. Table 2 showed that all the sizes of *junzao* fruits were positively skewed. The length and width of *junzao* fruits had platykurtic distribution while the thickness had leptokurtic distribution with the value of 0.259. The *huizao* fruit mean length, width and thickness were found to be 34.40 mm, 21.80 mm and 20.57 mm, respectively (Table 1). Their length was a little positively skewed in 0.092 while the width and thickness were largely negatively skewed in -0.627 and -0.652 respectively. The width of *huizao* fruits had leptokurtic distribution while the length and thickness had platykurtic distribution. Especially the length of *huizao* fruits had a nearly uniform distribution with the value of -1.341. The values for the length, width and thickness of the *junzao* fruits are higher than that of the *huizao* fruits. And it was also larger than the both date fruit *dairi* variety and *lasht* variety from Iran (Jahromi et al., 2008a; Jahromi et al., 2008b). While the *huizao* fruits was smaller than the date fruit *lasht* variety in all the three sizes (Jahromi et al., 2008b), but bigger in width and thickness than the *dairi* variety except the length (Jahromi et al., 2008a). Omobuwajo et al. (1999) have discussed the importance of these and other characteristic axial dimensions in determining aperture size of machines, particularly in separation of materials. These dimensions may be useful in estimating the size of machine components.

Table 2 Frequency distribution for measured and calculated fruit physical properties of two varieties of Chinese jujube (*junzao* and *huizao*)

Parameter	*Junzao*		*Huizao*	
	Skewedness	Kurtosis	Skewedness	Kurtosis
Mass, g	0.719	-0.072	-0.102	-1.252
Volume, cm^3	0.633	-0.163	0.228	-0.012
Length, mm	0.437	-0.091	0.092	-1.341
Width, mm	0.605	-0.011	-0.627	0.427
Thickness, mm	0.699	0.259	-0.652	-0.330
True density, g/cm^3	-0.030	-0.416	0.203	-0.338
Geometric mean diameter, mm	0.746	0.060	0.004	-0.952
Sphericity, %	-0.029	0.472	0.471	0.173
Aspect ratio, %	-0.393	0.351	0.119	0.144
Surface area, mm^2	0.959	0.427	0.116	-0.987
Bulk density, g/cm^3	-0.512	-0.612	-0.405	-0.178
Porosity, %	0.405	-0.178	0.552	0.868

The sphericity and aspect ratio of *junzao* fruits were found to be 75.78% and 68.60%, respectively, and both had leptokurtic distribution in negatively skewed. The high sphericity of the *junzao* fruits is indicative of the tendency of the shape towards a sphere. Taken along with the high aspect ratio of 68.60% (which relates the fruit width to length), it may be deduced that the *junzao* fruits will rather roll than slide on their flat surfaces. However, the aspect ratio value is being close to the sphericity values may also mean the *junzao* fruits will undergo a combination of rolling and sliding action on their flat surfaces. The sphericity and aspect ratio of the *huizao* fruits were found to be 57.18% and 63.49%, respectively, and both had leptokurtic distribution in positively skewed. One interesting trend to be noted is the higher values of sphericity index 75.78% and aspect ratio 68.60%, respectively, for the *junzao* fruits compared to the values for the *huizao* fruits, which is 57.18% and 63.49%, respectively. This indicates that *junzao* fruits has a higher tendency to have its shape towards a sphere than the *huizao* fruits. The sphericities of the date fruit *dairi* variety (63%) and *lasht* variety (69%) from Iran were both smaller that of *junzao* fruits and larger than that of *huizao* fruit.

The average mass and volume of the *junzao* fruits were 14.90 g and 20.02 cm^3 respectively, and both had platykurtic distribution in positively skewed. The average mass of the *huizao* fruits was 8.50 g and had a nearly uniform distribution with the kurtosis value of -1.252 in negatively skewed. The volume of the *huizao* fruits was 9.93 cm^3 in average and had a nearly normal distribution in positively skewed. The average mass and volume of the *junzao* fruits are higher than the *huizao* fruits.

The true density and bulk density of *junzao* fruits were 0.73 g/cm^3 and 0.41 g/cm^3 respectively, and both were negatively skewed and had platykurtic distribution at -0.416 and -0.612 respectively. For the *junzao* true density value, there is a tendency for the jujube fruit to float on water (density 1.00 g/cm^3). The lower porosity (43.40%) or percentage volume of voids in the *junzao* fruits may be due to the higher sphericity and aspect ratio, which ensure a more compact arrangement of the fruits. The true density and bulk density of *huizao* fruits were 0.86 g/cm^3 and 0.47 g/cm^3 respectively, and both had leptokurtic distribution but were positively and negativity skewed respectively. From the true density value, there is a tendency for the *huizao* fruit to be partially submerged in water. The true and bulk density of the *huizao* fruits were higher than that of *junzao* fruits, which might induced the porosity of *huizao* fruits (45.80%) was higher than that of *junzao* fruits. These properties may be useful in the separation and transportation of the fruit by hydrodynamic means.

As shown in Table 3, the seeds of *junzao* are bigger than that of *huizao* by 18.00%, 20.00%, and 11.96% for length, width and thickness respectively. The average mass of the *junzao* seeds was 0.50 g which accounted for 3.36% of fruit weight, while that of the *huizao* seeds was 0.41 g which accounted for 4.82% of fruit weight. The width and thickness of *junzao* seeds both had leptokurtic distribution and were largely negatively skewed having -0.801 and -0.755 respectively, while the length had platykurtic distribution in positively skewed (Table 4). And the mass of *junzao* seeds had platykurtic distribution in negatively skewed. All the dimensions and mass of *huizao* seeds had leptokurtic distribution, especially the frequency distributions of the width and thickness were logistic distributions at 2.061 and 2.991 respectively. The mass, length and width of *junzao* seeds were positively skewed except the thickness were negatively skewed having -0.402. There were significant differences between all the seed dimensions and mass measured of the two varieties. This information will aid in developing machines for removing seeds.

Table 3 Summary for measured seed physical parameters of two varieties of Chinese jujube (*junzao* and *huizao*)

Parameter	Number of observations	*Junzao*	*Huizao*
Mass, g	100	0.50 (0.14)[a]	0.41 (0.09)[b]
Length, mm	100	26.94 (2.38)[a]	21.55 (1.44)[b]
Width, mm	100	8.11 (1.01)[a]	7.09 (0.70)[b]
Thickness, mm	100	7.61 (0.99)[a]	6.70 (0.60)[b]

Note: Standard deviation values in the parentheses.

[a-b] Letters indicate the statistical difference in rows ($p \le 0.05$).

Table 4 Frequency distribution for measured seed physical parameters of two varieties of Chinese jujube (*junzao* and *huizao*)

Parameter	*Junzao*		*Huizao*	
	Skewedness	Kurtosis	Skewedness	Kurtosis
Mass, g	-0.019	-0.516	0.605	0.172
Length, mm	0.159	-0.319	0.816	0.808
Width, mm	-0.801	0.804	0.472	2.061
Thickness, mm	-0.755	0.101	-0.402	2.991

Table 5 shows the results of the compression test of two varieties of Chinese jujube (*junzao* and *huizao*) fruits. The mean values of rupture force for *junzao* were 156.24 N in horizontal orientation and 127.05 N in vertical orientations under compression. They were significantly different ($P < 0.05$) which was also obtained from the results of rupture forces for *huizao* when being compressed from the two different orientations. The largest hardness was found in *junzao* at horizontal orientation with the mean value of 37.51 N/mm, which was significantly larger than that of *junzao* at vertical orientation and *hunzao* at both orientations. Greater force was required to rupture of fruits with both cultivars being tested at the horizontal orientation. And higher hardness was obtained at the horizontal orientation of both cultivars. Therefore, postharvest handling of layers of fruits during transportation may cause more damage to fruits being vertical arranged than horizontal arranged.

Table 5 Rupture force and hardness of two varieties of Chinese jujube (*junzao* and *huizao*) fruits in horizontal and vertical orientations under compression (50 mm diameter flat probe, probe speed: 10 mm/min)

	Horizontal orientation		Vertical orientation	
	Junzao	*Huizao*	*Junzao*	*Huizao*
Rupture force (N)	156.24 (28.02)^{a}	136.67 (29.58)^{ab}	127.05 (26.54)^{bc}	119.49 (24.34)^{c}
Hardness (N/mm)	37.51 (7.63)^{a}	26.81 (3.84)^{b}	17.67 (2.08)^{c}	16.67 (2.49)^{c}

Note: Standard deviation values in the parentheses.

$^{a\text{-}c}$ Letters indicate the statistical difference in rows ($p \le 0.05$).

4 Conclusions

The physical characteristics and mechanical properties of two varieties of Chinese jujube (*Zizyphus jujube* cv. *junzao* and *Zizyphus jujube* cv. *huizao*) fruits were determined. The fruits and seeds of *junzao* were larger in all the dimensions and heavier than that of *huizao*. But the fruits of *junzao* were smaller in true density, bulk density and porosity than that of *huizao*. The aspect ratio and sphericity of both cultivars fruits were spherical and more likely to roll than slide. All the physical parameters measured and calculated of both cultivars fruits and seeds were significant different to each other. The rupture force of *junzao* was higher than that of *huizao* at both orientations under compression. Greater rupture force and higher hardness were found at the horizontal orientation of both cultivars. Therefore, postharvest handling of layers of fresh fruits during transportation may cause more damage to fruits being vertical arranged than horizontal. The relevant data obtained for the two varieties would be useful for designing and developing machines and equipment for harvesting and processing operations.

Acknowledgments

This study was supported by the China Postdoctoral Science Foundation (Grant No. 2015M572602), and the National Natural Science Foundation of China (Grant No. 31301242), and the Natural Science Basic Research Plan in Shaanxi Province of China (Program No. 2015JQ3065), and the International Scientific and Technological Cooperation Foundation of Northwest A&F University (A213021505).

References

Altuntas, E. 2015. The post-harvest engineering properties of Japan flowering crabapple (Malus floribunda) fruits. *Agricultural Engineering International: CIGR Journal*, 17(1):264-272.

Choi, S. H., J. B. Ahn, N. Kozukue, C. E. Levin, and M. Friedman. 2011. Distribution of free amino acids, flavonoids, total phenolics, and antioxidative activities of jujube (Ziziphus jujuba) fruits and seeds harvested from plants grown in Korea. *Journal of Agricultural & Food Chemistry*, 59(12):6594-6604.

Ehiem, J. C., and K. J. Simonyan. 2012. Physical properties of wild mango fruit and nut. *International Agrophysics*, 26(1):95-98.

Fu, L., H. Su, R. Li, and Y. Cui. 2014. Harvesting technologies for sea buckthorn fruit. *Engineering in Agriculture, Environment and Food*, 7(2):64-69.

Fu, L., S. Sun, R. Li, and S. Wang. 2016. Classification of kiwifruit grades based on fruit shape using a single camera. *Sensors*, 16(7):1012.

Huang, Y. L., G. C. Yen, F. Sheu, and C. F. Chau. 2008. Effects of water-soluble carbohydrate concentrate from Chinese jujube on different intestinal and fecal indices. *Journal of Agricultural & Food Chemistry*, 56(5):1734-1739.

Jahromi, M., S. Rafiee, A. Jafari, M. R. G. Bousejin, R. Mirasheh, and S. S. Mohtasebi. 2008a. Some physical properties of date fruit (cv. Dairi). *International Agrophysics*, 22(3):221-224.

Jahromi, M., S. Rafiee, A. Jafari, M. R. G. Bousejin, R. Mirasheh, and S. S. Mohtasebi. 2008b. Some Physical properties of Date Fruit (cv. Lasht). *Agricultural Engineering International: CIGR Journal*, 22(3):221-224.

Jiang, J., X. Huang, J. Chen, and Q. Lin. 2007. Comparison of the sedative and hypnotic effects of flavonoids, saponins, and polysaccharides extracted from Semen Ziziphus jujube. *Natural Product Research,* 21(4):310-320.

Kabas, O., A. Ozmerzi, and I. Akinci. 2006. Physical properties of cactus pear (Opuntia ficus india L.) grown wild in Turkey. *Journal of Food Engineering,* 73(2):198–202.

Koetter, U., M. Barrett, S. Lacher, A. Abdelrahman, and D. Dolnick. 2009. Interactions of Magnolia and Ziziphus extracts with selected central nervous system receptors. *Journal of Ethnopharmacology,* 124(3):421-425.

Kohno, Y., N. Kondo, M. Iida, M. Kurita, T. Shiigi, Y. Ogawa, T. Kaichi, and S. Okamoto. 2011. Development of a mobile grading machine for citrus fruit. *Engineering in Agriculture, Environment and Food,* 4(1):7-11.

Krska, B., and S. Mishra. 2008. Sensory Evaluation of Different Products of Ziziphus jujuba Mill. *Acta Horticulturae,* 840(1):557-562.

Li, X., A. Zhang, G. Atungulu, T. McHugh, M. Delwiche, S. Lin, L. M. Zhao, and Z. L. Pan. 2014. Characterization and Multivariate Analysis of Physical Properties of Processing Peaches. *Food and Bioprocess Technology,* 7(6):1756-1766.

Liu, M. 2000. The Present Status, Problems and Countermeasures of Chinese Jujube Production. *Review of China Agricultural Science & Technology,* 2(2):76-80.

Liu, M. 2003. Genetic diversity of Chinese jujube (Ziziphus jujuba Mill.). *Acta Horticulturae,* 623(1):351-355.

Liu, M. 2010. Chinese jujube: Botany and Horticulture. *Horticultural Reviews,* 32(5):229-298.

Lu, H., H. Lou, H. Zheng, Y. Hu, and Y. Li. 2012. Nondestructive Evaluation of Quality Changes and the Optimum Time for Harvesting During Jujube (Zizyphus jujuba Mill. cv. Changhong) Fruits Development. *Food and Bioprocess Technology,* 5(6):2586-2595.

Mahajan, R., and M. Chopda. 2009. Phyto-Pharmacology of Ziziphus jujuba Mill - A plant review. *Pharmacognosy Reviews,* 3(6):320-329.

Moghadam, J., and K. Kheiralipour. 2015. Physical and nutritional properties of hawthorn fruit (Crataegus pontica L.). *Agricultural Engineering International: CIGR Journal,* 17(1):232-237.

Omobuwajo, T. O., E. A. Akande, and L. A. Sanni. 1999. Selected physical, mechanical and aerodynamic properties of African breadfruit (Treculia africana) seeds. *Journal of Food Engineering,* 40(4):241–244.

Outlaw, W., S. Zhang, K. A. Riddle, A. K. Womble, L. C. Anderson, W. M. Outlaw, N. N. Outlaw, E. C. Outlaw, and A. B. Thistle. 2002. The jujube (Ziziphus jujuba Mill.), a multipurpose plant. *Economic Botany,* 56(2):198-200.

Owolarafe, O. K., M. T. Olabige, and M. O. Faborode. 2007. Physical and mechanical properties of two varieties of fresh oil palm fruit. *Journal of Food Engineering,* 78(4):1228-1232.

Rafiq, S. I., S. Singh, and D. C. Saxena. 2016. Physical, physicochemical and anti-nutritional properties of Horse Chestnut (Aesculus indica) seed. *Journal of Food Measurement and Characterization,* 10(2):302-310.

Sharifi, M., S. Rafiee, A. Keyhani, A. Jafari, H. Mobli, A. Rajabipour, and A. Akram. 2007. Some physical properties of orange (var. Tompson). *International Agrophysics,* 21(4):391-397.

Sirisomboon, P., and P. Pornchaloempong. 2011. Instrumental textural properties of mango (cv Nam Doc Mai) at commercial harvesting time. *International Journal of Food Properties*, 14(2):441-449.

Tabar, F., A. Lorestani, R. Gholami, A. Behzadi, and M. Fereidoni. 2012. Physical and mechanical properties of Oak (Quercus Persica) fruits. *Agricultural Engineering International: CIGR Journal,* 13(4):1-4.

Tabatabaekoloor, R. 2013. Engineering properties and bruise susceptibility of peach fruits (Prunus persica). *Agricultural Engineering International: CIGR Journal,* 15(4):244-252.

Vursavus, K., H. Kelebek, and S. Selli. 2006. A study on some chemical and physico-mechanic properties of three sweet cherry varieties (Prunus avium L.) in Turkey. *Journal of Food Engineering,* 74(4):568–575.

Wu, L., J. He, G. Liu, S. Wang, and X. He. 2016. Detection of common defects on jujube using Vis-NIR and NIR hyperspectral imaging. *Postharvest Biology and Technology,* 112(1):134-142.

Yao, S. 2013. Past, Present, and Future of Jujubes—Chinese Dates in the United States. *HortScience,* 48(6):672-680.