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Physical and Nutritional Properties of Jujube (*Zizyphus jujuba* Mill.) Growing in Turkey

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Several physical and nutritional properties of jujube fruits (*Zizyphus jujuba* Mill.) grown in Turkey were investigated. These properties are necessary for the design of equipments for harvesting, processing, transportation, sorting, separating and packing. The average fruit length, width, thickness, the geometric mean diameter, sphericity index, fruit mass, thousand of fruit mass and volume of fruit of jujube fruits were determined as 17.75 mm, 14.81 mm, 14.19 mm, 15.43 mm, 87.56 %, 1.26 g, 1139 g and 1.99 cm^3, respectively. The bulk density, fruit density and porosity were 380 kg/m^3, 639 kg/m^3 and 39.35 %, respectively. The static friction coefficient on galvanized iron sheet, iron sheet, thin plate, wood and rubber were 0.369, 0.528, 0.633, 0.475 and 0.844, the dynamic friction coefficient on the same surfaces were 0.317, 0.475, 0.581, 0.422 and 0.792, respectively. The moisture content, titratable acidity, ascorbic acid, rupture strength and terminal velocity were 20.04 %, 0.33 %, 118.4 mg/100 g fresh weight, 21.49 N/mm^2 and 5.44 m/s, respectively. Protein, K, Ca, P, Mg and N amount were 14.13 %, 1.12 %, 0.21 %, 0.12 %, 0.07 % and 2.26 %, respectively.

Key Words: Jujube (*Zizyphus jujuba* Mill.), Physical & Nutritional properties.

INTRODUCTION

Jujube (*Zizyphus jujuba* Mill.) is called as Azufaifo, Bedara China, Chinese Date, Chinese Jujube, Common Jujube, Dara, Hong Zao, Indian Jujube, Jujube, Jujubier, Kan Tsao, Kola, Liane Crocs Chien, Liang Tsao, Mei Tsao, Nabug, Nan Tsao, Pei Tsao, Perita Haitiana, Petite Pomme, Pomme Malcadi, Ponsere, Suan Tsao, Ta Tsao, Tsao, Unnab, Unnap Agaci, Widara in different parts of the World. It grows wild in forests and also on dry gravelly or stony slopes of hills and mountains in Asia, China,

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Dominican Republic, Europe, Haiti, India, India (Santal), Iraq, Java (Import), Malacca (Import), Nigeria, Spain and Turkey[1,2]. In Turkey, it is grown in Alanya, Gazipasa, Buyuk Ada, Sinop, Genos Mountain (Tekirdag) and also in Denizli[3].

A small spreading tree with dropping branches; height 5 to 8 m; trunk girth 85 cm; bark, rough, gray or dull black, irregularly cracked, covered with a thick layer of green moss in the case of older trees and, thus, looking green, branches, bearing at each node two spines, which are modified stipules; one spine is curved and the other is straight.

Leaves, ovate, petiolate (petiole, 5 mm long), with fine serration, 3.8 cm long, 2.9 cm broad, dark green and shining from above, white tomentose from beneath; venation, palmate convergent. Flowers, bisexual, hermaphrodite, cyclic, yellowish green; inflorescence, an axillary cyme, bearing flowers in a crowded manner; calyx, polysepalous, with 5 sepals, actinomorphic, greenish yellow, 2 mm long; corolla, polypetalous, with 5 petals, actinomorphic, white, 1.5 to 2 cm long; androecium, polyandrous, with 5 stamens, white, 1.5 to 2 cm long; gynoecium with two carpels, which are fused at the base, 1 to 2 mm long. Fruits, oblong, 1.3 cm in diameter, 1.45 g in weight, 1.05 mL in volume, colour marsh orange. Seeds, wrinkled, stony, 419 mg in weight; volume, 410 microlitres; 1 seed per fruit[1,4].

The plant prefers light (sandy), medium (loamy) and heavy (clay) soils, requires well-drained soil and can grow in nutritionally poor soil. The plant prefers acid, neutral and basic (alkaline) soils and can grow in alkaline soil. It cannot grow in shape. It requires dry or moist soil and can tolerate drought[2]. The flowering season was observed to range from June to July and the fruiting season was observed in December. The average yield of this species was recorded to be 9.5 kg per tree[1].

The fruits contain 68.0 % moisture. Their pulp contains, 3.92 % acidity, 8.68 % total sugars, 6.73 % reducing sugars, 1.85 % non-reducing sugars, 1.72 % pectin and 1.32 % tannins. Vitamin C contents of this fruit is 2.56 mg per 100 g of pulp. The total mineral content of the fruit pulp, as represented by its ash, is 1.38 %. The protein content of the pulp is 2.56 %. Some of the mineral elements in the fruit pulp, 0.069 % phosphorus, 0.583 % potassium, 0.083 % calcium, 0.065 % magnesium and 0.006 % iron[1,2].

Fruit could be consumed raw or cooked or in production of a sourish-sweet flavour. The fruit can be eaten fresh, dried like dates or cooked in puddings, cakes, breads, jellies, soups, *etc*. The dried fruit has the best taste. The fruits are often left to become wrinkled and spongy, which increases their sweetness and then eaten fresh or cooked. The dried fruit can also be ground into powder. This powder is used in the preparation of 'kochujang', a fermented hot pepper-soybean paste that resembles miso. The fruit can also be used as a coffee substitute[2,5,6].

Jujube is both a delicious fruit and an effective herbal remedy. It helps with weight gain, improves muscular strength and increases stamina. It is prescribed as a tonic to strengthen liver function in China. Jujube increases immune system resistance according to Chevallier[7]. Jujube is also antidote, dioretic, emollient and expectorant[1,2,5,8]. The dried fruits are anodyne, anticancer, pectoral, refrigerant, sedative, stomachic, styptic and tonic[2,9-11]. They are considered to purify blood and help digestion[2,12]. They are used internally in the treatment of chronic fatigue, loss of appetite, diarrhoea, anaemia, irritability and hysteria[10,13]. The seed is hypnotic, narcotic, sedative, stomachic and tonic[10,11]. It is also used internally in the treatment of palpitations, insomnia, nervous exhaustion, night sweats and excessive perspiration[10,13].

The physical properties of any product are valuable for design of equipments for handling, transportation, sorting, separating, packing and also processing into different foods. Any system designed without taking these criteria into consideration results in inadequate applications decreasing work efficiency and increasing product loss. Therefore, for the proper mechanization of Jujube, its physical properties are a pre-requisite for the design and development of any equipment[14].

In recent years, physical and nutritional properties have been studied for various crops such as okra seeds[15], lentil seeds[16], hackberry[17], sweet cherry[18], plum[19], fenugreek seeds[20], garlic[21], hawthorn[22], terebinth[23], locust bean seed[24], myrtle[25], juniperus drupacea fruits[26] and gumbo fruit[27].

However, no detailed studies have been published on physical and nutritional properties of jujube. The aim of this work was to establish the proximate composition and some technological properties, namely, fruit dimensions, fruit density, bulk density, porosity, volume, projected area, spread area, terminal velocity, rupture strength, static and dynamic coefficient of friction.

EXPERIMENTAL

Jujube fruits were supplied from a local market in May of 2006 from Denizli-Turkey. The fruits were transferred to the laboratory in polythene bags to reduce water loss during transport. All foreign matters and immature fruits were cleaned away. The initial moisture content of fruits was determined by using a standard method[28].

The physical and nutritional properties of Jujube were determined as follows. The linear dimensions of the fruits and stones were measured in three directions using a digital caliper gauge (± 0.01 mm). The major dimension was the length (L), the intermediate dimension was the width (W) and the minor dimension was the thickness (T). The caliper was held perpendicular to the direction of the dimension being measured. The linear dimensions were measured on 100 samples for fruits and 20 samples for stones.

The mass of fruits and stones was determined on 20 randomly selected samples by using an electronic balance with 0.01 g sensitivity then also converted to a 1000 mass basis.

Geometric mean diameter (D_g), sphericity index (S_p) and aspect ratio (R_a) were calculated using the following equations[29-31]:

$$D_g = (LWT)^{1/3} \quad (1)$$

$$S_p = \frac{D_g}{L} 100 \quad (2)$$

$$R_a = W/L \quad (3)$$

To obtain the surface area (S) of the fruits and stones, the relationship given by several authors[29,32,33] was used:

$$S = \pi D_g^2 \quad (4)$$

The volume of fruit (V) and fruit density (P_k) defined as the ratio of the mass of a sample to the solid volume accordingly occupied was determined by the liquid displacement method. The amount of displaced toluene was recorded from the graduated scale of the measuring cylinder[15,29,34-36]. The bulk density (P_b) is the ratio of the mass of a sample of a fruit to its total volume and was determined with a weight per hectoliter tester, which was calibrated in kg m^{-3}. The hectoliter tester filled with fruits from a height of about 15 cm, striking the top level and then weighing the contents[20,29,37-39].

Porosity of bulk fruit (ε) is defined as the ratio of the intergranular space to the total space occupied by the fruit and can be calculated from fruit and bulk densities[29,40,41];

$$\varepsilon = 100[1 - (P_b/P_k)] \quad (5)$$

Projected area (P) of fruits and stones were determined in x and y-axis using a digital camera (Kodak DC5000) and Sigma Scan Pro 5 program[21,42-44].

The angle of repose was measured by using a specially constructed box with a removable front panel. The box is filled with fruits and then the front panel is quickly removed. This allows the fruit to flow along its natural slope. This slope is taken as a measure of the angle of repose[20,41,45]. Spread area of fruits was determined by spreading 1 kg of fruits.

The skin colours of 20 jujube fruits were determined with CR-300 chromometer (Minolta, Japan). The measurements were recorded using the L*a*b* colour space[46].

Rupture strength of fruits were measured with a Test Instrument of Biological Materials using the procedure described by Aydin and Ogut[47] (Fig. 1). The device has three main components (a) a stationary and moving platform (b) a driving unit (AC electric motor and electronic variator) and (c) data acquisition (Dynamometer, amplifier and XY recorder) system. Rupture strength was measured by the data acquisition system. The fruit was placed on the moving bottom platform and was pressed against the stationary platform. The probe used in the experiment had a 1.20 mm diameter and was connected to the dynamometer. The experiment[27] was conducted at a loading velocity of 50 mm min^{-1}.

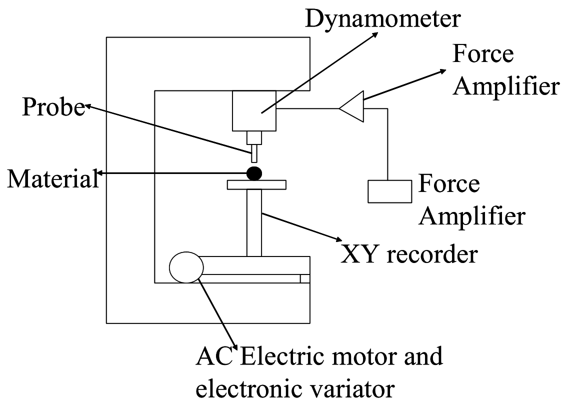

Fig. 1. Schematic diagram of biological material test unit

The terminal velocities (V_t) of fruits and their stones were measured using an air column. For each test, a sample was dropped into an air stream from the top of the air column, up which air was blown to suspend the material (Fig. 2). The air velocity near the location of the suspended fruits was measured by electronic anemometer with at least count[22,23,45,48] of 0.1 m s^{-1}.

The coefficients of frictions of fruits were measured using a friction device. It has three main components (a) a stationary sample container with its support shaft (b) a driving unit with rotating disc and (c) data acquisition system. The samples were placed on the rotating surface and the torque necessary to restrain the sample was measured by the data acquisition system. This torque was used to determine the static (μ_s) and dynamic (μ_d) coefficients of friction using the following equation;

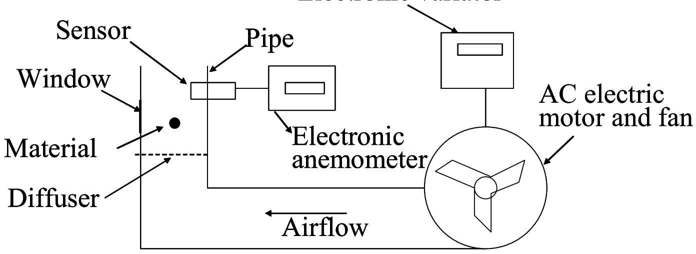

Fig. 2. Schematic diagram of terminal velocity measuring unit

$$\mu = T_m/(w\ q)$$

where μ is the coefficient of friction, T_m the measured torque, q the length of the torque arm and w the sample weight on the rotating surface. The maximum value of torque obtained as the disc started to rotate was used to calculate the static coefficient of friction and average value of the torque during the rotation of disc was used to calculate the dynamic coefficient of friction[36,49-51].

The samples were dried at 65 ºC and then wet digested in HNO_3 and $HClO_4$ acid (4/1, v/v) mixture[52]. Fe, Ca, Mg, K, Mn, Zn and Cu concentration were determined by atomic absorption spectrophotometry. Phosphorus was determined according to vanadomolybdate yellow colour method with spectrophotometer[53].

To determine protein content in jujube fruit, first N concentrations of fruit were determined according to a Kjeldahl method[54]. Then N concentration was multiplied by 6.25 factor.

RESULTS AND DISCUSSION

Some of the physical properties of jujube are presented in Table-1. The moisture content changed between 19.55 and 20.22 % (w.b.) for jujube fruit. The mean fruit length was 17.75 mm, fruit width was 14.81 mm and thickness was 14.19 mm for jujube fruit. While the mean mass of fruit and 1000 fruits mass were 1.26 and 1139 g, respectively. These values were 0.27 g and 278.1 g for its stones, respectively. The flesh thickness was determined as 3.56 mm. The stone dimensions (length, width and thickness) were 13.40, 6.58 and 6.65 mm, respectively. The average values of the geometric mean diameter were calculated as 15.43 mm for fruits and 8.35 mm for stones, respectively. Sphericity is an expression of a shape of a solid relative to that of a sphere of the same volume, while the aspect ratio relates the width to the length of the fruit, an indicative of its tendency toward being oblong in shape[30]. These values were 87.56 % and 0.84 for fruits and 62.42 % and 0.49 for stones, respectively.

The volume of fruit was 1.99 cm^3. Fruit and bulk densities were between 471 and 937 kg m^{-1} and 367 and 391 kg m^{-1}, respectively. The porosity ranged from 34.29 to 44.89 % for jujube fruits.

The angle of repose changed between 12.78 and 20.04 degrees for jujube fruits. The mean spread area was 0.212 m^2 kg^{-1}.

The static coefficients of friction ranged from 0.369 for galvanized iron sheet and 0.844 for rubber. The dynamic coefficient of friction changed between 0.317 for galvanized iron sheet and 0.792 for rubber. Static and dynamic friction coefficient reached their maximum values on rubber surface in different studies[26,33,55-58].

TABLE-1
SOME PHYSICAL PROPERTIES OF JUJUBE

	Min	Max	Mean	SD
Fruit moisture content (%w.b.)	19.55	20.22	20.04	0.28
Fruit length (mm)	11.00	23.45	17.75	2.45
Fruit width (mm)	10.75	23.25	14.81	2.00
Fruit thickness (mm)	10.85	18.15	14.19	1.64
Fruit geometric mean diameter (mm)	11.67	19.75	15.43	1.68
Fruit sphericity index (%)	74.11	115.05	87.56	7.59
Fruit aspect ratio	0.60	1.22	0.84	0.11
Fruit surface area (mm^2)	427.85	1225.27	756.22	165.79
Mean mass of fruits (g)	0.54	1.86	1.26	0.33
Mass of 1000 fruits (g)	1082	1173	1139	38.11
Volume of fruit (cm^3)	1.00	3.00	1.99	0.46
Fruit density (kgm^{-3})	471	937	639	135
Bulk density (kgm^{-3})	367	391	380	11
Porosity (%)	34.29	44.89	39.35	4.25
Spread area (m^2kg^{-1})	0.209	0.217	0.212	0.003
Angle of repose (°)	12.78	20.04	16.71	1.99
Flesh thickness (mm)	2.75	4.55	3.56	0.50
Rupture strength (Nmm^{-2})	17.56	25.83	21.49	2.50
Terminal velocity of fruit (ms^{-1})	4.798	6.099	5.438	0.514
Terminal velocity of stone (ms^{-1})	7.481	8.152	7.894	0.207
Fruit projected area (cm^2) x-axis	1.46	2.00	1.73	0.19
y-axis	1.41	2.87	2.01	0.38
Skin colour				
L*	39.10	62.25	48.83	6.34
a*	12.84	24.44	20.68	3.31
b*	23.56	41.63	34.87	5.36
Stone length (mm)	9.20	16.80	13.4	1.97
Stone width (mm)	4.15	8.10	6.58	0.93
Stone thickness (mm)	4.30	8.15	6.65	1.02
Stone geometric mean diameter (mm)	5.57	10.06	8.35	1.16
Stone sphericity index (%)	56.10	75.66	62.42	3.53
Stone aspect ratio	0.43	0.68	0.49	0.04
Stone surface area (mm^2)	97.42	317.48	222.83	57.01
Mean mass of stone (g)	0.12	0.38	0.27	0.071
Mass of 1000 stone (g)	231.2	313.6	278.1	24.56
Stone projected area (cm^2) x-axis	0.33	0.75	0.53	0.12
y-axis	0.36	0.58	0.46	0.08
Static/dynamic coefficient of friction				
Galvanised iron sheet	0.360/ 0.312	0.377/ 0.327	0.369/ 0.317	0.009/ 0.009
Iron sheet	0.521/ 0.470	0.534/ 0.479	0.528/ 0.475	0.006/ 0.004
Thin plate	0.629/ 0.576	0.638/ 0.585	0.633/ 0.581	0.005/ 0.004
Wood	0.466/ 0.412	0.483/ 0.433	0.475/ 0.422	0.008/ 0.010
Rubber	0.840/ 0.780	0.851/ 0.804	0.844/ 0.792	0.006/ 0.012

The rupture strength changed between 17.56 and 25.83 N mm^{-2}. While terminal velocity values were ranged from 4.80 to 6.10 m s^{-1} for jujube fruits, it was changed between 7.48 and 8.15 m s^{-1} for its stones, respectively.

Titrable acidity varied from 0.30 to 0.37 % for jujube fruits. Total soluble solid content value was 82.47 %. While titratable acidity ranged from 0.24 to 0.34 %, total soluble solids (TSS) changed between 12.5 to 17.5 % for different ripped jujube fruits[59]. Ascorbic acid content ranged between 105.6 and 134.4 mg 100 g^{-1} fresh weight. This value is higher than those reported for cornelian cherry[58] and different orange varieties[60].

While the brightness was L* 48.83, the redness a* 20.68 and the blueness was b* 34.57 for jujube fruits.

Some nutritional properties of jujube fruits are given in Table-2. Protein content was found as approximately 14.13%, which is about the same with some walnut genotypes.

TABLE-2
NUTRITIONAL PROPERTIES OF JUJUBE

	Min	Max	Mean	SD
K (%)	1.00	1.20	1.12	0.084
Mg (%)	0.06	0.08	0.07	0.010
Ca (%)	0.16	0.24	0.21	0.040
N (%)	2.21	2.31	2.26	0.040
P (%)	0.11	0.14	0.12	0.010
Fe (ppm)	145.70	158.0	152.92	5.470
Mn (ppm)	53.40	74.50	61.38	8.790
Zn (ppm)	9.50	12.30	10.76	1.050
Cu (ppm)	10.40	12.90	11.62	0.920
Protein (%)	13.81	14.44	14.13	0.260
TSS (%)	81.00	84.00	82.47	1.200
Ash (%)	2.00	2.00	2.00	0.000
Titratable acidity (%)	0.30	0.37	0.33	0.040
Ascorbic acid content (mg 100 g^{-1} fresh weight)	105.60	134.40	118.40	14.70

Conclusions

(i) Moisture content was between 19.55 and 20.22 % for jujube fruit. The average fruit length, fruit width, fruit thickness and geometric diameter were 17.75, 14.81, 14.19 and 15.43 mm for fruit and 13.40, 6.58, 6.65 and 8.35 mm for its stones, respectively. The average mass, 1000 fruit mass and volume of fruits were 1.26 g, 1139 g and 1.99 cm^3. (ii) The fruit density, bulk density, porosity, angle of repose and spread area were 639 kg m^{-3}, 380 kg m^{-3}, 39.35 %, 16.71° and 0.212 m^2 kg^{-1} for jujube fruits, respectively. (iii) The sphericity index and aspect ratio were 87.56 % and

0.84 for jujube fruits and 62.42 % and 0.49 for its stones, respectively. (iv) The flesh thickness was 3.56 mm, rupture strength 21.49 N mm^{-2} and terminal velocity 5.44 m s^{-1}. (v) The static and dynamic friction coefficient was highest for rubber and followed by thin plate, iron sheet, wood and galvanized iron sheet.

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