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Estimation of maximum height for bulk of white mulberry

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Abstract

Fruits are generally transported in containers. The static and dynamic forces which then act on the fruit will cause damage if they exceed given value. To avoid the vulnerability of fruit, drop heights and allowable static pressure are important. The former is important in planning harvesting and handling operations, the latter is important in selecting the height of transport containers. The static force may be calculated from the weight of the fruit column being transported while the dynamic load is a consequence of vibration caused by transport. The permitted static load for a given fruit may be determined experimentally. In this study, physical properties of interest were determined for fresh white mulberry fruit then calculations for the design of a suitable height were conducted based on the measured properties using Ross and Isaacs's theory. Maximum height for packing and storing of fresh white mulberry fruit in the box was determined to be less than 54.7 cm based on a rupture force of 3.1 N.

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Introduction

Mulberry fruit is a traditional Chinese edible fruit that is used effectively in folk medicines to treat fever, protect liver from damage, strengthen the joints, and facilitate discharge of urine and lower blood pressure (Chang *et al.*, 2005). Mulberry fruit contains essential fatty acids that humans cannot synthesis, and must be obtained through diet. These essential fatty acids are necessary for the formation of healthy body (Ercisli & Orhan, 2007). There are three kinds of mulberry: white mulberry (*Morus alba* L.), black mulberry (*Morus nigra L.*), and red mulberry (*Morus rubra L.*) that extensively are used for their leaves and fruits (Doymaz, 2004).

The physical and mechanical properties of white mulberry fruit are important for the design of equipment for post harvesting technology transporting, harvesting, sizing, storing, separating, cleaning, packaging and processing it into different foods. Since the currently used systems are designed without taking these criteria, the resulting designs lead to inadequate applications. These designs result in a reduction in work efficiency and a rise in product loss. Thus, determination and consideration of these criteria play an important role in designing of this equipment (Stroshine, 1998). There were a lot of studies on physical properties and mechanical behavior of some agricultural products such as physical properties and mechanical behavior of olive fruits (Kilickan and Guner, 2008), physical and mechanical properties of Egyptian onion (Bahnasawy *et al.*, 2004), physical and mechanical properties of aonla fruits (Goyal *et al.*, 2007), okro fruit (Owolarafe and Shotonde, 2004), kiwi fruit (Lorestani and Tabatabaeefar, 2006), mechanical properties of Tarocco orange fruit under parallel plate compression (Pallottino *et al.*, 2011), also some Physical properties of date fruit (Keramat Jahromi *et al.*, 2008), But no detailed study concerning the mechanical damage of white mulberry fruit was found in the literature.

The mechanical resistance to the damage of fruits and seeds among other mechanical and physical properties plays a very important role in the design of harvesting and other processing machines (Baryeh, 2002). The value of this basic information is necessary, because during operations, in these sets of equipment, products are subjected to mechanical loads which may cause damage. Mechanical damage of fruits and seeds depends on several factors such as product's structural properties, product variety, products moisture content, stage of ripeness, fertilization level and incorrect settings of the subassemblies of the machines (Shahbazi, 2011). Damage can occur during harvesting and handling as a result of impact loads or shear forces produced by contact with the hard surfaces of machinery or storage containers. Fruits and vegetables can be deformed during storage as a result of static or quasi-static forces at points of contact with other fruits and vegetables or storage containers. Static forces are applied on individual fruits, vegetables grains and seeds when they are in piles or storage containers because they interact with each other at the points where they make contact (Bilanski, 1962). The mechanization of various harvesting and subsequent manipulation operations has an unfavorable consequence that leads to an increase in damage to the material processed. In every case the quality of the product is directly lowered as a result, and in numerous cases mechanical damage is followed by rapid spoiling, whereby the material deteriorates completely. In the course of longer storage, spoiled material also endangers sound material which is in contact with it. Thus it is understandable that the reduction of mechanical damage is of high economic importance. Experimental results for peaches indicating that they can support about 15 N static loads without damage. This corresponds to the weight of a column of fruit approximately 70 cm height. The deeper the container, the lower the volume ratio represented by the upper layer. Thus the proportion of fruit damaged may be reduced significantly by increasing the depth of the container up to a certain point (Sitcki, 1986; Stroshine, 1998).

Considering the above facts, the objectives of this study were: 1- Determination of some physical and mechanical properties of white mulberry fruits. 2- Calculation of maximum height of box for storage and handling white mulberry fruits. This information could be used to design and to optimize post harvesting mechanisms.

Materials and methods

Sample preparation

Mature fresh white mulberry fruits from Tehran province of Iran, in May 2012. The fruits were cleaned manually to remove all foreign materials and defective fruits. Then 100 healthy fruits were stored in a refrigerator at 4˚C until the experiments were carried out. Before each test, the required quantity of samples was taken out of refrigerator and allowed to warm up to room temperature (25˚C). Moisture content of the samples was determined according to AOAC approved vacuum oven (Memmert-ULE500, Germany) method (AOAC, 2005). All the physical properties were determined at the moisture contents of 77.8 % (w.b.). All the experiments were replicated at least five times and the average values were reported.

Theoretical Principles and Experimental design

In bins or shipping containers, only a portion of the surfaces of individual fruits, vegetables, grains and seeds are in contact. If the force acting at a point can be determined, then the area of contact and the maximum stress at the point of contact can be estimated using the contact stress theory. The forces at points of contact can be estimated using the approach described by Ross and Isaacs (1961). This requires several assumptions. The particles are assumed to be spherical with a uniform diameter D_g. Their contact is assumed to be inelastic, which has the following two implications: 1- The particles do not deform appreciably and therefore the distance between particles does not change. 2- The inter particle forces act at the points of contact. The particles are assumed to be arranged in the rhombic stacking model, shown in Fig. 1.

The individual particles are in contact along a line which makes an angle θ with the horizontal. In this model, the angle θ is dependent on N, the number of particles per unit volume, and D_g, the characteristic diameter of the particles. These three variables are related by the following equation (Stroshine, 1998):

$$N = \frac{1}{4D_g^{\,3}\cos^2\theta\sin\theta} \qquad (1)$$

Number of particles per unit volume is obtained from ratio of bulk density to mass of each particle multiplied by its unit volume.

The maximum static force occurs in the last layer of fruits (Fig. 2). There are four forces acting from above on the particle in contact with the floor (Fig. 3). They will sum to (Stroshine, 1998):

$$F = n \times w \qquad (2)$$

Where F is the total force on fruit in the last layer (rapture force) and w is fruit weight.

Angle of the fruit and number of layers is calculated from Eq. (1 and 2), respectively. Thus box height is calculated from Eq. (3) (Stroshine, 1998):

$$h = nD_g\sin\theta \qquad (3)$$

Where, h is height of box, D_g is geometric mean diameter, n is number of layers and θ is angle of contact line with horizontal.

Physical properties

Measurements of the three major perpendicular dimensions of the fruit were carried out with a digital caliper (AND GF-600. JAPON) to an accuracy of 0.01 mm. The geometric mean diameter, D_g of the fruit was calculated by using the following relationship (Mohsenin, 1980):

$$D_g = (abc)^{1/3} \qquad (4)$$

The length, width and thickness are in mm as shown in Fig. 4.

The bulk density (P_b) was determined using the mass/volume relationship, by filling an empty plastic container of predetermined volume (75 cm^3) and tare weight with the grains by pouring from a constant height, striking off the top level and weighing (Ghasemi Varnamkhasti *et al.*, 2008; Aydin and Ozcan, 2007). Using equation 5:

$$\rho_b = \frac{m_b}{V_b} \quad (5)$$

Where: m_b is the total mass of fruit in container and V_b is the volume of container.

Mechanical properties

Maximum force (F_{max}= rapture force) of white mulberry fruit was determined by the testing machine (H50 K-S, Hounsfield, England), equipped with a 50 N compression load cell and integrator (Fig. 5). The measurement accuracy was ±0.001 N in force and 0.001 mm in deformation. The individual seed was loaded between two parallel plates of the machine and compressed along with thickness until rupture occurred as is denoted by a rupture point in the force–deformation curve. The rupture point is a point on the force–deformation curve at which the loaded specimen shows a visible or invisible failure in the form of breaks or cracks. This point is detected by a continuous decrease of the load in the force-deformation diagram. While the rupture point was detected, the loading was stopped. These tests were carried out at the loading rate of 0.1 mm/min for all moisture levels. (Aydin and Ozcan, 2007).

Results and discussion

A summary of the descriptive statistics of the various physical dimensions is shown in Table 1. The average of major, intermediate and minor diameters for white mulberry fruits at moisture content of 77.8 % (w.b) was 28.8, 18.1 and 16.7 mm, respectively. The geometric mean diameter of white mulberry fruits in this research was 20.6 mm. With a geometric mean of 20.6 mm, The white mulberry fruits were thus smaller than fig fruit with reported average principal dimensions of 32.1, 43.1 and 40.2 mm, respectively (Shahbazi and Rahmati, 2013), and also smaller than olive fruit with principal dimensions of 29.2, 22.1 and 18.1 mm (Kilickan and Guner, 2008). The white mulberry fruits were bigger than rasa grape fruit with principal dimensions of 16.6, 14.1 and 13.7 mm, respectively (Khodaei and Samimi Akhijahani). The importance of these and other characteristic axial dimensions in determining the aperture size of machines, particularly in separation of materials, as discussed by Mohsenin (1980) and highlighted by other researchers (Omobuwajo *et al.*, 2000).

Table 1. selected some physical and mechanical properties of white mulberry fruit.

property	Observations	Mean ±SD
Moisture content, (% w.b)	5	81.9±1.8
Fruit mass, (g)	100	28.4±1.12
Fruit length, (mm)	100	39.66±4.62
Fruit width, (mm)	100	37.07±2.56
Fruit thickness, (mm)	100	31±1.94
Geometric mean diameter, (mm)	100	35.68±3.81
Bulk density, (kg/m^3)	5	424±19.49
Rupture force, (N)	5	8.9±1.63

Table 2. Estimated parameters to calculate the maximum height of box for white mulberry fruit maintenance.

Parameter	Observations	Mean±SD
N	5	14930±43.17
θ, (deg.)	5	42.2±3.12
W, (N)	100	0.28±0.1
n	5	32±1.81
h, (cm)	5	76.5±4.34

The average fruit mass of the white mulberry was 3.6 g compared with 2.5 g in rasa grape fruit, 4.11 g in olive fruit and 35.4 g for fig fruit. Thus, the white mulberry fruit has a mass smaller than fig fruit and olive fruit, but bigger than rasa grape fruit (Shahbazi and Rahmati, 2013; Kilickan and Guner, 2008; Khodaei and Samimi Akhijahani).

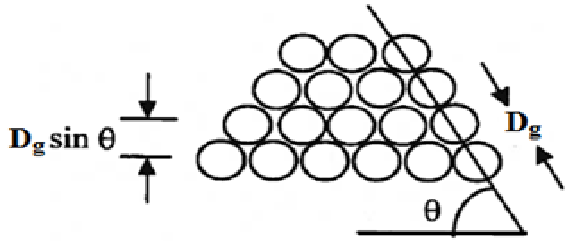

Fig. 1. Rhombic stacking model for fruits.

The bulk density of white mulberry was 375.3 kg/m3. This value was smaller than 712.7 and 556.1 kg/m3 for rasa grape and olive fruit, respectively (Kilickan and Guner, 2008; Khodaei and Samimi Akhijahani). This property could prove useful in the separation and transportation of the fruits by processing machines.

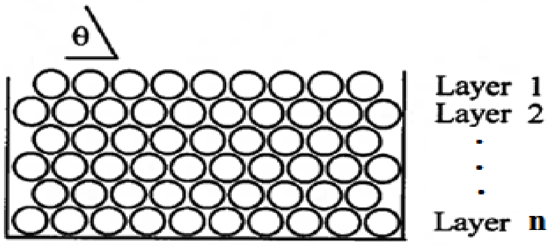

Fig. 2. Diagram of stack of samples having n layers and confined by a vertical wall and a floor.

The average rupture force for white mulberry fruit was 3.1 N (87 layers of fruits) compared with 9.75 N in apricot, 22.39 N in mango fruit and 57.38 N for olive fruit. Thus, the white mulberry fruit has a smaller rupture force and more firmness than apricot, mango fruit and olive fruit (Haciseferogullari *et al.*, 2007; Jha *et al.*, 2006; Kilickan and Guner, 2008).

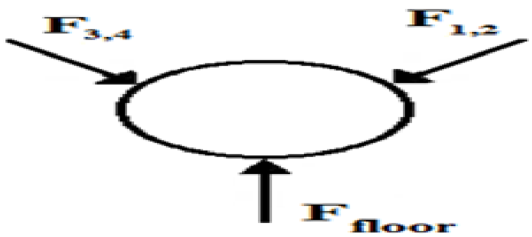

Fig. 3. Static forces on the last layer of fruit.

The maximum height of box and estimated parameters of white mulberry fruit to calculate the maximum height of box is shown in Table 2. According to these results, the maximum height of storage and handling box for white mulberry fruit was obtained 54.7 cm. Then for caution this fruit should be not stored in containers with over 54.7 cm height. This value is shorter than the value reported for peach fruit (70 cm) because ratio of rupture to mass for white mulberry fruit is smaller than the ratio of peach fruit (Sitkei, 1986).

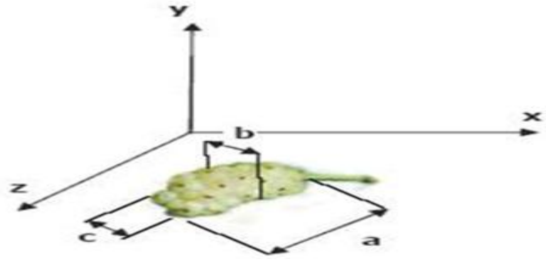

Fig. 4. Dimensions of white mulberry fruit; a, b and c are the length, width and thickness.

Fig. 5. Universal testing machine.

Conclusions

Measuring maximum height of box for white mulberry storage and handling was performed in this study. Also some physical and mechanical properties were measured. The following conclusions may be made based on statistical analysis of the data: Length, width, thickness, geometric mean diameter, bulk density and mass of white mulberry fruit were 28.8 mm, 18.1 mm, 16.7 mm, 20.6 mm, 375.3 kg/m3 and 3.6 g, respectively. Rupture force for white mulberry fruit was 3.1 N that equal with 87 layers of fruits. Consequently, it is recommended for transporting and storing of white mulberry fruits that use less than 54.7 cm of box until the fruit not broken due to the weight force of fruit bulk during handling and storing.

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