DETERMINATION OF ENGINEERING PROPERTIES OF POMEGRANATE FRUIT TO CALCULATION THE HEIGHT OF BOX FOR HANDLING

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ABSTRACT

In avoiding damage to fruit species the permissible falling height and permissible static pressure are of great importance. The former is important in planning harvesting and handling operations, the latter in selecting the height of transport containers. 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. 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 pomegranate 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 pomegranate fruit in the box was determined to be less than 123 cm based on a rupture force of 40.7 N.

Keywords: pomegranate fruit; static force; height box; physical properties

INTRODUCTION

Pomegranate *(Punica granatum* L.) belongs to *Punicacea* family. It is one of the important and commercial horticultural fruit which is generally very well adapted to the Southern coastal countries of the Mediterranean Sea climate [1,2]. It has been cultivated extensively in Iran, India and some parts in the U.S.A (California), China, Japan, Spain and Russia. Pomegranate fruits are consumed fresh or processed as juice, jellies and syrup for industrial production [3,4]. Different parts of its tree (leaves, fruits and bark skin) have been used traditionally for their medicinal properties and for other purposes such as in tanning. It is proved to have high antioxidant activity and good potency for cancer prevention [5-7].

The physical and mechanical properties of pomegranate are important for the design of equipment for post harvesting technology transporting, harvesting, sizing, storing, separating, cleaning, packaging and processing it into different food. Since currently used systems are designed without taking these criteria into consideration, 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 [8].

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 [9], physical and mechanical properties of Egyptian onion[10], physical and mechanical properties of aonla fruits [11], okro fruit[12], kiwi fruit[13], mechanical properties of Tarocco orange fruit under parallel plate compression[14], also some Physical properties of date fruit[15]. But no detailed study concerning the mechanical damage of pomegranate 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 [16]. 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 number factors such as products structural features, product variety, products moisture content, stage of ripeness, fertilization level and incorrect settings of the particular working subassemblies of the machines [17].

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 [18].

The mechanization of various harvesting and subsequent manipulation operation has an unfavorable consequence in that it 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 peaches 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 [8,19].

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

MATERIALS AND METHODS

Sample preparation:

Pomegranate fruits were collected from Saveh in Markazi province of Iran, in October 2012. The fruits were cleaned manually to remove all foreign material and defective fruits. Then 100 healthy fruits were stored in the refrigerator at temperature of 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[20]. All the physical properties were determined at the moisture contents of 69.3 % (w.b.). All the experiments were replicated at least of 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 [21]. 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

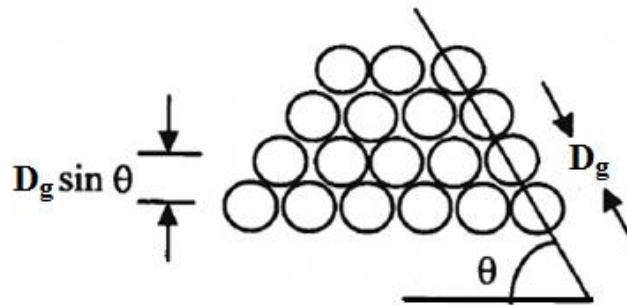contact. The particles are assumed to be arranged in the rhombic stacking model shown in Figure 1.

Figure 1: Rhombic stacking model for fruits.

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 [8]:

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

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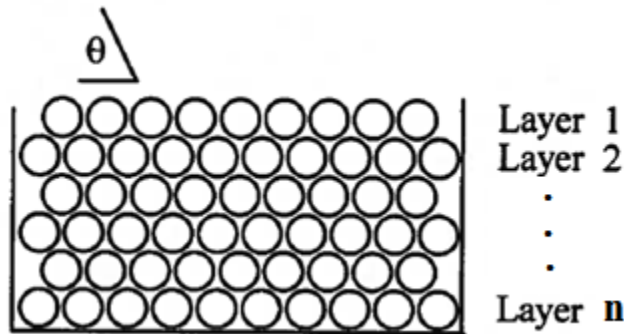

Figure 2: Diagram of stack of samples having n layers and confined by a vertical wall and a floor.

The maximum static force occurs in the last layer of fruits (Figure 2). There are four forces acting from above on the particle in contact with the floor (Figure 3). They will sum to [8]:

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

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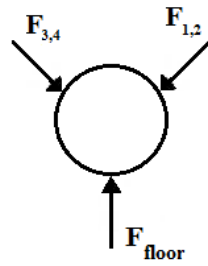

Figure 3: Static forces on the last layer of fruit.

Angle of the fruit and number of layers is calculated from Equation (1 and 2), respectively. Thus box height is calculated from Equation (3) [8]:

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

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 [22]:

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

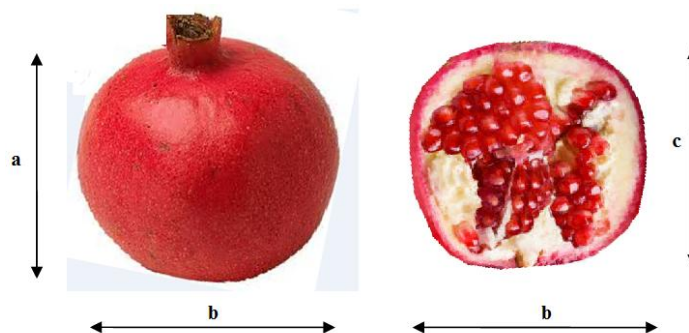Where the length, width and thickness are in mm as shown in Figure 4.

Figure 4: Dimensions of pomegranate fruit; a, b and c are the length, width and thickness.

The bulk density (P_b) was determined using the mass/volume relationship, by filling an empty plastic

container of predetermined volume (75 cm³) and tare weight with the grains by pouring from a constant height, striking off the top level and weighing [23]. Using equation 5:

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

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 pomegranate fruit was determined by the testing machine (H50 K-S, Hounsfield, England), equipped with a 100 N compression load cell and integrator. 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 (Figure 5) 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 [23].

Figure 5: Universal testing machine.

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 pomegranate fruits at moisture content of 69.3% (w.b) was 87.45, 80.8 and 73.1 mm, respectively. The geometric mean diameter of pomegranate fruit in this research was 80.14 mm. With a geometric mean of 80.14 mm, The pomegranate fruits were thus bigger than

cactus pear and kiwi fruit with reported average principal dimensions of 71.93, 57.57, 52.08 mm, and 68, 50.25, 46.38 mm, respectively [24,25], but smaller than the cantaloupe fruit with principal dimensions of 147, 140, 134 mm [26]. 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 [22] and highlighted by other researchers [27].

property	Observations	Mean ±SD
Moisture content, (% w.b)	5	69.3±0.6
Fruit mass, (g)	100	227.52±15.42
Fruit length, (mm)	100	87.45±4.86
Fruit width, (mm)	100	80.8±4.75
Fruit thickness, (mm)	100	73.1±3.68
Geometric mean diameter, (mm)	100	80.14±4.71
Bulk density, (kg/m^3)	5	451.6±18.39
Rupture force, (N)	5	40.7±2.53

Table 1: selected some physical and mechanical properties of pomegranate fruit

The average fruit mass of the pomegranate was 227.52 g compared with 109.8 g in cactus pear fruit, 98.7 g in kiwi fruit, 1397 g in cantaloupe fruit and 171.5 g for wild mango fruit. Thus, the pomegranate fruit has a bigger mass than kiwi, wild mango fruit and cactus pear fruit but smaller than the cantaloupe fruits[24-26,28].

The bulk density of pomegranate was 451.6 kg/m^3. This value was close to the corresponding values of 515.27 and 563.2 kg/m^3 reported for orange and kiwi fruits, respectively [25,29]. This property could prove useful in the separation and transportation of the fruits by processing machines.

The average rupture force for pomegranate fruit was 40.7 N compared with 13 N in kiwi fruit, 9.75 N in apricot, 22.39 N in mango fruit and 57.38 N for olive fruit. Thus, the pomegranate fruit has a bigger rupture force and more firmness than kiwi, apricot and mango fruit but smaller than the olive fruit [9,28,30,31].

The maximum height of box and estimated parameters of pomegranate 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 pomegranate fruit was obtained 123 cm. Then for caution this fruit should be not stored in containers with over 123 cm height. This value is higher than the value reported for peach fruit (70 cm) because rupture force of pomegranate fruit is greater than the force required to break the peach fruit (15 N) [19].

Parameter	Observations	Mean±SD
N	5	1985±11.37
θ, (deg.)	5	57.4±3.18
W, (N)	100	2.23±0.1
n	5	18±2.11
h, (cm)	5	123±5.64

Table 2: Estimated parameters to calculate the maximum height of box for pomegranate fruit maintenance

CONCLUSIONS

Measuring maximum height of box for pomegranate 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 pomegranate fruit were 87.45mm, 80.8 mm, 73 mm, 80.14 mm, 451.6 kg/m^3 and 227.52 g, respectively. Rupture force for pomegranate fruit was 40.7 N that equal with 18 layers of fruits. Consequently, it is recommended for transporting and storing of pomegranate fruit that use less than 123 cm of box until the fruit not broken due to the weight force of fruit bulk during handling and storing.

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