Direct RESEARCH JOURNALS

Estimation of suitable box height based on engineering properties of pomegranate fruit (var. Malas)

Direct Research Journal of Agriculture and Food Science (DRJAFS) Vol.1 (6), pp.80-84,December 2013
Available online at directresearchpublisher.org/drjafs
ISSN 2354-4147

Research Paper

Isa Hazbavi

Department of Engineering, Shahre- Rey Branch, Islamic Azad University, Tehran, Iran.

ABSTRACT

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. 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. 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 (var. Malas) 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 120 cm based on a rupture force of 40 N.

Key words: Pomegranate fruit; Static force; Height box; Engineering properties.

*Corresponding Author E-mail: hazbavi2000@gmail.com. Tel: +989166199034; Fax: +9(21) 44196524

Accepted 28 December 2013

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 (Biale and Young, 1981; Harde et al., 1970). 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 (Hodgson, 1917; Nagy et al., 1990). 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 (Afaq et al., 2005; Gil et al., 1995; Rania et al., 2007).

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 (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 et al., 2008). But no detailed study concerning the mechanical damage of apple 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 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 (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 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 (Sitkei, 1986; Stroshine, 1998).

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

Mature fresh pomegranate fruits of Malas variety were collected from Tehran 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 (AOAC, 2005). All the physical properties were determined at the moisture contents of 70 % (w.b.). All the experiments were replicated at least of five times and the average values were reported.

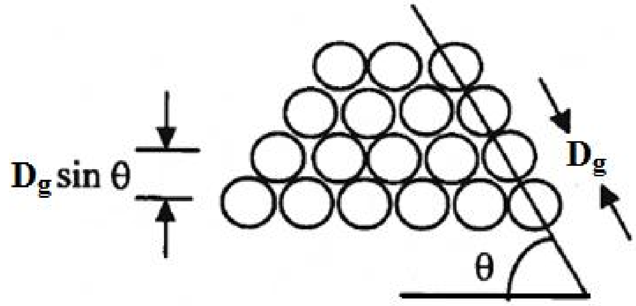

Figure 1. Rhombic stacking model for fruits.

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 Figure 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):

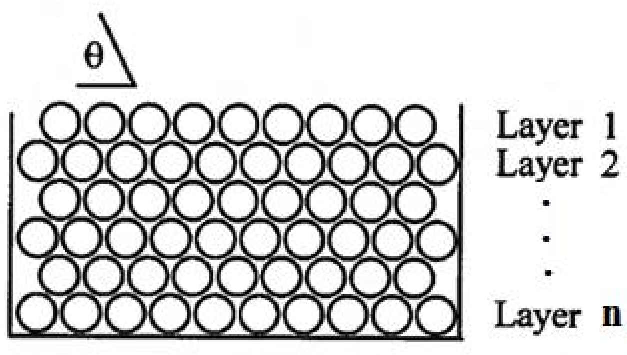

Figure 2. Diagram of stack of samples having n layers and confined by a vertical wall and a floor.

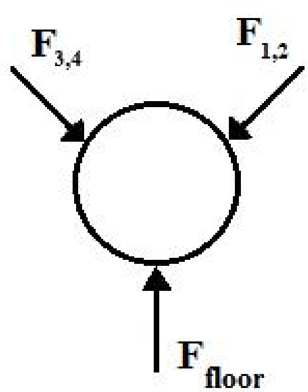

Figure 3. Static forces on the last layer of fruit.

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

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 (Figure 2). There are four forces acting from above on the particle in contact with the floor (Figure 3). They will sum to (Stroshine, 1998):

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

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):

$$h = nD_g \sin{-} \quad (3)$$

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.

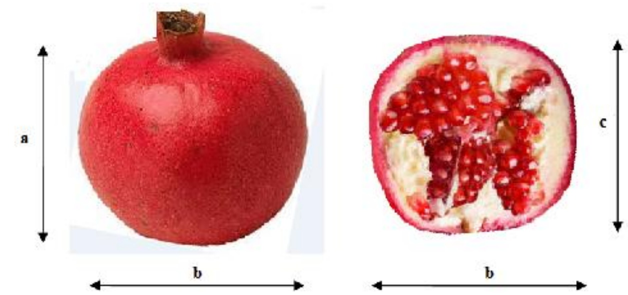

Figure 4. Dimensions of pomegranate fruit; a, b and c are the length, width and thickness.

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):

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

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

The bulk density (ρ_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 (Gupta and Das, 1997; Aydin and Ozcan, 2007; Paksoy and Aydin, 2004):

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

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 fruit was determined

Figure 5. Universal testing machine.

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

Property	Observations	Mean ±SD
Moisture content, (% w.b)	5	70±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±2.53

by the testing machine (H50 K-S, Hounsfield, England), equipped with a 100 N compression load cell and integrator (Figure 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 pomegranate fruits at moisture content of 70 % (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 (Kabas et al., 2006; Razavi and BahramParvar, 2007), but smaller than the cantaloupe fruit with principal dimensions of 147, 140, 134 mm (Rashidi and seyfi, 2007). 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).

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 (Ehiem and Simonyan, 2012; Rashidi and seyfi, 2007; Kabas et al*.,* 2006).

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

Property	Observations	Mean ±SD
N	5	1985±11.37
θ, (deg.)	5	57.4±3.18
W, (N)	100	82.23±0.1
n	5	18±2.11
h, (cm)	5	120±5.64

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 (Topuz et al., 2005; Razavi and BahramParvar, 2007). 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 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 (Ehiem and Simonyan, 2012 ; Haciseferogullari et al., 2007; Jha et al., 2006; Kilickan and Guner, 2008).

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 120 cm. Then for caution this fruit should be not stored in containers with over 120 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) (Sitkei, 1986).

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 N that equal with 18 layers of fruits. Consequently, it is recommended for transporting and storing of pomegranate fruit that use less than 120cm of box until the fruit not broken due to the weight force of fruit bulk during handling and storing.

REFERENCES

Afaq F, Saleem M, Krueger CG, Reed JD, and Mukhtar H (2005). Anthocyanin and Hydrolyzable Tannin-Rich Pomegranate Fruit Extract Modulates MAPK and NF-kB Pathways and Inhibits Skin Tumorigenesis in CD-1 Mice. Int. J. Cancer, 113: 423–433.

AOAC (2005). Official Methods of Analysis, 18^h Ed. Association of Official Analytical Chemists, Washington DC, U.S.A.

Aydin C, Ozcan M (2007). Some physico-mechanic properties of terebinth (*Pistacia terebinthus* L.) fruits. J. Food Eng., 53: 97–101.

Bahnasawy AH, El-Haddad ZA, El-Ansary MY (2004). Physical and mechanical properties of some Egyptian onion cultivars. J. Food Eng., 62: 255-261.

Baryeh EA (2002). A simple grain impact damage assessment device for developing countries. J. Food Eng., 56: 37-42.

Biale JB, Young RE (1981). Respiration and ripening in fruits-retrospect and prospect In: Recent advances in the biochemistry of fruit and vegetables Friend J and Rhodes M.J.C. ed., Academic press, London, 1981.

Bilanski WK (1962). Damage Resistance of Seed Grains. Trans. A. S. A. E., 9(3): 360-363.

Ehiem JC, Simonyan KJ (2012). Physical properties of wild mango fruit and nut. Int. Agrophys., 26: 95-98.

Gil MI, Viguera C, Artes F, Barberan FA (1995). Changes in pomegranate juice pigmentation during ripening. J. Sci. Food Agric., 5(68): 77-81.

Goyal RK, Kingsly ARP, Kumar P, Walia H (2007). Physical and mechanical properties of aonla fruits. J. Food Eng., 82 (4): 595-599.

Gupta RK, Das SK (1997). Physical properties of sunflower seeds. J. Agric. Eng. Res., 66: 1–8.

Haciseferogullari H, Gezer I, Ozcan MM, MuratAsma B (2007). Post harvest chemical and physical-mechanical properties of some apricot varieties cultivated in Turkey, J. Food Eng., 79: 364–373.

Harde H, Schumacher W, Firbas F, Deffer D (1970). Strasburg's Textbook of Botany. Chaucer, London.

Hodgson RW (1917). The pomegranate, Calif, Agric. Expt. Sta. Bul.

Jha SN, Kingsly ARP, and Chopra S (2006). Physical and mechanical properties of mango during growth and storage for determination of maturity. J. Food Eng., 72: 73–76.

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

Keramat JM, Mohtasebi SS, Jafari A, Mirasheh R, Rafiee S (2008). Determination of some physical properties of date fruit (cv. Mazafati). J. Agric. Technol., 4(2): 1-9.

Kilickan A, Guner M (2008). Physical properties and mechanical behavior of olive fruits (*Olea europaea* L.) under compression loading. J. Food Eng., 87: 222–228.

Lorestani AN, Tabatabaeefar A (2006). Modeling the mass of kiwi fruit by geometrical attributes. Int. Agrophys., 20 (2): 135-139.

Mohsenin NN (1980). Physical properties of plants and animal materials. Gordon Breach Sci. Press, New York, USA.

Nagy P, Shaw PE, Wordowski WF (1990). Fruit of Tropical and Subtropical Origin. Florida Science Source, Florida, USA.

Omobuwajo TO, Akande EA, Sanni LA (2000). Selected physical, mechanical and aerodynamic properties of African breadfruit (Treculia africana) seeds. J. Food Eng., 40: 241–244.

Owolarafe OK, Shotonde HO (2004). Some physical properties of fresh okro fruit. J. Food Eng., 63: 299–302.

Paksoy M, Aydin C (2004). Some physical properties of edible squash (*Cucurbita pepo* L.) seeds. J. Food Eng., 65(2) 225–231.

Pallottino F, Costa C, Menesatti P, Moresi M (2011). Assessment of the mechanical properties of Tarocco orange fruit under parallel plate compression. J. Food Eng., 103 (3): 308-316.
Rania J, Nejib H, Messaoud M, Mohamed M, Mokhtar T (2007). Characterization of Tunisian pomegranate *(Punica granatum* L.) cultivars using amplified fragment length polymorphism analysis, Scientia Horticulturae, 115 (3), 231–237.
Rashidi M, Seyfi K (2007). Classification of fruit shape in cantaloupe using the analysis of geometrical attributes. World J. Agric. Sci., 3(6): 735-740.
Razavi SMA, and BahramParvar M (2007). Some physical and mechanical properties of kiwi fruit, Int. J. Food Eng., 3(6): 1-14.
Ross IJ, Isaacs GW (1961). Forces Acting in Stacks of Granular Materials (Part I). Trans A. S. A. E., 4(1): 92-96.
Shahbazi F (2011). Impact Damage to Chickpea Seeds as Affected by Moisture Content and Impact Velocity. Appl. Eng. Agric., 25(7): 771-775.
Sitkei G (1986). Mechanics of Agricultural materials. Elsvier Science Publishers, Amsterdam.
Stroshine R (1998). Physical Properties of Agricultural Material and Food products. West Lafayette: Dept of Agricultural Engineering Purdue Univ. Press. New York, USA, 1998.
Topuz A, Topakci M, Canakci M, Akinci I, Ozdemir F (2005). Physical and nutritional properties of four orange varieties. J. Food Eng., 66: 519–523.