Determination of physical properties of apricot fruit and proper box height for storing and handling the apricot fruit

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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. The aim of this study was design of a suitable height based on the measured properties using Ross and Isaacs's theory by determination of physical and mechanical properties of fresh apricot fruit. Maximum height for packing and storing of fresh apricot fruit in the box was determined to be less than 49.5 cm based on a rupture force of 6.5 N.

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

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1 Introduction

Apricot (*prunus armeniaca L.*) is classified under the *prunus* species of *prunoidae* sub –family of the *Rosaceae* family of the *Rosales* group. This type of fruit is a cultivated type of *zerdali* (wild apricot) which is produced by domestication (Ozbek, 1978). Apricot plays an important role in human nutrition, and can be used as a fresh, dried or processed fruit such as frozen apricot, jam, jelly, marmalade, pulp, juice, nectar, extrusion products, etc. Moreover, apricot kernels are used in production of oils, cosmetics, active carbon and aroma perfume (Yildiz, 1994). Australia, France, Hungary, Iran, Italy, Morocco, Spain, Tunisia and Turkey are among the most important apricot producer countries. While some of the countries such as Hungary, Morocco, Iran and Tunisia are considered as fresh apricot exporters, the others, such as Australia and Turkey, are major dried apricot producers and exporters. Turkey and Iran (having cultivated area with 20,000 ha and with average annual production of 275,580 t) have been the largest producers of apricot in the world (USDA, 2012).

The physical and mechanical properties of apricot fruit 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),

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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 apricot 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).

Experimental results for peaches indicate 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 (Sitcki, 1986; Stroshine, 1998).

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

2 Materials and methods

2.1 Sample preparation

Mature fresh apricot fruit of Ghavami variety were collected from Semnan province of Iran, in October 2012. The fruits were cleaned manually to remove all foreign material and defective fruits. Then 100 healthy fruits (randomly selected) 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 and mechanical properties were determined at the moisture contents of 79.8% (w.b.). All the experiments were replicated at least of five times and the average values were reported.

2.2 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.

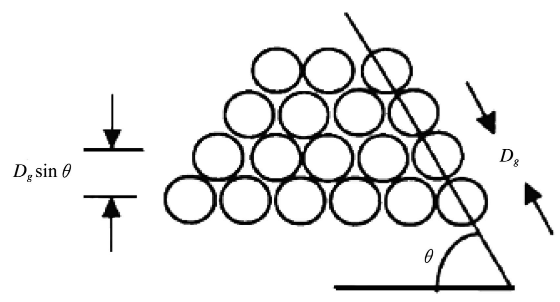


Figure 1 Rhombic stacking model for fruits

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 (1) (Stroshine, 1998):

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

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 (Equation (2)) (Stroshine, 1998):

$$F = n \times w \tag{2}$$

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

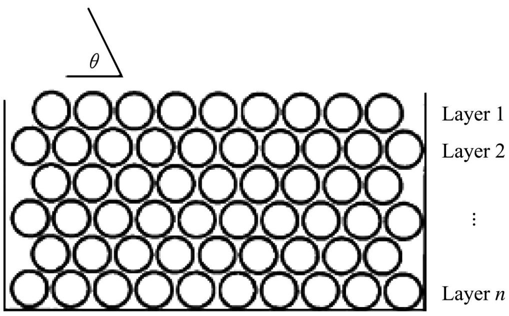


Figure 2 Diagram of stack of samples having n layers and confined by a vertical

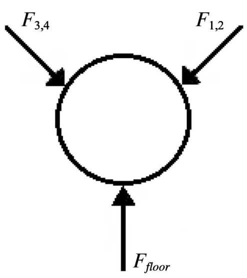


Figure 3 Static forces on the last layer of fruit

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

$$h = nD_g \sin\theta \tag{3}$$

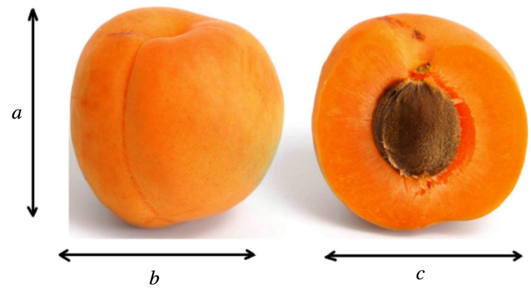
where, h is height of box; D_g is geometric mean diameter; n is number of layers and θ is angle of contact line with horizontal.

2.3 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 (Equation 4) (Mohsenin, 1980):

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

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



a, *b* and *c* are the length, width and thickness

Figure 4 Dimensions of apricot fruit

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 (Equation (5)) (Gupta and Das, 1997; Aydin and Ozcan, 2007; Paksoy and Aydin, 2004):

$$\rho_b = \frac{m_b}{V_b} \tag{5}$$

where, m_b is the total mass of fruit in container and V_b is the volume of container.

2.4 Mechanical properties

Maximum force (F_{max}= rapture force) of fig 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 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^{-1} for all moisture levels (Aydin and Ozcan, 2007).

Figure 5 Universal testing machine

3 Results and discussion

A summary of the descriptive statistics of the various physical dimensions is shown in Table 1.

Table 1 Selected some physical and mechanical properties of apricot fruit

Property	Observations	Mean ±SD
Moisture content/%	5	79.8±0.7
Fruit mass/g	100	41.5±10.32
Fruit length/mm	100	46.68±2.56
Fruit width/mm	100	40.43±2.45
Fruit thickness/mm	100	36.73±2.68
Geometric mean diameter/mm	100	41.15±2.71
Bulk density/kg m^{-3}	5	459.17±18.59
Rupture force/N	5	6.5±1.13

The average of major, intermediate and minor diameters for apricot fruits at moisture content of 79.8% (w.b) was 46.68, 40.435 and 36.73 mm, respectively. The geometric mean diameter of apricot fruit in this research was 41.15 mm. With a geometric mean of 41.15 mm, The apricot fruits were thus smaller than cactus pear with reported average principal dimensions of 71.93, 57.57 and 52.08 mm, respectively (Kabas et al., 2006), and also 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, was discussed by Mohsenin (1980) and highlighted by other researchers (Omobuwajo et al., 2000).

The average fruit mass of the apricot was 41.5 g compared with 109.8 g in cactus pear fruit, 1397 g in cantaloupe fruit and 171.5 g for wild mango fruit. Thus, the apricot fruit has a mass smaller than wild mango fruit, cactus pear fruit and cantaloupe fruits (Ehiem and Simonyan, 2012; Rashidi and Seyfi, 2007; Kabas et al., 2006).

The bulk density of apricot was 459.17 kg m^{-3}. This value was close to the corresponding values of 515.27 kg m^{-3} reported for orange (Topuz et al., 2005). This property could prove useful in the separation and transportation of the fruits by processing machines.

The average rupture force for apricot fruit was 6.5 N compared with 22.39 N in mango fruit and 57.38 N for olive fruit. Thus, the apricot fruit has a smaller rupture force and more softness firmness than mango fruit and olive fruit (Jha et al., 2006; Kilickan and Guner, 2008).

The maximum height of box and estimated parameters of apricot 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 apricot fruit was obtained 49.5 cm. Then for caution this fruit should be not stored in containers with over 49.5 cm height. This value is higher than the value reported for peach fruit (70 cm) because rupture force of peach fruit (15 N) is greater than the force required to break the apricot fruit (Sitkei, 1986).

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

Property	Observations	Mean ±SD
N	5	11064±14.27
θ/(deg)	5	49±3.12
W/N	100	0.4±0.1
n	5	16±1.42
h/cm	5	49.5±3.14

4 Conclusions

Measuring maximum height of box for apricot 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 apricot fruit were 46.68 mm, 40.43 mm, 36.73 mm, 41.15 mm, 459.17 kg m^{-3} and 41.5 g, respectively. Rupture force for apricot fruit was 6.5 N that equals with 16 layers of fruits. Consequently, it is recommended for transporting and storing of apricot fruit that use less than 49.5 cm of box until the fruit not broken due to the weight force of fruit bulk during handling and storing.

References

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

Aydin, C. and M. Ozcan. 2007. Some physico-mechanic properties of terebinth (*Pistacia terebinthus* L.) fruits. *Journal of Food Engineering*, 53(1): 97–101.

Bahnasawy, A. H., Z. A. El-Haddad, and M. Y. El-Ansary. 2004. Physical and mechanical properties of some Egyptian onion cultivars. *Journal of Food Engineering*, 62(3): 255-261.

Baryeh, E. A. 2002. A simple grain impact damage assessment device for developing countries. *Journal of Food Engineering*, 56(1): 37-42.

Bilanski, W. K. 1962. Damage resistance of seed grains. *Transactions of ASAE*, 9(3): 360-363.

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

Goyal, R. K., A. R. P. Kingsly, P. Kumar, and H. Walia. 2007. Physical and mechanical properties of aonla fruits. *Journal of Food Engineering*, 82 (4): 595-599.

Gupta, R. K. and S. K. Das. 1997. Physical properties of sunflower seeds. *Journal of Agricultural Engineering Research*, 66(1): 1–8.

Jha, S. N., A. R. P. Kingsly, and S, Chopra. 2006. Physical and mechanical properties of mango during growth and storage for determination of maturity. *Journal of Food Engineering*, 72(1): 73–76.

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.

Keramat Jahromi, M., S. S. Mohtasebi, A. Jafari, R. Mirasheh, and S. Rafiee. 2008. Determination of some physical properties of date fruit (cv. Mazafati). *Journal of Agricultural Technology*, 4(2): 1-9.

Kilickan, A. and M. Guner. 2008. Physical properties and mechanical behavior of olive fruits (Olea europaea L.) under compression loading. *Journal of Food Engineering*, 87(2): 222–228.

Lorestani, A. N. and A. Tabatabaeefar. 2006. Modeling the mass of kiwi fruit by geometrical attributes. *International Agrophysics*, 20 (2): 135-139.

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

Omobuwajo, T. O., E. A. Akande, and L. A. Sanni. 2000. Selected physical, mechanical and aerodynamic properties of African breadfruit (Treculia africana) seeds. *Journal of Food Engineering*, 40(4): 241–244.

Ozbek, S. 1978. Special Horticulture. C.U.Faculty of Agriculture no.128, Adana, Turkey.

Owolarafe, O. K. and H. O. Shotonde. 2004. Some physical properties of fresh okro fruit. *Journal of Food Engineering*, 63(3): 299–302.

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

Pallottino, F., C. Costa, P. Menesatti, and M. Moresi. 2011. Assessment of the mechanical properties of Tarocco orange fruit under parallel plate compression. *Journal of Food Engineering*, 103 (3): 308-316.

Rashidi, M. and K. Seyfi. 2007. Classification of fruit shape in cantaloupe using the analysis of geometrical attributes. *World Journal of Agricaltureal Sciences*, 3(6): 735-740.

Ross, I. J. and G. W. Isaacs. 1961. Forces acting in stacks of granular materials (Part I). *Transactions of ASAE*, 4(1): 92-96.

Shahbazi, F. 2011. Impact damage to chickpea seeds as affected by moisture content and impact velocity. *Applied Engineering in Agriculture*, 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.

Topuz, A., M. Topakci, M. Canakci, I. Akinci, and F. Ozdemir. 2005. Physical and nutritional properties of four orange varieties. *Journal of Food Engineering*, 66(4): 519–523.

USDA. 2012. Economic Research Service (ERS). Food Consumption (per capita) Data System. Available at: http://www.ers.usda.gov. (accessed December 23, 2012)

Yildiz, F. 1994. New technologies in apricot processing. J standard, Apricot Special Issue, Ankara pp8: 67-69.