JAP&T
TPA-Timişoara

Available online at http://journal-of-agroalimentary.ro

Journal of Agroalimentary Processes and Technologies 2014, 20(1), 33-38

Journal of Agroalimentary Processes and Technologies

Maximum Height Calculation for Bulk of apple Fruits (var. *Golden Delicious*)

Anam Isa Hazbavi

Department of Engineering, Shahr-e Ray Branch, Islamic Azad University, Tehran, Iran.

Received: December 2013; Accepted: 02 March 2014

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. 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 apple fruit (var. *Golden Delicious*) then calculations for the design of a suitable height were conducted based on the measured properties using Ross & Isaacs's theory. Maximum height for packing and storing of fresh apple fruit in the box was determined to be less than 78 cm based on a rupture force of 31 N.

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

1. Introduction

The apple, with scientific name of Malus domestica is a pomaceous fruit from Rosaceae family. There are more than 7500 known cultivars of apples in world [1]. Iran, with 190,000 ha of cultivation area (2.8% of the world production area) is tertiary country of apple producer posterior China and USA countries in world. In spite of 2.66 million tons of annual Iranian apple production, exportation of that is very low [2].

The physical and mechanical properties of apple 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 [3].

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 [4], physical and mechanical properties of Egyptian onion [5], physical and mechanical properties of aonla fruits [6], okro fruit [7], kiwi fruit [8], mechanical properties of Tarocco orange fruit under parallel plate compression [9], also some Physical properties of date fruit [10].

Corresponding author: *e-mail:*Hazbavi2000@gmail.com. Tel: ++989166199034; Fax: ++9(21) 44196524

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 [11]. 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 [12].

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 [13].

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 [3,14].

In light of above facts, the objectives of this study were to: 1- Determination of some physical and mechanical of apple fruits (var. *Golden Delicious*). 2- Calculation of maximum height of box for apple 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 apple fruit (var. Golden Delicious) were collected from Tehran province of Iran, in December 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 [15]. All the physical properties were determined at the moisture contents of 85.3 % (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 [16]. 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.

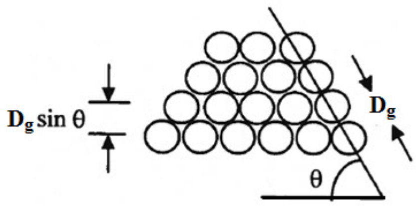

Figure 1. Rhombic stacking model for fruits.

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 [3]:

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

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

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

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

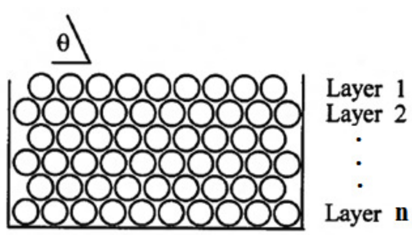

Figure 2. Diagram of stack of samples having n layers and confined by a vertical

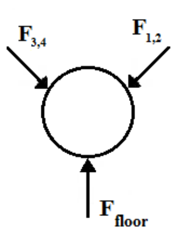

Figure 3. Static forces on the last layer of fruit.

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

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

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.

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 [17]:

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

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

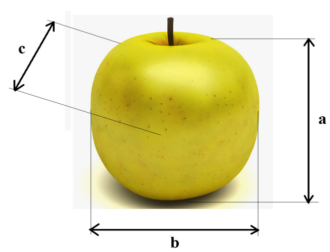

Figure 4. Dimensions of apple fruit; a, b and c are the length, width and thickness.

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 [18-20]:

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

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

2.4 Mechanical properties. Maximum force (F_{max}= rapture force) of apple fruit was determined by the testing machine (H50 K-S, Hounsfield, England), equipped with a 250 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 [19].

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. The average of major, intermediate and minor diameters for apple fruits at moisture content of 84.2 % (w.b) was 54.2, 51.6 and 50.3 mm, respectively. The geometric mean diameter of apple fruit in this research was 52.1 mm. With a geometric mean of 52.1 mm, The apple fruits were thus smaller than cactus pear with reported average principal dimensions of 71.93, 57.57 and 52.08 mm, respectively [21], and also smaller than the cantaloupe fruit with principal dimensions of 147, 140, 134 mm [22]. 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 [17] and highlighted by other researchers [23].

Table 1. selected some physical and mechanical properties of apple

Property	Observations	Mean ±SD
Moisture content, (% w.b)	5	85.3±0.7
Fruit mass, (g)	100	88.1±10.32
Fruit length, (mm)	100	54.2±2.56
Fruit width, (mm)	100	51.6±2.45
Fruit thickness, (mm)	100	50.3±2.68
Geometric mean diameter, (mm)	100	52.1±2.71
Bulk density, (kg/m^3)	5	450.1±18.59
Rupture force, (N)	5	45±1.13

The average fruit mass of the apple was 88.1 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 apple fruit has a mass smaller than wild mango fruit, cactus pear fruit and cantaloupe fruits [21,22,24].

The bulk density of apple was 450.1 kg/m^3. This value was bigger than orange with bulk density of 515.27 kg/m^3 [25]. This property could prove useful in the separation and transportation of the fruits by processing machines.

The average rupture force for apple fruit was 45 N compared with 22.39 N in mango fruit, 9.75 N in apricot and 57.38 N for olive fruit. Thus, the apple fruit has a smaller rupture force and more softness firmness than olive, but bigger than mango fruit and apricot [4,26,27].

The maximum height of box and estimated parameters of apple 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 apple fruit was obtained 194 cm. Then for caution this fruit should be not stored in containers with over 194 cm height. This value is higher than the value reported for peach fruit (70 cm) because rupture force of peach fruit (15 N) is smaller than the force need to break the apple fruit [14].

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

Parameter	Observations	Mean±SD
N	5	5113±14.27
θ, (deg.)	5	45.9±3.12
W, (N)	100	0.86±0.1
n	5	52±1.42
h, (cm)	5	194±3.14

4. Conclusions

Measuring maximum height of box for apple 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 apple fruit were 54.2 mm, 51.6 mm, 50.3 mm, 52.1 mm, 450.1 kg/m^3 and 88.1 g, respectively. Rupture force for apple fruit was 45 N that equal with 52 layers of fruits. Consequently, it is recommended for transporting and storing of apple fruit that use less than 194 cm of box or container until the fruit not broken due to the weight force of fruit bulk during handling and storing.

Compliance with Ethics Requirements

Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human and/or animal subjects (if exists) respect the specific regulations and standards.

References

1. Dobrzanski, B.; Rabcewicz, J.; Rybczynski, R., *Handling of Apple*. Institute of Agrophysics polishes Academy of Sciences (IA PAS) Press, Lublin, Poland, **2006**, pp. 1-13.
2. FAO, FAOSTAT database, **2011**, Available at: http://faostat.fao.org.
3. Stroshine, R., Physical Properties of Agricultural Material and Food products. West Lafayette: Dept of Agricultural Engineering Purdue Univ. Press, New York, USA. **1998**, pp. 175-189
4. Kilickan, A.; Guner, M., Physical properties and mechanical behavior of olive fruits (*Olea europaea* L.) under compression loading, *Journal of Food Engineering* **2008**, *87*, 222–228.
5. Bahnasawy, A. H.; El-Haddad, Z. A.; El-Ansary, M. Y., Physical and mechanical properties of some Egyptian onion cultivars. *Journal of Food Engineering* **2004**, *62*, 255-261.
6. R. K. Goyal, A. R. P. Kingsly, P. Kumar, H. Walia, Physical and mechanical properties of aonla fruits. *J. Food Eng.*, **2007**, *8*(4), 595-599.
7. Owolarafe, O. K; Shotonde, H. O., Some physical properties of fresh okro fruit. *Journal of Food Engineering* **2004**, *63*, 299–302.
8. Lorestani, A. N.; Tabatabaeefar, A., Modeling the mass of kiwi fruit by geometrical attributes. *International Agrophyscs* **2006**, *20*(2), 135-139.
9. Pallottino, F.; Costa, C.; Menesatti, P.; Moresi, M., Assessment of the mechanical properties of Tarocco orange fruit under parallel plate compression. *Journal of Food Engineering* **2011**, *103*(3), 308-316.
10. [Keramat Jahromi, M.; Mohtasebi, S. S.; Jafari, A.; Mirasheh, R.; Rafiee, S., Determination of some physical properties of date fruit (cv. Mazafati). *Journal of Agricultural Technology* **2008**, *4*(2) 1-9.
11. Baryeh, E. A., A simple grain impact damage assessment device for developing countries. *Journal of Food Engineering* **2002**, *56*, 37-42.
12. [Shahbazi, F., Impact Damage to Chickpea Seeds as Affected by Moisture Content and Impact Velocity. *Applied engineering in agriculture* **2011**, *27*(5), 771-775.
13. Bilanski, W. K., Damage Resistance of Seed Grains. *Transactions of ASAE* **1962**, *9*(3), 360-363.
14. Sitkei, G., Mechanics of Agricultural materials. Elsvier Science Publishers, Amsterdam, **1986**, pp.166-186.
15. AOAC., Official Methods of Analysis, 18th Ed. Association of Official Analytical Chemists, Washington DC, U.S.A. **2005**.
16. Ross, I. J.; Isaacs, G. W., Forces Acting in Stacks of Granular Materials (Part I). *Transactions of ASAE* **1961**, *4*(1), 92-96.
17. Mohsenin,. N. N., Physical properties of plants and animal materials. Gordon Breach Sci. Press, New York, USA, **1980**, pp.79-127.
18. Gupta, R. K.; Das, S. K., Physical properties of sunflower seeds. *Journal of Agricultural Engineering Research* **1997**, 66, 1–8.
19. Aydin, C.; Ozcan, M., Some physico-mechanic properties of terebinth (*Pistacia terebinthus* L.) fruits. *Journal of Food Engineering* **2007**, *53*, 97–101.
20. Paksoy, M.; Aydin, C., Some physical properties of edible squash (*Cucurbita pepo* L.) seeds. *Journal of Food Engineering* **2004**, *65*(2), 225–231.

21. Kabas, O.; Ozmerzi, A.; Akinci, I., Physical properties of cactus pear (*Opuntia ficus india* L.) grown wild in Turkey. *Journal of Food Engineering* **2006**, *73*,198–202.
22. Rashidi, M.; Seyfi, K., Classification of fruit shape in cantaloupe using the analysis of geometrical attributes. *World Journal* of *Agricultural Sciences* **2007**, *3*(6), 735-740.
23. Omobuwajo, T. O.; Akande, E. A.; Sanni, L. A., Selected physical, mechanical and aerodynamic properties of African breadfruit (Treculia africana) seeds. *Journal of Food Engineering* **2000**, *40*, 241–244.
24. Ehiem, J. C.; Simonyan, K. J., Physical properties of wild mango fruit and nut. International Agrophysics **2012**, *26*, 95-98.
25. Topuz, A.; Topakci, M.; Canakci, M.; Akinci, I.; Ozdemir, F., Physical and nutritional properties of four orange varieties. *Journal of Food Engineering* **2005**, *66*, 519–523.
26. Haciseferogullari, H.; Gezer, I.; Ozcan, M. M.; MuratAsma, B., Post harvest chemical and physical–mechanical properties of some apricot varieties cultivated in Turkey. *Journal of Food Engineering* **2007**, *79*, 364–373.
27. Jha, S. N.; Kingsly, A. R. P.; Chopra, S., Physical and mechanical properties of mango during growth and storage for determination of maturity. *Journal of Food Engineering* **2006**, *72*, 73–76.