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HOW TO OBTAIN THE PROPER BOX HEIGHT OF KIWI FRUIT FOR HANDLING AND STORING

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Abstract

Avoiding damage to fruit species the permissible falling height and permissible static pressure are of great importance. The shape of fruits is important in planning harvesting and handling operations, the latter in selecting the height of transport containers. Fruit is generally transported in containers. The static and dynamic forces which then act on the fruit will cause damage if they exceed the 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 kiwi 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 kiwi fruit in the box was determined to be less than 93 cm based on a rupture force of 21 N.

Key words: *kiwi fruit, static force, height box, physical properties.*

INTRODUCTION

Kiwi fruit originated from indigenous plant of Southern China (*Actinidia chinensis*) which was first developed commercially in New Zealand at the beginning of the 20th century (Luh & Wang, 1984). Nowadays, it is commercially cropped in many countries such as Italy, New Zealand, Chile, France, Iran and Greece. Based on FAO statistics, Iran produced about 69400 Mt of kiwi fruit in 2012, which is approximately 5.7% of the world's kiwi fruit production and is ranked as 5th among other producers (FAO, 2012). The kiwi fruit is not only consumed fresh, but also used to produce dried kiwi, frozen kiwi, jam, jelly, marmalade, juice, nectar etc.
The physical and mechanical properties of kiwi 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 fruit (Kilickan and Guner, 2008), physical and mechanical properties of Egyptian onion (Bahnasawy et al., 2004), physical and mechanical properties of aonla fruit (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 kiwi fruit was found in the literature.
The mechanical resistance to the damage of fruit 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 fruit and seeds depends on different 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. Fruit and vegetables can be deformed during storage as a result of static or quasi-static forces at points of contact with other fruit or storage containers. Static forces are applied on individual fruit, 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 decreased as a result, and in numerous cases mechanical damage is followed by rapid spoiling, whereby the biological 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 (Sitcki, 1986; Stroshine, 1998).

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

MATERIALS AND METHODS

Sample preparation

Mature fresh kiwi fruit of Hayward variety were collected from Mazandaran province of Iran, in October 2012. The fruit were cleaned manually to remove all foreign material and defective fruit. Then 100 healthy fruit 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 ambiental 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 82.9% (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 fruit, 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.

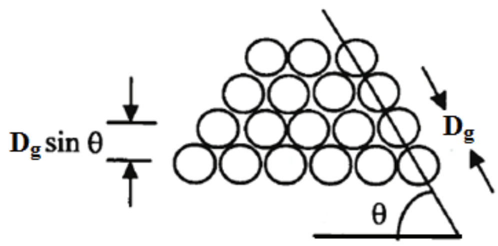

Figure 1. Rhombic stacking model for fruit

The individual particles are in contact along a line which makes an angle θ with the horizontal one. 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 fruit (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):

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

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.

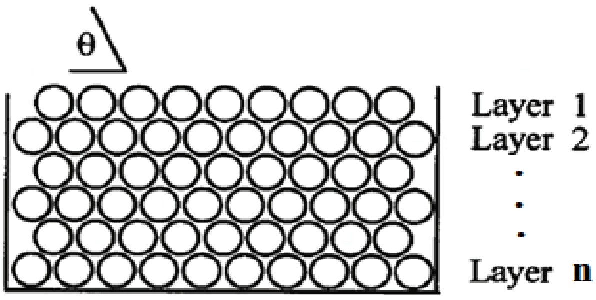

Figure 2. Diagram of stack of samples having n layers and confined by a vertical wall and a floor

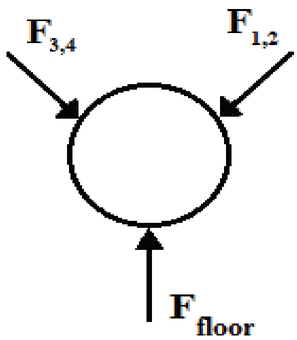

Figure 3. Static forces on the last layer of fruit

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):

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

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):

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

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

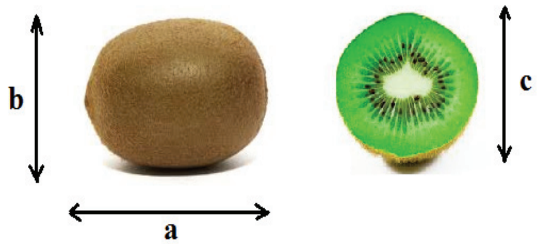

Figure 4. Dimensions of kiwi fruit; a, b and c are the length, width and thickness

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 for all moisture levels (Aydin and Ozcan, 2007).

Figure 5. Universal testing machine

RESULTS AND DISCUSSIONS

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 kiwi fruit at moisture content of 82.9% (w.b) was 68.1, 50.25 and 46.38 mm, respectively. The geometric mean diameter of kiwi fruit in this research was 54.07 mm. With a geometric mean of 54.07 mm, the kiwi fruit 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, as discussed by Mohsenin (1980) and highlighted by other researchers (Omobuwajo et al., 2000).

Table 1. Selected some physical and mechanical properties of kiwi fruit

Property	Observations	Mean ±SD
Moisture content, (% w.b)	5	82.93±0.8
Fruit mass, (g)	100	100.22±12.62
Fruit length, (mm)	100	68.1±3.76
Fruit width, (mm)	100	50.25±3.65
Fruit thickness, (mm)	100	46.38±2.88
Geometric mean diameter, (mm)	100	54.07±3.81
Bulk density, (kg/m^3)	5	563.2±19.49
Rupture force, (N)	5	21±1.63

The average fruit mass of the kiwi was 100.22 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 kiwi fruit has a mass smaller than wild mango fruit, cactus pear fruit and cantaloupe fruit (Ehiem and Simonyan, 2012; Rashidi and Seyfi, 2007; Kabas et al., 2006).

The bulk density of kiwi was 563.2 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 fruit by processing machines.

The average rupture force for kiwi fruit was 21 N compared with 9.75 N in apricot, 22.39 N in mango fruit and 57.38 N for olive fruit.

Thus, the kiwi fruit has a bigger rupture force and more firmness than apricot but smaller than the mango fruit and olive fruit (Haciseferogullari et al., 2007; Jha et al., 2006; Kilickan and Guner, 2008).

The maximum height of box and estimated parameters of kiwi 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 kiwi fruit was obtained 93 cm. Then for caution this fruit should be not stored in containers with over 93 cm height.

This value is higher than the value reported for peach fruit (70 cm) because rupture force of kiwi fruit is greater than the force required to break the peach fruit (15 N) (Sitkei, 1986).

Table 2. Estimated parameters to calculate the maximum height of box for kiwi fruit storage

Parameter	Observations	Mean±SD
N	5	5630±13.17
θ, (deg.)	5	53.7±3.12
W, (N)	100	0.98±0.1
n	5	21±1.81
h, (cm)	5	93±4.34

CONCLUSIONS

Measuring maximum height of box for kiwi 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 kiwi fruit were 68.1 mm, 50.25 mm, 46.38 mm, 54.07 mm, 563.2 kg/m^3 and 100.22 g, respectively. Rupture force for kiwi fruit was 21 N that equal with 21 layers of fruit. Consequently, it is recommended for transporting and storing of kiwi fruit that use less than 93 cm of box until the fruit not broken due to the weight force of fruit bulk during handling and storing.

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