Some Physical Properties of Apple cv. 'Golab'

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ABSTRACT

Apple is among the popular fruits and of a high economic value. Sorting and grading of apple is needed for the fruit to be presented to local and foreign markets. A study of apple physical properties therefore is imperative. Some physical properties of apples were determined. These properties include: dimensions, mass, volume, surface area, porosity, packaging coefficient and coefficient of static friction. The maximum, average and minimum diameters of apple were 65.04, 53.50 and 35.14 mm respectively. Average volume and mass were 104.5 cm^3 and 74.87 g respectively. As for an apple pile, the density and apparent density were respectively calculated as 0.7427 and 0.2401 g/cm^3. Maximum, average and minimum porosity of apples were 57.24, 54.13 and 50.17 percent with their sphericity being 1.0028, 0.93 and 0.84 respectively. Average static friction angle of apple on galvanized, glass and plywood surfaces were 20, 26.3 and 26.8 degrees respectively. Average packaging coefficient for the apples studied was 0.45.

Keywords: Physical properties, apple, static friction angle, packaging coefficient

1. INTRODUCTION

Among fruits, apple is the most important economically and industrially. It is consumed in different forms, such as fresh fruit, concentrated juice or thin dried slices. Apples contain a high percentage of their fresh weight as water. Apple was introduced into Iran many years ago. Iran currently ranks 6th among the apple producing countries of the world (ASB, 2005). Grading and sizing of fruits is a prerequisite for proper packaging, but unfortunately not much importance has been attached to its study (ICRI, 2005). There is no suitable set of standards for grading and sorting of fruits.

Physical specifications of agricultural products constitute the most important parameters needed in the design of grading, transferring, processing, and packaging systems. Physical specifications, mechanical, electrical, thermal, visual, acoustic and chemical properties are among attributes of useful engineering application. Mass, volume and center of gravity are the most important physical parameters of agricultural products used in sizing systems (Safwat and Moustafa, 1971). Morphological parameters, measurable through sizing systems are: dimensions (length, width and height), surface area and weight (Khojastehpour, 1996).
Mass, volume, surface area, dimensions, apparent volumetric mass, real volumetric mass, geometric mean diameter, packaging coefficient, porosity, sphericity and static friction angle were measured through the experiment.
Tabatabaeefar (2000) in a study of physical properties of Iranian potatoes measured the parameters of physical dimensions, mass, volume, specific mass, mean geometrical diameter, sphericity and surface area for four varieties: Vital, Draga, Agria, and Ajax. Test samples of the four varieties (350 samples) have been collected from different areas throughout the

country. Parameters, such as physical dimensions, mass, volume, specific mass, average diameter, sphericity and surface area were determined for each, as well as for a mixture of varieties. Also, Pitts et al. (1987), through a study of potato physical properties, found models for prediction of tuber mass based upon dimensions. Tabatabaeefar et al. (2000) found 11 models for prediction of mass of orange fruits based upon dimensions, volume and surface areas. Lorestani (2001) studied physical properties of two cultivars of kiwifruit (Abbot, Hayward) and established 11 models for estimating fruit mass based on dimensions and surface area.

Tabatabaeefar and Rajabipour (2005) predicted apple mass through models that were based upon apple's physical properties. Khojastehpour in 1996, based upon a study of physical properties, presented a report on the design and development of a potato grading machine that suited Iranian conditions. Safwat and Moustafa (1971) studied theoretically and predicted volume, surface area and center of gravity of different agricultural products. Safa and Khazaei (2003) and Al-Maiman and Ahmad (2001) studied the physical properties of pomegranate and found models for predicting fruit mass while employing dimensions, volume and surface area. Topuz et al. (2005) studied the physical and nutritional properties of four varieties of orange. They presented results of measurements based on dimensions, volume, mean geometrical diameter, surface area, fruit density, pile density, porosity, packaging coefficient, and friction coefficient. Owolarafe et al. (2007) investigated physical properties of two varieties of palm fruit useful in production of palm oil and palm kernel. It becomes imperative to characterize fruits with a view to understand the properties that may affect the design of machines to handle their processing. Some physical properties such as size, shape, sphericity, true density, bulk density, porosity and mechanical properties such as coefficient of friction, angle of repose as well as fracture resistance are very important in the design of processing machines for major agricultural crops. Rafiee et al. (2006) estimated mass of date cv. 'Ghasb' by artificial neural network. They used a multi-layer feed forward network structure with input, output and hidden layer(s). Two neural network models were constructed to predict the mass using the dimension properties of the date. Jahromi et al. (2007) estimated some physical properties of date fruit, such as mass, length, thickness, volume and projected area. Also many studies have reported on the physical properties of gumbo fruit (Akar and Aydin, 2005) and chick pea split (Ghadge et al., 2008).

Shape, size, surface area, density, porosity, static friction angle are among physical specifications that are of paramount importance in either design of a machine or in an analysis of material behavior during transfer. In the present study, the above mentioned properties have been determined for apple cv. 'Golab'. Corresponding calculations have been made and results reported.

2. MATERIALS AND METHODS

2.1 Sample Preparation

In this study, the apples were selected from cv. 'Golab' which is an Iranian cultivar of apple. From the whole, about 100 apples were randomly obtained from a local market (Tajrish market) in Tehran. The apples were transferred to the Physical Laboratory of Biosystems Faculty in the University of Tehran for experiments.

2.2 Physical Characteristics

Some parameters, such as coefficient of sphericity, mean geometrical diameter, apparent specific mass, an apple pile's specific mass and packing coefficient (Mohsenin, 1986) were obtained. In this measurement, dimension *a* is the main (major) diameter, *b* (intermediate diameter) is the longest dimension perpendicular to *a* and *c* (minor diameter) is the longest dimension perpendicular to *a* and *b*.

Fruit mass was determined through a digitalized sensitive balance (GF3000, A&D, Japan) with a capacity of 0–3000 g and accuracy of ±0.01 g.

In order to determine fruit volume, a water containing container was placed on the balance, one needle was thrust in the fruit and one lever moved the needle, so that the fruit floated in water and the mass of displaced water was calculated.

$$volume(cm^3) = \frac{displaced\ water(g)}{water\ specific\ mass(g/cm^3)} \quad (1)$$

Other parameters derived from primary physical attributes were obtained as well. Bulk density was calculated by using the following equation (Mohsenin, 1986):

$$BD = \frac{M_C}{V_C} \quad (2)$$

Where BD is apparent specific density (g/cm^3), M_c is carton mass (g), V_c is carton volume (cm^3). A pile of fruit's specific mass was calculated using the relationship given by Mohsenin (1986) as:

$$SD = \frac{M}{V} \quad (3)$$

Where SD is solid density (g/cm^3), M is fruit mass (g) and V is fruit volume (cm^3). The porosity was calculated as:

$$\mathrm{P} = \left(\frac{V_c - V_o}{V_c}\right) * 100 \quad (4)$$

Where P is porosity and V_o is volume of apples present in the carton (cm^3). Static friction angle was obtained through use of an inclinometer and 3 (galvanized, glass and wooden) planes (Al-Maiman and Ahmad, 2001). Mean geometrical diameter was determined from equation (5) (Topuz et al., 2005):

$$GM = \sqrt[3]{abc} \quad (5)$$

Where GM is mean geometrical diameter (mm), *a* is the main diameter (mm), *b* (mm) is the longest diameter perpendicular to *a*, and *c* (mm) is the longest diameter perpendicular to *a* and *b*. Sphericity was obtained from equation (6):

$$S_{ph} = \frac{GM}{a} \quad (6)$$

Where S_{ph} is sphericity, GM is mean geometrical diameter and *a* is the main diameter of the fruit. The surface area was calculated using the relationship given by Topuz et al. (2005) as:

$$S = \pi \times GM^2 \quad (7)$$

Where S is surface area and GM is mean geometrical diameter. The Coefficient of packaging was computed (Topuz et al., 2005) as:

$$\lambda = \frac{V_o}{V_c} \tag{8}$$

Where V_o is volume of fruit present in the carton and V_c is volume of carton.

2.3 Regression Models

Fruit mass can be estimated on the basis of independent variables of the three dimensions, length, width, and density of the fruit. Towards this end, SPSS (version 13, SPSS Inc., USA) software and stepwise method were employed. The overall model is based on the following equation

$$M = k_1 a + k_2 b + k_3 D + k_4 V + k_5 \tag{9}$$

Where M is fruit mass (g); *a* and *b* are length and width of apples (mm); D is density (g/cm^3); V is volume (cm^3) and k_1, k_2, k_3 … are coefficients of regression. In the stepwise method, independent variables were entered into the equation successively based upon their degree of dependency. The fruit model introduced bears the least independent variable. Other succeeding variables gradually got into the model according to the order of their prominence.

3. RESULTS AND DISCUSSION

3.1 Results

Determined physical properties of apple samples are presented in table 1. The maximum, average and minimum length of apples were 64.87, 57.02 and 48.01 mm, and 65.04, 57.52 and 48.25 mm were obtained for width, respectively. As observed from table 1, the maximum, average and minimum thickness of apples were 59.55, 45.98 and 35.14 mm, respectively. As also seen in the same table, the maximum, average and minimum volumes of apples were 137.06, 104.50 and 76.09 cm^3, respectively. The maximum, average and minimum apparent specific masses of apples were 0.7966, 0.7427 and 0.6836 g/cm^3, respectively. The maximum, average and minimum porosity of apples were 57.24, 54.13 and 50.17 %, respectively. Maximum, average and minimum static friction angles for apple cv. ‘Golab’ on different surfaces were as follows: galvanized iron 22.0, 20.0 and 18.0°; glass surface 29.0, 26.3 and 24.0°; and wooden surface 29.0, 26.8 and 24.5°. Packing coefficients, as indicated in table 1, were 0.50, 0.45, and 0.42.

3.2 Evaluation of the Regression Models

The equations were calculated using stepwise method and on the basis of independent. Volume was the first independent variable on the basis of which fruit mass was estimated (coefficient of determination R^2=0.991).

$$M = 0.6699V + 7.5001 \tag{10}$$

Taking into account all the independent variables, the mass of apple was best evaluated with a determination coefficient of R^2=0.999.

$$M = 0.7471V + 101.4295SD - 75.9579 \tag{11}$$

As indicated by figure 1, apple mass can be estimated on the basis of length. Prediction of apple mass on the basis of any of the variables of length, volume and width has been made (fig. 1-3). The coefficients of determination were 0.776, 0.963 and 0.764 respectively. Any of the above variables was in significant correlation with apple mass and can be employed in development of the one degree regression model for estimation of the apple mass. Since measurement of the length is the easiest, this parameter can be employed in an equation of apple mass determination as follows (R^2=0.7762):

$$M = 2.6025a - 73.952 \quad (12)$$

Table 1: Some physical properties of apples cv. 'Golab'

Physical property		Number of observations	maximum	average	minimum
a (length),mm		100	64.87	57.02	48.01
b (width), mm		100	65.04	57.52	48.25
c (thickness), mm		100	59.55	45.98	35.14
fruit mass, g		100	103.06	74.87	50.29
fruit volume, cm^3		100	137.06	104.50	76.09
Bulk density, g/cm^3		50	0.3406	0.2401	0.1230
Fruit density, g/cm^3		50	0.7966	0.7427	0.6836
Porosity, %		50	57.24	54.13	50.17
Geometric mean diameter, mm		100	60.72	53.04	45.14
Sphericity, %		100	1.0028	0.93	0.84
Surface area, mm^2		100	11.6×10^3	8.9×10^3	6.4×10^3
Packaging coefficient		30	0.50	0.45	0.42
Coefficient of	Glass	30	29.0	26.3	24.0
static friction	Galvanized steel	30	22.0	20.0	18.0
(deg)	Plywood	30	28.0	26.8	24.5

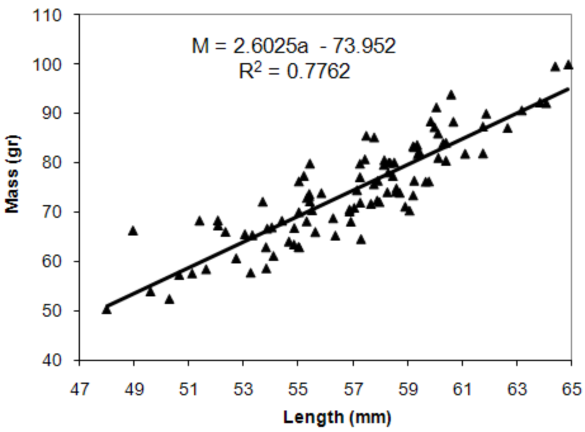

Figure 1. The relationship between length and mass of apple

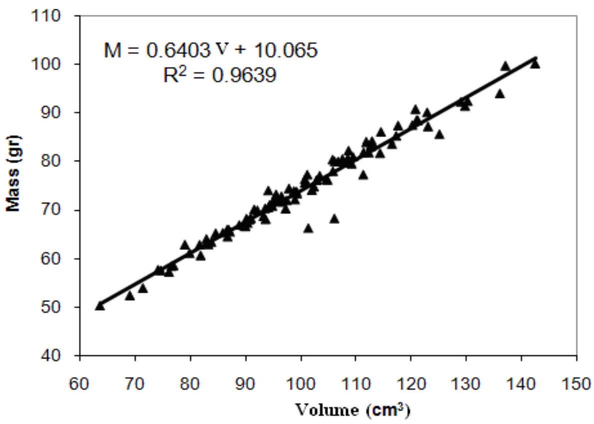

Figure 2. The relationship between volume and mass of apple

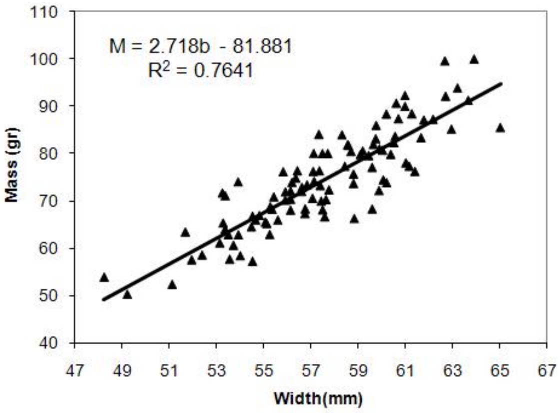

Figure 3. The relationship between width and mass of apple

4. CONCLUSIONS

- Maximum, average and minimum length, width, thickness, volume and mass were determined for apples as follows:
  - Maximum: 64.87, 65.04 and 59.55mm, 137.06 (cm^3), and 103.06 (g)
  - Average: 57.02, 57.52 and 45.98 mm, 104.50 (cm^3), and 74.87 (g)
  - Minimum: 48.01, 48.25 and 35.14 mm, 76.09 (cm^3), and 50.29 (g)
- Maximum, average and minimum apparent specific mass for apples were 0.796, 0.7427 and 0.683 (g/cm^3) respectively. Maximum, average and minimum bulk density of apple were respectively 0.340, 0.240 and 0.123 (g/cm^3). Maximum, average and minimum porosity for apples were recorded as 57.24, 54.13 and 50.17 %, respectively.
- Maximum static friction angle was recorded on galvanized, glass and wooden surface as 22.0°, 29.0° and 28.0° respectively. Average angles were 20.0°, 26.3° and 26.8°; minimum angles were 18.0°, 24.0° and 24.5°.
- A linear model of the apple mass was developed on the basis of the independent variables of length and width, as well as on the basis of volume. The mass of apple was best evaluated with a determination coefficient of R^2=0.999 that was estimated by $M = 0.7471V + 101.4295SD - 75.9579$

The most recommended regression model to fit apple mass was a linear model and one based upon the volume of apple**.**

5. ACKNOWLEDGMENT

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