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Some Physical Properties of Full-Ripe Banana Fruit (*Cavendish* variety)

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Physical properties of fruits and vegetables are the subject of many researches because of its importance in designing of agricultural machinery. Banana fruit is one of important fruit. In this study some physical properties of banana fruit (*Cavendish* variety) were determined. Properties which were measured included weight of whole fruit peel and pulp weight, dimensions, surface area and projected area. The actual surface area and projected area were measured by image processing technique. The calculated attributes were geometric mean diameter, sphericity, radius of curvature, assumed ellipsoidal volume, surface area and projected area. The diameters of fruit varied as quadratic form. High correlation was observed among assumed ellipsoidal attributes and measured properties. The highest correlation was between estimated projected area and measured projected area as R^2= 0.978. **[Mahmoud Soltani et al. Some physical properties of full-ripe banana fruit (*Cavendish* variety). International Journal of Agricultural Science, Research and Technology, 2011; 1(1):1-5].**

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1. Introduction

Physical properties of fruits and vegetables are necessary data to design an agricultural machine for handling, cleaning, conveying, sorting and other treatments, also the size of individual units of a product can significantly affect consumer appeal, handling practice, storage potential, and market selection. So investigation of agricultural products physical characteristics is the subject of numerous researches and studies. Many studies have been reported on the physical and mechanical properties of fruits, such as bergamot (Keramat Jahromi et al, 2007), coconut (Terdwongworakula et al, 2009), date fruit (Keramat Jahromi et al, 2008), kiwi fruit (Lorestani and Tabatabaeefar, 2006), longan fruit (Varith et al, 2008), melon (Emadi et al, 2009), orange (Khojastehnazhand et al, 2009) and citrus fruits (Omid et al, 2010). Keramat Jahromi et al (2007) modeled mass and surface area of bergamot by physical attribiutes such as dimensional characteristics and projected areas. They reported all determining coefficients for surface area modeling were higher than R^2= 0.92 and the highest determining coefficient in all models was obtained as R^2 =1 for some combinations of projected areas. Lorestani et al (2006) measured The physical characteristics of kiwi fruit included mass, volume, dimensions and projected areas perpendicular to major diameters. They used these properties to predict the mass of kiwi fruit. Khojastehnazhand et al (2008) determined volume and projected area of orange by image processing technique. They assumed each orange was composed of a number of right elliptical cone. They computed the volume and surface area of each frustum by the segmentation method. They approximate the total volume and surface area of the orange by suming of all elementary frustums.

Among fruits and vegetables, banana fruit has exclusive physical properties that make it different from other fruits and vegetables such as shape and curvature. Also banana is one of fruits that need to extract its physical properties as a result of its importance. Banana is a popular fruit and the fourth most important food crop in the world, after rice, wheat and maize, in terms of gross domestic product, with a world production of about 70 million tons in 2003 (Lorestani and Tabatabaeefar, 2006). Banana fruit is grown in many countries in sub-tropical areas and the big exporters are located in South East Asia, South America and the Caribbean. The *Cavendish* variety is widely produced by these countries. This huge volume of banana cultivation needs to design

related machinery. Physical properties play an important role in machine designing.

For banana fruit, some researches were accomplished about its physico-mechanical properties. For example, Kachru et al (1995) investigated physical and mechanical characteristics of two varieties of green-mature banana fruit. Ahmad et al (2001) conciliated the temperature effect of ripening treatment on properties of banana fruit. Salvador et al (2007) studied the changes in color and texture of banana during storage at 10 ºC and 20 ºC. They found that during storage, the change in peel color from green to yellow was gradual in the *M. Cavendish* samples, whereas the *M. Paradisiacal* variety presented a different pattern, remaining green for the first 8 days and then changing rapidly to a yellow tone from day 12 onwards. While the flesh texture of the *M. Cavendish* type bananas softened quite rapidly during storage, it evolved more slowly in the *M. Paradisiacal* variety and there was little variation in the flesh hardness values over the storage time.

This paper aims to investigate some physical properties of *Cavendish* variety of banana fruit include weight of pulp and peel, peel to pulp ratio, external and internal length, diameters, geometric mean diameter, sphericity, actual surface and projected area, assumed ellipsoid surface and projected area.

2. Material and Methods

Banana fruits (*Cavendish variety*) shipped out from the Ecuador were used in this experiment. The banana fruits have been stored at 14 ºC temperature during transportation. The samples were randomly selected from banana boxes in Damirchilo warehouse located in Karaj city of Alborz province and transferred to the Physical Properties of Materials Laboratory, Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran.

The external and internal length of banana (L_o, L_i) was measured by a flexible ruler (Figure 1). The perpendicular diameters (D_i, d_i) were measured to 0.01 mm accuracy by a digital caliper (Figure 2). The mass of each sample was measured by a digital balance with an accuracy of 0.01 g.

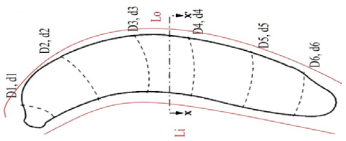

Figure 1. Longitudinal section of banana fruit

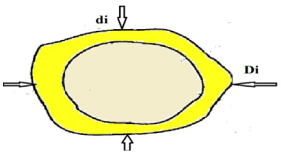

Figure 2. Plane of cut along the longitudinal axis of the banana

The average value of L is calculated from:

$$L = \frac{(L_o + L_i)}{2}$$

The difference between L_o and L_i was defined as:

$$\Delta L = L_O - L_i$$

Geometric mean diameter (D_g) and sphericity (ϕ) values were determined using the following equations [11]:

$$Dg = (L_{ave} \cdot D_{ave} \cdot d_{ave})^{0.333}$$

$$\phi = \frac{D_g}{L}$$

$$D_{ave} = \frac{D_3 + D_4}{2}$$

$$d_{ave} = \frac{d_3 + d_4}{2}$$

The intermediate section of banana was assumed as a part of ring (Figure 3). So the radius of curvature was obtained from:

$$R = \frac{L_i}{\Delta L} D_{ave}$$

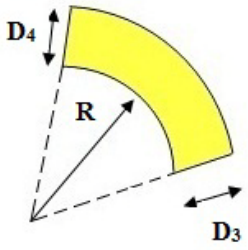

Figure 3. The assumed intermediate part of banana

The banana fruit shape was assumed as an ellipsoidal shape and thus its estimated volume (V_{ellip}), surface area and projected area (S_{ellip}) were estimated as:

$$V_{ellip} = \frac{\pi}{6 \times 1000} L_{ave} \cdot D_{ave} \cdot d_{ave}$$

$$S = \pi . D_g^2 \quad (9)$$

$$P_{ellip} = \frac{\pi}{6 \times 100} L_{ave} \cdot D_{ave} \quad (10)$$

The actual projected area and surface area were measured by image processing technique. This system consisted of the light emitting chamber utilized as to emit light from behind the fruit. The equipment was set as a whole are composed of the three different basic sections of light source, diffuser, and camera holding stand. The function of the light source (4×20W lamps) is to emit light to the bottom section of the diffuser. The diffuser task is to diffuse light at its level. The camera (model Canon Power Shut A85, Japan) was mounted on 40 cm above the diffuser. To measure the projected area, the banana fruit was laid on a flat surface and allowed to reach its natural rest position, then the image was captured, after that the banana was peeled and the peel was weighted. The rind was set between the diffuser and a vitreous brede to tabulate it and the image was acquired again. The acquired images from digital camera were transmitted to the MATLAB 7 software and then the area was computed as following procedure:

A single grayscale threshold was used to determine if an image pixel belongs to the background or the object. Once the threshold was determined, the object boundary can be traced and the number of pixels can be enumerated. System calibration was performed by attaching a quadrangular card (100 cm^2 area). The card was employed to provide pixel per cm^2 ratio.

3. Results and discussion

The Weighting properties of banana fruit as a weight of whole fruit, weight of peel and pulp, the percent of peel and pulp and pulp-peel ratio are presented in Table 1. The average weight of whole, peel and pulp of fruit were 180.56 g, 66.02 g and 114.54 g respectively. Kachru et al [3] reported 89.69 g and126.16 g of whole fruit for Dwarf *Scavendish* and *Nendran* variety respectively. The average value of banana peel percent was 36.6, while Kachru et al (1995) reported the average value 41.9% and 30.23% for peel percent for Dwarf *Scavendish* and *Nendran* variety respectively. Also they reported 1.39 and 2.32 as pulp to peel ratio respectively, while we obtained the pulp-peel ratio as 1.74. These results show the *Cavendish* banana has a thicker peel than *Nendran* variety and has a thinner peel than *Dwarf Scavendish* variety.

Table 1. Weighting properties of full-ripe banana fruit (Cavendish).

Property	Average	Min	Max	Sd
Weight of fruit (g)	180.56	121.10	272.50	36.25
Weight of peel (g)	66.02	47.20	99.30	13.11
Weight of pulp (g)	114.54	73.90	173.20	23.74
Peel percent (%)	36.6	32.15	40.87	1.89
Pulp percent (%)	63.38	59.13	67.86	1.89
Pulp/peel	1.74	1.45	2.11	0.14

The dimensional properties of banana fruit are presented in Table 2. The average value of external and internal length was 235.33 mm and 165.17 mm. it is because of being curvature in structure of banana fruit. Banana has a cushioned shape. Figure 4 shows the average values of D_1 to D_6 and d_1 to d_6 respectively. Changes in these perpendicular diameters were as function of their position on banana. Diameters varied as a polynomial form.

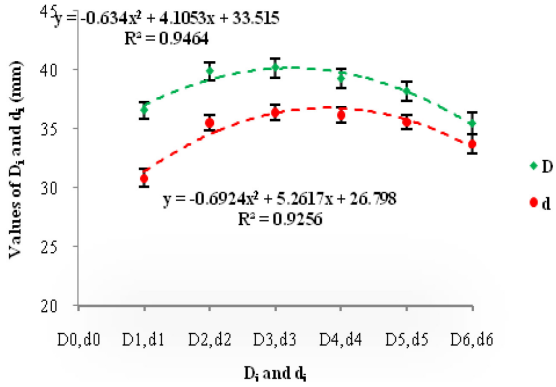

Figure 4. The average values of banana fruits. The vertical lines represent 5% confidence interval

The D_{ave} and d_{ave} were obtained 40.34 mm and 36.56mm respectively. Kachru et al (1995) obtained the maximum diameter as 30.86 mm and 23.13 mm for Dwarf *Scavendish* and *Nendran* variety respectively. The size of Cavendish variety was larger than Dwarf *Scavendish* and *Nendran* variety.

Table 2. Dimensional properties of full-ripe banana fruit

Property (mm)	Average	Min	Max	Sd
L_o	235.33	202	288	24.24
L_i	165.17	135	220	21.95
L	200.25	168.50	247.50	22.29
ΔL	70.16	45	89	12.28
D_1	36.60	31.38	42.36	2.49
D_2	39.89	34.18	48.96	2.66
D_3	40.20	33.41	49.15	2.84
D_4	39.25	32.69	48.90	2.89
D_5	38.20	32.06	47.36	2.73
D_6	35.48	28.34	45	3.22
d_1	30.83	26.17	36.36	2.66
d_2	35.52	30.38	39.56	2.32
d_3	36.40	31.46	40.90	2.38
d_4	36.20	31.17	40.70	2.23
d_5	35.61	31.06	39.37	2.14
d_6	33.72	22.32	38.60	2.95
D_{ave}	40.34	34.88	49.15	2.64
d_{ave}	36.56	31.46	40.90	2.30

Results of other estimated and calculated properties are presented in Table 3. The radius of curvature was 98.67 mm. it means a circle with a 98.67 mm radius is tangent to middle section of banana fruit. Average value of geometric mean diameter was 66.52 mm that varied between 56.97 mm and 78 mm. the sphericity was obtained as 0.33.

Table 3. Physical properties of full-ripe banana fruit

Property	Average	Min	Max	Sd
R (mm)	98.67	65.52	174.4	26.46
D_g (mm)	66.52	56.97	78	4.42
ϕ	0.33	0.30	0.37	0.02
V_{ellip} (cm^3)	156.10	96.77	248.42	32.16
S_{ellip} (cm^2)	139.62	101.96	191.17	18.86
P_{ellip} (cm^2)	63.76	46.14	94.53	10.91
S (cm^3)	181.48	141.27	242.63	27.67
P (cm^2)	75.87	54.78	116.29	13.38

The sphericity of banana was low; it is acceptable, because banana is an elongated shape fruit (oblong shape). The average ellipsoid volume was calculated as 156.1 cm^3. High correlation was found between the weight of fruit and ellipsoid volume of banana (Figure 5).

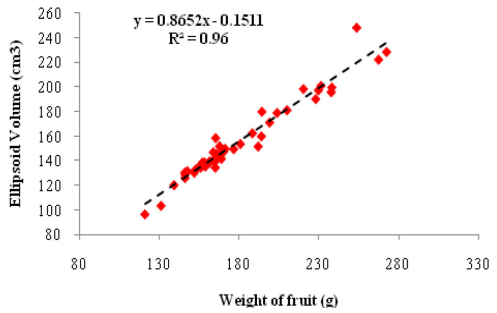

Figure 5. Estimation of ellipsoid volume of banana fruit by weight

The R^2 was obtained 0.96, so by measuring of weight, the ellipsoid volume can be estimated precisely. The average value of measured surface area was obtained as 181.48 cm^2. Result of regression estimation shows that the measured surface area had high correlation with S_{ellip}.

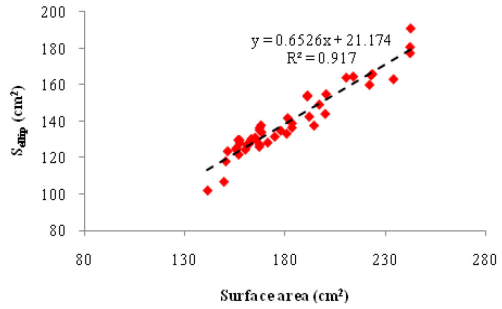

Figure 6. Correlation between measured surface area of banana fruit and estimated ellipsoid surface

The measured projected area varied between 54.78 cm^2 and 116.29 cm^2 with average value of 75.78 cm^2. Figure 7 shows that a very good correlation was found among P_{ellip} and measured projected area. The coefficient of determination (R^2) was obtained 0.978.

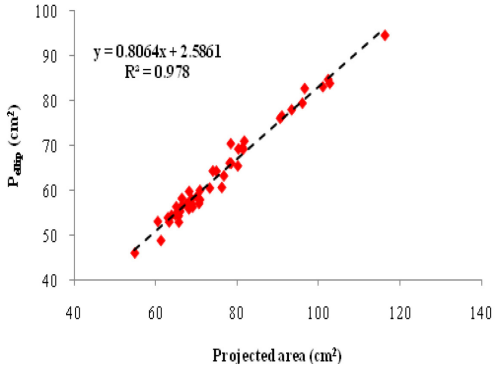

Figure 7. Correlation between ellipsoid projected area and measured projected area

4. Conclusions

Some physical properties of banana fruit (*Cavenish* variety) were investigated. From the difference between perpendicular diameters is concluded the section shape of banana is near to ellipse. It is concluded from ΔL that there is a curvature in the shape of banana fruit. The diameters (D_i and d_i) were varied in quadratic form. The actual values of surface and projected areas of banana were measured by image processing technique. Ellipsoidal estimation of banana fruit volume, surface area and projected area highly correlated with measured attributes. The highest correlation was obtained between ellipsoid projected areas and measured projected area. Image processing is a time consuming and complicated method. Also water displacement method is time consuming, besides water can be absorbed by fruit and influences chemical properties of sample. By ellipsoidal estimation the volume, surface and projected areas is calculated easily and reliably. Volume and surface area are beneficial in proper prediction of drying rates and hence the drying time in the dryer. Also, surface and projected areas are important to indicate physical properties such as water loss, gas permeability, heat transfer, quantity of pesticide applications and respiration rates, so ellipsoidal estimation is a useful method.

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