Physical Properties of Some Tropical Fruits Necessary for Handling

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Abstract
Some engineering properties of three vegetable fruits have been determined to enhance handling and processing of these fruits. The fruits are *Abelmoschus esculentus* (okra), *Solanum aethiopicum* (garden egg) and C*apsicum annum* (sweet pepper).Experiment was carried out on three fruit varieties to determine shape, volume, and surface area. The results of the experiments revealed that average values of volumes and surface areas of the three fruits, okra, sweet pepper, and garden egg were 13.28cm^3, 24.14cm^3 and 7.97cm^3; and 52.69cm^2, 33.67cm^2 and 26.58cm^2 respectively. The observed and the predicted values of volume for pepper and okra fruits were similar as the ANOVA test was insignificant at both 95 and 99% confidence interval except for that of garden egg. Also there were significant differences between the observed and the predicted surface areas of the fruit studied; hence the need for regression equation to predict the needed surface area for easy handling. Their shapes were also determined to be conical for okra and sweet pepper and prolate spheroid for garden egg.
Keywords: Prolate spheroid, Postharvest, Biomaterials, Storage structure, Pneumatic conveying, Silo.

1. Introduction

A vegetable fruit is a term used to describe the mature seed bearing structure of a flowering plant. Vegetables are soft and edible plant parts, some are leaves, stems, stalks and roots which are rich in vitamins, minerals, sugars and fibres (Ezeike, 1991). Fruits and vegetables are known to be highly perishable due to their high moisture content. This makes them susceptible to pest and microbial attack resulting in postharvest losses in the range of 30-50% (Oyeniran, 1985).

A study of the physical properties of biomaterials is essential for the design of processing machines, storage structures, and environmental parameter controls. Such data are useful in the analysis and determination of the efficiency of a machine or an operation, development of new products and new equipment and final quality of new products (Mohsenin, 1986). The size of agricultural materials such as grains, pulses and oil seeds have been described by measuring their principal axial dimensions (Kukello et al, 1987; Oje et al, 2001, Koya and Adekoya, 1994; (Perez – Alegria et al, 2001). Geometrical mean of the axial dimensions have also been shown to be adequate for calculating Reynold's number, projected areas and drag coefficient of food grain. These parameters are needed in the design of machine for pneumatic conveying, fluidization and separation of ground straw mixtures (Gorial and O'Callaghan, 1990). Density and specific gravity of biomaterials play important roles in many applications, and are useful in drying and storage of hay products, design of silos and storage bins. Mohsenin (1970) reported that specific gravity and mass density of fruits have useful applications in mechanical compressing of ensilages, separation of undesirable materials and grading. Bulk density of a product is a major consideration in designing near ambient drying and aeration systems because these physical properties affect the resistance to air flow of stored mass (Bern and Charity, 1975) . To reduce post harvest losses in fruits and vegetables scientist and engineers in recent times have developed efficient handling and processing techniques (of biomaterials) through the use of mechanical, thermal, electrical, optical and sonic devices. In spite of all these ever increasing applications, an enough work is yet to be done about the basic physical characteristics and properties of these materials especially for tropical fruits. There is therefore need to determine the physical properties of these fruits to give more information that will enhance handling and processing. In this work the objective is to determine some physical properties of okra, garden egg and pepper.

2. Materials and Method

The experimental materials used for the research were bought from Ekonuwa market, Owerri, Imo State ,Nigeria. The vegetable fruits were *Abelmoschus esculentus* (okra); the shape being broad at the stem end, and tapering towards the apex end, *Solanum aethiopicum* (garden egg) which lies longitudinally in its natural rest position and *Capsium annum* (sweet pepper) has a shape which is broad at the stem end and tapering towards the apex end. The samples bought from the market were cleaned, sorted out and sixty (60) fruits were randomly selected for the experiments. For each fruit selected the shape of the biomaterial was determined by placing it on a graph paper and tracing its outline with a pencil in terms of longitudinal and transverse axes. A vernier calipers of accuracy + 0.02mm was used to measure the major, intermediate and minor diameters of the fruits. Measurements were also taken in three orientations of the fruit at each point and at constant intervals along the major diameter. The average values of the three replicates were then recorded for further analysis. Each fruit was weighed on an electronic weighing balance (Ohaus instrument model: Scout Pro SPU 402) to an accuracy of 0.01g to obtain the average mass of the fruits.

The actual (observed) volume of a fruit was determined by liquid displacement method following principle of Archimedes (Mohsenin, 1980). The calculated (predicted) volume was obtained by applying the appropriate mathematical formula using the axial dimensions of a solid. The volumes of okra and pepper fruits with shapes (tapering towards the apex end) (Mohsenin, 1980), were obtained using the equation:

$$V_{o,p} = \frac{1}{3}\pi r^3 h \qquad (1)$$

Where;

$V_{o,p}$ = Volume of okra, pepper.(cm^3); π = constant = 3.142; h, r = height, base radius of the conic section (cm)

The volume of garden egg was evaluated thus:

$$V_g = \frac{4}{3}\left(\pi ab^2\right) \qquad (2)$$

Where;

V_g = volume of garden egg (cm^3); π = constant = 3.142; a, b = major, minor semi axis of the elliptical section (cm). The actual surface area however was determined (using a non-destructive approach). The surface area of each fruit was determined by wrapping polyethylene paper around the surface of the fruit and cutting it off at the point of complete enclosure of the fruit. The paper was then unwrapped and spread across on a graph paper for surface area determination. For okra and pepper fruits, equation (3) was used to determine the predicted surface area.

$$S_{o,p} = \pi rl + \pi r^2 \qquad (3)$$

Where;

$S_{o,p}$ = Surface area of the fruit okra, pepper (cm^2); l = slant height of the fruit (cm);

r = base radius of the fruit (cm); π = a constant = 3.142

For garden egg the expression reported by Mohsenin (1980), equation (4), was used to evaluate the predicted surface area

$$S_g = 2\pi b2 + 2\pi\left(ab / e\right)\sin^{-1} e \qquad (4)$$

Where;

S_g = surface area of the garden egg (cm^2); π = a constant = 3.142; e = eccentricity, and defined as:

$$e = \left[1 - \left(\frac{b}{a} \right)^2 \right]^{1/2} \quad (5)$$

a, b, c, are as defined in equation (2)

The solid density, $\rho_{s,}$ was also determined using Archimedes' principle. In this technique the fruit was first weighed in air and force into water by means of a sinker rod for volume determination. Hence;

$$\rho_s = \frac{\text{Mass of the fruit in air(g)}}{\text{Volume of the fruit (cm}^3\text{)}} \quad (6)$$

The axial dimensions taken earlier on were also used to calculate the geometric mean diameter, spherecity and roundness as shown below:

$$S_p = \frac{\text{Geometric mean diameter}}{\text{Major diameter}}$$

i.e.

$$S_p = \frac{[a\,b\,c]^{1/3}}{a} \quad (7)$$

$$R = \frac{d_i}{d_c} \quad (8)$$

Where;

S_p = spherecity (decimal); R = Roundness (decimal); d_i = diameter of the largest inscribed circle (cm); d_c = diameter of the smallest circumscribed circle (cm); a = major diameter of the fruit (cm) b = intermediate diameter of the fruit (cm) c=minor diameter of the fruit.(cm)

An Analysis of Variance (ANOVA) using a completely randomized design was also carried out on the volume and surface area measurements.

3. Results and Discussion

From the experimental results obtained, it was found that okra fruit had a geometric mean diameter ranging from 1.66cm to 2.80cm with a mean value of 2.15cm. The mass, surface area and volume had mean values of 13.93g, 52.69 cm^2 and 13.28cm^3 respectively. The average values for density, roundness and sphericity were 1.04g/cm^3, 0.3 and 0.31 respectively. The predicted values for okra fruit based on the assumed conical shape were an average surface area of 34.7 cm^2 and average volume of 12.78cm^3. Standard errors of these measurements were as included in parenthesis (tables 1 and 2). The ANOVA tables for both volume and surface area are as shown on Tables 3 and 4 respectively.

It was found that the treatment combination in the measurement of volume was insignificant at both 95 and 99% confidence interval (Table 3), hence, it could be said that both the observed and estimated volumes were essentially the same.

From Table 4, it could be seen that the treatment combinations in the measurement of surface area of okra fruit differed significantly at both 95% and 99% confidence interval; thus, both the observed and the estimated surface areas differed from each other. A linear regression was however carried out to find an equation for the line of best fit as shown below:

$y = -18.173 + 2.04x$ ($r = 0.827$); where y = predicted surface area, x = observed surface area

The regression equation for the volume of okra was as follows:

$y = 1.00 + 0.9593x$ ($r = 0.973$); where y = predicted volume, x = observed volume.

These equations were summarized as shown in Table 5.

For measurements carried out on pepper fruits, the geometric mean diameter of the fruit ranged between 2.30 and 4.72cm with a mean value of 3.24cm (Table 1). The volume, surface area and mass had mean values of

24.18cm^3, 83.6cm^2 and 25.04g respectively. Density, roundness and sphericity had average values of 1.03g/cm^3, 0.16, and 0.43 respectively as shown in Table 2. Average values for surface area and volume based on the estimated shapes were 44.98cm^2 and 23.79cm$^{3.}$ Similarly, analysis of variance was also carried out and the summary is as shown on the Tables 3 and 4. In Table 3, the treatment combination of volume measurement has been found to be insignificant at both 95% and 99% confidence interval; hence the observed volume could be approximated as the predicted volume.

In Table 4, the ANOVA table has shown that the treatment combination of the surface area is significant at both 95% and 99% confidence interval; hence the observed surface area is not exactly the same as the predicted surface area. As a consequence a linear regression equation was used to estimate a line of best fit for the two measurements. Hence the equation for predicting the surface area of pepper fruit was $y = 12.55 + 1.58x$ ($r = 0.966$). A regression equation for the volume of pepper fruit is thus $y = 46.56 + 0.817x$ ($r = 0.914$) as shown on Table (5). Considering measurements taken on garden egg, the geometric mean diameter ranged between 1.50 and 2.80cm. The mean values of the mass, surface area and volume were 8.77g, 26.58cm^2 and 7.97cm^3 respectively; whereas density, roundness and sphericity had mean values of 1.11g/cm^3, 0.18 and 0.76. The mean values of predicted surface area and volume were 12.27cm^3 and 4.28cm^3. These values were as shown on Tables 1 and 2 with their respectively standard errors of the measurement (in parenthesis). Analysis of Variance was also carried out on the volume and surface area measurements of garden egg as shown on Tables 3 and 4.

From Table 3, it was observed that the treatment combination of volume measurement was found to be significant at 95% and 99% confidence interval. This implies that the observed volume cannot be estimated directly from the formula which relates to the shape of the fruit.. More so a similar observation was noticed in the case of surface area. The treatment combination was significant at 95 and 99% confidence interval implying that no direct estimate of the surface area from the assumed shape will be reliable. However a linear regression was carried out to derive an acceptable model for the two parameters. Hence, surface area was $y = 13.957 + 1.026x$ ($r = 0.833$) and for volume $y = 0.3842 + 1.950x$ ($r= 0.9905$). A summary of these equations are shown on Table 5

4. Conclusion

From the physical properties of the vegetable fruits studied, the following conclusions were arrived at:

(1) That the predicted and observed volumes of okra and pepper fruits showed no significant difference at probability levels of 5% and 1%; revealed by ANOVA test except for garden egg which showed significant differences at the same point.

(2) There were significant differences in both predicted and observed values of surface area of the three vegetables fruits - okra, pepper and garden egg - at probability levels of 5% and 1%, hence the need to establish a linear regression model to establish a relationship between them.

(3) As a result of the significant differences between the observed and the predicted values, regression models were developed to enhance estimation of the needed values for handling.

(4) Based on the above analysis and the models used for the prediction, it could be concluded that the shape of okra and pepper fruits are conical whereas the shape of garden egg is a prolate spheroid.

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Note 1: Values in parentheses, in the tables, are the standard errors of the measurements.

Table 1: Mean Values of Physical Properties of the Fruits

Vegetable fruit	**Major diameter (cm)**	**Intermediate diameter (cm)**	**Minor diameter (cm)**	**Geometrical diameter (cm)**	**Mass (g)**	**Surface area (cm^2)**	**Volume(cm^3)**	**Density(g/cm^3)**
Abelmuscus esculentus (Okra)	714 (0.21)	2.30 (0.01)	0.61 (0.02)	2.15 (0.05)	13.9 (2.54)	52.69 (9.61)	13.28 (0.95)	1.04 (0.01)
Capsicum annum (pepper)	7.37 (0.29)	3.39 (0.12)	1.48 (0.09)	3.24 (0.09)	25.04 (1.80)	83.67 (4.81)	24.18 (1.84)	1.03 (0.01)
Solanum aethiopicum (garden egg)	2.81 (0.09)	2.02 (0.05)	1.69 (0.06)	2.09 (0.06)	8.77 (0.50)	26.58 (1.29)	7.97 0.49)	1.11 (6.13)

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Table 2: Values of Physical Properties of the Fruits

Vegetable fruit	**Roundness**	**Spherecity**	**Average Estimated values of**	
			Surface area cm^2	**Volumecm^3**
Abelmuscus esculentus (Okra	0.31 (0.01)	0.32 (0.01)	34.72 (1.70)	12.78 (0.95)
Capsicum annum (pepper)	0.43 (0.01)	0.43 (0.01)	44.98 (2.95)	23.79 (2.08)
Solanum aethiopicum (garden egg)	0.76 (0.01)	0.76 (0.01)	12.27 (0.99)	4.28 (0.24)

Table 3: Analysis of Variance (ANOVA) of the Fruits Volumes

Fruit	Source of Variance	Degree of Freedom (df)	Sum of Square (SS)	Mean square (MS)	Fcal	Ftab	
						5%	1%
Abelmoschus esculentus (okra)	Among volume	1	3.69	3.69	0.13	4.0	7.08
	Within volume	58	1604.72	27.66			
	Total	59	1608.41				
Capsicum annum (sweet pepper)							
	Among volume	1	1.32	1.32	0.99	4.0	7.08
	Within volume	58	7039.94	12.13			
	Total	59	7041.26				
Solanum aethiopicum (garden egg)							
	Among volume	1	204.35	204.35	44.50	4.0	7.08
	Within volume	58	266.65	4.59			
	Total	59	471.30				

Table 4: Analysis of Variance (ANOVA) of the Fruits Surface Area

Fruit	Source of Variance	Degree of Freedom (df)	Sum of Square (SS)	Mean square (MS)	Fcal	Ftab	
						5%	1%
Abelmoschus esculentus (okra)	Among surface area	1	4819.32	4819.32	27	4.0	7.08
	Within surface area	58	10030.68	172.94			
	Total	59	14850				
Capsicum annum (sweet pepper)							
	Among surface area	1	22449.08	22449.08	45.27	4.0	7.08
	Within surface area	58	28758.60	495.83			
	Total	59	51207.68				
Solanum aethiopicum (garden egg)							
	Among surface area	1	3069.29	3069.29	73.48	4.0	7.08
	Within surface area	58	2422.42	41.76			
	Total	59	5491.71				

Table 5: Summary of Linear Regression Equations for the Vegetable Fruits

Vegetable fruit	Volume	R	Surface Area	R
Okra fruit	1.00 + 0.9593x	0.973	-18.173 + 2.04x	0.827
Pepper fruit	4.656 + 0.817x	0.914	12.55 + 1.58x	0.966
Garden egg	0.384 + 1.950X	0.99	13.957 + 1.026X	0.833