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Modeling the Length-Weight Relationship of Okra (*Abelmoscus esculentus* L.) Fruits for Separation Operations

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Abstract: The relationship between weight and length of okra (*Abelmoscus esculentus* L.) Moench fruits were modeled using the principle of dimensional homogeneity. Results showed that, at 95% confidence level, the developed power model comfortably predicted the weight of okra fruits based on length. Statistical parameters also indicated that there is no significant difference between model-predicted weight and the measured ones. Since okra fruits are often sorted and graded based on size, it is pertinent to understand the relationship between size and weight. This model can therefore be applied for the proper design of okra grading systems.

Key words: Grading · Fruits · Modeling · Okra · Size

INTRODUCTION

In agricultural processing, the importance of understanding the relationship between some linear attributes of biomaterials and their mass and volume cannot be overemphasized. This is because fruits and vegetables are often classified based on size (linear attributes), mass and volume either during processing or sales. Thus, their interrelationships are needed for the design of handling, sorting, processing and packaging systems. This has led many researchers to investigate the relationships between mass, length, width and volume of different agricultural materials *viz.,* [1] for pomegranate fruit; [2] for apple fruit; [3] for tangerine; [4] for apricot; [5] for bell pepper and [6] for onions.

Okra (A*belmoscus esculentus* L.) is a commonly used vegetable in Nigeria, especially in the southern parts of the country and therefore always found on the manual sorting-tables of producers and retailers. It is known to be nutritious and contain many vitamins and minerals. Therefore, studying the relationships between lengths, weight, volume and density of this vegetable could aid in the design of sorting, grading and packaging systems. Furthermore, investigating the fruit size could also aid in modeling fruit growth, yield predictions and growth curve monitoring [7]. However, there is little or no information on estimation of okra weight based on spatial attributes. It is therefore the objective of this study to develop a mathematical model to analytically predict the weight of okra using fruit length.

MATERIALS AND METHODS

Freshly harvested okra (ladies finger) fruits were obtained from Ebiburu Farms and transported in sack bags to the Food Processing Laboratory of the Niger Delta University, Amassoma in Bayelsa State. At the laboratory, all foreign materials were removed and 100 healthy samples of okra were randomly selected for analysis. The lengths and widths were measured using digital caliper (Mitutoyo, Japan) with accuracy of 0.01mm and the mass determined with digital balance with accuracy of 0.01g. The property of measured volume was determined by water displacement method for both okra fruits immediately after measuring the other parameters.

Mathematical Formulations: Literature review above disclosed that the following pertinent variables have a significant effect on the weight of fruits and vegetables. They are:

- Dependent variable;
  - Weight, $W = MLT^{-2}$

- Independent variables;
  - Density, $ñ = ML^{-3}$
  - Volume, $V = L^{3}$

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Thus, the dependent variable, weight (W) can be expressed as a function of the other variables as

$$Weight = f(density\ volume) \quad (1)$$

This implies that

$$w = f(\rho, v) \quad (2)$$

By Rayleigh's method, we get

$$w = v^a \rho^b \quad (3)$$

Dimensionally, we get

$$MLT^{-2} = (L^3)^A (ML^{-3})^B \quad (4)$$

Equating the powers of MLT on both sides of the equation yields
For M

$$1 = b \quad (5)$$

For L

$$1 = 3a - 3b \quad (6)$$

Substituting b=1 into equation (6) gives

$$a = \frac{4}{3}$$

Substituting the values of **a** and **b** into equation (3) where $V = L^3$ yields

$$w = L^4 \rho \quad (7)$$

Therefore, the weight- length relationship of fruits and vegetables can be presented in a general form as

$$W = KL^n \quad (8)$$

where **k** is the density factor and **n** is the power to which length must be raised to correlate weight and must vary from fruit to fruit.

Thus, plotting ***W*** against $\boldsymbol{L^4}$ yields a straight line and the value **K** is obtained as the slope. It is also important to note here, that the length was measured as the distance between the fruit cap scar at the base to the tip end of the fruit.

Data Analysis: All the data were then subjected to linear regression analysis using XLstat 2010 software and the goodness of fit was assessed based on the highest coefficient of determination (R^2) value.

RESULTS AND DISCUSSION

The physical attribute data for okra is presented in Table 1. Results show that okra length varied between 120.75mm and 52.04mm with an average value of 76.83mm and the diameter varied between 27.92mm and 14.16mm with an average value of 19.99mm.

Prediction Models for Okra: A regression analysis of Okra length (L^3) against okra weight (W) was performed using XLSTAT software and the following results (Table 2) were obtained;

Table 1: Summary of okra physical properties.

Properties	Max	Min	Mean±Std
L(mm)	120.75	52.04	76.83±4.70
D(mm)	27.92	14.16	19.99±3.04
M(g)	32.06	6.64	16.71±6.02
V(cm^3)	18779.79	2604.48	7606.74±5.27

Table 2: Statistical Results of the regression

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1	702.3964	702.3964	53.88108	1.09E-07
Residual	25	325.9012	13.03605		
Total	26	1028.298			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	12.06611	1.110391	10.86654	5.84E-11	9.779216	14.353	9.779216	14.353
X Variable 1	0.001208	0.000165	7.340374	1.09E-07	0.000869	0.001547	0.000869	0.001547

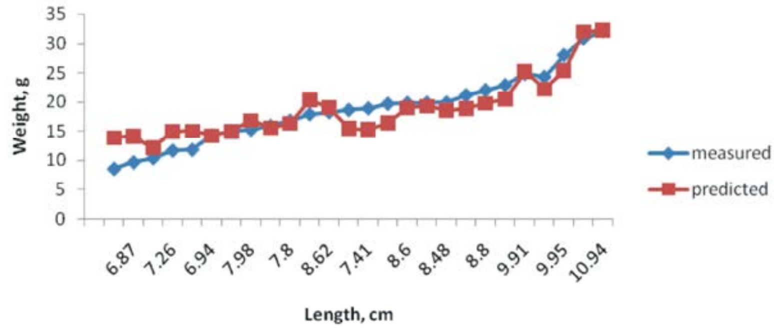

Fig. 1: Measured and Predicted weights of okra fruits against length.

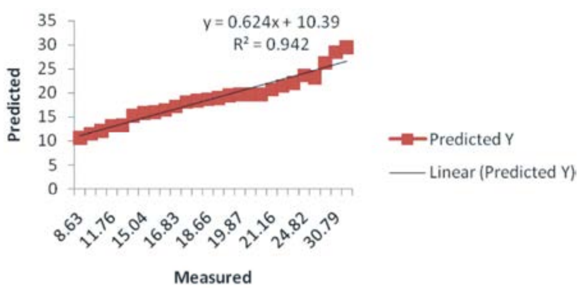

Fig. 2: Relationship between predicted and measured weights of okra fruit

Table 3: Paired t-test for Measured and Predicted Weights of okra fruits.

	Measured	Predicted
Mean	18.81346	18.85692
Variance	36.78894	29.87341
Observations	26	26
Pearson Correlation	0.902343	
Hypothesized Mean Difference	0	
Df	25	
t Stat	-0.08477	
P(T<=t) one-tail	0.46656	
t Critical one-tail	1.708141	
P(T<=t) two-tail	0.933121	
t Critical two-tail	2.059539	

$$W = 0.00012L^4 + 12.07 \quad (9)$$

where W is the weight (g) of okra and L the length (cm). This model was therefore validated and the goodness of fit evaluated as shown in given Table 2 and Fig. 1.

Statistical Parameters: From Table 2, it is obvious that a good correlation exist between length of okra fruit and its weight, thereby yielding the regression coefficient otherwise called slope of 0.001208 and intercept of 12.06611. The model predicted and measured weight values of okra fruits based on length are also shown in Fig. 2. The paired sample t-test results (Table 3) at 95% confidence interval, shows that the weight values predicted were not significantly different from that measured with digital balance, since t Stat < t Critical two-tail. Similar reports had been made on different fruits i.e. [8] proposed a power model for predicting the weight of cantaloupe using intermediate diameter; [4] recommended power-law model with minor diameter to predict the mass of apricot; [2] also recommended a quadratic regression equation to predict the weight of apple fruits and [9] on apricot mass.

CONCLUSIONS

In this study, the weight of okra fruit with respect to fruit length was modeled using the principle of dimensional homogeneity. At 95% confidence level, the developed model was able to successfully predict the weight of okra fruit based on length parameters. The model is therefore recommended for the design and development of sorting and grading systems.

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