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Formulation of Experimental Database Model of Indian Plantain Banana

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Abstract **- This research paper looks at the properties of green plantain banana fruit and develops mathematical models to predict its mass, surface area and projected area. The study is important because these properties help in designing equipment used in grading, sorting, peeling, storage, packaging, drying and transportation in banana processing industries. Indian plantain banana is used to make products such as banana chips, banana powder, starch, soup, confectionery and baby food.**

Keywords: Plantain banana, Physical characteristics, Mathematical models, Mass, Surface area, Projected area, Grading, Sorting, Food processing.

I. INTRODUCTION

Banana is one of the widely grown fruits in tropical and subtropical regions and is very important in the food processing industry. Green plantain banana is used for making products. For processing of bananas it is important to understand their physical and thermal properties. These properties are useful in designing machines for sorting, grading, slicing, drying, cooling, packaging, storage and transportation. Consumers usually prefer bananas that're uniform in size, shape and mass. Therefore industries need grading and sorting systems.

This study was carried out to determine the properties of green plantain banana and to develop mathematical models for predicting mass, surface area and projected area. The findings can help improve the design of machines used in banana processing industries.

II. LITERATURE REVIEW

Many earlier studies on produce have shown that physical properties such as length, width, thickness, volume, mass, projected area and surface area are essential for understanding the shape and handling behavior of fruits. These properties are directly related to fruit quality, market acceptability and machine design. Fruits of size and mass are generally preferred by consumers and are easier to process in industrial applications.

Researchers have explained that dimensional properties are important for determining the shape of the fruit, size of sieve sorters and slicing requirements. Studies on apple fruit pear fruit, kiwi fruit, olive fruit, apricot, citrus fruit and sohiong fruit also showed that dimensional and physical properties are useful in developing sorting and grading systems for fruits.

Dimensional attributes are critical factors in defining fruit geometry, optimizing the aperture sizes of sieve sorters, and establishing precise slicing parameters (Mohsenin, 1986). Building on this foundational principle, numerous studies have evaluated the physical and dimensional profiles of various cultivars, including apples (Tabatabaeefar & Rajabipour, 2005), pears (Wang, 2004), kiwifruits, olives, apricots, citrus fruits, and sohiong fruits. Collectively, this body of research underscores the utility of physical properties in engineering automated sorting and grading systems.

This methodology has been progressively adapted to banana cultivation and post-harvest research. Initial investigations by Kachru et al. (1995) demonstrated that primary physical attributes, such as mass and dimensional metrics, are crucial for optimizing post-harvest handling and industrial processing. Subsequent morphometric analyses of 'Cavendish' and 'Grand Nain' cultivars have characterized their geometric profiles, confirming their value in refining grading and packaging designs. Unlike symmetrically round fruits, the distinctly elongated and non-spherical morphology of the banana introduces unique complexities to mechanized handling systems, necessitating precise physical data.

Complementing direct physical measurements, mathematical modelling has emerged as a vital tool for predicting fruit characteristics. To bypass the labor-intensive process of manual measurement, regression equations are frequently deployed to estimate complex fruit properties from easily measurable dimensions. Linear, quadratic, power, and S-curve models have all demonstrated high predictive accuracy across diverse crops. For instance, Ghabel et al. (2010) successfully utilized quadratic models to predict onion mass from length measurements. Similarly, Mahawar et al.

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(2019) leveraged geometric mean diameter and ellipsoid volume to forecast the mass of kinnow mandarins, while Naderi-Boldaji et al. (2008) established that apricot mass could be reliably predicted using fruit volume. Taken together, these studies validate mathematical modelling as both an economically viable and highly efficient strategy for optimizing fruit grading operations and equipment design.

III. MATERIALS AND METHODS

India is one of the leading countries in the production and export of fruits and agricultural products. Among these banana is one of the important commercial fruits widely used for fresh consumption as well as for food processing industries. In the case of plantain banana grading and categorization are important to ensure that fruits of a particular size, shape and mass reach the market and consumers.

A. Sample Preparation for Training Data Set

All samples of plantain banana were collected from the local market of Pune, Maharashtra, India. To prepare a proper and reliable experimental data set all banana samples were carefully examined for surface defects, bruises, blemishes, cuts, over-ripeness, fungal infection or any physical damage. The damaged or impure samples were removed from the study to maintain accuracy in data collection.

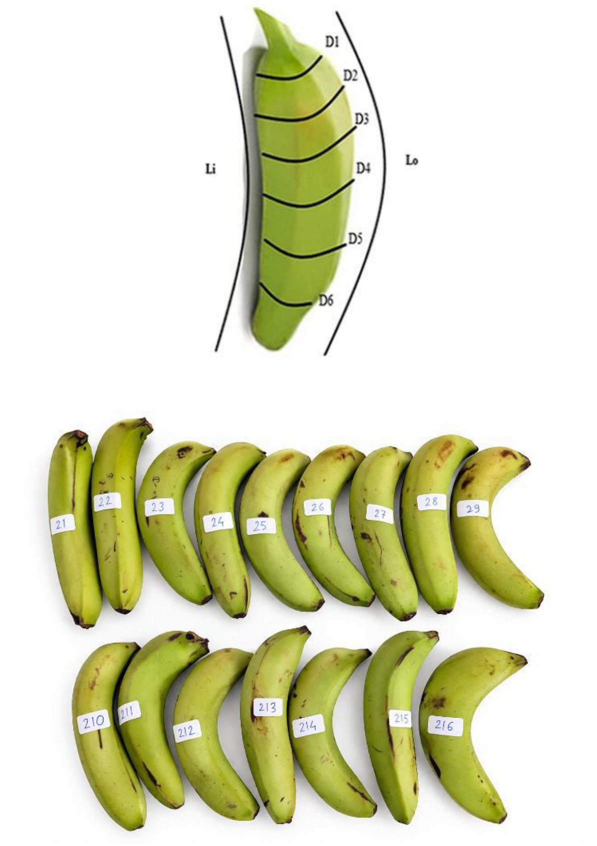

Figure 1: Banana Sample

The selected banana samples were washed gently with water to remove any dirt, dust or foreign particles present on the fruit surface. After washing the samples were dried using an soft cloth to remove excess moisture. Proper labelling and coding of each banana sample were done for identification and database entry during the experimental study.

The primary physical dimensions of each banana sample such as length, width and thickness were measured using thread and scale and width and thickness using a Vernier caliper. The mass of each banana sample was measured using a weighing balance and density of banana is measured using water displacement method. These measured values were recorded carefully. Used for the formulation of the experimental database model

Figure 2: Determine Weight of Banana Using Weighing Machine

B. Determination of Density Using Water Displacement Method

The density of Indian plantain banana was determined by measuring its **mass and displaced water volume**. The fruit volume was obtained using the **water displacement method**, in which the banana sample was completely immersed in water and the change in water level was recorded. The mass of the fruit was measured using a digital balance. Density was then calculated using the ratio of mass.

Figure 3: Measure Density Using Water Displacement Method

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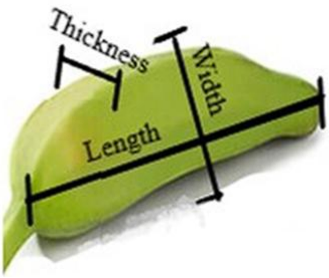
IV. DIMENSIONAL PROPERTIES

The properties of Indian plantain banana were determined to evaluate its physical characteristics and to develop the experimental database model. The main dimensional parameters measured were length, width, thickness, geometric mean diameter, arithmetic mean diameter, sphericity and aspect ratio.

A. Length, Width, and Thickness

The length, width and thickness of plantain banana were determined using the average values of measured dimensions. Since banana is a fruit, both outer and inner curved lengths were considered for more accurate length determination. The average values were calculated using the following equations.



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

$$T = \frac{d_3 + d_4}{2}$$

Where:

- **L** = Length of fruit (cm)
- **L_o** = Outer side curved length of fruit (cm)
- **L_i** = Inner side curved length of fruit (cm)
- **W** = Width of fruit (cm)
- **T** = Thickness of fruit (cm)
- **D_3, D_4** = Intermediate diameters representing fruit width (cm)
- **d_3, d_4** = Intermediate diameters representing fruit thickness (cm)

These measurements were used to represent the actual physical size of the banana fruit for further calculations.

B. Geometric Mean Diameter *(Dg)* and Arithmetic Mean Diameter *(Da)*

The geometric mean diameter and arithmetic mean diameter are dimensional parameters used to describe the overall size and shape of the fruit. The geometric mean diameter and arithmetic mean diameter were calculated using the following equations.

$$Dg = \sqrt[3]{LWT}$$

$$Da = \frac{L + W + T}{3}$$

$$W = \frac{D_3 + D_4}{2}$$

Where:

- **Dg** = Geometric mean diameter (cm)
- **Da** = Arithmetic mean diameter (cm)
- **L** = Length of fruit (cm)
- **W** = Width of fruit (cm)
- **T** = Thickness of fruit (cm)

The geometric mean diameter is also referred to as the equivalent mean diameter, which indicates the dimensional state of the fruit.

C. Sphericity *(Ø)* and Aspect Ratio *(Ra)*

Sphericity is a measure used to determine how closely the shape of a fruit resembles a sphere. It helps in understanding the shape characteristics of produce and is useful, in machine design and fruit handling operations. The sphericity of plantain banana was calculated using the following equation.

$$\phi = \frac{Dg}{L} \times 100$$

The **aspect ratio (Ra)** was calculated as:

$$Ra = \frac{W}{L}$$

Where:

- **Ø (ϕ)** = Sphericity (%)
- **Ra** = Aspect ratio
- **Dg** = Geometric mean diameter (cm)
- **L** = Length of fruit (cm)
- **W** = Width of fruit (cm)

The Sphericity of plantain banana tells us if the Indian plantain banana is round or long..The Aspect Ratio of plantain banana helps us understand the shape of Indian plantain banana..For plantain banana these values are useful in identifying its curved and long shape.

D. Flakiness Ratio and Elongation Ratio

The flakiness ratio and elongation ratio were used to evaluate the shape characteristics of Indian plantain banana. These parameters were calculated using Eqs.:

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$$Flakiness\ Ratio = \frac{T}{W}$$

$$Elongation\ Ratio = \frac{L}{W}$$

Where, **L, W,** and **T** represent the length, width, and thickness of the fruit, respectively.

E. Surface Area *(SA)*

The Surface Area of Indian plantain banana is the total area of Indian plantain banana. It is a parameter in post-harvest engineering and food processing. The Surface Area of plantain banana was calculated using a formula:

$$SA = \pi Dg^2$$

Where, **SA** is the surface area (cm^2) and **Dg** is the geometric mean diameter (cm).

F. Volume *(V)*

The Volume of plantain banana is the total space occupied by Indian plantain banana. The general Volume of plantain banana was calculated using a formula. The shape of plantain banana was approximated as a standard shape and its volume was determined using formulas:

$$V = \frac{\pi}{6} Dg^3$$

$$Vosp = \frac{\pi}{6} LW^2$$

$$Vellip = \frac{\pi}{6} LWT$$

where ***V*** is the general fruit volume (cm^3), V_{osp} is the oblate spheroid volume (cm^3), V_{ellip} is the ellipsoid spheroid volume (cm^3), and ***L, W, T,*** and ***Dg*** represent the geometric mean diameter.

G. Projected Area *(PA)*

The Projected Area of plantain banana in three directions was determined. This is an indicator of the size and weight of Indian plantain banana. The Projected Area was calculated in three directions:

- Projected area perpendicular to thickness (*PT*)
- Projected area perpendicular to length (*PL*)
- Projected area perpendicular to width (*PW*)

$$PT = \frac{\pi TW}{4}$$

$$PL = \frac{\pi LW}{4}$$

$$PW = \frac{\pi W^2}{4}$$

The **total projected area *(PA)*** was then calculated as the sum of the three projected areas:

$$PA = PT + PL + PW$$

These projected area values were used as part of the experimental physical database for Indian plantain banana.

Where:

- **PA** = Total projected area (cm^2)
- **PT** = Projected area perpendicular to thickness(cm^2)
- **PL** = Projected area perpendicular to length (cm^2)
- **PW** = Projected area perpendicular to width (cm^2)
- **L** = Length of fruit (cm)
- **W** = Width of fruit (cm)
- **T** = Thickness of fruit (cm)
- ***π*** = 3.1416

These projected area values were used as part of the **experimental physical database** for Indian plantain banana.

Sr. No.	Parameter	Symbol	Unit
1	Length	L	cm
2	Width	W	cm
3	Thickness	T	cm
4	Mass	M	g
5	Volume	V	cm^3
6	Surface Area	SA	cm^2
7	Projected Area	PA	cm^2
8	Geometric Mean Diameter	Dg	cm
9	Arithmetic Mean Diameter	Da	cm
10	Sphericity	Ø	%
11	Aspect Ratio	Ra	-
12	Elongation Ratio	ER	-
13	Flakiness Ratio	FR	-

V. DATA ANALYSIS ALGORITHM

The experimental dataset collected for the Indian plantain banana was evaluated using a structured data analysis algorithm. First, primary physical properties—including

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length, width, thickness, mass, volume, projected area, surface area, and density—were systematically recorded. These empirical measurements were then integrated into standardized mathematical formulations to calculate derived geometric parameters, specifically the geometric mean diameter, arithmetic mean diameter, sphericity, aspect ratio, flakiness ratio, and elongation ratio.

Following these computations, the dataset underwent statistical analysis to evaluate the correlation and predictive relationships among the distinct physical properties. Ultimately, the processed values were organized into a structured repository to establish a comprehensive experimental database model for the Indian plantain banana.

$$\pi D1 = K_0 . \pi_1^a . \pi_2^b . \pi_3^c . \pi_4^d . \pi_5^e$$

Taking logarithm:

$$\log\left(\frac{M}{\rho L}\right) = logK + a\ log\left(\frac{W}{L}\right) + b\ log\left(\frac{T}{L}\right) + c\ log\left(\frac{D}{L}\right) + d\ log\left(\frac{SA}{L^2}\right) + e\ log\left(\frac{V}{L^3}\right)$$

$$X = \begin{bmatrix} N & \sum X1 & \sum X2 & \sum X3 & \sum X4 & \sum X5 \\ \sum X1 & \sum X1\times X1 & \sum X1\times X2 & \sum X1\times X3 & \sum X1\times X4 & \sum X1\times X5 \\ \sum X2 & \sum X2\times X1 & \sum X2\times X2 & \sum X2\times X3 & \sum X2\times X4 & \sum X2\times X5 \\ \sum X3 & \sum X3\times X1 & \sum X3\times X2 & \sum X3\times X3 & \sum X3\times X4 & \sum X3\times X5 \\ \sum X4 & \sum X4\times X1 & \sum X4\times X2 & \sum X4\times X3 & \sum X4\times X4 & \sum X4\times X5 \\ \sum X5 & \sum X5\times X1 & \sum X5\times X2 & \sum X5\times X3 & \sum X5\times X4 & \sum X5\times X5 \end{bmatrix}$$

$$B = \begin{bmatrix} \log K \\ a \\ b \\ c \\ d \\ e \end{bmatrix}$$

Y=XB

Coefficient	Value
$\log(K)$	−0.043616
a	0.068288
b	0.068303
c	0.001135
d	−0.000713
e	0.931508

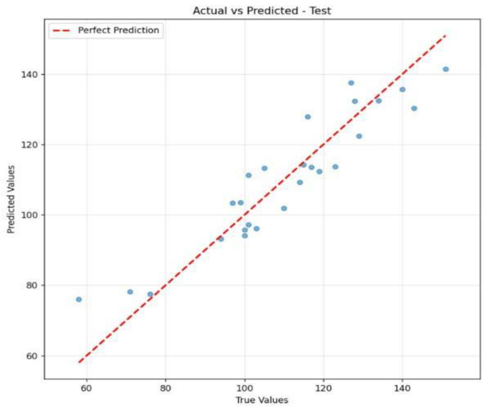
Correlation	0.994142
Mean Error (ME)	0.035231
Mean Absolute Error (MAE)	4.484154
Mean Percentage Error (MPE)	0.000707
Mean Absolute Percentage Error (MAPE)	0.026103
Root Mean Square Error (RMSE)	6.209477

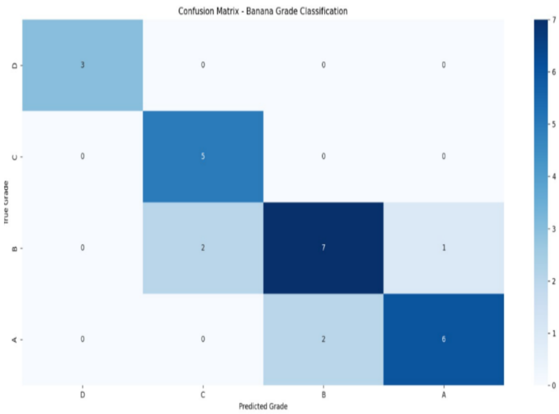
VI. ARTIFICIAL NEURAL NETWORK (ANN) MODEL

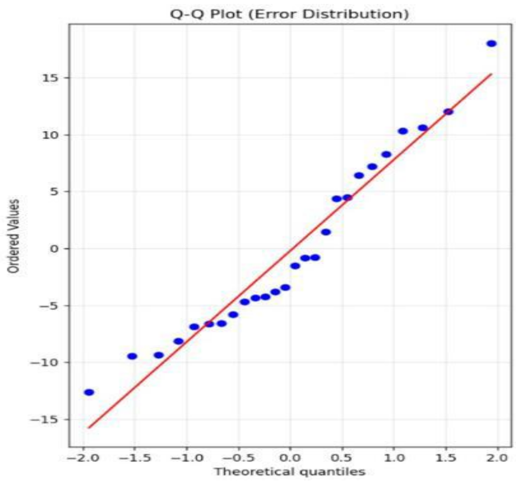
In this study Artificial Neural Network can be used to predict the properties of Indian plantain banana using measured values such as Length, Width and Thickness.

Based on these input values the Artificial Neural Network model can estimate output properties like Mass, Volume, density, Surface Area and Projected Area.

Artificial Neural Network is useful because it can understand relationships between different fruit properties and provide accurate predictions.







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VII. CONCLUSION

This study was done to create a database model for plantain banana. Different physical properties, such as size, shape, weight, Volume, Surface Area, Projected Area and density were studied. The results showed that Indian plantain banana has an long shape so it is important to measure its physical properties properly. These values are useful for making a database that can help in grading, sorting, packaging, transportation and processing of plantain banana fruits. This study will be helpful for research in agricultural engineering, food processing, machine design and automatic fruit analysis systems.

VIII. FUTURE SCOPE

The developed database model for plantain banana can be developed by including additional properties such as mechanical, thermal, optical and textural characteristics.

Future studies can apply image processing, computer vision, machine learning and artificial intelligence techniques for grading, quality evaluation and classification of Indian plantain banana fruits. The database can also be used in the design of grading, sorting, packaging, drying and transportation systems.

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