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SOUTH WEST ZONE**
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T H E M E

HOMIE GROWN TECHOLOGIES

**A PATHWAY TO NIGERIA
ECONOMIC FREEDOM**



CONFERENCE PROCEEDINGS

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THEME

HOME GROWN TECHNOLOGIES: A PATHWAY TO NIGERIA ECONOMIC FREEDOM

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SELECTED PHYSICAL AND THERMAL PROPERTIES OF SHERI MANGO SEED KERNELS

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ABSTRACT

Sheri mango is a widely cultivated tropical fruit with economic and nutritional significance. However, post-harvest losses due to improper drying and storage are a major concern. The quest for sustainable and efficient use of agricultural by-products is ever-growing, with mango seeds being no exception, studying selected thermal and physical properties of Sheri mango seed kernel will enhance its processing. This study was therefore aimed to investigate some physical and thermal properties of Sheri mango seeds to provide a database that can serve as a guide for its processing. Sheri mango seeds used in this study were obtained from overripe mango. The seeds were then carefully cracked to avoid damage. The moisture content was determined using the oven-drying method. The properties determined include the principal diameters, geometric and arithmetic mean diameters, mass, volume, density, thermal conductivity and thermal resistivity. An average moisture content (dry basis) of 46% was obtained for the seed kernel. The Sheri mango seed kernels had major, intermediate and minor diameters within the ranges of 47.2-62.70, 11.4-15.7 and 15.1-34.6 mm, respectively while the arithmetic and geometric mean diameters ranged between 21.80 and 37.10 mm. Gravimetric properties such as the average mass, volume and density were 25.024 ± 1.23 g, 18.52 ± 1.52 cm³ and 1.36 ± 0.12 g/cm³, respectively. The average thermal conductivity and thermal resistivity were 0.2786 W/m-k and 395.781 °C-cm/W, respectively. The physical properties suggest that the kernels are relatively large, which could impact their drying time and method of processing. The size also implies that the kernels have a substantial volume, which may be beneficial if the kernels are being processed for oil extraction or other value-added products. The thermal properties of Sheri mango kernels obtained indicate a moderate ability to transfer heat which can be tailored towards adjusting the processing methods to ensure optimal quality and efficiency.

Keywords: Physical properties, Thermal conductivity, Size and shape characterization, Mango seed.

1. INTRODUCTION

Mango (*Mangifera indica* L.) is a member of the *Anacardiaceae* family and one of the most important and cultivated in many tropical regions and distributed widely in the world. It is one of the most exploited fruits for food, juice, flavor, fragrance, and color. Mango wastes such as the seed kernel and peel have high functional and nutritional potentials (Fowomola, 2010). It is estimated that 35–60% of the fruit is discarded as waste after processing (O'Shea *et al.*, 2012). Mango processing is thought to produce between 150,000 and 400,000 t of trash annually worldwide, which could have an adverse effect on the ecosystem near the factories. Reducing environmental problems can be achieved by feeding animals with wastes from mangoes (El-Kholy *et al.*, 2008).

Every year, over a million tons of mango seeds are generated as waste and, as of now, they are not being used for any commercial activities (Leanpolchareanchai *et al.*, 2014). Moreover, it includes trypsin inhibitors (20 TIU/g DM), oxalates (42 mg/kg DM), and cyanogenic glucosides (64 mg/kg DM) (Ravindran and Sivakanesan, 1996).

There has been scientific interest in mango seed because it has been reported as a bio-waste material with a high content of bioactive compounds which are found useful in food additives, cosmetics, and biofuels (Jahurul *et al.*, 2015). Boiling or autoclaving effectively decreased the presence of anti-nutritional compounds like tannins and trypsin inhibitors (Farag, 2001). According to Ravindran and Sivakanesan (1996), soaking without boiling could also reduce



the anti-nutritional elements in mango seeds. This finding highlights the significance of exploring diverse approaches to enhance the nutritional value of these seeds. Consequently, investigating the engineering characteristics of mango seeds becomes crucial in this context. Such studies can provide a database for the development of various machines for handling and processing these seeds. Understanding the thermal and physical attributes of mango seeds, for instance, can help in enhancing and optimizing the processing operations. It can also pave the way for new uses for seeds as biofuels feedstock and other industrial applications. This study was therefore, designed to determine some physical and thermal properties of Sheri mango seed with a view to providing a database that can serve as a guide for the design and evaluation of the performance of its processing machines.

2. MATERIALS AND METHODS

2.1. Material Acquisition

The Sheri mango variety was chosen for this study due to its availability. The fruits were picked from the same tree at Odeda Local Government, Ogun State, Nigeria, and were transported to Crop Processing Laboratory, Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria, for the experiments.

2.2. Sample Preparation

The mangoes were allowed to ripen further until they reached an overripe state. The flesh (pulp) was then manually removed, and the remaining seeds were thoroughly washed with clean water to remove any adhering pulp residue. The seeds were then drained and carefully cracked to retrieve the kernels intact.

2.3 Determination of Moisture Content

The moisture content of the Sheri mango seeds was determined using the oven-drying method. Before the oven-drying process, the seeds were weighed using a digital weighing balance (Camry, model EK5055, China). The drying experiment was carried out with a forced convection laboratory oven (Isotherm, DIN 12880 Class 3.1, USA). The moisture content of the seeds was monitored periodically throughout the drying process. The moisture content was then calculated based on the gravimetric principle using Equation 1.

$$MC_{wb} = \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100 \quad (1)$$

where: MC_{wb} is the moisture content (% wet basis), W_1 is the weight of container (g), W_2 = weight of wet sample and container (g) and W_3 = weight of dry sample and container (g).

2.4 Determination of Physical Properties

The length, width, and thickness of each kernel in the sample were measured using a digital vernier caliper (Carrera Precision, model CP8812-T 12-inch, USA) while an electronic digital scale (Camry model EK5055, China) was used to measure the mass of each seed kernel (Oyefeso and Raji, 2018). Each measurement was carried out in triplicate. The volume of the seed kernel was measured using the water displacement method (Raji and Oyefeso, 2021; Oyefeso, 2021). The geometric mean diameter and the arithmetic mean diameter of the mango seed kernel were determined using Equations 2 and 3, respectively, while the surface area, sphericity and density of the kernels were calculated using Equations 4, 5 and 6, respectively (Sunmonu *et al.*, 2015).



$$D_g = (a \times b \times c)^{\frac{1}{3}} \quad (2)$$

$$D_a = \frac{(a+b+c)}{3} \quad (3)$$

$$S_a = \pi(D_g^2) \quad (4)$$

$$\Phi = \frac{D_g}{a} \quad (5)$$

$$\rho = \frac{m}{v} \quad (6)$$

where: D_g is the geometric mean diameter of the seed kernel (mm), D_a is the arithmetic mean diameter (mm), S_a = surface area (mm^2), Φ is the sphericity, ρ is the density (kg/m^3), a is the major diameter (mm), b is the intermediate diameter (mm) and c is the minor diameter (mm), m is the mass (g) and v is the volume (cm^3).

2.5. Thermal Properties of the kernels

The thermal conductivity and thermal resistivity of sheri mango seed kernels were determined with the aid of a thermal properties analyser (Tempos, KS-3, USA) according to the procedure described by Oyefeso and Raji (2019). Thermal conductivity is a measure of a material's capacity to transfer heat while thermal resistivity is the inverse of conductivity and indicates how well a material impedes heat flow. The interplay between these properties is governed by Fourier's Law for heat conduction.

2.6. Statistical Analysis

Data obtained from the experiments were statistical analysed using ANOVA and descriptive statistics, to assess the variability and significance.

3. RESULTS AND DISCUSSION

Selected physical and thermal properties of Sheri mango seed kernel were determined at an average moisture content (dry basis) of 46%. Summary of the determined physical and thermal properties of Sheri mango seeds is presented in Table 1.

Table 1: Selected thermal and physical properties of sheri mango seed kernels

Properties	Mean	Standard Deviation	Minimum	Maximum
Major diameter (mm)	56.366	4.357	47.200	62.700
Intermediate diameter (mm)	13.652	1.263	11.400	15.700
Minor diameter (mm)	24.906	5.918	15.100	34.600
Mass (g)	25.024	1.234	22.500	27.000
Volume (cm^3)	18.524	1.522	15.200	21.200
Thermal Resistivity ($^{\circ}\text{C-cm/W}$)	395.781	125.267	219.348	704.873
Thermal Conductivity (W/m-K)	0.279	0.086	0.140	0.453



3.1. Selected Physical Properties of Sheri Mango Seed Kernels

On average, the major diameter (56.37 mm) was the largest, the minimum major diameter observed was 47.2 mm, while the maximum was 62.7 mm. The mean minor diameter was approximately 24.91 mm, the minimum minor diameter observed was 15.1 mm, while the maximum was 34.6 mm. The minor diameter exhibits significant variability, with some kernels being relatively small and others quite large. Also, the intermediate diameter (13.65 mm). The minimum intermediate diameter observed is 11.4 mm, while the maximum was 15.7 mm.

However, considering the variability in size across the kernels. The standard deviation (SD) values for each diameter provide information on how spread out the measurements were from the average value. The major diameter (SD = 4.36 mm) has the highest SD, indicating the greatest variation in size among the kernels for this dimension. The minor diameter (SD = 5.92 mm) also shows considerable variation. In contrast, the intermediate diameter (SD = 1.26 mm) has the lowest SD, suggesting the most consistent size in this dimension.

The range (minimum and maximum values) for each diameter further emphasizes the variation observed. The major diameter ranges from 47.2 mm to 62.7 mm, with a spread of 15.5 mm. The minor diameter has an even wider range (15.1 mm to 34.6 mm) compared to the intermediate diameter (11.4 mm to 15.7 mm). This highlights the presence of a heterogeneous population of kernel sizes within the samples used in the study.

Having established that the mango seed kernels are elongated, as indicated by the larger major and minor diameters compared to the intermediate diameter, the wide range of minor diameters suggests diverse kernel shapes within the sample. Understanding these diameter measurements is crucial for designing equipment, optimizing drying processes, and predicting behavior during milling or extraction as larger kernels may have different thermal properties, affecting their suitability for specific applications.

3.1.1. Geometric mean diameter of Sheri mango seed kernels

The geometric mean diameter was calculated to be 26.76 mm. This provides a single representative value for the size of the mango seed kernels based on the three principal diameters. This value is significantly lower than the average major diameter (56.37 mm). This highlights the elongated shape of the mango seed kernels. Even though the major diameter has the largest average value, the smaller intermediate and minor diameters substantially influenced the overall typical size captured by the geometric mean diameter.

The calculated geometric mean diameter suggests that the kernels are relatively large, which could impact their drying time and method of processing. The size also implied that the kernels had a substantial volume, which may be beneficial if the kernels are being processed for oil extraction or other value-added products. The value of D_g is particularly useful in various applications such as the design equipment for sorting or grading the seeds based on size, computational models that simulate heat and mass transfer during drying or roasting. It serves as a crucial input parameter. Consistency in D_g across batches can be an indicator of uniformity in seed size, which is important for product quality.

3.1.2. Arithmetic mean diameter of Sheri mango seed kernels

The arithmetic mean diameter of approximately 31.64 mm provides a simple average of the three principal diameters. This value is useful for general Sizing as arithmetic mean diameter (D_a) gives a quick reference for the overall size of the kernels, which can be used in sorting



and grading processes. Also, knowing the average size helps in designing equipment and processes that are suitable for the average kernel size. It allows for a straightforward comparison between different batches or types of kernels. The calculated D_a suggests that the kernels have a substantial average size, which could influence their handling and processing.

3.1.3. Gravimetric properties of Sheri mango seed kernels

The individual masses of mango seed kernels depict a natural variation. The mean mass and standard deviation of the seed kernels are indicative of their density and consequently their thermal conductivity. The mean mass of the mango seed kernels was calculated to be 25.024 g and the standard deviation was 1.234 g, which suggests a higher density and potentially more uniform thermal properties among its kernels. The variability in mass, as indicated by the standard deviation, can also affect the rate of heat transfer within the seeds. Furthermore, the mass of the seed kernels can influence the rate of moisture loss during the drying process.

The volume measurements of individual Sheri mango seeds demonstrate a relatively consistent volume, with the mean volume at 18.524 cm³ with a standard deviation of 1.522 cm³. The substantial standard deviation indicates a diverse range of kernel volumes, which could be indicative of varying growth conditions or genetic diversity within the sample. The density of the Sheri mango seed was calculated to be 1.35g/ml. A higher density suggests the Sheri mango seed is composed of relatively dense materials. These materials could include carbohydrates like starches, proteins which are typically denser than water.

The gravimetric properties of mango seed kernels calculated provide valuable insights into their thermophysical properties, which are essential for optimizing processing techniques and enhancing the quality and safety of mango seed-based products.

3.1.4. Thermal Properties of Sheri Mango Seed Kernels

The thermal conductivity measured ranged from 0.1398 to 0.4532 W/m-K. This range indicates that there is considerable variability in the thermal conductivity of Sheri mango seeds, which could be due to differences in composition, density, or moisture content of the seeds. The average thermal conductivity of the seeds is calculated to be 0.2786 W/m-k, which indicates a moderate ability to transfer heat. However, the standard deviation of 0.0863 W/m-k points to some variability in the seeds' thermal conductivities. While this variability is not extreme, it does highlighted differences that could stem from natural variations in seed composition or processing methods.

Thermal resistivity, the inverse of thermal conductivity, represents the material's resistance to heat flow. The values measured span from 219.348 to 704.873 °C-cm/W. Seeds with higher resistivity, such as those with a value of 704.873 °C-cm/W, would be less efficient at transferring heat, which could be advantageous in applications where insulation is desired. The mean value stands at 395.781 °C-cm/W, suggesting that mango seeds generally offer substantial resistance to heat flow. This property is particularly advantageous for applications where insulation is beneficial or where slow and controlled heat transfer is desired. The considerable standard deviation of 125.267 °C-cm/W reveal a wide range of resistivity among the seeds. This variation is critical for selecting the appropriate seeds for specific thermal processes, as seeds with higher resistivity may be more suitable for applications requiring greater insulation. These findings are essential for determining the suitability of mango seeds for various thermal applications.



4.0. CONCLUSIONS

The study determined some physical and thermal properties of mango seed kernel at 46% moisture content (dry basis). The Sheri mango seed kernels had major, intermediate and minor diameters within the ranges of 47.2-62.70, 11.4-15.7 and 15.1-34.6 mm, respectively, while the arithmetic and geometric mean diameters ranged between 21.80 and 37.10 mm. Gravimetric properties such as the average mass, volume and density of the seed kernels were 25.024 ± 1.23 g, 18.52 ± 1.52 cm³ and 1.36 ± 0.12 g/cm³, respectively. The average thermal conductivity and thermal resistivity were 0.2786 W/m-k and 395.781 °C-cm/W, respectively. The investigated physical properties suggested that the kernels are relatively larger compared to some other fruit seeds and nuts, which could impact the methods of processing. Proper design of equipment for processing the Sheri mango seed kernels as well as the optimization of its various processing operations can be ensured based on the findings in this study. This will ensure careful selection of the processing methods and potential pre-treatment of the seeds to ensure consistent outcomes and maximize the quality and yield of Sheri mango seed-based products.

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