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PHYSICAL PROPERTIES OF WATERMELON *(CITRULLUS LANATUS)* SEEDS RELEVANT TO PROCESSING EQUIPMENT DESIGN

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ABSTRACT

This study investigated some physical characteristics of water melon seeds with the aim of utilizing them in the design of the processing machinery. Commonly applied techniques were employed to determine the length (mm), width (mm), thickness (mm), 1000-unit mass/mass (g), arithmetic mean diameter (mm), geometric mean diameter (mm), sphericity, surface area (mm), volume (mm3), true density, bulk density, porosity, static coefficient of friction of squash seeds at 7.5% moisture content, and angle of repose. Water displacement method was used to determine the seeds volume and density, while electronic weighing balance was used to determine weight. Five different structural surfaces were used to determine the static coefficients of friction of watermelon seeds: glass fiber, plywood, glass, rubber, and galvanized metal sheet. The results showed that the length was 14.0 mm, the width was 7.07 mm, the thickness was 3.69 mm, the mass of one thousand seeds was 40.79 g, the arithmetic mean diameter was 11.02 mm, the geometric mean diameter was 9.10 mm, the sphericity was 1.99 %, the surface area was 256.10 mm^2, the volume was 297.20 m^3, the true density was 743.96 kg/m3, the bulk density was 567.20 kg/m3, the porosity was 60.17%, and the static coefficients of friction was 7.5. Angles of repose pouring were 40.33°, angles of repose discharging were 37.24°, glass fiber was 0.37%, plywood was 0.75%, glass was 0.45%, rubber was 0.61%, and galvanized metal sheet was 0.59%. The findings will help with an effective layout of equipment for the culinary processing industry's seeding, harvesting, processing, conveyance, classification, grouping, and casing of watermelon seeds. Therefore, it is concluded that the results of the current research will provide more information about the requirements for machines used in watermelon processing as well as handling.

Keywords: Watermelon Seeds, Engineering Properties, Processing Equipment, Food Processing Industry

1.0 INTRODUCTION

Watermelon is a member of the cucurbitaceae category of flowering plants (Citrullus lanatus), a crop that can withstand dryness (Odo *et al.*, 2021). It can also be referred to as Citrullus vulgaris and belongs to the Citrullus species. In the category of fruits that are consumable, known as Pepo fruits, it can be categorized as basic plural-grain pulp fruits (Odo *et al.*, 2021). The fruit has characteristic strong greenish outer layers that are frequently peeled or speckled, and has a rounded, lengthy, or cylindrical form (Egbuonu, 2015). Many tropical, humid, and cold climates of the globe are home to watermelon cultivation. It was first discovered in Southern Africa, where the native population chose nourishment that had minimal sugar concentration while searching for nourishment that contained moisture (Odo *et al.*, 2021). It matures in August and September after being sodded in wide-open space in April and May (Suwannasom *et al.*, 2020). The following are the five broad types among the fifty popular watermelon kinds found worldwide: all yellow, flesh ice-box, seedless, scarlet, and sweet (Egbuonu, 2015). Watermelon is grown as a crop across the majority of the Earth's areas. Owing to their complete nutritional content (Suwannasom *et al.* 2020), watermelon seeds play a significant part in people's dietary habits. They are often used as seed oil, baked seeds, or hypertension medication (Odo *et al.*, 2021). According to Suwannasom

et al. (2020), watermelon seeds typically include 456 mg phosphorus, 130 mg calcium, 4.4% carbs, 57.1% fat, 7.5 mg iron, 31.9% protein, 6.2% ash, and 8.2% fiber. Tryptophan, isoleucine, valine, and Leucine are among the essential amino acids found in watermelon seeds (Suwannasom *et al.*, 2020). The fruit is composed of the mesocarp, seeds and epicarp. According to Odo *et al.* (2021), the mesocarp might be red, green, orange, yellow, pink, or white. Oil, protein, nutritional fiber, as well as micronutrients like potassium, phosphorus, vitamins, iron, zinc, calcium, and magnesium can all be found in abundance in watermelon seeds (Suwannasom *et al.,* 2020). Omega-3 fatty acids, as well as omega-6 fatty acids, are abundant in the seed. Watermelon seeds have an elevated magnesium content, which is particularly beneficial for cardiovascular wellness. The seed is often processed into powder, a material with great functional qualities, which renders it ideal for roasting or toasting and eaten as a nibble (Tak and Jain, 2016). The seed can be used as animal food because it is a great source of energy.

According to Abeshu and Kefale (2017), the oil extracted from the seeds is utilized in both cooking and the manufacturing of beauty products. These watermelon seeds are frequently thrown away while the flesh of the fruit is consumed, disregarding their numerous possible uses. Watermelon fruit coats, as well as the seeds that are thrown away, add to the amount of substantial trash, and garbage disposal in the nation nonetheless faces many difficulties. Exploiting food waste application in diets might enhance the environment, health, and food supply (Jacob *et al.,* 2015). We have very small appetite for watermelon seeds in Nigeria, notwithstanding the growing nutritional markets and growing need for them as nutritional additives. Harvesting, sorting, washing, handling, and storage are all steps in the processing of farm produce. When designing processing as well as handling machines, knowledge of the physical and mechanical specifications of farm produce is crucial. These characteristics need to be established in a research environment (Gursory and Guzel, 2010). The physical characteristics of the various farm produce have been studied by a number of authors (Adekanye and Adesoye, 2014; Davies, 2010; Manuwa and Muhammad, 2010). The most crucial elements for establishing the ideal pressure in a vacuum of the accurate suction seeder are the physical characteristics of watermelon seeds, which are crucial for the construction of handling, processing, and preservation devices (Adekanye and Adesoye, 2014). Depending on the species, watermelon seeds have different bodily characteristics. A deeper comprehension of the physical characteristics of watermelon seeds is also crucial for optimizing multiple variables, such as shredding effectiveness, hydraulic conveyance, and preservation (Adekanye and Adesoye, 2014). Agricultural engineering experts have recognized the necessity to create, employ, and enhance contemporary watermelon equipment innovation so as to boost the number and efficacy of watermelon seed generation (Aviara *et al.,* 2014). Subsequently, the goal of this study is the examination of some physical characteristics of watermelon seeds for the purpose of designing processing machinery that may be used in handling, processing, and storage. Some physical characteristics of seeds were examined, including length (mm), width (mm), thickness (mm), 1000-unit mass/mass (g), arithmetic mean diameter (mm), geometric mean diameter (mm), sphericity, surface area (mm), volume (m^3), and gravimetric characteristics like

true density, bulk density, porosity, and static coefficient of friction at 7.5% moisture content and repose angles.

2.0 METHODOLOGY

2.1 Evaluation Equipment

An electric multipurpose oven was used to find the moisture content of the seeds. We used an Instron Universal Testing Machine (Model 3340 series, single column, made in the USA) to test how the endocarps held up and how much they squish before breaking. And for size, a vernier caliper (with super precision of 0.01 mm) was used to measure the big, middle, and small diameters of each endocarp.

2.2 Collection of Watermelon Seeds

The Crop Science Department of Nnamdi Azikiwe University in Awka, Anambra State, Nigeria (lat. 6.283 ° N, long. 7.121 ° E) provided the watermelon (Citrullus lanatus) fruits as seen in (Figure 1), utilized in the present study.



Figure 1: Watermelon fruits

Watermelon brown species was chosen and recognized by color, then a sterile, high-quality scientific blade was the instrument used to break into each Watermelon fruit. The seeds, as shown in Figure 2, were sorted to remove contaminants such as grime, rocks, filth, adulterant items, and underdeveloped seeds.



Figure 2: Watermelon Seeds

About two thousand seeds were taken to the Department of Agricultural and Bioresources Engineering laboratory, Faculty of Engineering at Nnamdi Azikiwe University, Awka, for the study of the physical properties of watermelon seeds.

2.3 Physical Processing Parameters

2.3.1 Surface Area, Sphericity, Mean Diameters, and Dimensions

A collection of a hundred seeds was randomly selected, and their axial dimensions were examined to ascertain the standard size of the seed. Each of the main perpendicular measurements, such as length (l, mm), width (w, mm), and thickness (t, mm), was measured using a micrometer screw gauge reading to 0.001mm, as seen in Figure 3.

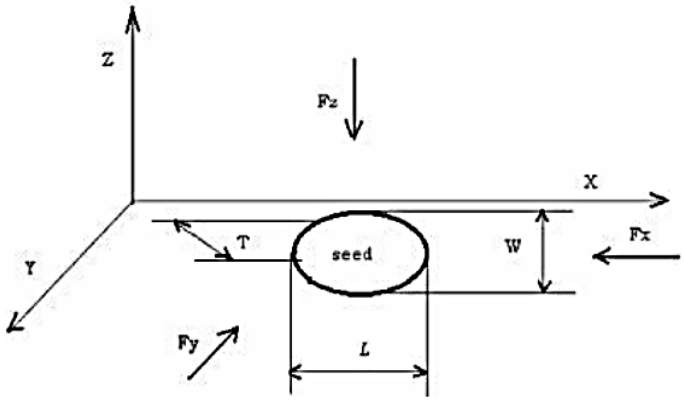

Figure 3: Watermelon seed orientations and three primary perpendicular measurements. *(Suwannasom et al. (2020)*

Length, width and thickness were among the measured physical properties. The largest dimension of the seed's largest surface is its length. Additionally, the width is the smallest measurement of the seed's largest exterior, while the thickness is the shorter measurement of its smallest surface (Figure 3). The subsequent equations were used to determine the seeds' geometric mean diameter (Dg, mm) and arithmetic mean diameter (Da, mm) as seen in (equations 1 and 2) below (Seyed *et al.*, 2020).

$$D_a = \frac{L+W+T}{3} \quad \ldots\ldots\ldots\

$$\Phi = \frac{(LWT)^{\frac{1}{3}}}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where,

$\Phi =$ sphericity,
L = (length, mm),
W = (width, mm),
and T = (thickness, mm)

Each of the accompanying formulas was used to determine the surface area (S, mm^2) of seeds as shown in (equations 4 and 5) below (Seyed *et al.*, 2020).

$$S = \frac{\pi BL^2}{2L-B} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

$$S = \pi D_g^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

Where,

π = Pi (3.142),
B = breadth (mm),
Dg = geometric mean diameter (mm),
L = length (mm)

2.3.2 Volume, True Density, Bulk Density and Porosity

Volume of the watermelon seeds was determined using the following formula, as seen in (equation 6) below (Seyed *et al.*, 2020):

$$V = \frac{M_{td}}{P_{tol.}} = \frac{(M_t - M_p)-(M_{pts}- M_{ps})}{P_{tol.}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where,

Mt is the weight (kg) of a pycnometer containing toluene;
M_p is the weight (kg) of a pycnometer;
M_{pts} is the weight (kg) of a pycnometer loaded with toluene as well as the sample;
M_{ps} is the weight (kg) of a pycnometer as well as the sample,
While P_{tol} is the density (kg/m^3) of toluene.

Next, the watermelon seed's true density (t in kgm^{-3}) was determined using the following formula, as shown in (equation 7) below (Seyed *et al.*, 2020):

$$P_t = \frac{M_{ps}- M_p}{V} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

Where,

P_t is the true density (kg/m^3);

M_{ps} is the weight (kg) of a pycnometer as well as the sample;
M_p is the weight (kg) of a pycnometer;
V is the volume (m^3) of toluene.

Bulk density was determined using the method described by Kashaninejad *et al.* (2006). A measuring vessel containing a specified volume and mass was filled up to the brim with watermelon seeds with the aim of determining the bulk density. From an elevation of approximately one hundred and fifty millimeters (Seyed *et al.,* 2020), the seeds were added to the vessel in abundance while maintaining a steady pace. Once the vessel was filled, extra seeds were taken out by making two crisscross movements with a level rod through the highest region. In no manner were the seeds compressed. A computerized scale (Model GT 2100, Germany) was used to measure the vessel, and the result was 0.01 g. The proportion of the weight of the seeds in the vessel (mb) to its volume (vb) was used to compute bulk density (b). Ten instances of the watermelon seeds were used to determine the bulk density. Employing the formula provided by (Seyed *et al.,* 2020), the porosity (%) of bulk seeds was calculated (equation 8) from the results of true density as well as bulk density in the following manner, as seen in (equation 8) below:

$$\varepsilon = \left[\frac{(\rho_d - \rho_y)}{\rho_d}\right] \text{ x } 100 \quad \ldots\ldots\ldots\

the seeds and positioned in the middle of an elevated round platform with a diameter of forty-five centimeters. On a round plate, the cylindrical vessel was gradually lifted until it produced a cone. The cone's height (H) and diameter (D) were noted. Razavi *et al.* (2007) provided a method for calculating the filling angle of repose (θ_f) as seen in (equation 10) below.

$$\theta_f = Arc\ tan\ \frac{2H}{R} \quad \ldots\ldots\ldots\

purpose of building seed hoppers, storing, as well as conveyance equipment, the mass of 1000 units of seeds is crucial (Mehra *et al.*, 2023).

3.3 Porosity, Bulk Density, Volume, and True Density

The research findings, which are displayed in Figure 5, revealed that the seeds' volume was 297.85 mm^3, their bulk density was 567.20 kg/m^3, their actual density was 743.96 kg/m^3, and their porosity was 60.17%.

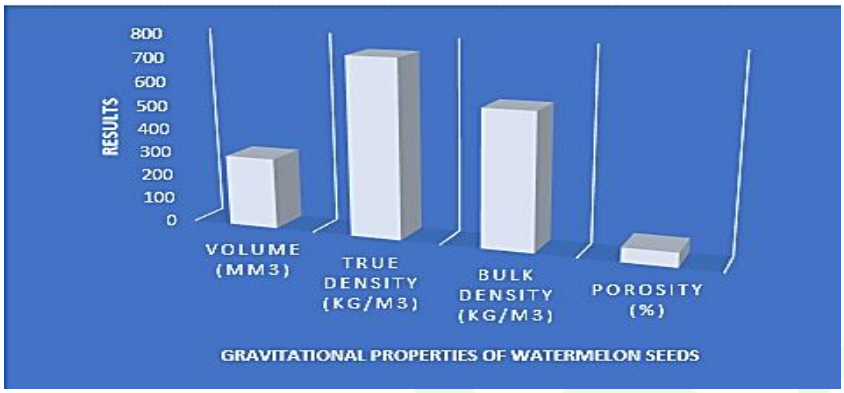

Figure 5: Gravitational Properties of Watermelon Seeds

The outcomes were consistent with those published by Mansouri *et al.* (2017) because porosity relies on bulk and true densities, and bulk and true densities help design separator machines.

3.4 Geometric Mean Diameter and Arithmetic Mean Diameter

The size of the seeds strongly influences both the geometric and arithmetic mean diameters. The arithmetic mean diameter as well as the geometric mean diameter will rise with a spike in length, breadth, and thickness (Mehra *et al.*, 2023). The watermelon seeds had an arithmetic mean diameter of 11.02 mm and a geometric mean diameter of 9.10 mm, according to the assessment data shown in Figure 6. The findings are consistent with the study conducted by Falalu (2024). When creating equipment to sort, grade, and size these seeds, these factors are crucial.

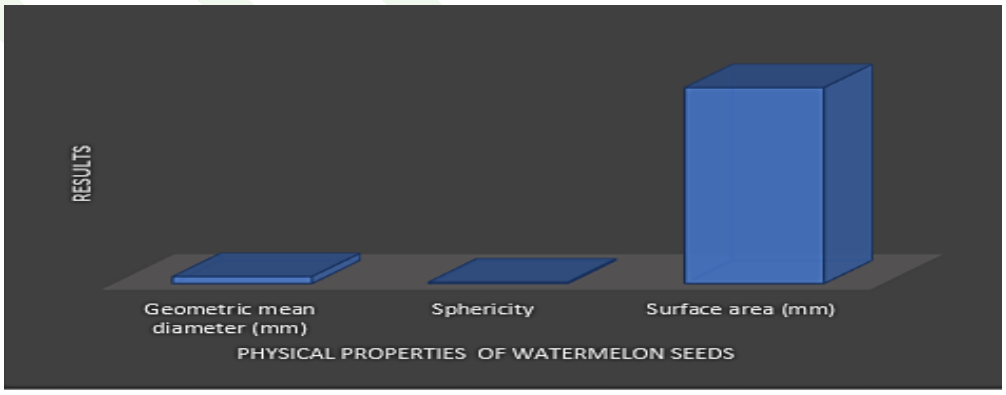

Figure 6: Geometric mean, sphericity and surface area of watermelon seeds

3.5 Sphericity

A material's sphericity is determined by dividing the area of its surface by the outer area of a sphere that has the same volume as the material in question. The assessment's findings, which are displayed in Figure 6, indicated that the watermelon seed's sphericity was 1.99%. Mansouri *et al.* (2017) found comparable sphericity results for the Samsori melon cultivar. Sieve perforations, along with other machine design characteristics, depend on these dimensions (Ehiem *et al.,* 2022). For instance, the advancement of size along with grade machines and the electrostatic method for separating farm produce from unwanted elements depend on the size and grade form. The form is a circle of perfection because the resulting sphericity result is more or less 0.5 (that is, fifty percent) (Ehiem *et al.,* 2022).

3.6 Area of Surface

The watermelon seed had a surface area of 256.10 mm, according to the assessment data shown in Figure 6. The outcome is consistent with the outcomes reported by Mansouri *et al.* (2017).

3.7 Angle of Repose and Static Coefficient of Friction

The watermelon seeds had a static coefficient of friction (∝s) of 0.37 for glass fiber surfaces, 0.75 for plywood surfaces, 0.45 for glass surfaces, 0.61 for rubber surfaces, and 0.59 for galvanized metal sheet surfaces, according to the data shown in Figure 7.

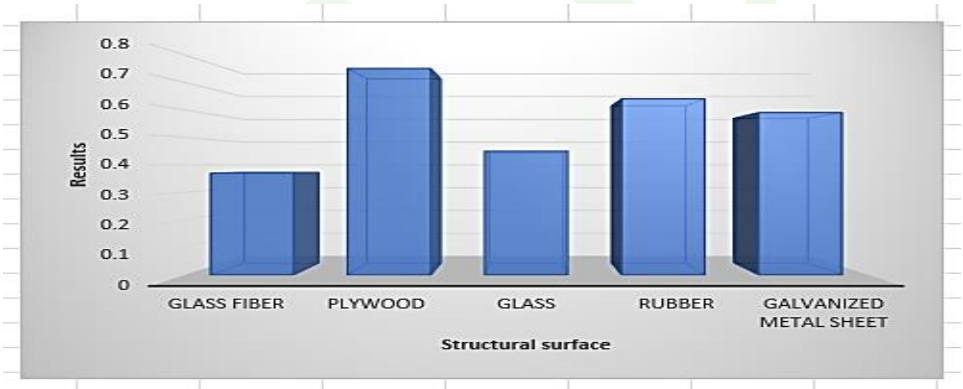

Figure 7: Static coefficient of friction

Plywood had the highest static coefficient of friction (s), while glass fiber had the lowest. This is perhaps explained by the fact that plywood has the highest rough surfaces, which reduces the seed's capacity to glide (Obi *et al.,* 2015). The static coefficient of friction is important when developing conveying systems because attraction keeps seeds on the conveying systems free of sliding or a rearward glide. The static coefficients of friction for rubber (0.64) and plywood (0.75) were close to those reported by Mehra *et al. (*2023).

3.8 Angle of Repose

According to Figure 8, the watermelon seed had an angle of repose pouring of 40.33° and an angle of repose discharging of 37.24°.

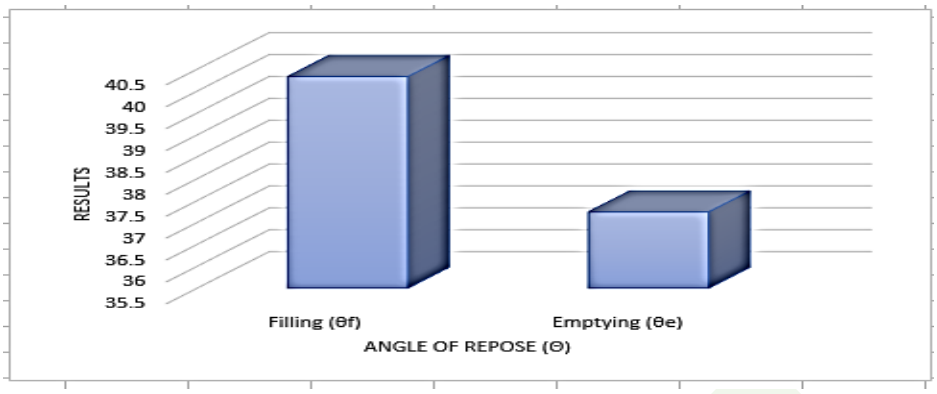

Figure 8: Angle of Repose

With respect to the seeds' little amount of moisture (7.5%), their angle of repose was similarly modest (Al-Hashemi et al., 2018). The angle of repose typically relies on the moisture level. Mansouri et al. (2017) and Mehra et al. (2023) reported similar outcomes.

4.0 CONCLUSION

The outcome of the research was that the identification of some watermelon seed engineering attributes for the purpose of designing processing machinery had given enough insight into their pertinent features. The physical characteristics of watermelon seeds at 7.5% moisture content, such as length, width, thickness, 1000-unit mass, arithmetic mean diameter, geometric mean diameter, sphericity, surface area, volume, true density, bulk density, porosity, repose angles, static coefficient of friction, and angle of repose, are critical when developing machinery for seed processing. The information gathered from this assessment could be useful in the development of methods for the shipment, treatment, and preservation of the seed. To ensure that these seeds are healthy to use in culinary preparations, more research regarding their harmful as well as unhealthy characteristics is advised.

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