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Full Length Research Paper

DETERMINATION OF PHYSICAL PROPERTIES OF ALMOND SEED RELATED TO THE DESIGN OF FOOD PROCESSING MACHINES

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Abstract

In this study, some selected physical properties of two varieties of Almond seed (Red and White) grown in Nigeria were determined. The physical properties of Red Almond were Major Diameter (49.35±4.16mm), Intermediate Diameter (33.05±2.79mm), Minor Diameter (23.37±2.31mm), Weight (10.20±2.24g), Geometric mean diameter (33.59±2.41mm), Arithmetic mean Diameter (35.26±2.45mm), Surface Area (3564.6±524.1mm^2), Sphericity (68.3±4.36%), Volume (0.5023±0.07cm^3), Density (19.53±3.82g/cm^3) while values of coefficient of static friction of 0.45±0.04, 0.40±0.06 and 0.52±0.06 were recorded for glass, metal and wood surface respectively in red almond. Also values of angle of internal friction of 24.12 ± 1.92, 21.93±3.00 and 27.50± 2.64 were recorded for glass, metal and wood surfaces in red almond. The properties of white Almond were: Major diameter (61.26±4.15mm), Intermediate diameter (29.61±3.05mm), Minor diameter (21.52±1.59mm), Weight (10.9±1.52g), Geometric mean diameter (33.86±2.09mm), Arithmetic mean diameter (37.47±2.13mm), Surface area (3616.10±453.7mm^2), Sphericity (55.39±3.46%), Volume (0.51±0.06cm^3), Density (22.33±3.48g/cm^3) while values of coefficient of static friction of 0.41±0.06, 0.41±0.07 and 0.51±0.05 were recorded for glass, metal and wood surface respectively in white almond. Also values of angle of internal friction of 22.20± 2.76, 22.38 ±3.45 and 26.96± 2.23 were recorded for glass, metal and wood surfaces in white almond. Statistical test (independent t test) on the properties showed there were significant difference at 5% level between Red Almond and White Almond.These properties are also needed for analytical prediction of the drying behaviour of agricultural materials. These properties are also use to determine heat transfer in agricultural materials.

Keywords: Almond seed, Processing design, Characteristics, Geometric, surface area, diameter,

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Introduction

Almond fruit majorly grown in South-West of Nigeria and it is popularly called “fruit”. The development of satisfactory harvesting and processing methods are greatly influenced by the physical properties of the product. Agricultural and food products have several unique characteristics which set them apart from engineering materials. Design of machines, process of harvesting, handling, storage, and conversion of agricultural materials into food and feed requires an understanding of their physical properties. (Mohsenin, 1986). In fact, the output of agricultural and processing machines depends on these engineering properties (Mohsenin, 1986). Furthermore, information on physical and aerodynamic properties of agricultural products is needed in design and adjustment of machines used during harvesting, separating, cleaning, handling and storage of agricultural materials and converting them into food, feed and fodder. The properties which are useful during design must be known and these properties must be determined at laboratory conditions.

The geometric properties such as size and shape are one of most important physical properties considered during the separation and cleaning of agricultural grains. In theoretical calculations, agricultural seeds are assumed to be spheres or ellipse because of their irregular shapes.

However, it is essential to understand the physical laws guiding the response of these agricultural products so that machines, processes and handling operations can be designed for maximum efficiency and the highest quality of the final product can be obtained (Mohsenin, 1986).

Potential health benefits of almond seed include improved complexion and possibly a lower risk of cancer. A preliminary trial showed that using almond seed in the daily diet might lower several factors associated with heart disease, including cholesterol and blood lipids (Novelli, 2002).

Since the size and shape are important in designing of separating, harvesting, sizing and grading machines in food industry, there is need to determine the physical properties of almond seed related to the designing of food processing machines. Also the data generated will be useful to food engineers in the design of food processing machines.

Material and Methods

Selection of Material

The almond fruits were harvested from two different trees at different locations in the University of Ilorin. Two varieties were used (red and white almonds) to compare their characteristics. The external coats of the fruits were removed with the aid of knife to reveal the kernel. Sample selection was randomised all through the tests.

Determination of Physical Properties

Size Determination

Fifty (50) kernels were selected at random from both samples, the three principal diameters; major diameter (a), intermediate diameter (b) and minor diameter (c) were measured using Vernier Calipers and the average was taken (Mohsenin, 1970).

Geometric Mean Diameter

The geometric mean diameter was determined from the major, intermediate and minor diameters using the formula:

Geometric mean diameter $Dg = (a.b.c)^{\frac{1}{3}}$(Mohsenin, 1970) **(1)**

Arithmetic Mean Diameter

The arithmetic mean diameter of the kernel was determined from the three principal diameters using the relationship by (Mohsenin, 1970).

$$Da = \frac{a+b+c}{3} \quad \textbf{(2)}$$

Weight Determination

The weight of the kernel was determined by using weighing balance. Results were obtained for 50 replicates and the average recorded.

Surface Area Determination

The surface area was determined by using the following equation as sighted by (Sacilik *et al.*, 2003)

$$Sa = \pi GMD^2 \quad \textbf{(3)}$$

Where *Sa* = Surface Area (cm^2), and GMD = Geometric mean diameter (cm)

Sphericity Determination

The sphericity of the kernel was calculated by using the following relationship (Mohsenin, 1970).

$$Sphericity = \frac{Dg}{a} \times 100\% \quad \textbf{(4)}$$

Where Dg = Geometric mean diameter (cm)

a = Major diameter (cm)

Volume Determination

The volume of the kernel was determined by using by using the mathematical relation given by (Orhevba, 2013)

$$Volume = \frac{\pi B L^3}{6(2L - B)} \quad \textbf{(5)}$$

Where $B = (WT)^{1/2}$ L = Major diameter (mm), W = Minor diameter (mm) and

T = Intermediate diameter (mm)

Density Determination

The density of the kernel was determined using the ratio of weight to volume (Mohsenin, 1970).

$$Density\ \rho = \frac{Weight(g)}{volume(cm^3)} \quad \textbf{(6)}$$

Determination of Moisture Content

The samples were dried at 120˚C for 24 hours in an electric oven (Gallenkamp: BS. OV-330), the loss in weight was recorded as the moisture.

$$\%\ \text{moisture content} = \frac{M1 - M2}{MI} \times 100\%\ wb \quad \textbf{(7)}$$

Where M1= initial weight of the sample, and M2 = final weight of the sample

Statistical analysis

The statistical package used in determining the mean, standard deviation and the t-test for independent means was statistical package for social sciences (SPSS 16.0)

Results

The physical properties of the two varieties of Almond seeds (red and white Almond) are presented in Table 1. These were moisture content of 36.5% and 45.9% for red and white almond respectively. The two moisture content levels were observed to be the range at which almond seed can be extracted with least percentage of crushing. Further decrease in the moisture content will make the kernel to be brittle, while a higher moisture level will make the kernel to stick to the shell, therefore, resulting to crushing if cracked.

The average major, intermediate and minor diameters were found to be: 49.35 ± 4.16mm, 33.05 ± 2.79mm, 23.37 ± 2.31mm for red almond and 61.26 ± 4.15mm, 29.61 ± 3.05mm, 21.52 ± 1.59mm for white almond respectively.

The independent t test was conducted on the results of the physical properties of red and white almond seeds. This is to ensure that any statistical inference drawn on the differences betweenthephysical properties of a randomly selected red and white almond seed is scientifically acceptable and have a global application. Table 2 shows the result of the independent test. A t-test wasused to determine significance differences between means of the two improved varieties of cowpea studied.

Figure 1and 2 shows the graphical illustration of the average values of the physical properties of the two varieties of almond seeds.

Table 1: Result of the Physical Properties of Red and White Almond Seed

Physical Properties	Red Almond Seed									
	Mean	SD	Min	Max	CV	Mean	SD	Min	Max	CV
MD^1(mm)	49.35	4.16	41.52	57.57	0.08	61.26	4.15	50.56	70.03	0.07
IMD(mm)	33.05	2.79	27.70	42.25	0.08	29.61	3.05	20.04	37.35	0.10
MD^2(mm)	23.37	2.31	19.76	27.97	0.10	21.52	1.59	18.39	26.06	0.07
Wt (g)	10.20	2.24	6.00	14.00	0.22	10.90	1.52	8.00	14.00	0.14
GMD(m)	33.59	2.41	29.88	40.81	0.07	33.86	2.09	30.44	39.65	0.06
AMD(m)	35.26	2.45	31.13	42.60	0.07	37.47	2.13	33.35	42.51	0.06
SA(mm^2)	3564.6	524.1	2806.1	5233.8	0.15	3616.1	453.7	2912.4	4940.8	0.13
Sp(%)	68.29	4.36	57.09	81.04	0.06	55.39	3.46	47.65	61.85	0.06
vol(cm^3)	0.5023	0.07	0.3960	0.7389	0.14	0.51	0.06	0.41	0.69	0.12
Dn (g/cm^3	19.53	3.82	11.25	25.76	0.19	22.33	3.48	16.90	29.89	0.16
Sample (N)	50					50				
Angle of Internal Friction		Glass	Metal	Wood		Glass	Metal	Wood		
Mean		24.12	21.93	27.50	0.08	22.20	22.38	26.96		0.12
SD		1.92	3.00	2.64	0.14	2.76	3.45	2.23		0.15
Min		22.00	18.00	23.00	0.10	18.00	18.00	23.00		0.08
Max		27.50	27.00	32.00		26.50	27.00	30.50		
Coefficient of Static Friction (CSF)		Glass	Metal	Wood		Glass	Metal	Wood		
Mean		0.45	0.40	0.52		0.41	0.41	0.51		
SD		0.04	0.06	0.06		0.06	0.07	0.05		
Min		0.40	0.32	0.42		0.32	0.32	0.42		
Max		0.52	0.51	0.62		0.50	0.51	0.59		
Sample (N)		10				10				

IMD is intermediate diameter, Wt is weight, GMD is geometric mean diameter, AMD is Arithmetic mean diameter,

SA is surface area, Sp is sphericity, Vol is volume and Dn is density. MD^1 & MD^2 are major and minor diameter respectively.

CV is Coefficient of Variation

Table 2: Comparing the Physical Property of Red and White Almond Seed

						95% CI	
	T	*Df*	*Sig.*	*MD*	*SE*	*Lower*	*Upper*
MD^1(mm)	-13.977	96	0.001*	-11.730	0.839	-13.396	-10.064
IMD(mm)	5.858	96	0.001*	3.465	0.592	2.291	4.640
MD^2(mm)	4.805	96	0.001*	1.919	0.399	1.126	2.711
Wt (g)	-0.404	96	0.6870	-0.184	0.455	-1.086	0.719
GMD(mm)	-4.572	96	0.001*	-2.115	0.463	-3.034	-1.197
AMD(mm)	-0.349	96	0.7280	-34.548	98.900	-230.863	161.768
SA(mm^2)	16.182	96	0.001*	12.851	0.794	11.274	14.427
Sp(%)	-1.157	38	0.2540	-0.700	0.605	-1.924	0.524
Vol(cm^3)	-2.294	38	0.0270	-2.700	1.177	-5.082	-0.318
Dn (g/cm^3	-0.453	96	0.6520	-0.006	0.014	-0.034	0.0210
Angle of internal friction							
Glass	1.805	18	0.0883	1.920	1.064	-0.315	4.155
Metal	-0.311	18	0.7590	-0.450	1.445	-3.485	2.585
Wood	0.494	18	0.6270	0.540	1.093	-1.756	2.836
Coefficient of Static Friction							
Glass	1.78	18.00	0.09	0.04	0.02	-0.01	0.09
Metal	-0.33	18.00	0.75	-0.01	0.03	-0.07	0.05
Wood	0.51	18.00	0.62	0.01	0.02	-0.04	0.06

*MD is mean difference, SE is standard error, *significant @ 5% level*

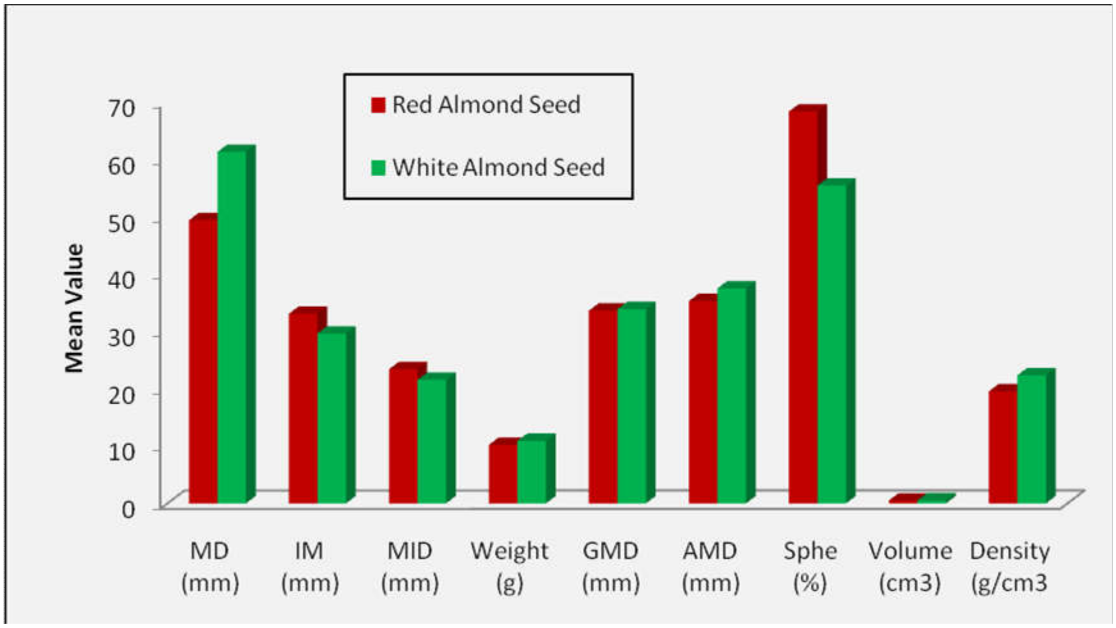

Figure 1: Physical Properties of Almond Seeds

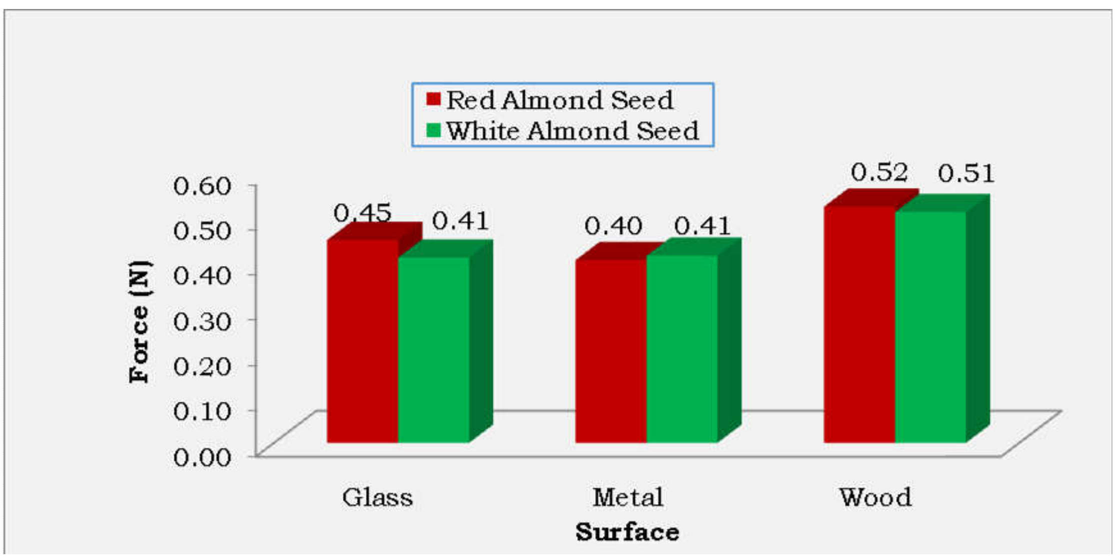

Figure 2: Coefficient of Static Friction (CSF)

Discussion

The physical properties of almond seed at the moisture content levels were found to differ. The dimensions in size of white almond were higher than those of red almond. The average weight was obtained as 10.2 ± 2.24N and 10.9 ± 1.52N for the red almond and white almond respectively. The co-efficient of variation (which is an important parameter in determining sieve sizes in dry cleaning operations) for the major, intermediate and minor diameters were found to be 0.08mm, 0.08mm and 0.09mm for the red almond seeds and 0,07 , 0.10 mm and 0.07mm for the white almond . The smaller the value of coefficient of variation the better the cleaning operation (Orhevba *et al.*, 2013).

The average value for geometric mean diameter, arithmetic mean diameter, volume and density were obtained as 33.59±2.41mm, 35.26±2.45mm, 0.5023±0.07mm^3, and19.53±3.82g/cm^{3}respectivelywhile their corresponding coefficient of variation were 0.07, 0.07, 0.14 and 0.19 for the red almond seeds. Similarly, the average value for geometric mean diameter, arithmetic mean diameter, volume and density were 33.86±2.09mm, 37.47± 2.13 , 0.51±0.06mm^3, 22.33±3.48g/cm^3 respectively while their corresponding coefficient of variations were 0.06, 0.06, 0.12 and 0.16 for the white almond seeds. The relatively high value of sphericity of 68.29% was obtained for the red almond seeds, while 55.39% was obtained for the white almond seeds. This property is relevant in the design of grain handling machineries and where ease of rolling is desirable, high moisture content of seed may be relevant. The average surface area obtained for red almond seeds was 3564.6±524.1mm^2 and the value for white almond seeds was 3616.1±453.7mm^2. The surface area increased with increase in moisture content. (Olalusi *et al.* (2010) reported that the surface area of bush mango increased with increase in grain moisture content which agrees with the findings in this research work. The coefficient of static friction are were 0.45, 0.40 and 0.52 for glass, metal and wood respectively for the red almond seeds and 0.41, 0.41, and 0.51 for glass, metal and wood respectively for the white almond seeds. The coefficient of static friction was highest on plywood and least for metal. Chandrasekar and Viswanathan (1999) and Gupta and Das (1997) reported a similar trend for coffee beans and sunflower seeds, respectively. These frictional properties will find useful application in design and construction of hopper for gravity flow. The angle of internal friction recorded were 24.1º, 21.9º and 27.5º for glass, metal and wood respectively for the red almond seeds and 22.2º, 22.4º and 27.0º for glass, metal and wood respectively for the white almond. The angle of internal friction indicates the angle at which chutes must be positioned in order to achieve consistent flow of materials through it (Olajide and Igbeka, 2003). The determination of the physical properties of agricultural produce has been found useful in the design of processing machine (Chukwu and Sunmonu, 2010).

It was revealed in this study that a randomly selected white almond seed have higher major diameter on the average than red almond seed. Unlike major diameter, the sphericity of randomly selected red almond seeds is higher than those of white almond seeds. Other physical properties such as minor and intermediate diameter, weight, geometric and arithmetic mean diameter, volume and density of a randomly selected red almond seed were relatively the same on the average when compare with those of white almond seed. The knowledge of some important physical properties such as shape, size, volume, surface area, thousand grain weight, density, porosity, hanging of ripples of different grains is necessary for the design of various separating, handling, storing and drying systems (Sahay and Singh, 1994). The size and shape are for instance important in their electrostatic separation from each other and in the development and sizing of grading machinery (Mohsenin , 1986). Based on the average values of coefficient of static friction for both varieties of almond seed using three surface medium namely; glass, metal and wooden surface, it can be deduced from that while the coefficient of static friction was slightly higher in red almond seed than white almond seed when determined using glass and wooden surface, it was however, slightly higher in white almond seed than red almond seed when metal surface was used. Coefficient of friction is needed by designers for predicting the motion of materials in harvesting and handling equipment and is also used to determine the pressure of the grains against the storage bins wall (Lvin, 1970).

Conclusions

It can be concluded from this study that there were significant differences between the engineering properties of the two seeds studied;. determination of engineering properties are vital for the design of postharvest handling, and agricultural processing systems, equipment for Almond seeds; It will be economical to load white Almond kernel in major axis to reduce energy demand when necessary to fracture or compress the Almond kernel whereas loading of red almond kernel should in the intermediate axis; and Physical properties such as size and shape are also important in the electrostatic separation of agricultural product from undesirable materials and in the development of sizing and grading machinery.

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