International Journal of Engineering and Technology Research
Published by Cambridge Research and Publications

Vol. 19 No.5
September, 2020.

DETERMINATION OF PHYSICAL AND MECHANICAL PROPERTIES OF NEEM (*AZADIRACHTA INDICA A. JUSS*) FRUITS THAT ENHANCES DEPULPING

M. A. ADEDEJI, [1*] L.A SANNI, [2] O. S. ADESANYA, [2] I. K. ADESINA, [1] A. O. CHIKEZIE[3]

[1]Department of Agricultural and Bio-Environmental Engineering Technology, Federal Polytechnic, Ede, Osun State, Nigeria. [2]Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ile-Ife, Osun, State, Nigeria. [3]Department of Agricultural and Bio-Environmental Engineering Technology, Federal Polytechnic, Nasarawa, Nasarawa State, Nigeria.

Abstract

The main aim of this study was to determine some physical and mechanical properties of neem (Azadirachta indica a. juss) fruits. Physical and mechanical properties of neem (Azadirachta Indica) were investigated using ripe fruits obtained from surroundings neem trees on Obafemi Awolowo University, Ile-Ife campus and Ile-Ife environs. These engineering properties are essential in the designing, development and fabrication of handling and processing machines such as depulper and decorticator for bulk handling of neem fruits and seeds. These properties were studied using standard procedures. Results obtained showed that the average moisture content of the fruits at harvest was 81.95% (w.b). Physical properties such as; length, width, thickness, unit mass, geometric mean diameter, arithmetic mean, surface area, sphericity and aspect ratio were 14.89 mm, 9.22 mm, 8.95 mm, 0.75g, 10.7 mm, 11.02 mm, 33.6 mm^2, 71.91 and 61.94, respectively. 1000 unit mass, bulk density, true density and percentage porosity were 597.8 g 0.58 g/cm^3, 1.06 g/cm^3 and 45.42, respectively. Mechanical properties such as; static coefficient of friction on four different four surfaces; plywood, glass, mild steel and stainless steel were 0.19, 0.14, 0.24 and 0.06, respectively. Dynamic angle of repose was found to be 47.5 ^{o}. Computerized Istron Electromechanical Testing Systems (Model 3369) was used to determine the fruits compressive stress for longitudinal and transverse loadings. Compressive stress for the longitudinal and transverse were found to be 0.12 ± 0.03and 0.044 ± 0.013 MPa, respectively. The average yield stresses of 8.94 ± 2.44 N and 8.37 ± 2.24 N were required to crack the fruits when loaded in the longitudinal and transverse orientations, respectively.

Keywords: *neem fruits, physical, mechanical, properties, depulping*

Introduction

The botanical name of the neem is '*Azadirachta indica*' and it belongs to the mahogany family '*Meliceae*'. It is native to Indian Subcontinent and about 14 million neem trees are present in India (Oluwole et al., 2015). It has been described as the most researched tree in the world and is said to be the most promising tree of the 21st century. Other vernacular names for neem include '*Dongoyayo'* (in some Nigerian languages). In East Africa, it is known as *Maurubaini* (Swahili), which means *the tree of the 40*, as it is said to treat 40 different diseases, and in Somalia it is known as '*Geed Hindi'* which means '*the Indian tree'* (Rajeev, 2009; Adedeji & Owolarafe, 2015). Plates 1-3 illustrates the neem tree, neem twig and dried neem seeds, respectively (Oluwole et al., 2015).

Plate 1: Neem tree

Plate 2: Neem twig

Plate 3: Dried Neem seeds

Neem oil is a vegetable oil pressed from the fruits and seeds of the neem. While sharing many properties with tea tree oil, neem oil has the added advantage of a high fatty acid and low terpene content. Neem oil has been found to be an effective mosquito repellent. Neem tree has become focus of attention all over the world due to its medicinal and pest control activities. It is used in treating many kinds of diseases in Ayurveda (Dubhashi et al., 2013). Processing operations such as depulping and decortication to obtain the seed and kernel are still predominantly being carried out manually in Nigeria. Despite the economic importance of neem seed in many countries, only little information is known about the engineering properties of the fruit and seed. Using manual method in processing (cleaning, sorting, depulping, decorticating and extraction) neem is not only laborious and time consuming but also yields low quality and quantity products (Adedeji & Owolarafe, 2015). The knowledge of physical properties of this seed will enhance the development of appropriate machines and equipment relevant to bulk-handling during harvesting, sorting, dehusking, drying, storage, aeration, grinding, and extraction of oil from the seed. Neem seed which is available in abundance in Nigeria contains about 40% non-edible oil which can be used as biodiesel; this is an untapped and researched potential resource. This study intends to provide physical and mechanical properties parameters of fresh neem fruits that will enhance development of a depulping machine. In Nigeria presently there is no recognized commercial depulper, depulping of the fruits is still being done manually, hence the necessity for this research work. In April 2015, *A. indica* was declared a class B and C weed in the Northern Territory, Australia, meaning its growth and spread must be controlled and plants or propagules are not allowed to be brought into the NT. It is illegal to buy, sell, or transport the plants or seeds. Its declaration as a weed came in response to its invasion of waterways in the "Top End" of the territory.

Chemical composition of neem

The chemical composition of neem is shown in Table 1 below. *Nimbidin, Nimbin, and Nimbinin* are compounds extracted from neem oil, and they are bitter in taste (Ganguli, 2002), while the seed contains a complex secondary metabolite known as *azadirachtin*.

Table 1: Neem composition

Neem fruit (fresh)	Greenish brown kernels	30%
	Other shell, pulp etc.	70%
Neem seed	Shell	55.3%
	Kernel	44.7%
Neem kernel oil content	Kernel oil content	46 - 48%
Other ingredients	Azadirachtin	0.3%
	Nimbidin	1.2 – 1.6%
	Ni Nimbin	0. 0.1%
	Ni Nimbinin	0. 0.01%
	V Veepinin	00. 0.15%

Source: (Rao, 2003)

The objective of this study is to determine the physical and mechanical properties of neem fruits.

Neem Fruit Processing Technology

Collection and harvesting methods

The neem tree yields fruits during May to August every year. Being rich in carbohydrates, neem fruits get attacked by fungi when they come in contact with soil. Such fruits may damage the quality of the final products prepared from these fruits. Hence it is strongly recommended to avoid contact of neem fruits with soil. As the fruit ripens, they must be depulped as early as possible. The commercialisation of neem products requires an effective and reliable collection system for neem fruits, which does not exist in most countries. It turns out that reliable collection and preparation of neem kernels of good quality for a reasonable price is one of the highest hurdles in setting up neem processing in developing countries. Moreover, the kernels may be of inferior quality in the early stages or due to extraordinary weather conditions, e.g. contaminated with fungi *(Aspergillus spp.)*. In some other cases, the ripe fruit that fall off the tree can be collected (swept up) more cheaply but further cleaning from debris is still required. Table 2 illustrates the methods of collection of neem fruits.

Table 2: Methods of collection of neem fruits

Parameters	Traditional method	Improved method	Manual picking
Plucking method	Fallen near tree over a night	Branches shaken manually with a pole	Direct from tree by hand
Flooring under tree	Barren earth	200 micron thickness poly sheet	NA
Time taken, man-h	1.5	2	3
Fruit collected per tree, kg	17.62	20.9	10.5
Time taken in sorting, min/person	33	14.5	Nil
Weight of waste material, kg	5.3	4.6	Nil
Effective output (neem fruits), kg/h	6	7.27	3.5
Type of waste	Molds, stone, debris, sticks and leaves etc.	Unripe fruits, leaves and sticks	Nil
Start of decomposition	On 3rd day	On 4th day	On 6th day

Source: (Solanki et al., 2017)

Depulping of neem fruits

Depulping of neem fruit is a process of remove fruit coat and pulp from the neem fruit in order to produce neem seed (Dubhashi *et al*., 2013). Collected fruits should be kept immediately in warm water to avoid fungal growth. These fruits may be kept in water from 12-24 hours to further soften the pulp, and for best results be depulped within 48 h. Depulping can be done manually; by hand, and also with a mechanical depulper. To depulp manually, the ripe neem fruit is rubbed between palms in the bucket of water and seed washed. For the greenish (unripe) fruits it is very difficult to remove the pulp manually. In order to soften the pulp the greenish fruits can be picked out of the lot and after-ripened separately; they are spread out in a 2-3 fruit thick layer in the shade, protected from rain for 1-3 days and subsequently depulped. Mechanised scrubbers, macerators and washers can also be used for larger quantities. A simple alternative is to dump the fruits in ash or soil for a couple of days followed by trampling, rubbing and winnowing. A manually operated depulper to handle neem fruits was developed in India. After depulping and cleaning, drying the neem seeds in the shade in a thin layer is necessary. Neem seeds should be kept in a cool dry place. If processed properly, these neem seeds can be stored for about 6-12 months; (Dash, et al., 2008, Rao, 2013; Vahid and Khodayar, 2009). This might be due to the climatic conditions at the time of its maturity and its fast perishable quality. Keeping this in view, low-cost, small size neem depulper will be necessary to suit the need of landless and small farmers (Solanki et al., 2017, Nde et al., 2013).

Storage

For storage, the seeds should be disinfected by some means, e.g. calcium hypochlorite, and dried in the sun or by heating devices to achieve moisture content lower than 7%. The seeds should be stored in a shady and airy place. This is one of the main problems, especially on village level, due the lack of space in the huts of the poor collectors (Adedeji & Owolarafe, 2015).

Materials and Methods

Sampling and Sample Preparation

This study was conducted at the Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria between December 2019 and January 2020. The material sample needed (*Neem* fruit) was obtained by shaking the branches of neem trees located around Spider building, Chemical Engineering department, Botany department, Faculty of EDM and some surrounding OAU environs, and also around Ile-Ife environs. The fruits were gathered and cleaned manually to remove all foreign materials such as dust, dirt, moulds, stones, debris, sticks and leaves as well as immature and broken fruits. The samples were poured into a polyethylene bag and the bag sealed tightly, which was then kept in a freezer (-18°C) (Nde et al., 2013) to maintain their freshness. Before starting the test, the required quantity of the fresh fruits was taken out from the freezer and spread on a laboratory bench overnight to equilibrate to room temperature. Plates 4 and 5 show the unripe and ripe neem fruits.

Plate 4: Unripe neem fruits

Plate 5: Ripe neem fruits

Physical Properties Determination

100 fruits were selected randomly and their physical and mechanical properties in the fresh state were measured. The physical properties that were determined included: moisture content, axial dimensions (major, intermediate and minor diameters, geometric mean diameter, and arithmetic mean diameter), sphericity, 1000 unit-mass, volume, bulk density, true density, porosity and surface area. (Adedeji & Owolarafe, 2015)

Determination of Moisture Content

To determine the moisture content (w.b), fruits samples were randomly selected from the bulk sample. Electric oven (UNISCOPE SM9023), moisture content cans, desiccators containing desiccants, and electronic balance (METTLER TOLEDO) with accuracy of ± 0.001g were used to determine moisture content of the neem fruits. A known mass of each sample was measured using an electronic balance and placed in an oven at 80°C to constant mass. Measurement was replicated thrice and the average weight recorded (Nde et al., 2013; Adedeji and Owolarafe, 2015). The moisture content (w.b) was computed using the equation 1 below:

$$M.C\ (w.b) = \frac{M_b - M_a}{M_b - M_c} \times 100\% \qquad 1$$

where;
M.C = moisture content (w.b)
M_b = weight of can plus sample before drying (g)
M_a = weight of can plus sample after drying (g)
M_c = weight of can (g)

Axial dimensions and mass of fruit

To determine the average size of Neem fruits, 100 fruits were selected randomly from the bulk sample. Measurement of the three major perpendicular dimensions: major diameter, L, intermediate diameter, W, and minor diameter, T, were carried out using a digital Vernier-calliper with an accuracy of ± 0.01mm (Adedeji and Owolarafe, 2015). The corresponding mass of each fruit was also measured using an analytical balance (METTLER TOLEDO) with accuracy of ± 0.001g (Nde et al., 2013).

Determination of geometric mean diameter (Dg)

The geometric mean diameter was determined (Nde et al. 2013) from equation 2;

$$D_g = (LWT)^{\frac{1}{3}} \qquad 2$$

Dg is geometric mean diameter (mm).

Determination of arithmetic mean diameter (Da)

The arithmetic mean diameter was determined from equation 3 (Nde et al., 2013):

$$D_a = \frac{(L+W+T)}{3} \qquad 3$$

Determination of surface area of neem fruit

The surface area (S_A) of the fruit was determined using equation 4 (Sacilik et al., 2003).

$$S_A = \pi {D_g}^2 \qquad 4$$

S_A is surface area.

Sphericity determination

Sphericity was determined using equation 5 (Adedeji & Owolarafe, 2015):

$$\vartheta = \left(\frac{D_g}{L}\right) \qquad 5$$

Θ is sphericity.

Determination of aspect ratio

The aspect ratio from the 100 fruits was determined as recommended by Owolarafe et al., (2007) using equation 6 below:

$$R_a = \frac{W}{L} \times 100 \qquad 6$$

Determination of 1000 unit-mass

1000 unit-mass (M_{1000}) of fruits was determined by counting one hundred fruits and their mass was measured using an electronic balance. The mass obtained was then multiplied by 10. The experiment was repeated three times (Nde et al., 2013), and the mean and standard deviation was calculated and recorded.

Determination of bulk density

Bulk density was determined by using a container with known volume, filled with fresh Neem fruits samples in excess. After filling, the container was tapped gently, and then a flat ruler was passed across the top surface of the container using 2 zigzag motions to remove excess samples. The filled container was weighed using an electronic balance. The process was replicated thrice and the bulk density was calculated from equation 7 cited by Adedeji & Owolarafe (2015):

$$\rho_b = \frac{m}{v} \qquad 7$$

ρ_b is bulk density, m = mass of Neem fruits (g) and V = volume of container (cm^3).

Determination of true density

True density was determined by the water displacement method. Ten fruits of known mass was lowered into a 25 ml measuring cylinder containing diesel. The volume of diesel displaced by fruits was recorded. The ratio of mass to volume of the fruits was treated as true density (ρ_t) using equation 8 (Abdullah et al., 2011);

$$\rho_t = \frac{m}{v_w} \qquad 8$$

ρ_t is true density, m = mass of nuts (kg) and v_w = volume of water displaced in (m^3).

Determination of Porosity

The porosity (ε) value was calculated from the values of bulk and true density using equation 9;

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) 100 \qquad 9$$

Determination of Mechanical Properties

Mechanical properties determined include coefficient of friction, angle of repose and compressive strength;

Coefficient of friction determination

The static coefficient of Neem fruit was determined on four surfaces; plywood, glass, mild-steel, and stainless steel. A topless and bottomless material box was used for the fruits. The box was filled with the sample and placed on an adjustable tilting table onto which the material (plywood, glass, mild-steel, and aluminium) to be tested was fastened. The box was placed on one side of the surface and raised slightly so that it does not touch the material. The table was gently tilted until friction force between the fruit and the material was overcome by the gravity and moved down the slope. The angle of inclination was then read from the graduated protractor attached to the tilting table (Alonge and Adegbulugbe, 2005; Owolarafe et al., 2007; Adedeji and Owolarafe, 2015). The coefficient of static friction was equation 10:

$$\mu = \tan\theta \qquad 10$$

Determination of angle of repose

Angle of repose of the material was determined using an open-ended cylinder. The cylinder was placed at the centre of a circular plate and filled with Neem fruits. The cylinder was lifted slowly until the fruits form a cone on the circular plate. The diameter and height of cone formed was measured and recorded, and the angle of repose thus calculated using equation 11. This was replicated three times (Dash et al., 2008; Adedeji and Owolarafe, 2015).

$$\theta = \tan^{-1}\frac{2H}{D} \qquad 11$$

Compressive strength determination

Compressive strength of the neem fruit was carried out at the Centre for Energy Research and Development (CERD) of Obafemi Awolowo University, Ile-Ife, Osun State by using a computerised Universal Testing Machine (UTM) (Istron Electromechanical Testing Systems) Model 3369, 100kN, Istron Corporation, USA as shown in Plate 6 below. The sample fruit was loaded longitudinally and transversely as shown in Fig. 1 below between two parallel plates of the testing machine and compressed, and this was replicated three times for different loading orientation. Samples were loaded at 2.0 mm/minute, and test results were generated automatically through the computer attached to the machine. Data obtained include compressive stress at yield, compressive strain at yield, compressive load at yield and energy at yield.

Plate 6: IET machine

Source: Adedeji & Owolarafe, (2015).

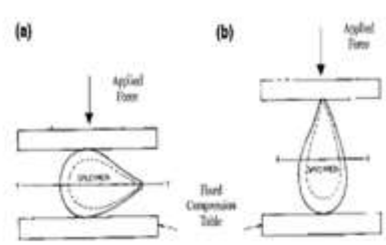

Fig. 1: Compression test of samples

Results and Discussions

Physical Properties

The summarized values for some of the physical properties of the fruits determined are presented in Table 3 below.

Moisture content

The average moisture content of the fruits was found to be 81.95% (w.b), with a standard deviation of 0.16. All the physical properties measured on the fruits varied as a function of moisture content, this result agreed with Nde et al., 2013.

Axial dimensions and corresponding mass

The mean axial dimensions for major (L), intermediate (W), minor (T) diameter and weight obtained for 100 fruits were 14.85 mm, 9.24 mm, 8.98 mm and 0.760 kg, respectively.

Size distribution

Table 4 shows the size distribution of neem fruit. For L, 19% of the fruit were between 18.2-16.22 mm (large), 55% between 16.21-14.19 mm (medium), with 26% between 14.18-12.17 mm (small). For W, 11% of the fruit ranged between 12.02-10.54 mm (large), 42% between 10.53-9.04 mm (medium), with 47% between 9.03-7.56 mm (small); while for T, 9% of the fruit ranged between 11.78-10.29 mm (large), 42% between 10.28=8.79 mm (medium), with 49% between 8.78-7.30 mm (small).

Table 3: Results of some physical properties of neem fruit

Property	N*	Mean Value ± **S.D
Moisture content (% w.b)	3	81.95 ± 0.16
Axial dimensions		
L (mm)	100	14.89 ± 1.24
W (mm)	100	9.22 ± 1.05
T (mm)	100	8.95 ± 0.98
Unit weight of fruit (g)	100	0.76 ± 0.21
Geometric mean diameter (mm)	100	10.70 ± 1.03
Arithmetic mean diameter (mm)	100	11.02 ± 1.02
Surface area	100	33.63 ± 3.24
Shape indices	42	33.63 ± 3.24
Sphericity (%)	100	71.91 ± 3.46
Aspect ratio (%)	100	61.94 ± 4.68

Gravimetric properties		
One thousand mass (g)	3	597.80 ± 15.88
Bulk density (gcm^{-3})	3	0.58 ± 0.01
Trye density (gcm^{-3})	3	1.06±0.08
Percentage porosity	3	45.42±3.62

*N = Number of Replicates. **S.D = Standard Deviation

Table 4: Results of size distribution of neem fruit

Properties	Size distribution		
	Large	**Medium**	**Small**
Major diameter(L), mm	16.79 ± 0.53	14.94 ± 0.46	13.37 ± 0.55
Intermediate diameter (W), mm	11.20 ± 0.45	9.73 ± 0.34	8.30 ± 0.36
Minor diameter(T), mm	10.84 ± 0.49	9.53 ± 0.39	8.11 ± 0.38

Observation of result above shows that fruits with larger length have corresponding larger width and thickness Solanki et al., (2007).

Geometric mean diameter (D_g)

The geometric mean diameter of the fruit was computed, and the mean value obtained was 10.7 ± 1.03 mm. It was observed that geometric mean diameter increases with an increase in fruit dimension, thereby, resulting in the fruits with the least dimension having the least geometric diameter.

Arithmetic mean diameter (D_a)

The arithmetic mean diameter of the fruit was computed, and the mean value obtained was 11.02 ± 1.02 mm.

Surface area, S_A

The mean value obtained for surface area of the fruit was 33.63 ± 3.24 mm^2. It was observed that surface area increases with increase in axial dimensions of fruit.

Sphericity, ω

The computed average value for sphericity was 71.91, with a standard deviation of 3.46. It was observed that sphericity reduces with decrease in physical dimensions of fruit. The shape of a biomaterial can be determined in terms of its sphericity, and this in turn affects the flow ability characteristics.

Aspect ratio, R_a
The aspect ratio of the fruit was computed from recorded values for axial dimension, and the mean value obtained was 61.94 ± 4.68.

1000-unit mass
The average thousand mass was computed, and a mean value of 597.80±15.88g.

Bulk density (ρ_b)
The value obtained for bulk density was 0.58±0.01 $gcm^{-3.}$

True density (ρ_t)
The true density was determined to be 1.06 ± 0.08 gcm^{-3}.

Percentage porosity (ϵ)
The percentage porosity was computed to be 45.42±3.62. The porosity shows the relationship between the bulk and true density, and the extent of pore space in the fruit mass. The porosity value is often needed in air flow studies. Result obtained agreed with Nde et al., (2013) and Adedeji & Owolarafe (2015).

Mechanical Properties
Static coefficient of friction
The coefficient of friction on these surfaces; plywood, glass, mild steel and stainless steel was determined using a Tilting Plane Apparatus in the department. The average value obtained for these surfaces were 0.19, 0.14, 0.24 and 0.06, respectively, with standard deviations of 0.03, 0.01, 0.05 and 0.02, respectively. The summarized values are shown in Table 6 below. The surface with the highest coefficient of static friction was mild steel, followed by plywood, glass, while stainless has the least value. It was observed that static coefficient of friction increases as surface becomes rougher.

Angle of repose
The mean value obtained for repose angle on smooth wood was 47.5 ± 1.4 º. The angle of repose indicates the force of cohesion among the units of a biomaterial. The hopper walls are mostly inclined at a greater angle than angle of repose, so as to allow materials flow freely under gravity. The result is shown in Table 6 below;

Table 6: Results of some mechanical properties of neem fruits

Property	N*	Mean value ± SD*
Coefficient of friction		
Plywood	3	0.19 ± 0.03
Glass	3	0.14 ± 0.01
Mild steel	3	0.24 ± 0.05
Stainless steel	3	0.06 ± 0.02

Angle of repose wood	3	47.5± 1.4

*N = Number of Replicates. **S.D = Standard Deviation

Compressive strength

Compression tests were conducted on the *neem* (*Azadirachta Indica*) fruit with the Universal Testing Machine shown earlier in plate 3.1. The average maximum compressive stress during transverse loading (0.044 MPa) was less than that of longitudinal loading (0.12 Mpa), while average compressive strain for transverse loading (41.88%) was higher than that of longitudinal loading. The mean energy at break point during longitudinal loading (0.015 J) was relatively higher than that of transverse loading (0.0066 J). Summarized values for both loading orientations are shown in Table 7 below.

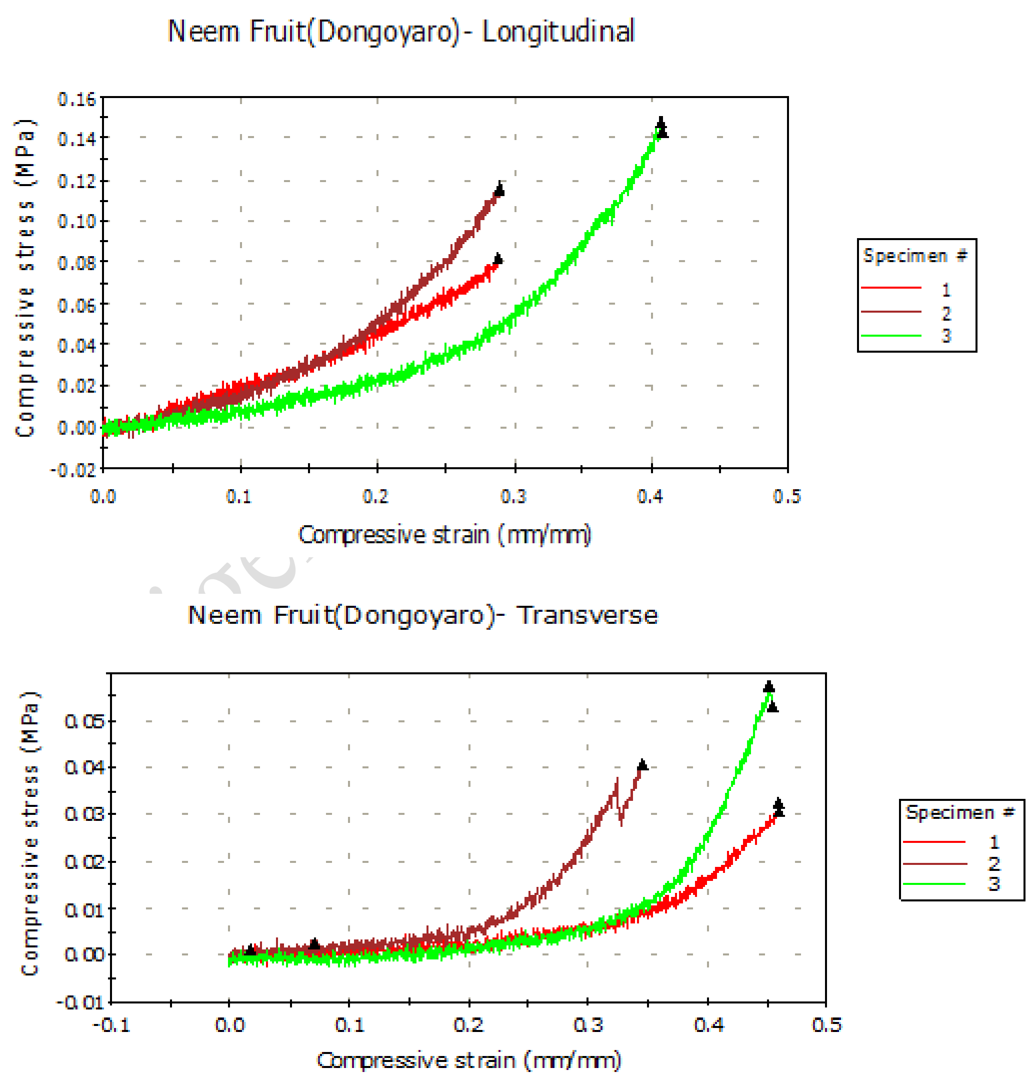

Figure 4: Stress vs. strain graph longitudinal and transverse loading of *neem* fruit

Table 7: Results of compression properties of neem fruits

	Longitudinal loading	Transverse loading
Maximum compressive stress (MPa)	0.12 ± 0.03	0.044 ± 0.013
Compressive strain at maximum compressive stress (%)	32.84 ± 6.84	41.88 ± 6.43
Energy at maximum compressive stress (J)	0.014 ± 0.004	0.0066 ± 0.00079
Compressive load at Maximum Compressive stress (N)	9.09 ± 2.61	8.79 ± 2.56
Compressive extension at Maximum Compressive stress	5.16 ± 1.07	4.31 ± 0.66
(mm)	0.11 ± 0.03	0.042 ± 0.011
Compressive stress at break (standard) (MPa)	8.94 ± 2.44	8.37 ± 2.24
Compressive load at break (standard) (N)	-9.09 ± 2.61	-8.79 ± 2.56
Load at maximum compressive stress (N)	-5.16 ± 1.07	-4.31 ± 0.66
Extension at maximum	-5.16 ± 1.07	-4.32 ± 0.67
compressive stress (mm)	0.015 ± 0.004	0.0066 ± 0.00088
Extension at break (mm)	-	0.0019 ± 0.00071
Energy at Break (standard) (J)		
Compressive stress at yield (zero slope) (MPa)		

Each value represents mean of three replicates ± standard deviation.

Conclusions and Recommendations

Conclusions

The following conclusions can be deduced from the results of the experiments and computations carried out on some of the physical and mechanical properties of the neem (*Azadirachta Indica)* fruits;

The mean value for the harvested neem fruits moisture content was 81.95 % (w.b). Some of the physical and mechanical properties has been carried out, results have been presented in this study. These results can be used to help in designing the needed depulping machine.

Recommendation

1. Some physical and mechanical properties of neem fruits were determined and these data obtained from these study can be a starting point information to designers' for basic parameters needed to design the shaft and other necessary and functional componet parts of the depulper.
2. The varying and relatively non-uniform dimensions of the fruit will likely make process of depulping tedious.

References

Adedeji, M. A. and Owolarafe, O.K. (2015). Mechanical and Aerodynamic Properties of *Neem* Seed (Azadirachta Indica) As Potentials for Developing Processing Machines. *Journal of Teacher Perspective.*

Adedeji, M. A. and Owolarafe, O.K. (2015). Some Physical Properties of *Neem* Seeds and Kernels (Azadirachta indica) as a Function of Moisture Content. Pp. 812-820. *International Journal of Scientific & Engineering Research*, Volume 6, Issue 1, January-2015 812. ISSN 2229-5518.

Alonge, A.F. and Adegbulugbe, T.A. (2005). Some physical properties of groundnut. *Journal of Agricultural Engineering and Technology*. 13, 35-41.

Amin, M.N., Hossain, M.A. and Roy, C. (2004). Effects of Moisture Content on Some Physical Properties of Lentil Seeds. *Journal of Food Engineering*, 65, 83 -87.

Bart-Plange, A. and Baryeh, E.A. (2003). The Physical Properties of Category B Cocoa Beans. *J. Food Engine*. 60:219-227.

Baryeh E.A. (2002). Physical Properties of Millet. *Journal of Food Engineering*. 51, 9 – 46.

Garnayak, D.K., Pradhan, R.C., and Bhatnagar, N. (2008). Moisture dependent physical properties of jatropha seed. *Industrial Crops Product* 27, 123-129.

Nde, B.D. Ngu, A.E. and Natang, M.I. (2013). Physical properties of *Neem* (Azadirachtaindicaa. juss) fruits, nuts and kernels. *Sky Journal of Food Science*. Vol. 2(8), pp.014-023,December,2013.Availableonline http://www.skyjournals.org/SJFS.

Ogunjimi, L.A.O., Aviara, N.A. and Aregbesola, O.A. (2002). Some Engineering Properties of Locust Bean Seed. *Journal of Food Engineering*, 55, 95- 99.

Oluwole, F. A; Oumaru, M. B.; and Abdulrahim, A. T. (2015). Traditional Method of Neem Seed Oil Extraction in North Eastern Nigeria: Challenges and Prospects. *Continental J. Engineering Science* 10(1): 1-8, 2015. ISSN: 2141- 4068. ttp://www.wiloludjournal.com doi:10.5707/cjengsci.2015.10.1.1.8.

Owolarafe O.K., Olabige M.T. and Faborode M.O. (2007). Physical and Mechanical Properties of two Varieties of Fresh Oil Palm Fruit. *Journal of Food Engineering*, 78: 1228 -1232.

Paksoy, M. and Aydin, C. (2004). Some physical properties of edible squash (*Cucurbita pepo L.*) seeds. *Journal of Food Engineering*, 65, 225-231.

Pradhan, R.C., Naik, S.N., Bhatnagar, N. and Vijay, V.K. (2009). Physical properties of tree borne oil seed: potential biodiesel feedstock in India. Assam Uni. *Journal of Science. and Technology: Physical Sc. and Tech.*4 (11), 46-53.

Rajeev, S. (2009). DinkaAgro Inc.: Organic for Healthy Living. *Indian Journal. Pediat*, 49,375-359.

Sadeghi, M., Ashtiani H.A and Herminat, A. (2010). Physic-mechanical properties of rough rice (Oryza sativa L.0 grain as affected by varieties moisture content. *Agricultural Engineering International: CIGR Journal*, Vol. 12, No 3-4.

Sahin, S. and Sumnu, S. G. (2006). Physical properties of Foods. Heldmsn, D.R, eds, Springer Science and Business Media, LLC, New York.

Solanki, R.C., Naik, S.N., Srivastava, A.P., Santosh, S. and Singh, S.P. (2017). Design, Development and Evaluation of Neem Depulper. VOL.48 NO.4 2017 *AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA*

Vahid A., Jafar M., and Khodayar H. (2009). Mechanical properties of promegrate seeds affected by moisture content. *American-Eurasian J. Agric. and Environ. Science*, 6 (4), 447-453.