MECHANICAL AND AERODYNAMIC PROPERTIES OF NEEM SEED (AZADIRACHTA INDICA) AS POTENTIALS FOR DEVELOPING PROCESSING MACHINES

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Abstract
In this study some selected mechanical and aerodynamic properties of neem (Azadirachta indica) seed, kernel and hull at different processing conditions have been evaluated as a function of moisture content ranging from 5.10 to 18.69 % (w.b.). Neem fruits were collected from a plantation in Dawaki town, Plateau State. Mechanical properties such as static coefficient of friction of the seed and kernel on four surfaces (mild steel, plywood, aluminium and glass) and angle of repose were determined. Compressive properties at yield (compressive load, compressive stress, compressive strain and energy) of the seed were determined at two orientations (longitudinal and transverse axes). Aerodynamic property (terminal velocity) of the seed, kernel and hull was also determined. Results showed that the seed ranges in values for angle of repose (27.1 to 32.4⁰), terminal velocity (4.30 to 5.34 m/s), static coefficient of friction on mild-steel (0.76 to 0.80), on plywood (1.63 to 1.74) on glass (0.52 to 0.54) and on aluminium (1.35 to 1.10) as moisture content increased. Reduction of crushing force (32.2 to 19.5 N for longitudinal) and (41.3 to 29.4 N for transverse) as the moisture content increased was also observed. The coefficient of friction of the seed kernel on plywood decreased with increase in moisture contents from 0.69 to 0.59 while the angle of repose of the seed kernel increased from 30.5 to 31.8⁰ terminal velocity from 4.66 to 5.38 m/s, There was increase in the static coefficient of friction of the kernel on mild-steel from 0.73 to 0.86, on aluminium from 0.55 to 0.69 and on glass from 0.45 to 0.54, as moisture content increased. The terminal velocity of the hull decreased from 3.43 to 3.08 m/s as moisture content increased. For all the properties considered moisture content was significant (p<0.05) for both seed and kernel.
Neem is a fast-growing tree that can reach a height of 15–20 m (about 50–65 feet), rarely to 35–40 m (115–131 feet). It is evergreen, but in severe drought it may shed most or nearly all of its leaves. The branches are wide spread. The fairly dense crown is roundish or oval and may reach the diameter of 15–20 m in old, free-standing specimens. This tree offers a great resource for environment-friendly bio-pesticides. Limonoids found in the leaves, seeds and bark are used as an effective insect-growth controlling substance. Neem oil is a vegetable oil pressed from the fruits and seeds of the neem. The oil contains quantities of steroids, including beta-sitosterol (used to treat men suffering from enlarged prostate glands) as well as linoleic and oleic acids (Omega 6 and 9), and is found to contain the well-known Omega 3 fatty acid (used to prevent arterial sclerosis). It is also used as an organic bio-pesticide repellant against insects such as Japanese beetles, meal worms, and aphids (National Research Council, 1992). The need to search for alternative sources of renewable energy, that will be safe and environmentally friendly with the view that fossil fuels are finite and are the major source of releasing sequestered carbon to the atmosphere as CO2 and CO causing global warming. Apart from this, uncertain supplies and sudden frequent price hikes of fossil fuels in the international market are posing severe economic threats for developing countries (Pradhan, R.C., Naik, S.N., Bhatnagar, N. and Vijay, V.K., 2009).

The cultivation of neem tree in Africa began in the 1920’s when it was introduced to Ghana, Nigeria, and the Sudan; now it is well established in more than 30 countries. The neem tree grows widely in the savannah part of Nigeria. It was noted that neem had been grown on a plantation scale in Nigeria since 1936, and that it was introduced to Sokoto State (Olatunde, 2011). Plates 1 (a) and 1 (b) display dried neem seeds and freshly harvested fruits, respectively.
An enormous increase in the number of automobile in recent years has resulted in greater demand for petroleum products. With crude oil estimated to last only for a few decades, therefore, efforts are underway to research into alternatives to diesel. Of the various alternate fuels under consideration, biodiesel, derived from esterified vegetable oils, appears to be the most promising alternative (Anbumani and Singh, 2010).

Mechanical properties may be defined as those having to do with the behaviour of the material under applied forces. Mechanical properties other than rheological properties usually deal with the motion of the material under applied force. Mechanical damage to seeds and grains which occur in harvesting, threshing, and handling can seriously affect viability and germination power, growth vigour, insect and fungi attack, and quality of the final product (Mohsenin, 1986).

Static and sliding coefficients of friction of grains forage materials and some other farm products on metals, wood, and other materials are needed by design engineers for rational design and prediction of motion of the material in harvesting and handling equipment. There are two angles of repose, that is, static angle of repose and dynamic angle of repose. The dynamic angle of repose is important than the static angle of repose as it arises in all cases where the bulk of material in motion such as the movement of solids discharging from bin and hoppers (Mohsenin, 1986).

Compression (deformation) test measures the distance that an agricultural material is compressed under a standard compression force. A lot of research works have been carried out to predict energy required for some processes. The design of machines such as shelling machine, decorticator, harvester, etc. requires the knowledge of the force and pressure required to perform the desired operation. Gbadamosi (2006) investigated some engineering properties of palm kernel and reported that the compression test along the major axis gave the best position of placing the seed as least force is required compared with the required force along intermediate axis. Also Owolarafe O.K., Olabige M.T. and Faborode M.O., (2007) reported that the average cracking force required to break the dura variety of fresh oil palm fruit was higher than that of the tenura variety. The report given by Solanki, R.C., Naik, S.N., Srivastava, A.P., and Santosh, S., (2011) in the investigation of physical and mechanical properties of neem fruit and seed relevant to depulping and decortication indicated that the shear and compressive force are the two important mechanical properties required for design of various machine components. It was observed that the shear force required to crush the pulp and the seed, both for fresh fruit and dry...
seed, was less than corresponding compressive force. This is an indication that the shearing mechanism would be preferable than removing the pulp or removing shell from kernel by compressive force.

Aerodynamic properties of agricultural materials are very important in separation of the materials. The properties which include particle diameter, frontal area, and terminal velocity and drag coefficients are influenced by some processing conditions. Alonge and Adigun (1999) studied the effect of moisture content on the aerodynamic and physical properties of two varieties of sorghum, *saccharatum* group (sweet sorghum) and *technicum* group (small seed sorghum) relevant to developing threshing and cleaning machine. Their results showed that within the moisture range of 12.50-25 % wb and 28.57-37.50 % wb for *saccharatum* and *technicum* groups respectively, the average terminal velocities varies between 6.99m/s and 9.89m/s. Khoshtaghaza and Mehdizabeh (2006) reported that mass and moisture content have significant effects on the terminal velocity.

Decortication and separation of the seed coat from the kernel are important operations in the processing of neem seed. The design of machines that can handle this operation requires mechanical and aerodynamic properties of the seed, hence this study.

**Materials and Methods**

**Sample Preparation**

This study was conducted at the Department of Agricultural and Environmental Engineering in Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria during the period of June–October 2012. *Neem* fruits (*Azadirachta indica*) of about 200 kg were collected from a plantation in Dawaki, Kanke Local Government Area of Plateau State. Ripe fruits (yellowish in colour) and unripe fruits (greenish in colour) were collected from the tree by shaking branches of the tree. These seeds were allowed to fall freely on poly bags spread under the tree. Sorting of matured fruits from immature ones was carried out manually in order to get good quality seeds, (Solanki *et al*., 2011). *Neem* seeds were obtained by manually depulping ripe fruits. The sorted matured seeds were later sundried to safe moisture content of about 5.10% (wb).

The initial average moisture content was determined using oven method. Three samples of 10.0g were heated for twenty-four hours at 105±2°C in Gallenkamp 300 plus series oven until constant weight was reached (Mahbobeh *et al*., 2011; Solanki *et al*., 2011). The experiment was replicated three times. The moisture content were calculated using equation 1:
where:

\[ M_C \text{ (w.b)} = \text{moisture content (wet basis)}. \]

\[ M_b = \text{the weight of can plus sample weight before heating (kg)}. \]

\[ M_a = \text{the weight of can plus sample weight after heating (kg)}. \]

\[ M_c = \text{weight of can (kg)}. \]

The mean value and standard deviation of the three samples was calculated.

The moisture content of the sample was adjusted to three levels, 9.95, 14.17 and 18.69% based on information from literature (Oluwole, F.A., Abdulrahim, A.T. and Olalere, R.K., 2007, Olatunde, 2011). Each sample weighing 300.0 g was sealed in a separate polythene bags with the calculated amount of distilled water that will change the moisture content to the desired level. The quantity of distilled water that was added in order to adjust the moisture was calculated using equation 2 given below (Davies and Zibokere, 2011);

\[ W_s = \left( \frac{M_2 - M_1}{100} \right) \times W_s 
\]

where;

\[ W_s = \text{weight of sample (kg)}. \]

\[ M = \text{weight of distilled water that was added (kg)}. \]

\[ M_f = \text{initial moisture content (%)}. \]

\[ M_f = \text{final moisture content (%)}. \]

After addition of the required distilled water (10% of the calculated distilled water was added to cater for losses), the samples were kept in refrigerator at a temperature of about 5°C for one week to enable the moisture to equilibrate. After one week, three replicates of the samples were randomly taken from each batch weighed in order to know the initial moisture content before they were oven dried for twenty-four hours at 105 ± 2°C. When constant weight was attained, the samples were weighed again to know the final weight. Equation 2.1 was used to determine the moisture content of the samples. The moisture content determination was replicated thrice with the mean and standard deviation values calculated.

**Determination of Mechanical Properties**

The mechanical properties determined include coefficient of friction \( \mu \) on four surfaces (mild-steel, plywood, aluminium and glass), the angle of repose \( \phi \) of neem seed and kernel, and the compressive strength of the neem seed. The static coefficient \( \mu = \) of neem seed and kernel was determined on four surfaces mild-steel, aluminium, plywood and glass. A topless and bottomless material box of 150 × 150 ×
40 was used for the seed, while a box of 60 × 90 × 20 was used for the kernel. Both boxes were filled with the sample and placed on an adjustable tilting table onto which the material (mild-steel, plywood, aluminium or glass) to be tested was fastened. The box was placed on one side of the surface and raised slightly so that it was not touching the material. The table was gently tilted until friction force between the seed or kernel and the material was overcome by the gravity and moved down the slope. The angle of inclination was read from the graduated protractor attached to the tilting table (Alonge and Adegbulugbe, 2005; Owolarafe et al., 2007).

The angle of repose (ϕ) of the two materials (Ø) was determined using an open-ended cylinder (diameter of 50 mm and height of 150 mm). The cylinder was placed at the centre of a circular plate (diameter of 200 mm) and it was filled with neem seeds or kernels. The cylinder was lifted slowly until the seeds or kernels form a cone on the circular plate (Fig.1). The diameter and height of the cone were measured and recorded and the angle of repose was calculated. This was replicated ten times. Equation.3 was used to calculate the angle of repose (Dash, A.K., Pradhan, L.M. and Naik, S.N., 2008)

\[
ϕ = \phi = 1 - \left(\frac{2h}{d}\right)
\]

where:

H = the height of the cone (cm)  \quad d = \text{diameter of cone (cm)}

![Fig.1: Determination of Angle of Repose](image)

The compressive strength of the neem seed was determined by using a computerized Universal Testing Machine (UTM) (Istron Electromechanical Testing Systems) Model 3369, 100kN, Istron Corporation, USA at Centre for Energy Research Development (CERD) of Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria (Plate 2). Seeds at different orientations (longitudinal and transverse) were loaded using the machine (Fig. 2). The test result and graphs were automatically generated through the computer attached to the machine. Data that were obtained include compressive load at yield, compressive stress at yield, compressive strain at yield and energy at yield. The samples were loaded at 2.0 mm/minute. For each of the moisture content, the experiment was replicated three times.
The terminal velocity of *neem* seed, kernel and hull was determined by using an air column made up of a vertical wind tunnel of diameter 44.48 mm and height of 600 mm, voltage regulator (FOSTER Transformer Ltd control unit). Digital anemometer (Model AM-4812) was used to determine the air speed (Plate 3). Each sample of the seed, kernel and hull at required moisture of 5.10, 9.95, 14.17 and 18.69 % were dropped, respectively, into the air stream from the top of the air column and the air velocity adjusted until the seed, kernel and hull as the case may be is suspended in the air stream. The respective velocity (m.s\(^{-1}\)) near the location of the seed suspension was measured with the help of the digital anemometer having accuracy of ±0.1m/s. Measurement of the air velocity was replicated ten times for each treatment (Mahbobeh et al., 2011).

**Plate 2: Computerized Istron Electromechanical Testing Systems (Model 3369).**

**Fig. 2: Compression Test of Neem Seeds under Different Orientation of Loading (Not To Scale). (A) Transverse Orientation and (B) Longitudinal Orientation**

**Determination of Aerodynamic Property of *Neem* Seed, Kernel and Hull**

The terminal velocity of *neem* seed, kernel and hull was determined by using an air column made up of a vertical wind tunnel of diameter 44.48 mm and height of 600 mm, voltage regulator (FOSTER Transformer Ltd control unit). Digital anemometer (Model AM-4812) was used to determine the air speed (Plate 3). Each sample of the seed, kernel and hull at required moisture of 5.10, 9.95, 14.17 and 18.69 % were dropped, respectively, into the air stream from the top of the air column and the air velocity adjusted until the seed, kernel and hull as the case may be is suspended in the air stream. The respective velocity (m.s\(^{-1}\)) near the location of the seed suspension was measured with the help of the digital anemometer having accuracy of ±0.1m/s. Measurement of the air velocity was replicated ten times for each treatment (Mahbobeh et al., 2011).

**Plate 3: A Pictorial View of a Digital Anemometer**

**Results and Discussion**

**Influence of Moisture on Mechanical Properties of *Neem* Seed and Kernel**

The result of the influence of moisture content on coefficient of friction, angle of repose and compression properties of the *neem* seed and kernel are discussed below.
Effect of Moisture Content on Coefficient of Friction of Neem Seed and kernel

The effect of moisture on coefficient friction for the four surfaces mild-steel, plywood, aluminium and glass for seed and kernel are shown in Figs. 3 and 4, respectively. It could be observed that the coefficient of static friction increased with increase in moisture content for all the surfaces in exception of aluminium surface for the seed and plywood surface for the kernel.

The coefficient of static friction increased from 0.76 to 0.80 for seed and 0.73 to 0.86 for kernel on mild-steel, 1.63 to 1.74 for seed and decreased from 0.69 to 0.59 kernel on plywood, decreased from 1.35 to 1.10 for seed while kernel increased from 0.55 to 0.69 on aluminium and 0.52 to 0.54 for seed and 0.45 to 0.54 on glass as the moisture content increased from 5.10 to 18.69 % w.b. These results agreed with the earlier result of Solanki et al. (2011) who reported an increase in coefficient of static friction for wood, aluminium and mild-steel, in the case of neem fruit and seed with increase in moisture content. Results obtained for neem seed for the three surfaces reported were slightly lower than those obtained in this study. The general relationship between moisture content and the coefficient of friction on all the surfaces is polynomial. At all moisture contents, the highest coefficient of friction were observed for plywood, followed by aluminium and mild-steel, while least value was for glass. The reason for the increase in friction coefficient at higher moisture content might be due to increase in the seed and kernel mass. From the results, neem seed has higher coefficient of friction than the kernel; the highest value of coefficient of friction for the seed was 1.82 on plywood while that of kernel was 0.86 on mild-steel.
At higher moisture contents it was observed that the seeds became a bit rough and sliding characteristics were diminished, this might be the reason for the increase in the coefficient of friction. Another possible reason could be that there was an increased adhesion between the seed and the surface at higher moisture values. Other researchers viz: Sedat C., Musa O., Haydar H. and Ugur Y., (2007) and Baryeh (2002) have reported similar results for okra and bambara groundnut, respectively.

These low values for both mild-steel and glass in the case of seed may occur as a result of the polished nature and smoothness of these structural surfaces as well as that of the seed. Whereas for kernel low values were recorded for aluminium and glass possibly for the same reason.
The regression analysis of the moisture content versus coefficient of friction indicated polynomial relationship (equations 3.4 to 3.11) for the range of moisture content considered. This is however contrary (linearly related with moisture) with the findings of other researchers for some crops (Konak et al., 2002, for cotton seed; Garnayak et al., 2008, for jatropha seed; Owolarafe et al., 2007, for fresh oil palm fruit; and Bamgboye and Adejumo, 2009, for roselle seed). This may be due to shape and texture characteristics of the seeds.

Mild-steel
\[ \mu_{mss} = -0.0004m^3 + 0.0385m^2 - 0.1692m_e + 0.8903 \]  
\[ \mu_{msK} = -0.0182m^3 + 0.1971m^2 - 0.5611m_e + 1.1116 \]  
\[ R^2=1 \]  
\[ (3.4) \]
\[ (3.5) \]

Plywood
\[ \mu_{pwK} = -0.0514m^3 + 0.3535m^2 - 0.6528m_e + 1.984 \]  
\[ \mu_{pws} = 0.0082m^3 - 0.0373m^2 - 0.0172m_e + 0.7312 \]  
\[ R^2=1 \]  
\[ (3.6) \]
\[ (3.7) \]

Aluminium Steel
\[ \mu_{Als} = 0.0533m^3 - 0.3439m^2 + 0.5166m_e + 1.1209 \]  
\[ \mu_{AlK} = -0.0231m^3 + 0.2006m^2 - 0.4693m_e + 0.8374 \]  
\[ R^2=1 \]  
\[ (3.8) \]
\[ (3.9) \]

Glass
\[ \mu_{Gls} = -0.0977m^3 + 0.7474m^2 - 1.6784m_e + 1.5449 \]  
\[ \mu_{GlK} = -0.004m^3 + 0.0619m^2 - 0.1972m_e + 0.5972 \]  
\[ R^2=1 \]  
\[ (3.10) \]
\[ (3.11) \]

**Influence of Variation of Moisture Content on Angle of Repose of Neem Seed and Kernel**

Figure 5 displays the influence of moisture content on the angle of repose of neem seed and kernel. It could be observed that increase in moisture content from 5.10 to 18.69 % (wb) increased the angle of repose from 27.1° to 32.4° and 30.5 to 31.8 for seed and kernel, respectively. The values of angle of repose for the seed and kernel were found to be within the value reported for other crops for jatropha seed (Garnayak et al., 2008); and for
neem fruit and seed (Solanki et al., 2011). The difference is also similar to that of bambara groundnut (Beryeh, 2002), sorghum malt (Grains) (Aviara et al., 2006) and roselle seed (Bangboye and Adejumo, 2009). The angle of repose for neem seed and kernel were found to be between 27.1º and 32.4º which is still below the highest possible angle of repose of 45º for most agricultural materials as reported by Mohsenin (1986). The regression equations relating the angle of repose to moisture content are presented below.

\[
\theta_s = 0.9578m_c^3 - 6.6744m_c^2 + 15.006m_c + 17.836 \quad (R^2 = 1) \quad (3.12)
\]

\[
\theta_k = 0.7096m_c^3 - 4.244m_c^2 + 6.7619m_c + 27.28 \quad (R^2 = 1) \quad (3.13)
\]

From the statistical analysis, the effect of moisture content on the angle of repose of the seed and kernel was significant at 0.05 levels. Based on the result the average recommended value for the angle of repose for neem seed and kernel should be within 29.2º and 30.1º, respectively.

Effect of Moisture Content on Compression Properties of the Seed

The effect of moisture content on compressive load at yield, compressive stress at yield, compressive strain at yield and energy at yield, are discussed here. The crushing strength of the seed at the two orientations was found to reduce from 32.2 to 19.5N for longitudinal and from 41.3 to 29.4 N for transverse loadings, as the moisture increased from 5.10 to 18.69 % w.b. (Fig. 6). The results show that the rupture strength is highly dependent on moisture content for the range of moisture content investigated.

A quick look at Fig. 6 indicates that the rupture force for transverse orientation is higher than longitudinal. The result agrees with the earlier findings of Owolarafe et al. (2007) for fresh oil palm fruit, Konak et al. (2002) for chick pea seed, Kubilay and Furük (2004) for
Effect of Moisture Content on Compressive Stress of Neem Seed at Yield

The compressive stress at break reduced as the moisture content increased from 5.10 to 18.69 % w.b. (Fig. 7). The compressive stress decreased from 1.74 to 1.05 MPa for longitudinal, 2.23 to 1.59 MPa for transverse. The highest stress was observed when the compression was at the transverse orientation. The regression equation relating moisture content and compressive stress at yield are presented below.

\[
C_{sy_L} = 0.08m_c^3 - 0.695m_c^2 + 1.565m_c + 0.79 \quad (R^2 = 1) \quad (3.16)
\]

\[
C_{sy_T} = 0.1433m_c^3 - 0.91m_c^2 + 1.3267m_c + 1.67 \quad (R^2 = 1) \quad (3.17)
\]

The result of the statistical analysis on the effect of moisture on the compressive stress shows that the effect was not significant on the two orientations of the seed at 5.0 % significant levels.
Figure 8 shows the effect of moisture content on compressive strain at yield. As the moisture content increased from 5.10 to 18.69 % w.b. the compressive strain at yield decreased from 0.58 to 0.55 mm/mm for longitudinal, 1.43 to 0.59 mm/mm for transverse. The ratio of the size of seed under pressure is very important in deciding the screen size in the design of a depulping, decorticating and cleaner. The regression analysis indicates a polynomial relationship between moisture content and compressive strain.

\[
C_{\text{stra}}L = -0.1124m_c^3 + 0.9278m_c^2 - 2.2885m_c + 2.0518 \quad (R^2 = 1) \quad (3.18)
\]

\[
C_{\text{stra}}T = 0.2921m_c^3 - 2.2273m_c^2 + 4.7256m_c - 1.365 \quad (R^2 = 1) \quad (3.19)
\]

The result of the statistical analysis on the effect of moisture on the compressive strain shows that the effect was significant on the two orientations of the seed at 0.05 significant levels.
Experimental result shows a reduction in the force required for initiating seed rupture as the moisture content increased. The maximum force required to initiate rupture was found to be 22.31 N and should not be exceeded to avoid crushing the embedded kernel.

Figure 9 shows the effect of moisture content on energy at yield. It could be seen that energy at yield depends on moisture content and orientation of the seeds. The energy at yield reduced from 0.009 J to 0.007 J for longitudinal, 0.053 to 0.016 J for transverse orientations as the moisture content increase from 5.10 to 18.69 % w.b. The result is in agreement with the report of Owolarafe et al. (2007) for fresh oil palm fruit, Solanki et al. (2011) for neem fruit and seed. It was observed that the energy required to break the seed at thickness orientation was much higher than at the rest orientation.

The mathematical relationships between the energy at yield and moisture content is as presented in equations 3.20 and 3.21.

\[
\text{Enry L} = -0.0042m^3 + 0.0324m^2 - 0.0744m + 0.0555 \quad (R^2 = 1) \quad (3.20)
\]

\[
\text{Enry T} = 0.0084m^3 - 0.0597m^2 + 0.1103m - 0.0058 \quad (R^2 = 1) \quad (3.21)
\]

The analysis shows that effect of moisture content is significant at 0.05% level on energy at yield.

Effect of Moisture Content on Aerodynamic Property of Neem Seed, Kernel and Hull

The experimental results for the terminal velocity of the neem seed, kernel and hull for four moisture content levels were as presented in Fig. 10. As the moisture content increased from 5.10 to 18.69 % w.b., the terminal velocity also increased from 4.30 m/s to 5.34 m/s, 4.66 to 5.38 m/s for seed, kernel, respectively, but the hull decreased from 3.43 to 3.08 m/s. The results were comparable to those reported by
Simonyan, K.J., El-Okene, A.M., and Yijep, Y.D., (2007) and Gursoy and Guzel, (2010). The increase in terminal velocity with increase in moisture content can be attributed to the increase in weight of an individual neem seed and kernel per unit frontal area presented to the stream. The polynomial relationship between the moisture content and terminal velocity can be represented by the following equations.

\[
T_V_S = 0.0633m_c^3 - 0.575m_c^2 + 1.8917m_c + 2.92 \quad (R^2 = 1) \tag{3.22}
\]

\[
T_V_K = 0.095m_c^3 - 0.765m_c^2 + 2.07m_c + 3.26 \quad (R^2 = 1) \tag{3.23}
\]

\[
T_V_H = -0.0633m_c^3 + 0.625m_c^2 - 1.9117m_c + 4.78 \quad (R^2 = 1) \tag{3.24}
\]

Statistical analysis indicates that the effect of moisture content on the neem seed, kernel and hull is significant at 0.05 level of probability. In the design of cyclone or cleaning chamber of a neem seed decorticator the terminal velocity should not be more than 5.07 m/s (terminal velocity of kernel), but higher than 3.11 m/s (terminal velocity hull). The data obtained from this study should be used to design neem sorting and depulping machines for the fruit together with a decorticator for the seed.

Conclusion

The overall outcome of this work is that much needed data had been generated to enhance the design and construction of processing machines such as decorticator, depulping and cyclone or cleaning machines for neem seed as an industrial product with high potentials. Specifically, the following conclusions can be drawn from the results obtained in this study:

a) The coefficient of friction on mild-steel, plywood and glass increased from 0.76 to 0.80, 1.63 to 1.74 and 0.52 to 0.54 for the seed while coefficient of friction on the following surfaces; mild-steel, aluminium and glass for the kernel
increased from 0.73 to 0.86, 0.55 to 0.69 and 0.45 to 0.54, respectively. Seed coefficient of friction value decreased on aluminium from 1.35 to 1.10, while kernel on plywood from 0.69 to 0.59.

b) Angle of repose increased from 27.1 to 32.4° and 30.5 to 31.8° for seed and kernel, respectively. This information will be useful to design the hopper for the necessary processing machines for both the seed and the kernel.

c) The fracture resistance of the seed and kernel were found to decrease with increase in moisture content. It is of opinion that the result of this experiment will provide good data useful in design and development of a decorticating machine for the seed to obtain the oil rich kernel.

d) Finally, as the moisture content increased the terminal velocity for the seed and kernel increased from 4.30 to 5.34 m/s and 4.66 to 5.39 m/s, respectively. However the terminal velocity of the hull decreased with increase in moisture from 3.43 to 3.08 m/s. In the design of cyclone or cleaning chamber of a neem seed decorticator the terminal velocity should not be more than 5.07 m/s (terminal velocity of kernel), but higher than 3.11 m/s (terminal velocity hull).

References


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