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MOISTURE DEPENDENT PHYSICAL PROPERTIES OF NUTMEG (*Myristica fragans*) RELEVANT FOR DESIGN OF PROCESSING MACHINES

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Abstract: This study investigated the degree of influence of moisture content on some physical properties of nutmeg. The nutmeg seeds were subjected to six different levels of moisture (5, 7, 9, 11, 13 and 15%db). Moisture content had a significant effect on the physical properties (p=0.05). A decrease in moisture content led to a decrease in length, width, thickness, geometric, arithmetic, square and equivalent mean diameters. Moisture content had a linear relationship with sphericity, projected and surface area, bulk and true density while it had an inverse relationship with porosity and angle of repose. Moisture content had a significant effect on coefficient of friction of nutmeg on the four surfaces considered (glass, stainless steel, plywood and rubber). Glass, stainless steel, plywood and rubber has an increasing coefficient of friction respectively; this implies that materials will move easily with lesser resistance on glass and stainless steel compared to more resistance on plywood. The data obtained will guide engineers, food processors and technicians in accurate selection of machine parts in design and constructions of sorting, separating, cleaning equipment and post-harvest machines which will eventually aid commercialization and efficient processing of the spice crop.
Keywords: Nutmeg, machine design, engineering properties

1. INTRODUCTION

Spices are aromatic and pungent vegetable substance used as a condiment and for seasoning food (Gadekar *et al.* 2006). They can be any of the various aromatic vegetable products that collectively enrich, or alter the quality/taste of food especially to a small degree, thus giving zest or pleasant flavouring or a relish. Perhaps the most widely utilized plant species in Nigeria are the spices (Erhenhi *et al.,* 2016), they are the major sources of powder and/or seeds used in cooking and have strong taste and smell (Schippers, 2000; Kayode and Ogunleye, 2008). Food habits all over the world are undergoing a sea change (Panda, 2010) and thereby more spicy food has become the order of the day in most developed and developing countries. The world demand for spices is now on the increase. India is the home to a number of spices because there is no Indian cuisine without the addition of one or more spices. Presently, there is a growing competition between spice producing countries as developed countries have now placed strict quality specifications on the import of spices. The bulk of the spices identified in Nigeria are found in the Southern rainforest zone of the country, while others such as garlic and ginger are found predominantly in the dry Northern zone with ginger and African black pepper being the major Nigerian spices in the international market, the rest are consumed locally (AGOA, 2019).

Nutmeg is the common name for a dark-leaved evergreen tree, *Myristica fragans*, which is cultivated for two spices derived from its fruit; "nutmeg" and "mace." Nutmeg is produced from the dried, ripe, inner seed (shown in Plate 1) and mace from the seed coat (arillus) that separates the seed from its outer husk. The term nutmeg also is used to refer to just the seed of this tree or to the ground or grated spice developed from this seed. In addition to being the source of the spices, it is also commercially important as a source of essential oil and nutmeg butter. The world production of nutmeg is estimated to average between 10,000 and 12,000 metric tons per year, with annual world demand estimated at 9,000 metric tons; production of mace is estimated at 1,500 to 2,000 tons (Mintah, 2018; NWE, 2020).

It remains widely used today as a spice for food and drinks due to its unique aroma and taste which has added to the human enjoyment of many foods. The intake of nutmeg helps in better intellectual performance (brain booster), controls heart beat and blood pressure, treats kidney infections and dissolves kidney stones, increases sexual desire, treats insomnia (sleeplessness) and removes bad breath. It has also been found to relieve toothache, dysentery, dermatitis, headache and as worm expeller in traditional medicine (Guardian, 2015). It also relaxes the muscles, removes gas from the digestive system, sedates the body, and of value for such stomach problems as indigestion (DeMilto and Frey, 2005) and it is used for chronic nervous disorders, to prevent nausea and vomiting, and for kidney disorders, and in Chinese medicine is used for diarrhea, inflammation, abdominal pain, and liver disease, among other aliments (DeMilto and Frey, 2005).

Plate 1: Nutmeg

In most cases, nutmeg is ground, grated, expressed and distilled manually to make butter, custards, baked goods, flavour among numerous applications. The post-harvest processing of Nutmeg in Nigeria is still crude due to non-availability of post-harvest handling equipment and some of the challenges facing spice production in Nigeria include lack of domestication and cultivation, influx of exotic spices, destructive methods of harvesting, low quantity and quality of harvest, bush burning, deforestation, lack of appropriate process technology and low level of investment in research and development activities (AGOA, 2019). Currently, the Raw Materials Research and Development Council (RMRDC) is working on partnering with entrepreneurs and researchers to improve spices production, processing and marketing in Nigeria in order to take stringent measures in ensuring that spices production, processing and packaging are in line with international standards. To ensure an adequate generic post-harvest operations, which are often the limiting factors in the establishment of a profitable production enterprise based around herbs, spices and essential oils in developing countries (UNIDO and FAO, 2005), it is essential that post-harvest and processing machines be developed to process the spice crops and improve their quality and in achieving this, the engineering properties including physical, mechanical and/or rheological, thermal, electrical and optical should be determined prior to design and construction of post-harvest machines hence, the need for this study.

In West Africa and Nigeria in particular, most spice crops are subjected to local processing method which includes cleaning, sorting, grading, drying and size reduction, which is labour intensive, with a low output. The aspect which is of interest to the engineer (food processor) is the physical properties, mechanical properties, electrical properties, and thermal properties. This gives the engineer guidelines for the designing of agricultural machine that will be suitable for the processing of the bio material. Most important among them is the physical property which is the first consideration in the design of the post handling and sorting equipment. When physical properties of agricultural materials are studied by considering either bulk or individual unit of the material, it is desired to have an accurate estimate of shape, size, volume, specific gravity, surface area and other physical characteristics which may be considered as engineering parameters for that product (Mohsenin, 1986). However, information on the physical properties of agricultural materials such as size dimensions, shapes, porosity, volume, density, and coefficient of friction is important in the design of harvesting, transporting, cleaning, separating, packing, storing, and processing equipment (Aremu *et al.* 2014; Ajav and Ogunlade, 2014; Ogunlade *et al.,* 2016; Aremu *et al.* 2016; Jaiyeoba *et al.* 2016 a and b; Jaiyeoba and Ogunlade, 2017, Ogunlade *et al.,* 2018).

Burubai *et al.* (2007) investigated some physical and frictional properties of African nutmeg (*Monodora myristica*) a moisture content level of 4.93% dry basis; Alonge and Udofot (2012) studied some physical properties of African Nutmeg at 7.36% moisture content dry basis seed relevant to its processing also, Kwino *et al.* (2017) investigated the effect of roasting on physical properties of African nutmeg. However, there is dearth of information on influence of moisture content on physical properties of nutmeg. Thus, the main aim of this study was to investigate the degree of influence of moisture content on some physical properties of nutmeg in relation to the design of post-harvest machinery.

2. METHODOLOGY

— Sample Collection and Preparation

Fresh garlic and nutmeg were procured from Ojee market at Oke-Gada, Ede, Osun State, Nigeria. They were cleaned and defective seeds were discarded appropriately while good ones were kept in air-tight polythene bags.

— Moisture Content of the Spice crops:

The choice of levels was determined by preliminary investigations and literature review. The initial moisture content of the spices was determined in accordance with American Standard for Agricultural Engineers (ASAE, 1998) method by oven drying the crops at 105°C to a constant weight. Samples weighing 100g were placed in the Electro-heating Standing-temperature Air Drying Oven (Jinotech Instruments, PCD-3000 Serials, Model No.: DHG-GD, 50 – 250°C ± 1°C) and allowed to cool, they were weighed, and the moisture content was calculated using Equation 1. In order to obtain different levels of the moisture content, the weights of the samples were taken and recorded as W_i, using an Electronic Analytical Weighing Scale (Model PA 413, 410 g ± 0.001g, S/N: B603007682, Switzerland), then an empty can was weighed, and the can with the samples inside was also weighed. The sample was dried in an electric oven at a temperature of 105°C for 24 h and the final weight of the samples after drying taken at the point at which no further loss in weight was noticed was recorded as W_f, according to ASAE Standard S358.2 (1983) as reported by Ajav and Ogunlade (2014). The initial moisture content of the samples in % dry basis was obtained using Equation 1:

$$Mc = \frac{W_i - W_f}{W_f} \times 100 \quad (1)$$

where: Mc is the moisture content (% db), W_i is the initial weight of the spice crops before oven drying (g), and W_f is the final weight after oven drying (g).

In order to obtain varying levels of moistures, samples were conditioned to five levels of moisture (8, 10, 12, 14 and 16 %db) to determine the influence of moisture content on selected physical properties of the spice crops by dehydration and rehydration; the mass of water added to obtain a predetermined moisture content level during rehydration was obtained using Equation 2 (Ogunlade and Aremu, 2019):

$$Q = \frac{A(b-a)}{(100-b)} \quad (2)$$

where: Q is the mass of water added (g), A is the initial mass of samples, a is the initial moisture content of samples and b is the final (desired) moisture content of samples

Conditioned samples were sealed in air-tight separate polythene bags and kept in the refrigerator for 48 hours to enable the moisture to distribute uniformly throughout the samples.

— Selected Physical Properties of the Spice Crops

The physical properties determined include axial dimensions (length, breadth and thickness), mean diameters (geometric, arithmetic, square and equivalent mean diameters), sphericity, area (surface and projected area), volume (unit and bulk volume), density (bulk and true density), porosity.

i. **Axial Dimensions:** The axial dimensions include major diameter (length), minor diameter (breadth) and intermediate diameter (thickness). They were determined independently for each of the spice crop using a Vernier Calliper (± 0.001 mm accuracy) as shown in Figure 1.

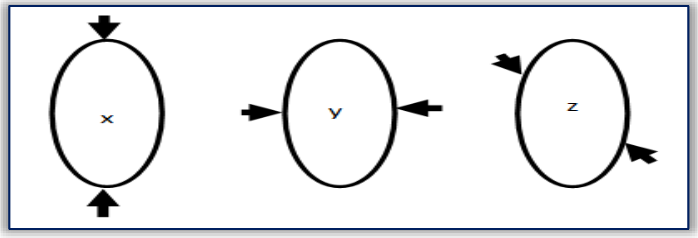

Figure 1: Measurement of Major (x), Minor (y) and Intermediate Diameters (z)

ii. **Mean Diameters:** The mean diameters of the spices were determined at every thirty minutes of oven drying for each of the spice crops selected; the axial dimensions were inputted into appropriate mathematical relations to determine the mean diameters. The mean diameters determined include: geometric mean diameter, arithmetic mean diameter, equivalent diameter and square mean diameter.

   a. **Geometric mean diameter:** this was calculated from the axial dimension of the spices using Equation 3 (Ajav and Ogunlade, 2014; Ogunlade *et al.*, 2016).

$$Gm = (xyz)^{\frac{1}{3}} \quad (3)$$

where: Gm is the geometric mean diameter (mm), x is the major diameter (or length) of each spice sample (mm), y is the minor diameter (or thickness) of each spice sample (mm) and z is the intermediate diameter (or width) of each spice sample (mm)

b. **Arithmetic Mean Diameter**: this was obtained using Equation 4.

$$A_m = \frac{x + y + z}{3} \quad (4)$$

where: Am is the Arithmetic mean diameter and other parameters remain as earlier defined.

c. **Square Mean Diameter**: this was determined using Equation 5 from the axial dimensions

$$Sm = \left[\frac{(x.y)+(y.z)+(z.x)}{3}\right]^{\frac{1}{2}} \quad (5)$$

where: Sm is the Square Mean Diameter (mm) and other parameters remains as defined above.

d. **Equivalent Mean Diameter**: this was calculated as the average of the geometric, arithmetic and square mean diameters using Equation 6.

$$E_m = \frac{G_m + A_m + S_m}{3} \quad (6)$$

where: Em is the equivalent mean diameter (mm), Gm is the Geometric mean diameter (mm), Am is the Arithmetic Mean Diameter and Sm is the square mean diameter (mm)

iii. **Sphericity:** The sphericity of the spices was calculated using Equation 7 as described by Mohsenin (1986).

$$\Phi = \frac{(xyz)^{\frac{1}{3}}}{x} = \frac{Gm}{x} \quad (7)$$

where: Φ is the sphericity in decimal (the higher the sphericity value for the material, the closer is its shape to a sphere).

iv. **Area:** The Surface area of each spice crop was calculated using Equation 8 (Oje and Ugbor, 1991; Asoegwu *et al.*, 2006) while the projected area was obtained using Equation 9.

$$S_a = \pi {E_m}^2 \quad (8)$$

$$\text{Area (projected)} = \frac{x.y}{4} \quad (9)$$

where: Sa is the Surface area of the spice crops.

v. **Volume:** The unit volume of the spices was calculated using Miller's (1987) relationship as presented in Equation 10 while the bulk volume was obtained by measuring the bulk of each crops on the analytical weighing scale. The bulk volume of the seed was determined using Archimedes's principle as was described by Ajav and Ogunlade (2014). The sample was weighed and immersed in a measuring cylinder containing a known volume of water. From the level of the water was subtracted the initial level, the difference between the new level of water in the measuring cylinder and the initial volume of water is the bulk volume of the seed.

$$V_c(mm^3) = \pi\left[\frac{(x.y.z)}{6}\right] \quad (10)$$

vi. **Density:** To determine the bulk density of the experimental samples at different moisture content, the method defined by Mohsenin (1986); Singh and Goswami (1996) was used. A container of known volume was used to determine bulk density. The container of known volume was filled to the brim and excess spices were removed by sliding a wooden stick along the top edge of the container. The bulk weight of the seeds in the container was measured. This was repeated 10 times and the average was determined. Bulk density was calculated as the ratio of the bulk weight and the volume of the container (Equation 11):

$$\text{Bulk density, } \rho_b = \frac{\text{Total(bulk) weight}}{\text{volume of the container}} \quad (11)$$

True density was determined by dividing the seed mass (measured directly from the balance) by the measured seed volume obtained. It was determined by using water displacement method, as described by Abalone *et al.* (2004) and Kibir *et al.* (2010). The weight of the samples at the particular moisture contents was first determined and samples were then submerged in water and the displacement volume was determined. In the second stage, the true density of sample was calculated by using Equation 12:

$$\text{True density, } \rho_t = \frac{\text{mass of submerged spices}}{\text{volume of displaced water}} \quad (12)$$

vii. **Porosity:** The porosity of the spices was calculated from bulk and seed densities using Equation 13 given by Mohsenin (1986) at each selected moisture level as follows:

$$\text{Porosity, } \varepsilon = \left[1 - \frac{\rho_b}{\rho_t}\right] \times 100\% \quad (13)$$

viii. Angle of Repose: The angle of repose was determined by using a specially constructed topless and bottomless box made of plywood, with a removable front panel (Ajav and Ogunlade, 2014). The box was filled with nutmeg and placed on the floor, the front panel was then quickly removed allowing the seeds to slide down and assume natural slope. Then, the angle of repose was calculated from the measurements of the height (h) of the free surface of the seeds and the length (l) of the heap formed outside the box using the Equation 14 (Bamgboye and Adejumo, 2009; Ajav and Ogunlade, 2014):

$$\theta = \tan^{-1}\frac{h}{l} \quad (14)$$

where: θ = angle of repose (degrees)

ix. Coefficient of friction: This was determined with respect to three structural materials (stainless steel, plywood, rubber and glass). The nutmeg seeds were placed parallel to the direction of motion. The table was raised gently and the angle at which the materials begin to slide (the angle of inclination) was read from a graduated scale. The coefficient of friction was taken as the tangent of this angle (Olaoye, 2000; Adejumo, 2003; Ajav and Ogunlade, 2014) and calculated using the relationship given by Mohsenin (1986) as presented in Equation 15:

$$\mu = \tan\theta \quad (15)$$

where: μ is the coefficient of friction (decimal) and θ is the angle of inclination (degrees).

3. RESULTS AND DISCUSSION

— Effect of Moisture content on axial dimensions

It was observed that the axial dimensions including major diameter (length), minor diameter (breadth) and intermediate diameter (thickness) decreases with an decrease in the moisture content, the major diameter ranged from 18.09 -21.07 mm with an average value of 20.02 mm; minor diameter ranged from 13.48 – 16.09 mm with an average value of 15.01 mm; the intermediate diameter ranged from 13.87 – 16.36 mm with an average value of 15.36 mm within the moisture range of 8.95 and 15%db. The reduction/decrease in the three axial dimensions with a decrease in moisture content (as presented in Figure 2) may be attributable to shrinkage of the biomaterial under drying air temperature which confirms that biomaterials are temperature and moisture dependent.

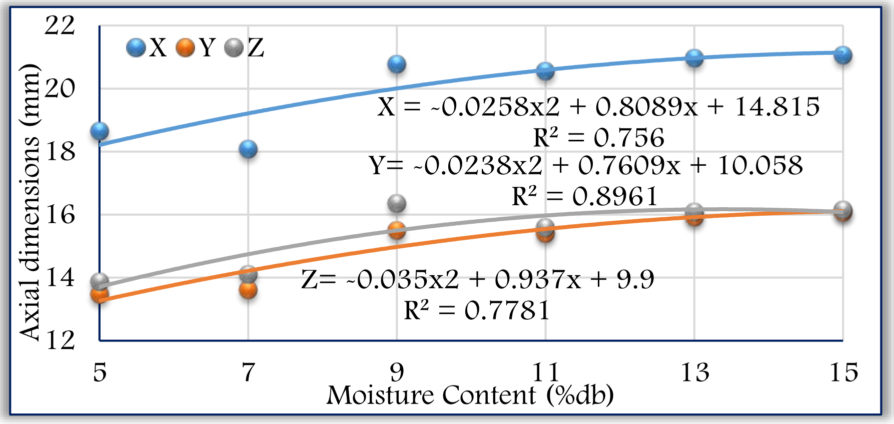

Figure 2: Effect of Moisture Content on the Axial Dimensions of Nutmeg

— Effect of Moisture Content on Mean Diameters

A decrease in the mean diameters as the moisture content decreases, a very close agreement was observed for the square mean and equivalent diameter (Figure 3).

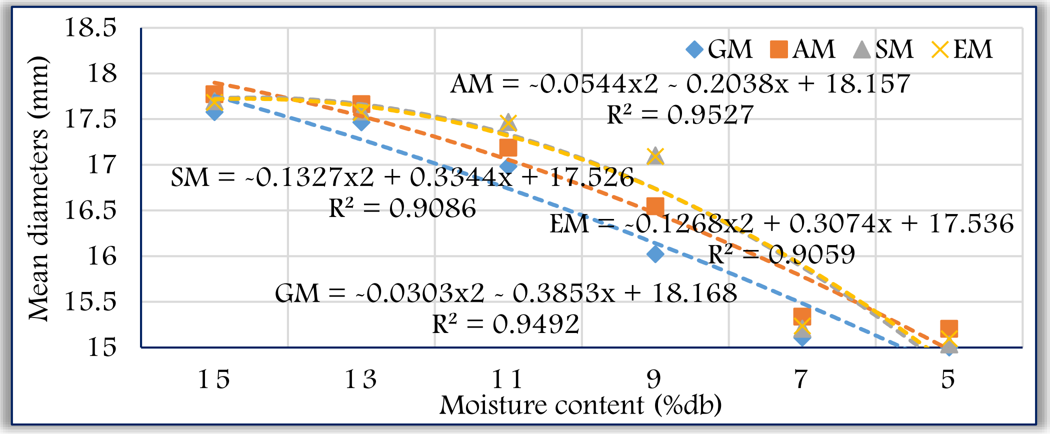

Figure 3: Influence of Moisture Content on Mean Diameters of Nutmeg

— Effect of Moisture content on the Sphericity of Nutmeg

Moisture content had a linear relationship with the sphericity of nutmeg, the minimum sphericity value (0.74) was obtained (this implies 74% of nutmeg is spherical in nature) at 5 %db while the highest value of 0.84 was obtained at 15% db as presented in Table 1. The value obtained is in tandem with Burubai *et al.* (2007); Alonge and Udofot (2012). This implies that the seeds will roll freely on any surface without necessarily being interrupted when placed on a particular orientation on processing equipment. This property have a practical application in handling operations such as conveying and grading, design of hopper and dehulling equipment for biomaterials as it dictates the ability of the biomaterials to either be retained or rolled away on the surface. A linear regression equation showing the relationship between moisture content and sphericity of nutmeg is presented in Equation 16.

$$S = 0.003x^2 + 0.0072x + 0.6979 \qquad (R^2 = 0.6772) \qquad (16)$$

Table 1: Physical Properties of Nutmeg at Different Moisture levels

Physical Property	Moisture content (%db)					
	5	7	9	11	13	15
Projected area (mm²)	856.4 (200.5)	978.41 (197.7)	1184.6 (176.9)	1345.96 (164.2)	1765.98 (201.76)	1940.19 (125.55)
Surface area (mm²)	398.31 (67.7)	404.93 (34.7)	453.2 (45.9)	597.7 (45.8)	632.32 (39.2)	697.54 (54.87)
Sphericity	0.74 (0.05)	0.74 (0.03)	0.83 (0.02)	0.81 (0.03)	0.79 (0.05)	0.89 (0.01)
Volume (mm³)	894.71 (321.45)	975.54 (219.33)	1024.55 (213.98)	1345.23 (198.21)	1487.86 (121.26)	1587.12 (127.23)
True density (kg/m³)	830.4 (9.8)	835.24 (7.9)	845.7 (5.3)	856.11 (7.7)	887.5 (6.4)	897.01 (5.9)
Bulk Density (kg/m³)	422.01 (8.1)	436.21 (8.7)	444.9 (9.1)	489.2 (6.3)	494.2 (7.1)	501.55 (6.9)
Porosity (%)	49.2 (0.8)	47.8 (1.2)	47.4 (1.5)	42.9 (1.9)	44.3 (0.9)	44.1 (1.8)
Angle of repose (°)	48.3 (0.3)	47.9 (0.79)	46.5 (1.25)	43.4 (1.76)	41.3 (1.93)	41.6 (1.32)

*Values in brackets are Standard Deviation values

— Effect of Moisture Content on the Projected and Surface Area of Nutmeg

There exists a linear relationship between moisture content and both projected and surface areas of nutmeg, both properties increases as moisture content increased from 5 to 15 %db. The minimum projected and surface area obtained was 856.4 and 398.31 mm² while the maximum values obtained were 1940.19 and 697.54 mm² respectively at 5 and 15%db as presented in table 1. These properties are essential in design of some post harvest processing machines like sorting, drying, size reduction, heat transfer equipment. Regression equations obtained to predict the relationship between moisture content and the projected and surface areas (Equations 17 and 18) showed a close agreement within experimental values considered when validated.

$$P_a = 4.983x^2 + 13.8\,x + 650.75 \; (R^2 = 0.9848) \qquad (17)$$

$$S_a = 1.0643\,x^2 + 11.897\,x + 292.85 \; (R^2 = 0.9482) \qquad (18)$$

— Effect of Moisture content on Volume of Nutmeg

Moisture content significantly affected the volume of the nutmegs; there was a linear decrease in the volume from 1587.12 to 894.71 mm³ within the moisture range of 15 to 5 %db respectively. This property is essential in design of processing machines like sorting, drying, size reduction, heat transfer equipment and most especially in packaging to determine the space to be occupied by the crop. A regression equation was obtained to predict the relationship between moisture content and volume of nutmeg (Equation 19) and the regression analysis shows a good correlation between moisture content and volume which is valid within the experimental limits.

$$V = 2.0832\,x^2 + 34.332\,x + 643.23 \quad (R^2 = 0.9551) \qquad (19)$$

This volumetric expansion with increase in moisture level may be attributed to the expansion in the dimensions which contributed to weight increase thereby resulting to the displacement of more liquid. The variation of the volume with moisture content is similar to the trend reported by Bamgboye and Adejumo (2009) for Roselle (*Hibiscus sabdariffa* L.) seeds, soyabean seeds (Desphande *et al*, 1993), Altuntas and Demirtola (2010) for some grain legume seeds, Simonya *et al* (2009) for *lab lab purpureus* (L.) Sweet Seeds, Zareiforoush *et al* (2009) for paddy grains, Asoiro and Anthony (2011) for African yam Beans, Ndukwu (2009) for *Brachystegia eurycoma* seeds.

— **Influence of Moisture Content on Bulk and True Density of Nutmeg**

It was observed that moisture content has a linear relationship with the bulk and true density of nutmeg. An increase in moisture level led an increase in the two properties; a minimum value of bulk and true density of 422.01 and 830.4 kg/m³ was obtained at 5 % moisture content dry basis while maximum values of 501.55 and 897.01 kg/m³ was obtained at 15 % moisture content dry basis, respective regression equations showing relationship between moisture content, bulk and true density is presented in Equations 20 and 21 respectively.

$$B_d = -0.2188\,x^2 + 13.175\,x + 357.36 \qquad (R^2 = 0.9307) \qquad (20)$$

$$T_d = 0.478\,x^2 + 2.4135\,x + 829.42 \qquad (R^2 = 0.9705) \qquad (21)$$

— **Influence of Moisture Content on Porosity of Nutmeg**

The minimum porosity value obtained was 49.2% at 5%db while the maximum value was 44.1% at 15 %db as presented in Table 1. It was observed that moisture had an inverse relationship with the porosity of nutmeg; an increase in moisture content led to a decrease in the porosity of the nutmegs. The regression equation showing the relationship between these variables is presented in Equation 22.

$$P = 0.0589\,x^2 + 1.7571\,x + 56.941 \qquad (R^2 = 0.8088) \qquad (22)$$

— **Influence of Moisture content on Angle of Repose**

It was observed that the angle of repose deceased with an increase in moisture content, a maximum value of 48.3° was obtained at 5 %db while a minimum value of 41.6° was obtained at 15 %db as shown in Table 1. This deviation and changes imply as water content of nutmeg increases, friction increases on their surface and the seeds will not be able to flow easily when piled on each other at higher moisture content. A linear relationship was obtained observed between the angle of repose and moisture content of nutmeg and the regression equation predicting the relationship (Equation 23) showed a good agreement.

$$A = 0.0031\,x^2 + 0.8682\,x + 53.167 \qquad (R^2 = 0.9239) \qquad (23)$$

This property is used in the design of agricultural machine hopper and other conveying equipment. The experimental values were seen to be higher than that of oilbean seed (Oje and Ugbor, 1991) and in similar trend with Roselle (*Hibiscus sabdariffa* L.) seeds (Bamgboye and Adejumo, 2009); Fababeans (Fraser *et al.,* 1978); Jatropha seeds (Gamayak *et al.,* 2008); *arecanut* kernels (Kalamullah and Gunasekar, 2002; Kerababa, 2006).

— **Effect of Moisture Content on Coefficient of friction of Nutmeg**

Moisture content had a significant effect on coefficient of friction of nutmeg on the four surfaces considered (glass, stainless steel, plywood and rubber). Glass, stainless steel, plywood and rubber has an increasing coefficient of friction respectively as presented in Figure 4, this implies that materials will move easily with lesser resistance on glass and stainless steel compared to more resistance on plywood and rubber, this could be due to the smooth surface of glass and stainless steel. This property is required in the choice of materials of construction of processing machines.

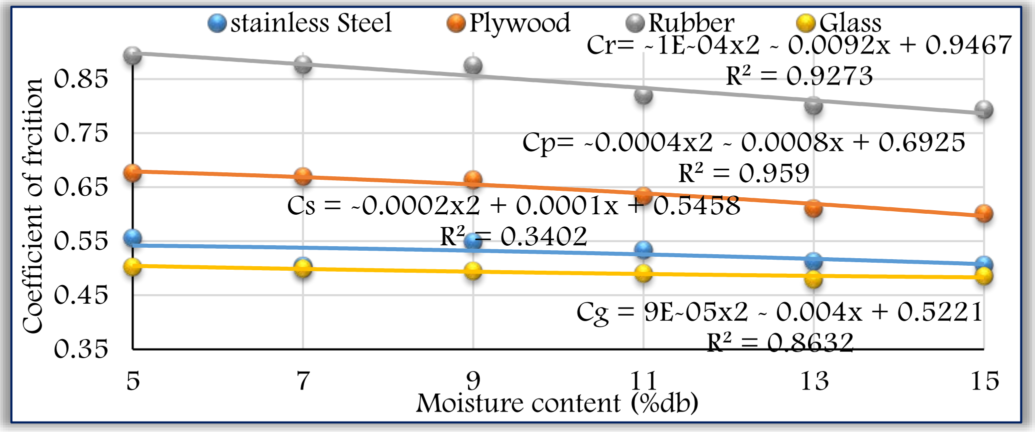

Figure 4: Influence of Moisture Content on Coefficient of Friction of Nutmeg
[Cr – Coefficient of friction on Rubberised surface, Cp – Coefficient of friction on plywood, Cs - Coefficient of friction on Stainless steel and Cg - Coefficient of friction on glass]

4. CONCLUSIONS

The physical properties of nutmeg at different moisture content relevant for design of post-harvest machineries were investigated. This include axial dimensions, mean diameters, sphericity, surface and projected area, volume and bulk volume which are essential in the design and construction of the processing and handling equipment in selecting and designing the suitable size of the screen perforations and similar post harvest equipment. It was observed that moisture content had a significant influence on the physical properties of nutmeg. The data obtained will guide engineers, food processors and technicians in accurate selection of machine parts in design and constructions of sorting, separating, cleaning equipment and post-harvest machines which will eventually aid commercialization and efficient processing of the spice crop.

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