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EXPERIMENTAL STUDY OF PHYSICAL PROPERTY CHANGES IN *MONODORA MYRISTICA* SEED DURING ROASTING

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ABSTRACT: *Thermal processes have been reported to affect the properties of biomaterials including seeds. Monodora myristica seeds are usually roasted prior to shelling, milling and use. The changes in the physical properties of Monodora myristica seeds during roasting were investigated in this study. The specific objectives of the study were to roast Monodora myristica seeds at different temperature and time combinations, determine the effect of the roasting parameters on the physical and frictional properties. Roasting parameters which include the roasting temperature at three levels (140, 170 and 200 °C) and roasting time at four levels (2, 7, 12 and 17 min.) were employed resulting in a 3 x 4 factorial experiment. The study revealed that the roasting temperature had no significant effect ($p>0.05$) on the size, shape and volume of the seeds. However, the roasting time significantly affected ($p<0.05$) the width, arithmetic and geometric diameters, and the volume except the length and the thickness. The length ranged from 17.22 to 18.87 mm, 17.93 to 18.08 mm, and 17.74 to 18.64 mm as the temperature increased from 140 to 200 °C and the time increased from 2 to 17 min. while the thickness ranged from 11.30 to 12.17 mm, 11.73 to 11.98 mm and 11.76 to 12.00 mm. The roasting parameters significantly affected ($p<0.05$) the complex geometric properties except the sphericity and the specific surface area. The effect of the roasting parameters on the angle of repose and the static coefficient of friction were significant ($p<0.05$) and followed the same trend. The highest mean coefficient of static friction values of 0.58, 0.53, and 0.53 were recorded at the 200 °C and 17 min. roasting condition on plywood, plastic and aluminum surfaces, respectively.*

Keywords: *Monodora myristica* ` Seeds ` Roasting ` Properties ` Change `
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INTRODUCTION

Plants are a valuable source of medicine and have helped in the maintenance of human health since time immemorial [1] Among other plants; spices hold good promise as potential harmless sources for obtaining natural antioxidants [2]. [3] Defined spices as vegetable substances of indigenous or exotic origin which is aromatic or has a hot piquant taste, used to enhance the flavor of foods or to add to foods the stimulating ingredients contained in them. One of such spices is *Monodora myristica*. *Monodora myristica* is a common spice widely used in Nigerian cuisines and is commonly called African nutmeg. It is known by various names, including the African Muscat Orchid (African Orchid Nutmeg), the Jamaican Nutmeg, and the Calabash Nutmeg. By these names it is easy to guess that this plant is used as a substitute for nutmeg.

The seeds are economically and medicinally important and the kernel obtained from the seed is a popular condiment used as a spicing agent in both African and continental cuisines in Nigeria [4]. The traditional processing of *Monodora myristica* seeds to obtain the cotyledonus kernels and flour normally involves such operation as toasting over fire or roasting prior to dehulling, and size reduction. The hulls are removed by running a bottle or stone tangentially on the surface of the seeds spread on a flat surface. The kernels are ground or pounded in a mortar using pestle, to obtain the flour. When ground to powder, the kernel is used to prepare pepper soup as stimulant to relieve constipation and control passive uterine hemorrhage in women immediately after child birth [5]. Roasting in this regard is considered to cause easy seed coat rupture with no consideration to the effect of the roasting process on the physical properties of the seeds. [6] Stated that effective and proper design of machines and processes for harvesting, handling and storage of agricultural materials and for converting these materials into food requires an understanding of their physical properties. These properties include the size, shape, mass, volume, sphericity, bulk density, true density, porosity, geometric mean diameter, projected area, surface area, radius of curvature, etc. The average major, intermediate, and minor diameters for African nutmeg were 16.67, 11.52 and 9.98 mm, respectively. These values of physical dimensions of African nutmeg are quite different from those reported by [7] for Sumac fruits, which are 4.72, 3.9 and 2.64 mm. The geometric dimension with an average value of 12.43 (±0.7) mm varied between 10.67 and 14.21 mm. Average sphericity was obtained as 0.74 (±0.64). This value is close to the values reported by [7] for Sumac fruits (0.77 ±0.003). The fairly high sphericity values for African nutmeg shows features favourable to rolling of the fruits and therefore have a practical application in handling operations such as conveying and grading. The volume of African nutmeg varied from 635.2 g mm^3 (seed mass: 0.83 g) to1489.47 mm^3 (seed mass: 1.07 g), with an average value of1008.59 mm3. This value is quite different from what [7] reported on Sumac fruits.

However, comparing seed major diameter, intermediate diameter, minor diameter and volume, a relationship is established using multiple linear regression analysis (r^2 = 0.89).The average values for the minimum and maximum radius of curvature of the seeds were 5.76 (± 0.458) and 9.42 mm (± 0.653), respectively.

Similarly, the average surface area was found to be 1216.72 mm^2 (±202.69). Average projected area varied from 357.18 to 630.33 mm^2, with a mean value of 483.71 (±53.71) mm^2. The true density of African nutmeg was found to be 830.54 (±17.50) kg m-3while the bulk density was obtained as 488.76 (± 10.10 kg m-3), yielding a porosity of 41.10% (±1.20). This porosity value is similar to that reported by [8] for soy beans (41-44%).Frictional properties data of African nutmeg on different surfaces is also presented. Values obtained reveal that the coefficient of static friction, using iron sheet, galvanized iron, plywood and rubber surfaces, were 0.554 (±0.022), 0.502 (±0.013), 0.632 (±0.037) and 0.702 (±0.0164), respectively. This trend indicates that rubber has the highest coefficient of static friction and galvanized iron sheet the least. It was observed from the experimental values that surface materials have a significant effect on the coefficient of static friction. Comparatively, the African nutmeg seed coefficient of static friction has semblance with that of Sumac fruits [7], Rose fruit [9] and *Juniperus drupacea* [10]. The true density of African nutmeg was found to be 830.54 (±17.50) kg m^{-3}while the bulk density was obtained as 488.76 (± 10.10 kg m^{-3}), yielding a porosity of 41.10% (±1.20). This porosity value is similar to that reported by (8) for soy beans (41-44%).Frictional properties data of African nutmeg on different surfaces is also presented. Values obtained reveal that the coefficient of static friction, using iron sheet, galvanized iron, plywood and rubber surfaces, were 0.554 (±0.022), 0.502 (±0.013), 0.632 (±0.037) and 0.702 (±0.0164), respectively.

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MATERIAL AND METHODS

Material Preparation

About 24 kg of *Monodora myristica* seeds were purchased from a local market in

Nsukka, Enugu State, Southeastern Nigeria. The seeds were manually cleaned to remove foreign matters, immature and broken seeds. The initial moisture content in Wet Basis (% W.B.) of the seeds was determined using the oven dry method at a temperature of 103±2°C until a constant weight was reached [11]. The moisture content was determined using equation 1.

$$MoistureContent, MC_{wb} = \frac{M_w - M_D}{M_w} x\ 100 \qquad (1)$$

Where, MC_{wb} is the moisture content of the seed in % wet basis, M_W is the initial weight of the seed sample in g, M_D is the weight of the seed sample after drying to constant weight in g. A 3 x 4 factorial experimental design was employed in carrying out the study resulting in a total of 12 experimental samples with three replicates. Three levels of roasting temperature of 140, 170, and 200°C, and four levels of roasting time of 2, 7, 12, and 17 minutes were used. The seed bulk was divided into thirteen batches of 1.5 kg each. The first batch was set aside as control for the experiments while the other twelve batches were roasted at different combinations of roasting temperature and time. The selection of the roasting temperatures and time was based on the observed roasting temperatures in published literatures which ranged from 100 to 240°C. The seeds were roasted in an electric oven (ELE Limited-serial no: S80F185-Hemel Hempstead Hertfordshire, England) at the preset roasting parameters. After roasting, the *Monodora myristica* seeds were allowed to cool to ambient temperature and each batch further divided into three portions for replication of the experiments. Appropriate quantities of the seeds were randomly selected from the portions to determine the physical properties of the roasted seeds. The following physical properties of the roasted seeds and the control sample were determined following the methods described below: size, shape, volume, bulk and solid density, porosity, surface area, specific surface area, aspect ratio, angle of repose and static coefficient of friction.

Size, Shape and Volume

The size of *Monodora myristica* seeds was determined being an important parameter in biomaterial processing [12]. The physical dimensions were determined by randomly picking 100 seeds from each portion of the roasted seeds and measuring the nut length a, width b, and thickness c, using a SKOLE digital vernier calliper measuring to accuracy of 0.001 mm. The geometric mean diameter, D_g, mm and the arithmetic mean diameter, D_a, mm of the seeds was calculated using the following equation by [13]:

$$D_g = (abc)^{1/3} \qquad (2)$$

and

$$D_a = \frac{a+b+c}{3} \qquad (3)$$

The degree of sphericity (Ø) was obtained using the formula given by [13] and [14] as follows:

$$\varnothing = \frac{(a.b.c)^{1/3}}{a} = \frac{D_g}{a} \quad (4)$$

The unit volume, V_u (cm^3) of the seeds was determined based on the assumption that *Monodora myristica* seed is similar to a scalene ellipsoid where a > b > c. The formula was derived from the scalene ellipsoid volume as follows [15]:

$$V_u = \frac{4}{3}\pi\,(a.b.c)/1000 \quad (5)$$

Bulk and Solid Density, and Porosity

The bulk density was determined by filling a cylindrical container of known volume with the material and then weighing the cylinder. The seeds were dropped from a known height to produce a tapping effect in the container similar to the settling effect during storage [16]. Excess materials were removed by sweeping the surface of the cylinder and not compressing the materials. The bulk density ρ_b was calculated as the ratio of weight of the seeds in the cylinder to the volume of the cylinder [17; 18]:

$$\rho_b = \frac{m}{V_c} \quad (6)$$

Where, m is mass of the samples (g); V_c is the volume of the cylinder (cm^3).

To calculate the solid or true density, the unit mass of the seeds was determined using an electronic balance (Mettler Toledo JL 620-GLA01) reading to accuracy of 0.001 g and the particle volume, V_u (cm^3) determined using the toluene displacement method [19; 20]. The true density was defined as the ratio of mass of the sample to its true volume [18; 15]

$$\rho_t = \frac{m}{n\,.V_u} \quad (7)$$

Where ρ_t is true or solid density (g/cm^3), n is number of nut in the sample.

The porosity (ε) which indicates the amount of pores in the bulk material, was determined in relation to the bulk density (ρ_b) and the true density (ρ_t) using the following equation [21]:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right).100 \quad (8)$$

Surface Area, Specific Surface Area, and Aspect Ratio

Approximate surface area, S (mm^2) of the seeds was determined by approximating its shape by prolate ellipsoids [18; 22; 15]:

$$S = 2\pi\left(\frac{b}{2}\right)^2 + 2\pi.\frac{a.b}{4d}.sin^{-1}d \quad (9)$$

Where

$$d = \left[1 - \left(\frac{b}{a}\right)^2\right]^{1/2} \quad (10)$$

The specific surface area, S_s (cm^2/cm^3) was calculated as follows [18]:

$$S_s = \frac{S\,.\rho_b}{m} \quad (11)$$

Where, m is the mass in g of one unit of the seed.

The aspect ratio (R_a) was calculated as follows:

$$R_a = \frac{b}{a} . 100 \qquad (12)$$

Static and Dynamic Angle of Repose

The angle of repose indicates the cohesion among individual units of a material; the higher the cohesion, the higher the angle of repose [18]. The angle of repose for *Monodora myristica* seeds was determined using two methods namely: (i) the filling method, to determine the static angle of repose and (ii) the emptying method, to determine the dynamic angle of repose. For the filling method, the methodology described by [23] was adopted. A fibre glass box of 15 × 15 × 15 cm having a removable front panel was used. The box was filled with the seeds, and then the front panel quickly removed allowing them to flow and assume its natural slope. The slope angle which is the static angle of repose (θ_s) was read with a protractor. For the emptying method, a bottomless cylinder (15 cm diameter, 10 cm height) was used. The cylinder was placed over a plain surface and *Monodora myristica* seeds filled in. The cylinder was raised slowly allowing the sample to flow down and form a natural slope [18; 21]. The dynamic angle of repose was calculated from the height and diameter of the pile as:

$$\theta_d = tan^{-1}\left(\frac{2h}{D}\right) \qquad (13)$$

Where, θ_d is the dynamic angle of repose (^{o}), h is the height of the pile (cm) and D is the diameter of the pile (cm).

Static Friction Angle and Coefficient

The static coefficient of friction (μ_s) of *Monodora myristica* seeds was determined on three different structural surfaces namely, plastic, Aluminum, and plywood using the inclined plane method. A plastic cylinder of 23 cm diameter and 15 cm height was placed on an adjustable tilting plate having the test surface firmly placed on it. The plastic cylinder was filled with the test material and raised slightly (about 5 mm) so as not to touch the test surface. The structural surface with the cylinder filled with the seeds resting on it was inclined gradually, using a screw device, until the cylinder just started to slide down [16]. The static friction angle (α) was read from a graduated scale and the tangent of this angle recorded as the static coefficient of friction on that surface.

$$\mu_s = \tan\alpha \qquad (14)$$

RESULTS AND DISCUSSIONS

The result of the effects of roasting conditions – temperature and time – of *Monodora myristica* seeds on its physical properties are presented in this section of the report. The temperature ranged from 140 to 200^{o}C and the time ranged from 2 to 17 min.

Effect of Roasting Conditions on the Physical Properties

Basic Geometric Properties

The effect of roasting temperature and time on the basic geometric properties of *Monodora myristica* seeds which include the length, width, thickness, arithmetic diameter, geometric diameter and volume is shown in Table 1. For the length and width of the seeds, it was observed that the mean values recorded at each roasting temperature level generally decreased as the roasting time increased from 2 to 17 min. At the 140°C roasting temperature, the length of the seed decreased from 18.87 mm at 2 min. roasting time to 17.22 mm at the 17 min. roasting time, while the width decreased from 12.17 to 11.30 mm as the roasting time increased from 2 to 17 min. However, for the thickness of the seed, no clear trend was observed as the roasting temperature and time increased. This suggests that the effect of roasting conditions were minimal or non-existent on the thickness of the seed. The arithmetic mean, geometric mean and the volume of the seeds were observed to decrease as the roasting temperature and time increased. This was expected following the steady decrease observed in the length and width of the seeds as the roasting parameters increased from 140 to 200°C and 2 to 17 min. At 140°C, the volume of the seeds decreased from 9.36 to 8.13 cm^3 while the volume decreased from 9.00 to 8.63 cm^3 and 9.59 to 8.80 cm^3 at the 170 and 200°C roasting temperatures respectively, as the roasting time increased from 2 to 17 min. The decrease generally observed in the mean values recorded for the basic geometric properties of the seeds could be attributed to the evaporation of moisture and as well as volatile organic matters present in the seed as the roasting temperature and time increased resulting in the shrinkage of the seed coat. This view was supported by the result reported by [24] on roasted cashew nuts. Analysis of variance (ANOVA) carried out on the results of the effect of roasting temperature and time on the basic geometric properties of *Monodora myristica* seeds revealed that roasting temperature of 140 – 200 °C had no significant effect ($p>0.05$) on the basic geometric properties while the effect of roasting time on the basic geometric properties was significant ($p<0.05$). The means of the basic geometric properties were compared using Duncan Multiple Range Test (DMRT) at $p<0.05$ and the result is shown in Table 2. The result revealed that the roasting time of 2 – 17 min. had no significant effect on the length and thickness of the seeds meaning that the mean values recorded were not significantly different from the value recorded for the control sample (raw

Monodora myristica seeds). The effect of roasting time was however significant ($p<0.05$) on the width, arithmetic and geometric diameters, and the volume. The significant effect was observed only at the 17 min. roasting time which suggests that the 2, 7, and 12 min. of roasting time had no significant effect on the width, arithmetic and geometric diameters, and the volume of the seeds.

Table 1: Mean Values of the Basic Geometric Properties of Roasted *Monodora Myristica* Seeds

Roasting Temperature (°C)	Roasting Time (min)	Length (mm)	Width (mm)	Thickness (mm)	Arithmetic Diameter (mm)	Geometric Diameter (mm)	Volume (cm^3)
140	2	18.87	12.17	9.69	13.58	13.03	9.36
	7	18.40	11.90	9.31	13.20	12.65	8.54
	12	17.82	11.50	10.05	13.12	12.70	8.67
	17	17.22	11.30	9.92	12.81	12.43	8.13
170	2	17.93	11.92	10.04	13.30	12.87	9.00
	7	18.17	11.74	9.70	13.20	12.72	8.70
	12	18.08	11.98	9.70	13.26	12.77	8.87
	17	17.93	11.73	9.70	13.12	12.65	8.63
200	2	18.64	12.00	10.18	13.61	13.12	9.59
	7	17.74	11.94	9.86	13.18	12.75	8.79
	12	18.07	11.81	10.06	13.31	12.86	9.02
	17	17.97	11.76	9.91	13.21	12.76	8.80

Table 2: Duncan Multiple Range Test for the Basic Geometric Properties of *Monodora Myristica* Seeds as Influenced by Roasting Conditions

Parameters	Factor Level	Length (mm)	Width (mm)	Thickness (mm)	Arithmetic diameter (mm)	Geometric diameter (mm)	Volume (cm^3)
Roasting Temperature, °C	0	18.69a	12.06a	9.62a	13.46a	12.92a	9.12a
	140	18.07a	11.72a	9.74a	13.18a	12.70a	8.67a
	170	18.03a	11.85a	9.79a	13.22a	12.75a	8.80a
	200	18.11a	11.87a	10.00a	13.33a	12.87a	9.05a
Roasting Time, min	2	18.53a	12.05a	9.95a	13.51a	13.02a	9.34a
	7	18.15a	11.88a,b	9.60a	13.21a,b	12.72a,b	8.70a,b
	12	18.04a	11.78a,b	9.92a	13.25a b	12.79a,b	8.87a,b
	17	17.75a	11.62b	9.83a	13.07b	12.62b	8.54b

Means with the same letter for each roasting parameter is not significantly different at $p>0.05$; Roasting temperature = 0 for raw *Monodora myristica* seeds

Complex Geometric Properties

Table 3 presents the result of the effect of roasting temperature and time on the complex geometric properties of *Monodora myristica* seeds which include the bulk density, true density, sphericity, porosity, surface area and the specific surface area. The bulk density of the seeds was observed to generally decrease as the roasting temperature and time increased from 140 to 200 °C and 2 to 17 min., respectively. The bulk density decreased from 0.50 to 0.47 and 0.49 to 0.47 at the 140 and 170 °C roasting temperatures, respectively as the roasting time increased from 2 – 17 min. This is in agreement with the result reported by [25] on roasted coffee beans. The decrease in the bulk density may be due to loss of integrity between starch–starch and starch–protein matrix and or due to formation of spaces within the seed [26]. [27] Reported a decrease in the bulk density of toasted oat cultivars and [28] reported a decrease from 31 to 44 % for bulk density after roasting of oats. At 200 °C, no change was observed in the bulk density of the seed as the mean value recorded remained 0.48 g/cm^3 as the roasting time increased. However, this was not the case for the true density at the 200 °C roasting temperature as it decreased from 0.97 to 0.91 g/cm^3. At 140 and 170 °C roasting temperature, the trend in the true density was unclear as the decrease and increase in the mean values were unsteady. Similar observation was made for the sphericity and porosity of the seeds. The surface area and the specific surface area of the seed were observed to decrease at the 140, 170 and 200 °C roasting temperatures as the roasting time increased from 2 to 17 min. The decrease in the dimensions of the seeds observed in Table 1 could be responsible for the observed decrease in the surface area and specific surface area of the seeds since they were calculated from the dimensions of the seeds.

Analysis of variance carried out on the mean values of the complex geometric properties revealed that roasting temperature and time significantly influenced ($p<0.05$) some of the complex geometric properties. Comparison of means carried out using DMRT showed that the roasting time had significant effects ($p<0.05$) on the bulk and true density only while the roasting time significantly affected all the complex geometric properties except the sphericity of the seeds (Table 4). Although the roasting temperature significantly influenced ($p<0.05$) the bulk density, the means recorded at the 140 to 200°C were not significantly different ($p>0.05$) from each other.

Table 3: Mean Values of the Complex Geometric Properties of Roasted *Monodora Myristica* Seeds

Roasting Temperature (°C)	Roasting Time (min)	Bulk density (g/cm³)	True density (g/cm³)	Sphericity (%)	Porosity (%)	Surface area (mm²)	Specific surface area (cm²/cm³)
140	2	0.50	0.85	69.42	41.70	23775.23	79.34
	7	0.48	0.89	69.13	45.96	22597.75	75.41
	12	0.48	0.83	71.67	42.42	21169.19	70.64
	17	0.47	0.93	72.53	49.87	20012.49	66.78
170	2	0.49	0.99	72.29	50.60	22008.88	73.44
	7	0.48	0.95	70.34	49.73	22051.67	73.59
	12	0.48	1.07	71.21	54.86	22350.39	74.58
	17	0.47	1.03	71.03	54.17	21783.22	72.69
200	2	0.48	0.97	70.83	50.01	23144.78	77.23
	7	0.48	0.92	72.30	47.34	21747.91	72.57
	12	0.48	0.77	71.74	37.70	22089.83	73.71
	17	0.48	0.91	71.54	47.11	21857.94	72.94

Table 4: Duncan Multiple Range Test for the Complex Geometric Properties of *Monodora Myristica* Seeds as Influenced by Roasting Conditions

Parameter	Factor Level	Bulk density (g/cm³)	True density (g/cm³)	Sphericity (%)	Porosity (%)	Surface area (mm²)	Specific surface area (cm²/cm³)
Roasting Temperature, °C	0	0.51a	0.94a	69.56a	45.93a	23306.35a	77.77a
	140	0.48b	0.88b	70.69a	44.99a	21888.87a	73.04a
	170	0.48b	1.01c	71.22a	52.34b	22048.29a	73.57a
	200	0.48b	0.89b	71.61a	45.54a	22209.34a	74.11a
Roasting Time, Min	2	0.49a	0.94a,c	70.73a	47.31a	23072.27a	76.99a
	7	0.48b	0.92a,b	70.47a	47.54a,b	22229.41a,b	74.18a,b
	12	0.48b	0.89b	71.42a	44.86c	21966.79a,b	73.30a,b
	17	0.48b	0.96c	71.58a	50.25b	2131433.b	71.13b

Means with different letters for each roasting parameter are significantly different at $p<0.05$; Roasting temperature = 0 for raw *Monodora myristica* seeds

The significant difference was only observed between the roasted seeds and the raw ones. The same observation was made on the effect of roasting time on the bulk density of the seeds. This could interpret to mean that roasting at different temperature and time may not significantly influence the bulk density of *Monodora myristica* seeds except when compared with the raw seeds. The effect of roasting time on the surface area and the specific surface area of the seeds was observed only at the 2 and 17 min. roasting time whose mean values of surface area and specific surface area recorded were significantly different ($p<0.05$) from each other.

Effect of Roasting Conditions on the Frictional Properties

The effect of increasing roasting temperature and time on the frictional properties of *Monodora Myristica* seeds which include the angle of repose and coefficient of static friction on three structural surfaces is presented in Table 5. The angle of repose was investigated using the filling and emptying methods. The angle of repose determined using the filling method was generally lower than the corresponding values determined using the emptying method. The angle of repose determined using the two methods were observed to increase at each level of roasting temperature as the roasting time increased. At 170 ^{o}C, the filling angle of repose increased from 21.19 to 25.69 ^{o} while the emptying angle of repose increased from 22.33 to 27.46 ^{o} as the roasting time increased from 2 to 17 min. The highest filling angle of repose was recorded at the 140 ^{o}C and 17 min. roasting condition with a value of 25.72 ^{o} while the highest emptying angle of repose was recorded at the170 ^{o}C and 17 min. roasting condition with a value of 27.46 ^{o}. The increase could be attributed to the expected reduction in the moisture content as well as in other volatile matter in the seed following its introduction into the oven. This could result in increased angle of repose due to loss in weight of the seeds. The coefficient of static friction was observed to increase steadily on all the three test structural surfaces as the roasting time increased from 2 to 17 min. at 140, 170 and 200^{o}C roasting temperatures.

On the plywood, plastic and Aluminum surfaces, the highest mean values of 0.58, 0.53 and 0.53 respectively, were all observed at the 200 ^{o}C and 17 min. roasting condition. On the Aluminum surface, the highest mean value of 0.53 was also recorded at the 200^{o}C and 12 min. roasting condition. Roasting generally result in shrinkage of biomaterial surfaces which consequently effects a level of roughness on the biomaterial surface [29] reported changes in the surface structure of Arai white and

Muki sesame seeds roasted at 170 and 200^{o}C. This could be responsible for the increase in the static coefficient of friction of the seeds as the roasting temperature and time increased.

Table 5: Mean Values of the Frictional Properties of Roasted *Monodora Myristica* Seeds

Roasting Temperature (°C)	Roasting Time (min)	Angle of Repose (°)		Coefficient of Static Friction		
		Filling	Emptying	Plywood	Plastic	Aluminum
140	2	20.13	22.28	0.41	0.31	0.38
	7	21.42	22.31	0.43	0.33	0.39
	12	23.22	26.17	0.47	0.38	0.41
	17	25.72	27.11	0.51	0.40	0.42
170	2	21.19	22.33	0.44	0.35	0.38
	7	22.83	23.40	0.48	0.41	0.44
	12	24.72	26.38	0.52	0.44	0.49
	17	25.69	27.46	0.55	0.46	0.52
200	2	21.16	23.43	0.47	0.38	0.46
	7	22.98	24.63	0.52	0.44	0.50
	12	23.74	25.81	0.54	0.49	0.53
	17	25.11	27.13	0.58	0.53	0.53

Table 6: Duncan Multiple Range Test for the Frictional Properties of *Monodora Myristica* Seeds as Influenced by Roasting Conditions

Parameters	Factor Level	Angle of Repose (°)		Coefficient static of Friction		
		Filling	Emptying	Plywood	Plastic	Aluminum
Roasting Temperature, °C	0	18.21a	21.41a	0.85a	0.68a	0.79a
	140	22.60b	25.25b	0.46b	0.36b	0.40b
	170	23.62b	24.89b	0.50c	0.42c	0.46c
	200	23.27b	24.47b	0.52d	0.46d	0.50d
Roasting Time, Min	2	20.80a	22.41a	0.47a	0.37a	0.43a
	7	22.42a	23.18a	0.50b	0.42b	0.47b
	12	23.91b	25.85b	0.54c	0.46c	0.50c
	17	25.53c	26.97c	0.57d	0.48d	0.52d

Means with different letters for each roasting parameter are significantly different at $p<0.05$; Roasting temperature = 0 for raw *Monodora myristica* seeds

The results suggest that roasting of *Monodora Myristica* seeds increases the mean value of its frictional properties. Analysis of variance carried out revealed that the roasting parameters – temperature and time – significantly affected ($p<0.05$) the frictional properties of the seeds. DMRT showed similar trends between the effect of roasting temperature and time on the angle of repose and on the coefficient of static friction (Table 6). On the filling angle of repose, the mean values recorded at the 140, 170 and 200°C were not significantly different ($p>0.05$) from one another but were significantly different from the mean value obtained from the control sample. The mean values recorded at the 2 and 7 min. roasting time were not significantly different ($p>0.05$) from each other but were significantly different ($p<0.05$) from other means. The same trend was observed on the effect of both the roasting temperature and time on the emptying angle of repose. The means obtained for the coefficient of static friction on plywood, plastic and Aluminum surfaces were all significantly different ($p<0.05$) from each other as they were influenced by the roasting temperature and time. The result obtained from the DMRT shown in Table 6 suggests that the effect of roasting temperature has on the angle of repose and coefficient of static friction of *Monodora myristica* seeds is the same as the effect of roasting time on the seed.

CONCLUSIONS

This study which investigated the effect of roasting conditions (temperature and time) on the physical properties of *Monodora myristica* seeds revealed that the thermal process of roasting significantly affected the properties of the seed. The roasting temperature ranged from 140 to 200°C and the time ranged from 2 to 17 min. The basic geometric properties of *Monodora myristica* seeds which include the length, width, thickness, arithmetic and geometric diameters, and the volume were not significantly affected by the roasting temperature ($p>0.05$) however, the roasting time significantly influenced the basic geometric properties ($p<0.05$) except the length and the thickness. The complex geometric properties of the seeds were significantly affected ($p<0.05$) by the roasting conditions except for the sphericity and the specific surface area of the seeds; and the roasting conditions showed significant effect on the frictional properties of the seeds in a manner similar to each other.

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