International Food Research Journal 24(3): 1148-1155 (June 2017)

Journal homepage: *http://www.ifrj.upm.edu.my*

Effects of roasting on the physical properties of *Monodora myristica* (African nutmeg)

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Article history

Received: 19 May 2016
Received in revised form: 27 June 2016
Accepted: 28 June 2016

Keywords

Roasting
Temperature
Time
Physical properties
African nutmeg

Abstract

Changes in the physical properties of *Monodora myristica* seeds during roasting were investigated. 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 physical properties of the seeds investigated include the size, shape, volume, bulk and solid density, porosity, surface area, specific surface area, angle of repose and the static coefficient of friction on plywood, plastic, and aluminum surfaces. The result from the study revealed that roasting temperature had no significant effect ($p>0.05$) on the size, shape and volume of the seeds. However, the roasting time significantly influenced ($p<0.05$) the width, arithmetic and geometric diameters, and the volume of the seeds. Furthermore, the roasting parameters had no significant effect ($p>0.05$) on the sphericity, surface area and the specific surface area of the seeds. The effects of the roasting parameters on the frictional properties of the seeds were significant ($p<0.05$). The angle of repose and the coefficient of static friction were all observed to increase as the roasting temperature and time increased from 140 to 200°C and 2 to 17 min respectively.

Introduction

Monodora myristica otherwise called African nutmeg is a climber tree belonging to the Anannacea family and grows well in the tropical forest regions of Africa. The seeds which are embedded in a white sweet-smelling pulp of the sub-spherical fruit are economically and medically important (Burubai *et al*., 2007). The kernel obtained from the seeds is a popular condiment used as a spicing agent in most cuisines and contain an important source of active natural antioxidants (Okwu, 2004). There are several reports of its medicinal use (Weiss, 2002); the bark is used in the treatments of stomach-aches, febrile pains, eye diseases and hemorrhoids. In many African countries, the kernels are used as condiment and drug in the treatment of headache and hypertension (Koudou *et al*., 2007). The kernel, when ground to powder, is used to prepare pepper soup as a stimulant to relieve constipation and control uterine haemorrhage in women immediately after child birth. Monodora myristica has also demonstrated ability to prevent sickle cell anemia (Uwakwe and Nwaoguikpe, 2008).

The traditional method of processing Monodora myristica seeds to obtain the kernels involves roasting over fire prior to cracking and size reduction. 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. Roasting is an important pre-processing treatment for a number of seeds such as almond nut (Lasekan *et al*., 2012), coffee beans (Budryn *et al*., 2015), cocoa beans (Oracz and Nebesny, 2016), and wattle seed (Ee *et al*., 2013). Roasting of Monodora myristica seeds has been adopted as a standard processing method by processors of the seed in obtaining the kernel; however, there is no existing scientific study that has assessed the effect of roasting on the physical properties of the seeds. This study is particularly important to the mechanization of the processing of the seeds which at the moment is still manually processed and in exploiting its full economic potentials.

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 (Burubai *et al*., 2007). 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 study of size of seeds is essential for uniformity and packing in standard cartons. Bulk density and porosity are useful

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in containerization, transportation and separation systems (Kachru *et al.*, 1994). Shape and physical dimensions are important in screening solids to separate foreign materials and in sorting out various sizes of fruits and vegetables (Stroshine, 2004). The knowledge of frictional properties is needed for design of handling equipment and storage structures. These physical properties are not only useful to the engineers but also to food scientist and processors who may exploit them in their various disciplines. Akinoso and Olatunde investigated the effect of cassava mash quantity and garification duration roasting on some physical, pasting and sensory properties of garri while Shakerardekani *et al.* (2011) investigated the effect of hot-air roasting temperature and time on the hardness, moisture content and colour of pistachio nut for the production of pistachio paste.

In order to appropriate the full economic potential of African nutmeg, there is need to evaluate the effect of roasting on the physical properties of the seeds. The objective of this study was to evaluate the effects of roasting time and roasting temperature on the physical properties of Monodora myristica seeds necessary for the design of its handling and processing equipment. The physical properties investigated were size, shape, volume, bulk and solid density, porosity, surface area, specific surface area, angle of repose and static coefficient of friction on different material surfaces.

Materials 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 (Kashaninejad *et al.*, 2005). The moisture content was determined using equation 1.

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

Where, MC_{wb} is the moisture content of the seed in % wet basis, M_W is the initial weight of the seed sample in grams, M_D is the weight of the seed sample after drying to constant weight in grams.

Experimental design

A 3 x 4 factorial experimental design was employed in carrying out the study resulting in a total of 12 experimental samples with six replications. 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 selection of the roasting temperatures and times was based on the observed traditional roasting parameters which ranged from 170 to 180oC and 5 to 8 minutes, respectively. Thirteen batches of 1.5 kg each were randomly selected from the seed bulk. A batch was used as control for the study while the other twelve batches were roasted at different combinations of roasting temperature and time. 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 seeds were allowed to cool to ambient temperature and each batch further divided into six portions for replication of the experiments. Appropriate quantities of the seeds were randomly selected from the portions to determine the physical properties of the seeds.

Determination of the physical properties

The size of *Monodora myristica* seeds was determined being an important parameter in biomaterial processing (Suthar and Das, 1996). The physical dimensions were determined by randomly picking 100 seeds from each portion of the seed samples and measuring the nut length a, width b, and thickness c, using a SKOLE digital vernier caliper measuring to accuracy of 0.001 mm. The length and width were the longest and shortest dimensions of the widest surface of the seed, respectively while the thickness was the shortest dimension of the smallest surface of the seed.

The geometric mean diameter, D_g, mm and the arithmetic mean diameter, D_a, mm of the seeds was calculated using the following equation in Mohsenin (1986):

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

and

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

The degree of sphericity (Ø) was obtained using the equation in Jain and Ball (1997). 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 (Mohsenin, 1980):

$$V_u = 4/3\ \pi\ (a.b.c)/1000 \quad (4)$$

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 height of 25 cm to produce a tapping effect in the container similar to the settling effect during storage (Obi and Offorha, 2015). Excess materials were removed by sweeping the surface of the cylinder without compressing the material. The bulk density, ρ_b was calculated as the ratio of weight of the seeds in the cylinder to the volume of the cylinder (Sharma *et al*., 2011). The solid or true density was determined as the ratio of mass of the sample to its true volume (Karaj and Müller, 2010). The unit mass of the seed was determined using an electronic balance (Mettler Toledo JL 620-GLA01) reading to accuracy of 0.001 g and while the true volume, V_u (cm^3) was determined using the toluene displacement method (Unal *et al*., 2013; Zare *et al*., 2013). 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 *(ρt)* (Garnayak *et al*., 2008).

Approximate surface area, S (mm^2) of the seeds was determined by approximating its shape by prolate ellipsoids as (Sirisomboon *et al*., 2007; Karaj and Müller, 2010):

$$S = 2\pi\left(\frac{b}{2}\right)^2 + 2\pi.\frac{a.b}{4d}.\sin^{-1}d \qquad (5)$$

Where

$$d = \left[1-\left(\frac{b}{a}\right)^2\right]^{1/2} \qquad (6)$$

The specific surface area, S_s (cm^2/cm^3) was calculated as follows (Karaj and Müller, 2010):

$$S_s = (s.\rho b)/m \qquad (7)$$

Where, m is the mass in g of one unit of the seed, and nut length *a* and width *b*.

Determination of the frictional properties

The angle of repose indicates the cohesion among individual units of a material; the higher the cohesion, the higher the angle of repose. 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, a fibreglass 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 (Garnayak *et al*., 2008; Karaj and Müller, 2010). The dynamic angle of repose was calculated from the height and diameter of the pile as:

$$\Theta_d = \tan^{-1}(2h/D) \qquad (8)$$

Where, Θ_d is the dynamic angle of repose (°), h is the height of the pile (cm) and D is the diameter of the pile (cm).

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 described by Dutta *et al*. (1988). 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 (Obi and Offorha, 2015). 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.

Statistical analysis

Six replications were carried out during the experiments at each roasting condition and the mean values of the properties investigated were reported. Effect of roasting conditions on the physical properties of *Monodora myristica* seeds were determined by statistically analyzing the data obtained. Analysis of variance (ANOVA) at 5 % probability level ($p<0.05$) and separation of means using Duncan multiple range test were carried out using GenStat analytical software.

Results and Discussion

The result of the effects of roasting conditions – temperature and time – on the physical properties of *Monodora myristica* seeds are discussed below. The roasting temperature and time ranged from 140 to 200°C and 2 to 17 min. respectively.

Basic geometric properties

The mean values recorded for the basic geometric

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

Roasting Temperature (°C)	Roasting Time (min)	Bulk density (g/cm^3)	True density (g/cm^3)	Sphericity (%)	Porosity (%)	Surface area (mm^2)	Specific surface area (cm^2/cm^3)
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 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 are not significantly different at p>0.05; Roasting temperature = 0 for raw *Monodora myristica* seeds

properties of *Monodora myristica* seeds which include the length, width, thickness, arithmetic diameter, geometric diameter and volume at different roasting conditions are 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 seeds, no clear trend was observed as the roasting temperature and time increased. This suggests that the effect of roasting conditions were inconsistent on the thickness of the seeds. The arithmetic and geometric mean diameters and the volume of seeds were observed to decrease as the roasting temperature and time decreased. This was expected following the 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 temperature, 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 as the roasting temperature and time increased resulting in the shrinkage of the seed coat. This view was supported by the result reported by Ogunsina and Bamgboye (2007) on roasted cashew nuts.

Analysis of variance (ANOVA) carried out revealed that roasting temperature of 140 to 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 showed that the means recorded for the

Table 3. Duncan Multiple Range Test for the complex geometric properties of *Monodora myristica* seeds as influenced by roasting conditions

Parameter	Factor Level	Bulk density (g/cm^3)	True density (g/cm^3)	Sphericity (%)	Porosity (%)	Surface area (mm^2)	Specific surface area (cm^2/cm^3)
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* seed

length and thickness of the seeds as the roasting time increased from 2 to 17 min. were not significantly different (p>0.05) from one another. However, the means recorded for the width were observed to differ significantly (p<0.05) from one another as the roasting time increased. This significantly influenced the arithmetic and geometric diameters, and the volume as they all use width as a variable in their equations. The results showed that while roasting temperature showed no significant effect on the basic geometric properties of *Monodora myristica* seeds, the roasting time may significantly alter some of the basic geometric properties.

Complex geometric properties

The means recorded for the complex geometric properties of *Monodora myristica* seeds which include the bulk density, true density, sphericity, porosity, surface area and the specific surface area at different roasting conditions are shown in Table 1. The bulk density of the seeds was observed to decrease as the roasting temperature and time increased from 140 to 170^{o}C and from 2 to 17 min., respectively. The bulk density decreased from 0.50 to 0.47 g/cm^3 and from 0.49 to 0.47 g/cm3 at the 140 and 170^{o}C roasting temperatures, respectively as the roasting time increased from 2 to 17 min. The decrease in the bulk density may be due to loss of integrity between starch–starch and starch–protein matrix or due to formation of spaces within the seed (Chandrasekhar and Chattopadhyay, 1990). Gujral *et al.* (2011) reported a decrease from 31 to 44 % for bulk density after roasting of oats. At 200^{o}C, no change was observed in the bulk density of Monodora myristica seeds as the mean value recorded remained as 0.48 g/cm3 as the roasting time increased. However, this was not the case for the true density at the 200^{o}C roasting temperature as it decreased from 0.97 to 0.91 g/cm3. At 140 and 170^{o}C roasting temperature, the trend in the true density was unclear as the decrease or increase in the mean values was unsteady. Similar observation was made for the sphericity and porosity of the seeds. The surface area and the specific surface area of the seeds were observed to decrease at the 140, 170 and 200^{o}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 revealed that the roasting temperature and time significantly influenced (p<0.05) the complex geometric properties of the seeds. Comparison of means using DMRT showed that the means recorded for the bulk and true density as influenced by the roasting temperature were significantly different (p<0.05) from one another. However, no significant difference was observed among the means recorded for the sphericity, porosity, surface area and specific surface area of the seeds as the roasting temperature increased (Table 3). The roasting time however significantly influenced (p<0.05) all the complex geometric properties except for the sphericity where no significant difference (p>0.05) was observed among the mean values.

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 4. 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

Table 4. 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 5. 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* seed

recorded at the 140°C and 17 min. roasting condition with a value of 25.72 ° while the highest emptying angle of repose was recorded at the170°C and 17 min. roasting condition with a value of 27.46°. 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 temperature and time increased. 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°C and 17 min. roasting condition. On the Aluminum surface, the highest mean value of 0.53 was also recorded at the 200°C and 12 min. roasting condition. Roasting generally results in shrinkage of biomaterial surfaces which consequently effects a level of roughness on the biomaterial surface. Sato *et al*. (2007) reported some changes in the surface structure of Arai white and Muki sesame seeds roasted at temperatures of 170 and 200°C. This could be responsible for the increase in the static coefficient of friction of the seeds as the roasting temperature and time increased. 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 influenced ($p<0.05$) the frictional properties of the seeds. Separation of means carried out using DMRT showed that the angle of repose recorded for the roasted seeds as influenced by the roasting temperature were not significantly different ($p>0.05$) from one another but were significantly different from the control sample (raw seeds) (Table 5). This suggests that increasing the roasting temperature of the seeds may not significantly ($p>0.05$) alter the angle of repose. The means observed for the filling and emptying angle of repose as influenced by the roasting time were significantly different ($p<0.05$) from one another. The means recorded for the static coefficient of friction were all significantly different ($p<0.05$) from one another as the roasting temperature and roasting time increased (Table 5). This shows that changing the roasting temperature or roasting time may result in a significant change in the coefficient of static friction of Monodora myristica seeds.

Conclusion

This study which investigated the effect of roasting conditions (temperature and time) on the physical properties of *Monodora myristica* seeds revealed that thermal process of roasting significantly affected the properties of the seed. The basic geometric properties of the seeds which include the length, width, thickness, arithmetic and geometric diameters, and the volume were not significantly affected ($p>0.05$) by the roasting temperature. However, the roasting time significantly influenced ($p<0.05$) the basic geometric properties except for the length and thickness. The complex geometric properties of the seeds were significantly affected ($p<0.05$) by the roasting conditions except for the sphericity. In addition to that, the roasting temperature had no significant effect ($p>0.05$) on the surface and specific surface area of the seeds. The frictional properties of the seeds were observed to be significantly influenced by the roasting conditions. The knowledge of the influence of roasting temperature and time on the physical properties of African nutmeg could be used in the design of appropriate processing and storage equipment in mechanizing the processing of the seeds.

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