INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Int. Agrophys., 2013, 27, 485-489
doi: 10.2478/intag-2013-0019

Note

Some physical properties of ginkgo nuts and kernels

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Received October 26, 2012; accepted May 2, 2013

A b s t r a c t. Some data of the physical properties of ginkgo nuts at a moisture content of 45.53% (±2.07) (wet basis) and of their kernels at 60.13% (± 2.00) (wet basis) are presented in this paper. It consists of the estimation of the mean length, width, thickness, the geometric mean diameter, sphericity, aspect ratio, unit mass, surface area, volume, true density, bulk density, and porosity measures. The coefficient of static friction for nuts and kernels was determined by using plywood, glass, rubber, and galvanized steel sheet. The data are essential in the field of food engineering especially dealing with design and development of machines, and equipment for processing and handling agriculture products.

K e y w o r d s: ginkgo, physical properties, nuts and kernels

INTRODUCTION

Ginkgo nuts are the seeds of *Ginkgo biloba* L. tree or maidenhair tree. Ginkgo nuts have long been consumed as food and as herbal medication among Chinese in Asia. This tree is originally native to mountainous areas of China. Today, cultivated ginkgo trees can be seen not only everywhere in China and Japan, but are also found all over the world. Rich sandy soils are most suitable for this plant. A ginkgo tree is pyramidal in shape, and can grow up to 30.50 m tall and 15.25 m in circumference (Zimmermann *et al*., 2002). It is regarded as one example of dioecious plants where there are male and female ginkgo plants. Generally, ginkgo trees are in flower from April to May, and the seeds ripen from October to November. Pollen grains from male trees are carried to female trees by the wind. While female trees bear paired ovules, which, when fertilized, develop into yellowish, plumlike seeds consisting of a large nut surrounded by a fleshy outer covering. The nut is silvery. When the nut ripens, it is harvested and processed manually to remove the fleshy exosperm; then, the nut is washed, steamed or scalded, baked until dry, followed by removal of its hard shell. After these procedures, it is ready to be used. When conducted manually, the above-mentioned operations are always time consuming and labour intensive.

According to National Bureau of Statistics of China (2005), the total volume of ginkgo nuts supplied by China has been estimated as a total volume of 3 848 and 4 199 t in the 2003 and 2004, respectively. China alone is believed to account for more than 90% of the world production of ginkgo nuts. Ginkgo has a long history of medicinal use in traditional Chinese medicine since 2800 BC, where the nut is most commonly used. Ginkgo nut is regarded to contain proteins, carbohydrates, fat, crude fibre, cyanogenetic glycosides, vitamins, and a variety of amino acids (Zhang *et al*., 2011). It may also be an excellent source of minerals such as iron and magnesium (Tadayyon, 2013). Some studies of the Gingko nuts have been carried out, for example, Zhang *et al*. (2011) studied the shelling performance of ginkgo nuts under compression loading, and Singh *et al*. (2008) studied the biology and chemistry of ginkgo biloba.

The physical properties of various types of nuts have been studied, as the knowledge is needed when there is an intention to design machines and equipment for handling, processing, and storing of the agricultural products effectively. Generally, the measurement of the mass, length, width, thickness, geometric mean diameter, surface area, volume, true density, bulk density, porosity, sphericity, aspect ratio, and static friction on different types of surfaces were reported by researchers as the required basic physical properties of nuts. In the literature, we can find some examples of physical and mechanical properties of nuts or seeds such as nutmeg seeds (Abdullah *et al*., 2010), almond nuts (Aydin, 2003), pistachio nuts (Kashaninejad *et al.*, 2006), and walnuts (Ercisli *et al*., 2011).

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The objective of this study is to determine some physical properties of ginkgo nuts and kernels with the use of similar methodologies addressed in the literature that can provide useful information to facilitate machine design for processing and handling.

MATERIALS AND METHODS

A one-kilogram packet of ginkgo nuts was purchased from one of the grocery stores in Perak. The nut samples used in this study were commercial products of China. The experiment was conducted in a physics laboratory of the Department of Applied Sciences at University of Technology MARA, Penang, Malaysia. The physical properties of the nuts and kernels were determined at the temperature and relative humidity in the range of 21.2-25.1°C and 70-90 %, respectively, for a period of five days. Before starting the experiment, the nut samples were cleaned to remove the impurities. For the purpose of this experiment, some nuts needed to be cracked using a hammer in order to separate the kernels from the shells. It was done manually. Broken nuts were eliminated from the experiment.

The moisture content of the nuts and their kernels were determined using the ASAE Standard (2003). Their three principal dimensions namely, length, width, and thickness were measured using a digital vernier calliper (Model CD-6BS-Mitutoyo Corporation, Japan) with a resolution of 0.01 mm. On the other hand, the unit mass was determined using an electronic balance (Model PS200/2000/C/2-RADWAG, Poland) with an accuracy of 0.001 g. The true volume was determined using the water displacement method. The geometric mean (GMD), degree of sphericity, aspect ratio, surface area, true density, bulk density, porosity, and the coefficient of static friction were calculated using standard equations as described by Mohsenin (1986). All the experiment data obtained were subjected to descriptive statistics analysis using Microsoft Excel 2007 software.

RESULTS AND DISCUSSION

The results of some physical properties of ginkgo nuts and their kernels determined in this study are shown in Table 1. The moisture content (wet basis) of the nuts was found to be in the range of 43.29-48.15%, while the value of the moisture content (wet basis) of the kernels varied between 57.48-62.36%. The moisture content is the valid determinant of storability for any nuts. It has been suggested that if the moisture content of nuts is high, it can easily cause growth of mould on the nut. Therefore, this indicates that the nut may have a short storage life. Table 1 shows that the nuts and kernels have the mean moisture content of 45.53 and 60.13%, respectively. Therefore, the nut has moderate storage potential because its moisture content is just slightly lower than 50%. On the other hand, it was found that the kernel also has some moderate storage potential because its moisture content is above the average. However, this finding would suggest that the kernel has poorer storage potential compared to the nut.

Figure 1 shows the frequency distribution curves of the three dimensions of the nut at the 45.53% moisture content and kernel at the 60.13% moisture content. Approximately 75% of the nuts had a length ranging from 24.10 to 27.90 mm,

Table 1. Some physical properties of ginkgo nuts and kernels

Parameter	Ginkgo nut			Ginkgo kernel	
	No. observation	Mean	Standard deviation	Mean	Standard deviation
Moisture content of seed (w.b.) (%)	5	45.53	2.07	60.13	2.00
Length (mm)	100	25.20	1.47	20.58	1.46
Width (mm)	100	15.66	0.79	12.84	1.17
Thickness (mm)	100	13.70	0.55	12.24	0.98
Geometric mean diameter (GMD) (mm)	100	17.54	0.73	14.76	0.86
Sphericity (%)	100	69.70	2.27	71.86	3.22
Aspect ratio (%)	100	62.24	3.26	62.52	5.57
Mass (g)	100	2.583	0.298	2.083	0.242
Surface area (mm^2)	100	968.45	81.15	686.86	79.37
Volume (mm^3)	10	2 480.00	278.09	1 905.00	226.63
True density (kg m^{-3})	10	1 033.28	35.91	1 106.01	183.19
Bulk density (kg m^{-3})	10	613.66	15.44	670.15	11.52
Porosity (%)	10	40.54	2.55	38.04	9.28

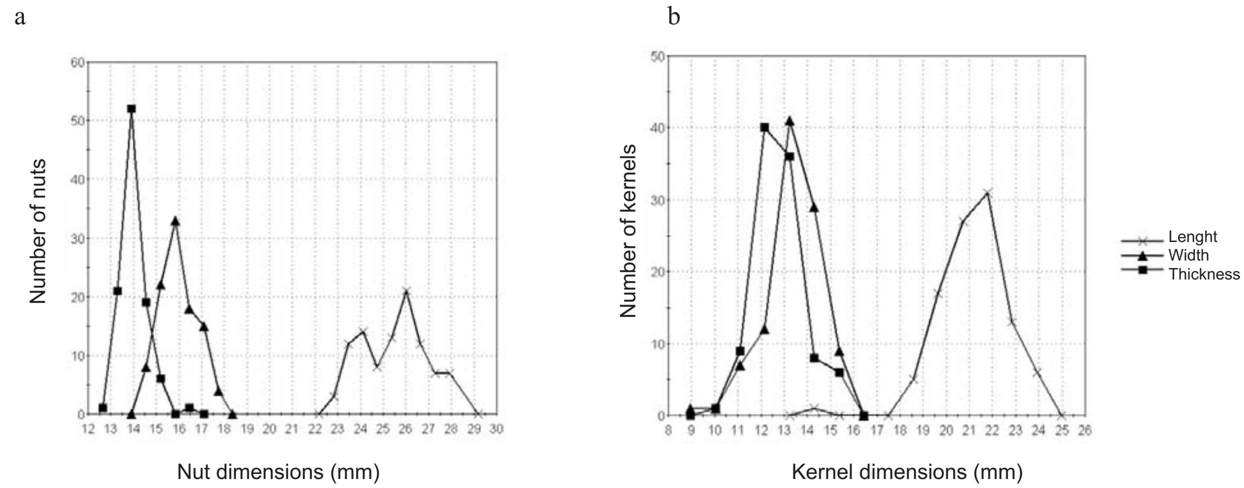

Fig. 1. The frequency distribution curves of ginkgo: a – nut, b– kernel dimensions (length, width, and thickness) at the 45.53 and 60.13% moisture content (w.b.), respectively.

73% of the samples had a width ranging from 15.19 to 17.09 mm, and 71% had a thickness ranging from 13.92 to 15.18 mm. On the other hand, about 75% of the kernels had a length ranging from 19.64 to 22.83 mm, 82% had a width ranging from 12.16 to 15.36 mm, and about 76% had a thickness ranging from 12.16 to 14.29 mm. The mean value of length, width, and thickness of the nuts was 25.20 (±1.47), 15.66 (±0.79), and 13.70 (±0.55) mm respectively. The dimensions of the ginkgo nuts were higher than those reported for coriander seeds (Balasubramanian *et al*., 2012) but lower than filbert nuts (Pliestic *et al*., 2006) and both varieties of walnuts *ie* Maraj-18 and Yalova-1 (Ercisli *et al*., 2011).

The mean value of length, width, and thickness of the ginkgo kernels were 20.58 (±1.46), 12.84 (± 1.17), and 12.24 (±0.98) mm, respectively. These values were higher than those reported for coriander seeds (Balasubramanian *et al*., 2012) and hemp seeds (Taheri-Garavand *et al*., 2012), but lower than for Parkia speciosa seeds (Abdullah *et al*., 2011) and for kernels of both varieties of walnuts (Maraj-18 and Yalova-1) (Ercisli *et al*., 2011). In comparison, it was found that the length of the ginkgo nut and its kernel was larger than that of the hazel nuts (Aydin, 2002), but for the width and the thickness, it was found that the hazel nuts and kernels were bigger than the ginkgo nuts and kernels, respectively. It is interesting to note that the thickness of the ginkgo nuts was larger than that of almond nuts, while the length and the width of the ginkgo nuts were smaller than that of almond nuts (Aydin, 2003). It was observed that the length of the ginkgo kernels was smaller than that of almond kernels but the width and their thickness was larger than that of almond kernels. These dimensions are essential for designing machine components such as to estimate the aperture size as well as to estimate the number of nuts that can be engaged at one time for processing purposes. In order to determine the natural rest position of the nut, some researchers may consider the major axis of the nut. Since its unique axis is longer than the other two equal axes (a > b = c) by observation, the shape of the ginkgo nut may be regarded as a prolate ellipsoid. The calculated geometric mean diameter of the nut ranged from 16.16 to 19.33 mm with a mean value of 17.54 mm (±0.73), while for the kernel, it ranged from 12.62 to16.55 mm with a mean value of 14.76 mm (±0.86).

The mean of sphericity and the aspect ratio of the nuts were 69.70% (±2.27) and 62.24% (±3.26), respectively. The corresponding values for their kernels were 71.86% (±3.22) and 62.52% (±5.57), respectively. In comparison, it was observed that the sphericity and the aspect ratio of the kernel were higher than that of the nut; therefore, during the experiment it was found that the kernel had a very high tendency to roll rather than slide on flat surfaces. These parameters are often referred to when designing hoppers to handle the nuts. When compared to other seeds, it was found that the sphericity of the ginkgo nut was similar to that of an almond nut (Aydin, 2003), but lower than that of the pistachio (*Pistacia vera* L.) nut (Kashaninejad *et al*., 2006), filbert nut (Pliestic *et al*., 2006), and hazel nut (Aydin, 2002). The sphericity of the ginkgo kernel was found to be higher than that of Parkia speciosa seeds (Abdullah *et al*., 2011), almond kernels (Aydin, 2003), and pistachio kernels (*Pistacia vera* L.) (Kashaninejad *et al*., 2006), but lower than that of hazel kernels (Aydin, 2002) and the kernels of both varieties of walnuts (Maraj-18 and Yalova-1) (Ercisli *et al*., 2011). The mean mass of the nuts was 2.583 g (±0.298), while the kernels were found to be 2.083 g (±0.242). The average surface area of the nuts was found to be 968.45 mm^2 (±81.45), while the kernels were found to be 686.86 mm^2 (±79.37). The mean volume determined for 10 nuts was 2 480.00 mm^3 (±278.09) , while the kernels were found to be 1 905.00 mm^3 (±226.63).

True density and bulk density of the nuts were 1033.28 (±35.91) and 613.66 kg m^{-3} (±15.44), respectively. The corresponding values for the kernels were 1106.01 (±183.19) and 670.15 kg m^{-3} (±11.52), respectively. The reported value of true density for both pistachio nuts and kernels (Kashaninejad *et al*., 2006) are quite similar to that of the ginkgo nut and its kernel, respectively. In addition, the true density for Parkia speciosa (Abdullah *et al*., 2011) is also very similar to that of the ginkgo kernel. It is interesting to note that the true density for the ginkgo nut is similar to that of the almond nut (Aydin, 2003), but it is higher for the ginkgo kernel than that of the almond kernel (Aydin, 2003). The bulk density of the gingko kernel was found to be higher than that of Parkia speciosa seed (Abdullah *et al*., 2011). However, it was found that the values of the bulk density of the ginkgo nut and kernel were higher than those for Pistachio nuts and kernels (Kashaninejad *et al*., 2006), hazel nuts and kernels (Aydin, 2002), filbert nuts and kernels (Pliestic *et al*., 2006), and hemp seeds (Taheri-Garavand *et al*., 2012). Generally, it was observed that the bulk density of nuts was always lower than that of kernels. This pattern was similar to that reported in a study of pistachio nuts and kernels (Kashaninejad *et al*., 2006). This is probably due to the shell, in which the nut is bigger in size than the kernel, hence a decrease in the total mass per unit volume occupied by the nut (Kashaninejad *et al*., 2006). The information about the bulk density of nuts is indeed useful in determining the nut storage capacity. The average porosity obtained for the ginkgo nuts was 40.54% (±2.55), while for the kernels it was found to be 38.04% (±9.28). These values were of the same order as for filbert nuts (Pliestic *et al*., 2006) and nutmeg seeds (Abdullah *et al*., 2010), but higher than that of the filbert kernel (Pliestic *et al*., 2006). In the drying process, the porosity of nuts is an indicator of resistance of the nuts to airflow.

The coefficient of static friction of ginkgo nuts and kernels against four different types of structural surface was determined in this experiment. The results obtained are listed in Table 2. It was found that the mean values for the kernels were greater than the values for the nuts on all the surfaces under examination. The means of the coefficient of static friction for the ginkgo nuts and kernels were greater than the values reported for pistachio (*Pistacia vera* L.) (Kashaninejad *et al*., 2006) and nutmeg seeds (Abdullah *et al*., 2010). The large value of the coefficient of static friction may be due to the high moisture content as well as the stickiness of the surface of the kernel. However, the mean of the coefficient of static friction for the ginkgo kernels was generally lower than the values reported for Parkia speciosa seeds (Abdullah *et al*., 2011). It was found that the nut had the highest mean of the coefficient of static friction on rubber followed by plywood, glass, and galvanized steel sheet. Conversely, the kernel had the highest mean of the coefficient of static friction on plywood followed by glass, galvanized steel sheet, and rubber. This property is crucial in determining the steepness of the storage container, hopper, or any other loading and unloading devices.

Table 2. Coefficient of static friction of ginkgo nuts and kernels on four types of structural surface

Coefficient of static friction on	Ginkgo nut		Ginkgo kernel	
	Mean	Standard deviation	Mean	Standard deviation
Galvanized steel sheet	0.383	0.018	0.862	0.027
Glass	0.404	0.026	0.905	0.058
Plywood	0.435	0.012	0.964	0.036
Rubber	0.531	0.038	0.806	0.035

CONCLUSIONS

1. The mean mass and volume of the gingko nuts were 2.583 g and 2 480 mm^3, respectively, while their kernels were 2.083 g and 1 905 mm^3, respectively.

2. The dimensions of the nuts were in the range from 22.31 to 28.20 mm in length, 14.15 to 17.49 mm in width, and 12.65 to 15.83 mm in thickness, while their kernels were in the range from 14.06 to 23.61 mm in length, 8.96 to 15.11 mm in width, and 9.58 to 14.92 mm in thickness.

3. The geometric mean diameter and surface area of the nuts were calculated as 17.54 mm, 968.45 mm^2, respectively. The corresponding values for the kernels were calculated as 14.76 mm and 686.86 mm^2, respectively.

4. The sphericity and aspect ratio for the nuts were 69.70, 62.24%, respectively. The corresponding values for the kernels were 71.86, 62.52 %, respectively.

5. The true density and bulk density of the nuts obtained were 1 033.28 and 613.66 kg m^{-3}, respectively, while for the kernels, they were 1 106.01 and 670.15 kg m^{-3}, respectively.

6. The porosity was estimated as 40.54% for the nuts and 38.04% for the kernels.

7. The highest static coefficient of friction for the nuts was found on rubber, followed by plywood, glass, and galvanized steel sheet. Conversely, the highest coefficient for the kernel was found on plywood, followed by glass, galvanized steel sheet, and rubber.

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