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Some physical properties of simarouba fruit and kernel

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A b s t r a c t. Physical properties are often required for the development of post harvest equipment. The study was conducted to investigate the physical properties of *Simarouba glauca* L. fruit and kernel, namely, dimensions, 1000 unit mass, fruit part fraction, arithmetic mean diameter, geometric mean diameter, surface area, sphericity, aspect ratio, bulk density, true density, porosity and angle of repose. The kernel had 8.51% (w.b.) moisture and 61.04% oil content, which is higher than the fruit and shell. The average fruit length, width, thickness and 1000 unit mass were 21.26, 13.81, 11.03 mm; and 1120.16 g, while the corresponding value for kernel were 13.78, 7.77, 6.71 mm; and 330.26 g, respectively. The sphericity and surface area of fruit were 5.8 and 63.36% more, respectively, than those of kernel. Bulk densities of fruits and kernels were 622.27 and 727.73 kg m^{-3}, the corresponding true densities were 931.96 and 1019.3 kg m^{-3}, and the corresponding porosities were 33.23 and 28.61%, respectively. The angle of repose of fruit and kernel were 31.35 and 35.02°, respectively.

K e y w o r d s: simarouba, physical properties, moisture content

INTRODUCTION

Simarouba glauca L. is a new crop having multiutilities that can be tapped for production of biofuel in India and Central America. As the kernel has high non-edible oil content, this can be an appropriate candidate for production of biodiesel (simarouba oil methyl ester). Suitable post harvest technologies for simarouba fruit need to be identified, for which physical properties play an essential role.

Simarouba glauca L., commonly known as aceituno, paradise-tree or bitter wood, is a medium sized evergreen tree (height 7-15 m) as shown in Fig.1a. It grows well up to 1000 m above sea level in all types of well drained soils (pH 5.5 to 8) and has been found to be established in places with 250 mm to 2500 mm annual rainfall and temperatures going up to 45° C (Joshi and Hiremath, 2000). In El Salvador, it is found in dry areas. As it withstands dry and semi arid conditions, it can be planted in areas where no other plants of economic value can be grown. In a hectare of land about 200 trees can be accommodated. It produces fruits similar in size, shape and colour to olives. There are two varieties: one produces greenish white fruit and the other violet to almost black fruits (Reddy *et al*., 2003). The tree begins to produce fruit at about four years of age, but it comes to full production at six years of age.

The tree starts flowering during December and bears fruits in January and February. The fruits are ready to harvest in May (Fig. 1b). Though the tree commences bearing fruit from the fourth year of planting, economic yields of about 20 kg fruits per tree can be harvested only from the 10th year of planting. The average yield of fruit from a hectare of a 10 year old plantation of simarouba will be about 6,000 to 8,000 kg (Joshi and Hiremath, 2001).

In recent years, physical properties have been studied for various agricultural products such as ackee apple seeds (Omobuwajo *et al*., 2000), locust bean seed (Ogunjimi *et al*., 2002), millet (Baryeh, 2002), wheat (Tabatabaeefar, 2003), hemp seed (Sacilik *et al*., 2003), groundnut kernel (Olajide and Igbeka, 2003), almond nut and kernel (Aydin, 2003), lentil seed (Amin *et al*., 2004), edible squash seed (Paksoy and Aydin, 2004), garlic (Haciseferođullari *et al*., 2005), sheanut (Aviara *et al*., 2005), coriander seeds (Coşkuner and Karababa, 2007), white speckled red kidney bean grains (Işik and Ünal, 2007), watermelon seed (Koocheki *et al*., 2007), orange (Sharifi *et al*., 2007), African nutmeg (Burubai *et al*., 2007), jatropha seed (Garnayak *et al*., 2008) and karanja kernel (Pradhan *et al*., 2008).

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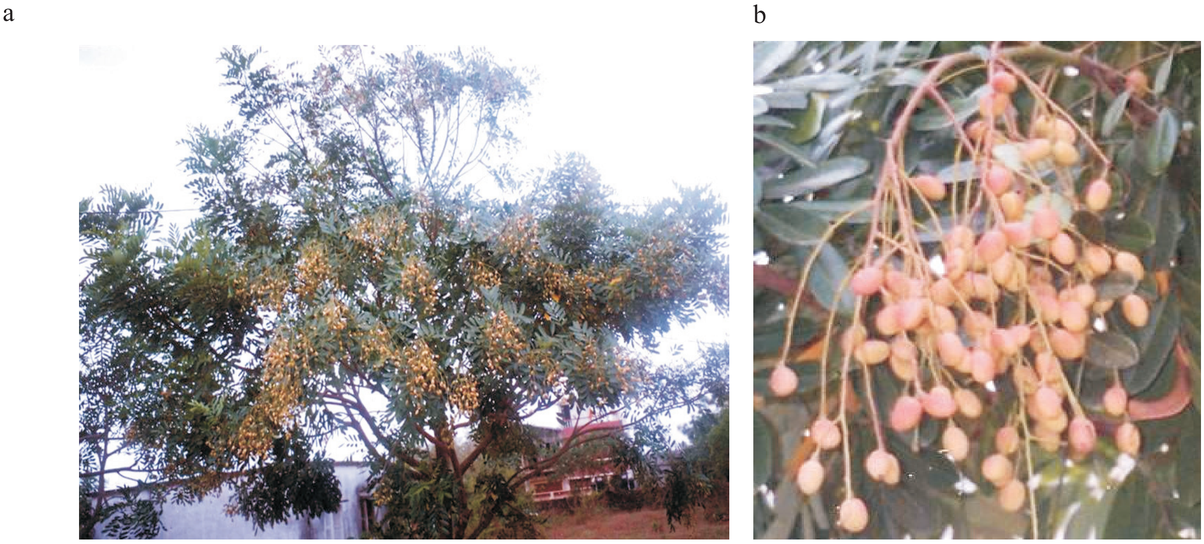

Fig. 1. *Simarouba glauca* L.: a – grown-up tree, b – ripe fruits.

The physical properties of oilseeds are important in designing and fabricating particular equipments and structures for handling, transporting, processing and storage, and also for assessing the behaviour of the product quality (Kashaninejad *et al*., 2006; Bart-Plange and Baryeh, 2003). Physical properties of simarouba fruit and kernel are essential to design equipments for decortication, drying, cleaning, grading, storage and oil extraction. Though literatures are available on simarouba plant and its oil characteristics (Reddy *et al.*, 2003; Joshi and Hiremath, 2001), no study has been done on its physical properties. Moisture content is useful information in the drying process. The size (such as length, breadth, thickness, arithmetic mean diameter and geometric mean diameter) and shape are important in designing separating, harvesting, sizing and grinding machines. The product shape can be determined in terms of its sphericity and aspect ratio which affect the flow ability characteristics of the products. Bulk density, true density and 1000 unit mass are used in determining the size of storage bins and also affect the structural loads. The angle of repose is important in designing storage and transporting structures. Porosity (calculated from bulk density and true density) and surface area affect the resistance to airflow through the bulk material bed and data on them are necessary in designing the drying process. Fruit part fraction gives an overall idea about the composition of kernel and shell which affect the oil yield of the product.

The aim of this study was to investigate the physical properties of *Simarouba glauca* L. fruits and kernels. The parameters studied include moisture content, oil content, size, 1000 unit mass, fruit part fraction, arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio, surface area, bulk density, true density, porosity and angle of repose.

MATERIALS AND METHODS

Sample

Simarouba fruit was procured for the study from Orissa, eastern part of India. The sample was cleaned manually to remove all foreign materials such as dust, dirt, immature fruits *etc*., and pooled together to obtain approximately 100kg of fruit materials. The fruits were sun-dried and kept in jute bags and allowed to dry under ambient room conditions (27-32°C, 75-80% RH) to the equilibrium moisture. The simarouba fruits were decorticated with the help of a hammer to obtain kernels. The fruit breaks into two halves when it is hit on the rib, more easily so when the fruit is kept in an upright position. The shells and kernels were separated manually. Then the kernels were collected for further analysis (Fig. 2).

Fig. 2. Simarouba dried fruits, broken fruits, shells and kernels (top to bottom).

Moisture and oil contents

The samples were prepared for analysis by grinding about 50 g of fruit to pass through a sieve with circular openings of 1 mm diameter and mixed thoroughly. Two grams of the comminuted material were dried in a hot-air oven (Yorco Sales Pvt. Ltd., India) at 80°C for 10 h, cooled in a desiccators and weighed. Weight loss on drying to a final constant weight was recorded as moisture content of the material. For oil content determination (AOAC, 1984), the dried sample for the previous determination was extracted in a Sxhlet-type extractor with petroleum ether (boiling point 60-80°C). The extract was dried for 30 min at 100°C, cooled and the residual oil weighed. The above procedure outlined for determination of moisture and oil content was repeated for kernel and shell. Reported values of fruit, kernel and shell are means of five determinations.

Physical characteristics

The fruit and kernel material was divided into 5 lots each and 20 samples were selected at random from each lot of fruit and kernel to obtain 100 samples each for conducting the experiment. Hence, measurements of all size and shape indices as well as the fruit mass and kernel mass were replicated one hundred times. The fruit size, in terms of the three principal axial dimensions, that is (in mm): length, L, width, W, and thickness, T, was measured using a vernier caliper (Mitutoyo, Japan) with an accuracy of 0.02 mm. The dried fruit consists of two parts, namely, the outermost part that is the shell fraction and the inner portion that is the kernel fraction. These measurements of the two fractions were replicated twenty times to get mean values.

The arithmetic mean diameter, D_a, and geometric mean diameter, D_g, of the fruit and kernel were calculated by using the following relationships (Mohsenin, 1980):

$$D_a = (L+W+T)/3, \quad (1)$$

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

The sphericity, ϕ, of fruit and kernel were calculated by using the following relationship (Mohsenin, 1980):

$$\phi = \frac{(LWT)^{1/3}}{L}. \quad (3)$$

The aspect ratio, R_a, was calculated (Maduako and Faborode, 1990) as:

$$R_a = \frac{W}{L}100. \quad (4)$$

The 1000 unit mass was determined by means of a digital electronic balance (Shimadzu Corp., Japan, AY120) having an accuracy of 0.001 g. To evaluate the 1000 unit mass, 50 randomly selected samples were weighted and multiplied by 20. The reported value is a mean of 20 replications.

The surface area of bulk sample (fruit and kernel) was found by analogy with a sphere of the same geometric mean diameter, using the following relationship (Garnayak *et al.*, 2008; Altuntaş *et al.*, 2005; Tunde-Akintunde and Akintunde, 2004; Sacilik *et al.*, 2003):

$$S = \pi D_g^2, \quad (5)$$

where: S is the surface area (mm^2).

The bulk material (fruit or kernel) was put into a container with known weight and volume (500 ml) from a height of 150 mm at a constant rate (Garnayak *et al.*, 2008). No separate manual compaction of fruits was done. Bulk density was calculated from the mass of bulk material divided by volume containing the mass. The true density, defined as the ratio between the mass and the true volume of the bulk material (fruit or kernel), was determined using the toluene (C_7H_8) displacement method (Mohsenin, 1980). The density ratio is the ratio of mass density to bulk density expressed as percentage, while porosity of bulk materials was calculated from bulk and true densities using the relationship (Mohsenin, 1980), as follows:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right)100, \quad (6)$$

where: ε is the porosity (%) ; ρ_b is the bulk density (kg m^{-3}); and ρ_t is the true density (kg m^{-3}). Reported values of all density characteristics are means of 20 replications.

The angle of repose was determined by using an open-ended cylinder of 15 cm diameter and 50 cm height. The cylinder was placed at the centre of a circular plate having a diameter of 70 cm and filled with fruit or kernel. The cylinder was raised slowly until it formed a cone on the circular plate. The height of the cone was recorded by using a movable pointer fixed on a stand having a scale of 0-1 cm precision. The angle of repose, θ, was calculated using the formula:

$$\theta = \tan^{-1}\left(\frac{2H}{d}\right), \quad (7)$$

where: H is the height of the cone (cm) and d is the diameter of cone (cm). Other researchers have used this method (Garnayak *et al.*, 2008; Karababa, 2006; Sacilik *et al.*, 2003; Kaleemullah and Gunasekar, 2002). The reported value is mean of 20 replications.

RESULTS AND DISCUSSION

Moisture and oil contents

The average moisture and oil content of simarouba fruit and kernel are shown in Table 1. The kernel contains high moisture as compared to shell and fruit. This indicates that the drying process should be carried out after the kernel is separated from the fruit. The kernel contains 61.04% oil and the shell does not have oil. So it is wise to separate the shell from kernel before oil expulsion. The oil content of simarouba kernel is greater as compared to the oil content of seed like karanja, jatropha and neem (Garnayak *et al.,* 2008; Srivastava and Verma, 2007; Visvanathan *et al.*, 1996; Kandpal and Madan, 1995; Bringi and Mukerjee, 1987).

Other physical properties

A summary of the results of determined physical parameters of fruit and kernel is shown in Table 2. The 1000-unit mass, fraction of fruit parts, arithmetic diameter and geometric diameter are provided along with other physical parameters. The fruit length, width and thickness are found to be 21.26±2.01, 13.81±0.98, and 11.03±0.64 mm, respectively. Corresponding values for the jatropha seed (Garnayak *et al.*, 2008; Sirisomboon *et al.*, 2007) are 18.65 to 21.02, 11.34 to 11.97 and 8.91 to 9.58 mm. The length and stem-end diameter of neem nut are 14.56 and 7.72 mm, respectively (Visvanathan *et al.,* 1996). The simarouba fruit is thus bigger than jatropha seed and neem nut. The importance of these dimensions in determining aperture sizes and other parameters in machine design have been discussed by Mohsenin (1980) and highlighted lately by Omobuwajo *et al.* (1999).

The fruit shape is determined in terms of its sphericity and aspect ratio. The sphericity of simarouba fruit and kernel are found to be 0.69 and 0.65, respectively. These values are closer to the corresponding values of 0.64 and 0.68 as reported for jatropha (Sirisomboon *et al.*, 2007). As per the investigations by Bal and Mishra (1988) and Garnayak *et al.,* (2008), they have considered the grain as spherical when the sphericity value is more than 0.80 and 0.70, respectively. In this study, simarouba fruit should not be treated as an equivalent sphere for calculation of the surface area. A similar result is also found for jatropha seed and is reported by Garnayak *et al.* (2008).

T a b l e 1. Average moisture and oil content of simarouba fruit and different parts of the fruit (number of samples n=5)

Part of fruit	Mean values	
	Moisture content (%, w.b.)	Oil content (%)
Total fruit	6.21 ± 0. 23	15.28 ± 2.35
Kernel	8.51 ± 0.52	61.04 ± 5.67
Shell	4.16 ± 0.11	0

T a b l e 2. Physical properties of simarouba fruit and kernel

Physical properties	n	Fruit	Kernel
Length (mm)	100	21.26 ± 2.01	13.78 ± 1.08
Width (mm)	100	13.81 ± 0.98	7.77 ± 0.86
Thickness (mm)	100	11.03 ± 0.64	6.71 ± 0.37
1000 unit mass (g)	20	1120.16 ± 52.34	330.26 ± 29.35
Kernel fraction (%)	20	29	100
Shell fraction (%)	20	71	N.A.
Arithmetic mean diameter (mm)	100	15.37 ± 0.87	9.42 ± 0.58
Geometric mean diameter (mm)	100	14.78 ± 0.82	8.95 ± 0.57
Sphericity (decimal)	100	0.69 ± 0.03	0.65 ± 0.03
Surface area (mm^2)	100	687.94 ± 37.68	252.08 ± 32.36
Aspect ratio (%)	100	64.95 ± 6.51	56.41 ± 5.54
Bulk density (kg m^{-3})	20	622.27 ± 15.64	727.73 ± 15.54
True density (kg m^{-3})	20	931.96 ± 33.08	1019.3 ± 19.65
Porosity (%)	20	33.23 ± 2.03	28.61 ± 2.861
Angle of repose (°)	20	31.35 ± 0.45	35.02 ± 1.42

n – number of samples, N.A. – not applicable.

The aspect ratio of fruit is 64.95% and that of kernel is 56.41%. Taking these high aspect ratios (which relates the ratio of seed width to length), it may be concluded that the simarouba fruit will not roll like gram, but will slide along its flat surface like oil bean seed (Oje and Ugbor, 1991). This tendency to either roll or slide is very important in the design of hoppers.

The 1000 fruit and kernel mass are 1120.16 and 330.26 g, respectively. The corresponding reported values of jatropha seed (1322.4 g) and kernel (688 g) are higher than simarouba (Sirisomboon *et al.*, 2007).

The surface area of fruit is larger than that of kernel by 63.36%, indicating that mass or energy transfer rate through the surface of the fruit might be slower than the rate for kernel.

The bulk density of fruit and kernel are 622.27 and 727.73 kg m^{-3}, respectively. This indicates that the bulk density of the fruit is 14.49% lower than that of kernel. This indicates that fruits need more space per unit mass than kernels. The true density of the fruit is less than the density of water (1000 kg m^{-3}) due to the air pores between the shell and the kernel. The true density of kernel is higher than that of fruit. This indicates that separation of fruit shells from kernels after decortication could be done by blowing air (winnowing) or floating in water.

The porosity of simarouba fruit and kernel are found to be 33.23 and 28.61%, respectively. Since the porosity depends on the bulk as well as true densities, the magnitude of variation in porosity depends on these factors only. The porosity of the bulk of kernel is lower than that of the fruits. This indicates that aeration of the bulk of fruit is easier than of the bulk kernel.

Adhesion between container wall and material affected the value of angle of repose. The angle of repose of simarouba fruit is 10.48% lower than that of the kernel. This might have been due to the viscous surface and the least hardness of kernels leading to the highest cohesion among the individual kernels and therefore to the higher angle of repose. This value implies the lowest flow ability of the kernels compared to the fruits. It is, nevertheless, important to note that the angle of repose for the simarouba fruit and kernel is lower than for the jatropha seed and kernel (Sirisomboon *et al.*, 2007).

CONCLUSIONS

1. At present simarouba has a great role as a resource for biofuel because its kernel oil content can be a substitute for diesel.

2. In the oil extraction process, the fruit must be decorticated and the kernels must be dried and then oil has to be extracted. The oil content of kernel is 61.04%.

3. Some physical properties of simarouba fruit and kernel are determined at a moisture level of 6.21 and 8.51% (w.b.), respectively.

4. The physical properties of simarouba fruit and kernel, including moisture and oil content, 1000-unit mass, fruit part fraction, dimensions, geometric mean diameter, sphericity, bulk density, true density, porosity, surface area and angle of repose are investigated and reported.

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