

Studies on properties of *Simarouba glauca* fruit and kernel relevant to mechanical decortication

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ABSTRACT The high non-edible oil content in the *Simarouba glauca* DC. kernel makes it an appropriate candidate for production of biodiesel. Mechanical decortication is a need based operation for mass production of biodiesel from *Simarouba glauca* fruit. The properties of *Simarouba glauca* 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 were studied. The kernel has 8.51% (w.b.) moisture and 61.04% oil content which was higher than the fruit and shell. The average fruit length, width, thickness and 1000 unit mass were 21.26 mm, 13.81 mm, 11.03 mm and 1120.16 g while the corresponding value for kernel are 13.78 mm, 7.77 mm, 6.71 mm and 330.26 g respectively. The sphericity and surface area of fruit were 5.8% and 63.36% more respectively than that of kernel. Bulk densities of fruits and kernels were 622.27 and 727.73 kg/m³ and the corresponding true densities were 931.96 and 1019.3 kg/m³ respectively. The porosities of fruits and kernels were 33.23% and 28.61% respectively. The angle of repose of fruit and kernel were 31.35° and 35.02° respectively. The static coefficient friction for simarouba fruit was 31-39% higher than the kernel for different surfaces tested. On the basis of this study, design values for different parameters relevant to mechanical decortications were selected.

Key words: *Simarouba glauca*; moisture content; mechanical decortication.

India ranks sixth in the world in terms of energy demand accounting for 3.5% of world commercial energy demand. The energy demand is expected to grow at 4.8 percent. Indian economy is essentially diesel driven and the consumption of diesel fuel is six times that of motor gasoline which is unlike of several developed economics. We, therefore, need to look for application of alternative fuels for diesel substitution. Biodiesel, another option has been researched fairly extensively for its use in diesel engines in USA and Europe, but the sources of such biodiesel have been edible oils like soyabean, sunflower and rapeseed. Biodiesel helps to preserve and protect natural resources as it cuts down the targeted emissions [1]. But, the use of edible oils for biodiesel production seems insignificant in Indian context. Till 1965, India was an exporter of oilseeds and edible oils but after that India's position in the

vegetable oil scenario steadily slides from one of exporter to largest importer of vegetable oils. On the other hand, India has vast and diverse agro-climatic conditions to produce varieties of non-edible tree-borne oilseeds like karanja, jatropha, neem etc. [2]. Non-edible oilseeds also have huge employment potential for collection, processing and production of biodiesel from these oils.

Simarouba glauca is a crop having multi-utilities that can be tapped for production of biofuel in India. As the kernel has high non-edible oil content, this can be the appropriate candidate for production of biodiesel (*Simarouba oil methyl ester*). The physical properties of oilseeds are important in designing and fabricating particular equipments and structures for handling, transporting, processing and storing and also for assessing the behavior of the product

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Simarouba glauca is a crop having multi-utilities that can be tapped for production of biofuel in India. As the kernel has high non-edible oil content, this can be the appropriate candidate for production of biodiesel (*Simarouba oil methyl ester*). The physical properties of oilseeds are important in designing and fabricating particular equipments and structures for handling, transporting, processing and storing and also for assessing the behavior of the product quality [3]. Physical properties of *Simarouba* fruit and kernel are essential to design equipments for decortication, drying, cleaning, grading, storage and oil extraction. Decortication of *Simarouba* seed by hand with help of hammer is the present day practice. However, mechanical decortication by rollers appears to present some problems. When attempted for decortication in a groundnut decorticator, it does not decorticate. As the seed is very hard and substantial quantity of seed has to be decorticated for expulsion of oil, mechanical decortication is a necessity. Literatures are available on *Simarouba* plant and its oil characteristics [4-5]. Some of the studies done on physical properties of gram [6], white lupin [7] and karanja seed [8], but no study has been done on the physical properties of fruit and kernel of *simarouba*. Hence, the present study is to investigate the physical properties of *Simarouba glauca* 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

Simarouba fruit procured from Orissa, eastern part of India was cleaned manually to remove all foreign materials such as dust, dirt, immature fruits etc. and pooled together to obtain approximately 100 kg of fruit materials. The fruits are sun-dried and kept

in a jute bags and allowed to dry under ambient room conditions (27-32°C, 75-80% RH) to the equilibrium moisture. The *Simarouba* fruits are decorticated with help of hammer to obtain kernel. It 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 are separated manually. Then the kernels are collected for further analysis (Fig. 1).



Fig. 1. *Simarouba* dried fruits, broken fruits, shells and kernels (top to bottom)

Moisture and oil contents

About 50g of fruit was ground and passed 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 desiccator and weighed. Weight loss on drying to a final constant weight was recorded as moisture content of the material. For oil content determination [9], the dried sample for the previous determination is extracted in a soxhlet-type extractor with petroleum ether (boiling point 60-80°C). The extract is dried for 30 min at 100°C, cooled and the residual oil weighed. The above procedure outlined for determination of moisture and oil content is repeated for kernel and shell. Reported values of fruit, kernel and shell are means of five determinations.

Size and shape

Size and shape of the fruit and kernel were relevant to the design of sieves. Measurement 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 length (L), width (W) and thickness (T) are measured using the vernier calliper (Mitutoyo, Japan) with an accuracy of 0.02 mm. The dried fruit consisted of two parts namely, the outer most part is shell fraction and the inner portion is kernel fraction. These measurements of two fractions are replicated twenty times to get mean value.

The arithmetic mean diameter, D_a and geometric with fruit or kernel. The cylinder is raised slowly until it formed a cone on the circular plate. The height of the cone is recorded by using a moveable pointer fixed on a stand having a scale of 0 - 1 cm precision. The angle of repose θ is calculated using the formula.

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

$$D_g = (L.W.T.)^{1/3} \dots\dots\dots (2)$$

Where, L is the longest intercept, mm;
 .W is the longest intercept normal to L, mm;
 T is the longest intercept normal to L and W, mm.

The sphericity, ϕ of fruit and kernel are calculated by using the following relationship [10]:

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

The aspect ratio, R_a is calculated as:

$$R_a = \frac{W}{L} \times 100 \dots\dots\dots (4)$$

The surface area of bulk sample (fruit and kernel) is found by analogy with a sphere of the same geometric mean diameter, using the following relationship [11-14].

$$S = \pi D_g^2 \dots\dots\dots (5)$$

Where, S is the surface area (mm²).

True density and bulk density

True density and bulk density are relevant to the design of hopper. The 1000 unit mass is determined by means of a digital electronic balance (Shimadzu corporation, Japan, AY120) having an accuracy of 0.001g. To evaluate the 1000 unit mass, 50 randomly selected samples are weighted and are multiplied by 20. The reported value is mean of 20 replications.

The bulk material (fruit or kernel) is put into a container with known weight and volume (500 ml) from a height of 150 mm at a constant rate [11]. No separate manual compaction of fruits is done. Bulk density is 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), is determined using the toluene (C₇H₈) displacement method [10]. The density ratio is the ratio of mass density to bulk density expressed as percentage, while porosity of bulk materials is calculated from bulk and true densities using the relationship, as follows:

$$\epsilon = \left(1 - \frac{\rho_b}{\rho_t} \right) 100 \dots\dots\dots (6)$$

Where, ϵ is the porosity (%); \tilde{n}_b is the bulk density (kg/m³); and \tilde{n}_t is the true density (kg/m³). Reported values of all density characteristics are means of 20 replications.

Angle of repose and static coefficient of friction

The angle of repose is the determinant of slope of hopper walls and static coefficient of

$$\theta = \tan^{-1} \left(\frac{2H}{D} \right) \dots\dots\dots (7)$$

Where, H is the height of the cone (cm) and D is the diameter of cone (cm). Other

researchers have used this method [11, 14-17]. The reported value is mean of 20 replications.

The static coefficient of friction was measured by using inclined plane method. Two different surfaces, namely Galvanized Iron (GI) and Mild Steel (MS) were considered for the study, as these were commonly used for fabrication of decorticator. The angle at which the material started to move downward was recorded. The static coefficient of friction was computed by the following relationship:

$\mu = \tan \theta$, Where, μ is the coefficient of friction and θ is the angle of tilt.

RESULTS AND DISCUSSION

Moisture and oil contents

The average moisture and oil content of Simarouba fruit and kernel has been given (Table 1). The kernel contained high moisture as compared to shell and fruit. The kernel contained 61.04% oil and the shell did not have oil. So it was wise to separate the shell from kernel before oil expulsion. The oil content of Simarouba kernel was more as compared to the oil content of seed like karanja, jatropha and neem [18-22].

Size

The size of simarouba fruit and kernel was shown (Table 2). 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 [11, 23] 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 [20]. 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 [10] and highlighted lately by Omobuwajo [24].

Shape

The fruit shape is determined in terms of its

sphericity and aspect ratio (Table 3). 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 [23]. As per the investigations by Bal and Mishra [25] and Dutta [6], the grain was considered 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 [11].

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. This tendency to either roll or slide is very important in the design of hoppers.

The 1000 fruit and kernel mass are 1120.16 g and 330.26 g respectively. The corresponding reported values of jatropha seed (1322.4 g) and kernel (688 g) are higher than Simarouba.

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

Bulk density and true density

The bulk density of fruit and kernel are 622.27 and 727.73 kg/m³ respectively (Table 4). This indicates that the bulk density of the fruit is 14.49% lower than 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/m³) 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

Table 1. Average moisture and oil content of Simarouba fruit, shell and kernel

| Parameters | N | Mean values | |
|------------|---|-----------------------------|-----------------|
| | | Moisture content (% , w.b.) | Oil content (%) |
| Fruit | 5 | 6.21 ± 0.23 | 15.28 ± 2.35 |
| Kernel | 5 | 8.51 ± 0.52 | 61.04 ± 5.67 |
| Shell | 5 | 4.16 ± 0.11 | 0 |

N is the number of samples. Data are mean values ± standard deviation.

Table 2. Size of Simarouba fruit and kernel

| Parameters | 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 | 1.03 ± 0.64 | 6.71 ± 0.37 |

N is the number of samples. Data are mean values ± standard deviation.

Table 3. Shape of Simarouba fruit and kernel

| Parameters | N | Fruit | Kernel |
|---------------------------------|-----|----------------|----------------|
| 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 |

N is the number of samples. Data are mean values ± standard deviation.

Table 4. Gravimetric Properties of Simarouba fruit and kernel

| Parameters | N | Fruit | Kernel |
|-----------------------------------|----|-----------------|----------------|
| 1000 Unit mass (g) | 20 | 1120.16 ± 52.34 | 330.26 ± 29.35 |
| 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 |

N is the number of samples. Data are mean values ± standard deviation.

Table 5. Frictional Properties of Simarouba fruit and kernel

| Parameters | N | Fruit | Kernel |
|-------------------------------------|----|---------------|---------------|
| Angle of repose (°) | 20 | 31.35 ± 0.45 | 35.02 ± 1.42 |
| Static coefficient of friction (GI) | 20 | 0.480 ± 0.037 | 0.345 ± 0.054 |
| Static coefficient of friction (MS) | 20 | 0.484 ± 0.039 | 0.368 ± 0.052 |

Note: 'N' is the number of samples. Data are mean values ± standard deviation.

(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 the fruits. This indicates that aeration of the bulk of fruit is easier than of the bulk kernel.

Angle of repose and static coefficient of friction

Adhesion between container wall and material affected the value of angle of repose and static coefficient of friction. 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 lead 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 the jatropha seed and kernel. The static coefficients of friction for both surfaces were similar. The static coefficient friction for fruit was higher than that of the kernel and the galvanized iron surface was less adhesive as compared to mild steel surface.

The kernel had 8.51% (w.b.) moisture and 61.04% oil content which was higher than the fruit and shell. The average fruit length, width, thickness and 1000 unit mass were 21.26 mm, 13.81 mm, 11.03 mm and 1120.16 g while the corresponding value for kernel were 13.78 mm, 7.77 mm, 6.71 mm and 330.26 g respectively. The sphericity and surface area of fruit were 5.8% and 63.36% more respectively than that of kernel. Bulk densities of fruits and kernels were 622.27 and 727.73 kg/m³ and the corresponding true densities were 931.96 and 1019.3 kg/m³ respectively. The porosities of fruits and kernels are 33.23% and 28.61% respectively. The angle of repose of fruit and kernel were 31.35 and 35.02

degrees respectively. The static coefficient of friction for fruit and kernel were 0.480 and 0.345 respectively for galvanized iron.

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