Physical, Mechanical Properties and Oil Content of Selected Indigenous Seeds Available for Biodiesel Production in Bangladesh

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ABSTRACT

This study identifies the physical and mechanical properties and oil contents of seeds of four indigenous plants in Bangladesh, namely the Jatropha, Karanj, Castor, and Rubber. Physical properties such as length, width, thickness, slender ratio, weight and bulk density were measured to find out the size, shape and space required by the seeds. Mechanical properties like hardness and crushing strength of the seeds were determined as well. All these properties are necessary for processing and storage of the seeds for oil extraction. Hardness and crushing strength of the seeds were measured by a Manual Hardness Tester. Oil content was measured by chemical method (Cold percolation method). Among the four types of seeds, Rubber seed was the largest with a length of 21.2 mm followed by Karanj 17.9 mm, Jatropha 17.1 mm and Castor 11.8 mm. The slender ratio of Jatropha, Karanj, Castor and Rubber seeds were found to be 1.8, 1.2, 1.9 and 1.1 respectively. Jatropha and Castor seeds had similar cylindrical shape with rounded tips. Karanj seed was found to be circular and flat. Shape of the Rubber seed was rectangular, inflated but slightly flattened in thickness. Rubber seed was the heaviest (4.3 g), as its size was also biggest followed by Karanj (1.2 g), Jatropha (0.8 g) and Castor (0.2 g), respectively. Hardness were found to be 2.7, 1.9, 1.7 and 8.6 kg for Jatropha, Castor, Karanj and Rubber seeds while crushing strength were 38.1, 26.6, 24.1 and 121.2 kg/cm^2, respectively. The oil contents of Jatropha, Karanj, Castor and Rubber seeds were 32.4%, 31.8%, 67.7%, 38.9% by weight respectively. All the four types of seeds contain satisfactory amount of oil which can be extracted commercially and checked for their suitability for the production of biodiesel.

Keyword: Oilseeds, physical properties, mechanical properties, oil content, Bangladesh

1. INTRODUCTION

Bangladesh is heavily dependent on import of fossil fuel and coal. Such dependency makes economy of Bangladesh more vulnerable to external price shocks in the international energy market. Price of fuel in the international market has been showing rising trend since last few years. Bangladesh annually imports about 3.5 million tons of different fuel oils. Of them, some 1.3 million tons are crude oil, 1.45 million tons diesel, 380 tons kerosene, 215 tons jet fuel and 155,000 tons petrol and octane (Energy & Power, 2003). The search for alternatives of fossil fuels is a major environmental and political challenge also. A promising alternative source of fuel, called biodiesel, has already been developed and is being used in some countries. Biodiesel is a chemical compound of methyl ester derived from raw or used vegetable oils and animal fats. Biodiesel is considered "carbon dioxide neutral" because all of the carbon dioxide released during combustion is sequestered out of the atmosphere during crop growth. Recent environmental and economic concerns (Kyoto Protocol) have prompted resurgence in the use of biodiesel throughout the world. In 1991, the European Community, proposed a 90% tax reduction for the use of biofuels, including biodiesel (Jatrophaworld, 2004). The superior lubricating properties of biodiesel increases functional engine efficiency. Their higher flash point makes it safer to store. The biodiesel molecules are simple hydrocarbon chains, containing no sulfur, or aromatic substances associated with fossil fuels. They contain higher amount of oxygen (up to 10%) that ensures more complete combustion of hydrocarbons (Global Farmer, 2009).

Biodiesel almost completely eliminates lifecycle of carbon dioxide emissions. When compared with petro-diesel it reduces about half of the emission of particulate matter, unburned hydrocarbons, and carbon monoxide; most part of the polycyclic aromatic hydrocarbons and entire sulphates on an average (Du *et al*., 2004). Lower emission of sulphur dioxide, soot, carbon monoxide, hydrocarbons, polyaromatic hydrocarbons, and aromatics are noted. NOx emissions from biodiesel are reported to range between plus or minus 10% as compared with petro-diesel depending on engine combustion characteristics (Tick *et al.*, 1999). Biodiesel can be mixed with petroleum-based diesel in any proportion (Khan *et al*, 2000). Biodiesel blends can be used in most compression-ignition (diesel) engines with little or no modifications.

For a truly renewable source of fuel, crops or other similar agricultural sources would have to be considered. Every year Bangladesh needs to import fuel from other countries and even now due to the shortage of the agricultural lands she needs to import food items from abroad. But, there are some native plants which grow well in the fallow lands and also can play a major role for getting the non-edible oil which could be possible to convert biodiesel or directly used as a source of alternative fossil fuel in Bangladesh. This can save the country's hardly earned foreign currency. Some of the well-known non-edible oil seed producing plants are Jatropha (*Jatropha curcas*), Karanj (*Pongamia pinnata*), Castor (*Ricinus communis*), Rubber (*Hevea barasiliensis*) seeds. India, Indonesia, Malaysia and China are already producing biodiesel successfully from *Jatropha curcus* and oil palm. These oils could be potential sources of biodiesel since the poor people in the rural areas use these for direct burning. There are many other indigenous plant seeds available in Bangladesh and these should be investigate for there potentiality to produce oil. In this context, the study was carried out with the following objectives:

i) To study the physical and mechanical properties of some selected indigenous seeds.
ii) To determine the oil content of these seeds.

2. METERIALS AND METHODS

The physical, mechanical properties and the oil content of the following selected indigenous seeds (Table 1 and Figure 1) were measured.

Table 1. English, local and scientific name of the seeds under study

English name	Local name	Scientific name
a. Jatropha	Sada mander, Jamal gota, Arenda, Ratan jot	*Jatropha curcas*
b. Karanj	Karanja	*Pongamia pinnata*
c. Castor	Veranda, Venna	*Ricinus communis*
d. Rubber	Rubber	*Hevea barasiliensis*

a) Jatropha seed b) Karanj seed c) Castor seed d) Rubber seed

Figure 1. Seeds under the study

2.1 Physical properties

Size, shape, weight, density, volume are some of the physical characteristics which are important in many problems associated with design of a specific machine or analysis of the behavior of the products. Size (length & width), weight, bulk density and moisture content of the seeds (Figure 1) were measured at the Processing Lab of the Department of Farm Power & Machinery, Bangladesh Agricultural University. The weight of the selected seeds (20 seeds from each type) were measured by a digital balance (TC-203, Denver Instrument Company, USA, with a readability of 0.001 g) and the average values were tabulated with standard deviation. The sizes (length and width) of the seeds were measured by a slide calipers and the bulk densities were measured by using a measuring cylinder (1000 ml) (Figure 2) and a digital balance as follows:

$$Bulk\ density, (g/cc) = \frac{Weight\ of\ the\ sample}{Volume\ of\ the\ sample} \quad (1)$$

Moisture content (MC) of the seeds was determined by oven dry method at 105° C for 24 hours. The moisture content was calculated in dry basis as follows:

$$MC(\%\ d.b.) = \frac{Weight\ of\ water\ in\ the\ sample}{Weight\ of\ bone\ dry\ matter} \quad (2)$$

2.2 Mechanical Properties

The seed hardness was measured at BRRI (Bangladesh Rice Research Institute) by using a manually operated hardness tester (Kiya Seisakusho Ltd. Tokyo, Japan) (Figure 2). The seeds were loaded flat under the indenter which moved vertically. When the seed started to crack then the reading of the tester was observed. There were two load indicators: the black one turned due to pressure and went back to “zero” when the seed broke and the red one remained still after breaking the seed indicating the breaking load or seed hardness. It is expressed as kg force applied. The crushing strength was calculated with respect to the projected area of the indenter used. The diameter of the indenter was 3 mm.

$$Crushing\ strength, (kg/cm^2) = \frac{Weight\ required\ cracking\ the\ seed}{Projected\ area\ of\ seed\ under\ load} \quad (3)$$

Figure 2. Measurement of the seed bulk density (left) and hardness (right)

2.3 Oil Extraction

Oil can be extracted from the seeds by applying heat, solvents or by pressure. Extraction by heat is not used commercially for vegetable oils. The oil from seeds can be extracted by three different methods. These are mechanical extraction using a screw press, solvent extraction and cold percolation method.

In this study the oil percentage of the seeds was estimated (Figure 3) by cold percolation method (Gravimetric method) in laboratory (Kartha *et al.,* 1957). The word cold in this context means no heat was applied and extraction occurs at room temperature. The applied method is described below.

Figure 3. Oil extraction by the cold percolation method

2.3.1 Preparation of Seeds

Matured seeds were collected from ripe fruits and were sun dried. They were decorticated manually. To prepare the seeds for oil extraction, they should be solar heated for several hours or roasted for 10 minutes. The seeds should not be overheated. The process breaks down the cells containing the oil. The heat also liquefies the oil, improves the extraction process.

2.3.2 Equipment and Chemicals Used

Agate mortar and pestle, percolator and sintered glass funnel, shaking machine, 20 ml air tight plastic bottle, 100 ml beaker, sand bath, Mattler electronic balance, Sodium sulphate (Na_2SO_4), Carbon tetrachloride (CCl_4) and finely crushed glass powder .

2.3.3 Procedure

0.3g of seed powder with 2g of glass powder and Na_2SO_4 was taken into a mortar. The mixture was grinded to a fine stage. Then 10 ml of CCl_4 was put into the mortar to make a solution. The solution was then taken in a 20 ml vial. The volume of the solution was made 20 ml by adding CCl_4. The vial was shaken over night by using a shaker. The solution was then filtered with the help of sintered glass funnel and percolator. The filtrate was collected in a pre weighted beaker with two glass ball. The beaker containing filtrate (oil + CCl_4) with two glass balls were placed on a sand bath for evaporation of CCl_4. Evaporation was done at 60-70° C in a sand drier. After the evaporation the beaker containing oil was kept in desiccators for cooling. Finally the beaker with oil and glass ball was weighed accurately.

2.3.4 Calculation of Oil Content

The percentage of oil was calculated from the Equation 4.

$$\% \text{ of oil} = \frac{(w_2 - w_1)\times 100}{w} \qquad (4)$$

Where, w = weight of sample, w_1= weight of the beaker with glass ball, w_2 = weight of the beaker with glass ball and oil, $w_2 - w_1$ = weight of oil.

3. RESULTS AND DISCUSSION

3.1 Physical properties of the seeds

Physical properties i.e. physical dimensions, slender ratio, weight, bulk density of the seeds of Jatropha, Karanj, Castor and Rubber at a moisture content range of 9-14% (dry basis) are detailed in Table 2.

Table 2. The physical properties of Jatropha, Karanj, Castor and Rubber seeds

Sample type	Weight of seed, g	Av. length, L, mm	Av. width, W, mm	Thickness, mm	Slender ratio (L/W)	Bulk density, g/cc	Av. MC,% d.b.
Jatropha	0.8	17.1	9.6	8.2	1.8	0.3	9.1
Karanj	1.2	17.9	14.4	6.3	1.2	0.6	10.9
Castor	0.2	11.8	6.3	4.1	1.9	0.8	10.1
Rubber	4.3	21.5	18.8	17.3	1.1	0.3	14.2

Jatropha seed was much larger than Castor seed although both the seeds were of similar shape with a slender ratio of 1.8 and 1.9, respectively having a cylindrical shape with rounded tips. Karanj seed was flattened with a circular shape having a slender ratio of 1.2. Rubber seed was the largest among the four types of seeds under study. Its shape was rectangular with rounded tips and slightly flattened thickness having a slender ratio of 1.1. Bulk density of Karanj and Castor seed were found to be around 0.6 g/cc while Jatropha and Rubber seeds showed the lower bulk densities of 0.3 g/cc and 0.3 g/cc respectively because they had hollow space between the endosperm and the outer hard shell. Moreover, endosperm of these two types of seeds was found to be spongy.

3.2 Mechanical properties of the seeds

Hardness and crushing strength of the dry seeds are shown in Fig.4. Moisture content of the seeds was in the range of 9-14% (w.b.). It is evident from the figure that the Rubber seed had the highest hardness value (8.6 kg). This is because it had a thick and hard shell covering the endosperm. Karanj and Castor seeds had the lowest hardness among the four types of seeds. Both these seeds had a similar hardness value around 1.8 kg. The reason was most part of the seeds was soft endosperm covered by a comparatively soft shell. Jatropha seed showed a relatively higher hardness (2.7 kg) than those of the Castor (1.9 kg) and Karanj (1.7 kg) seeds. Although Jatropha and Castor seeds had the similar shape and nature, hardness of Jatropha seed was higher because of its comparatively hard outer shell. Crushing strength of rubber seeds were found to be 121.1 kg/cm^2 followed by Jatropha seed (38.1 kg/cm^2), Castor seed (26.5 kg/cm^2) and Karanj seed (24 kg/cm^2) respectively. Rubber seed required much higher load to crack than other three types of seeds.

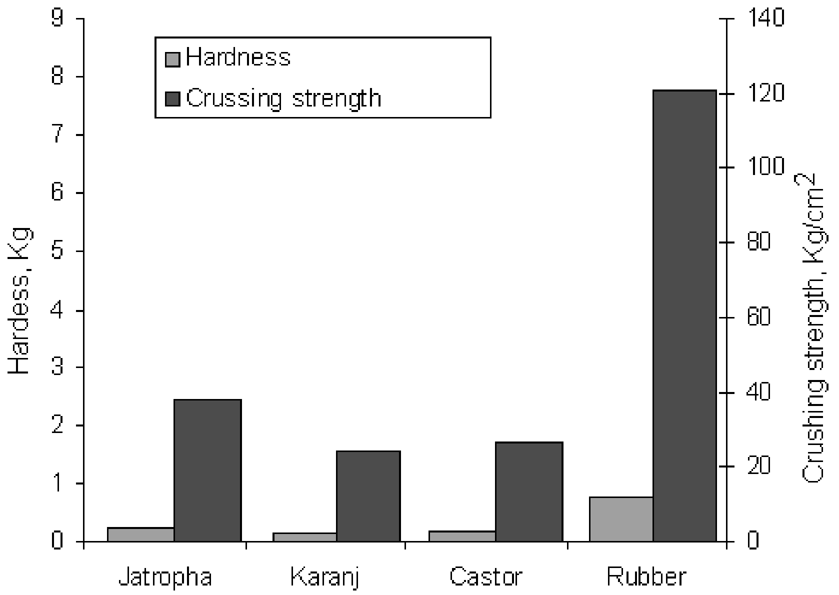

Figure 4. Hardness and crushing strength of the seeds

3.3 Oil content and cake yield of the seeds

Figure 5 shows the average percentage of oil and cake obtained from the seeds. The figure indicates that Castor seed had much higher oil content (67.7%) followed by Rubber seed, Jatropha seed and Karanj seed respectively. The oil content of Rubber seed was found to be 38.9% while the oil content of Jatropha seed and Karanj seed was similar (32.4% and 31.8%, respectively). All the four types of seeds contain satisfactory amount of oil (based on the proposition by Armstrong,1991; Edward *et al.*, 1994; Foidl *et al.*,1996 and Svelele,2009) for commercial extraction which can be checked for their suitability for the production of biodiesel.Yield of cake from the seeds were 68.8%, 67.6%, 61.3% and 32.3% for Karanj, Jatropha, Rubber and Castor seeds respectively just in reverse order of the oil contents of the seeds.

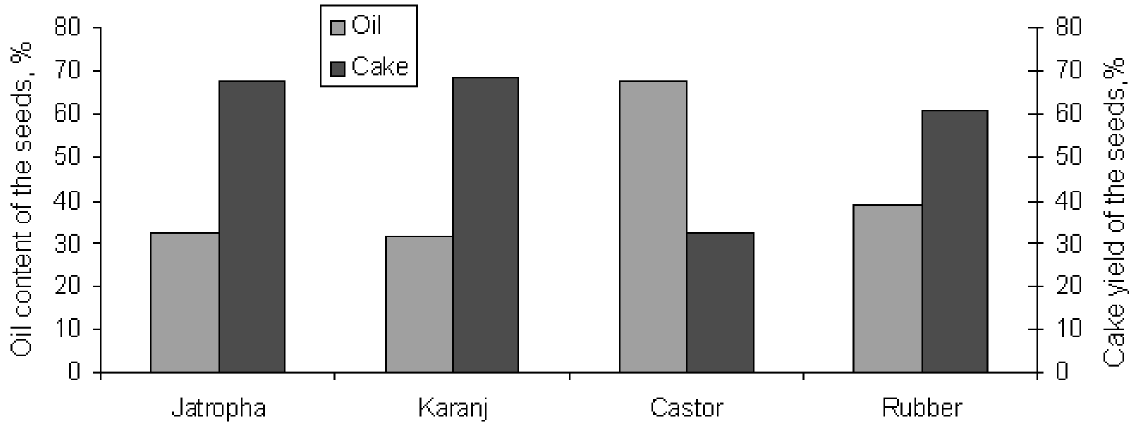

Figure 5. Oil content and cake yield of the seeds

4. CONCLUSIONS

Investigations were made into some basic properties of four different types of seeds obtained from indigenous trees available in Bangladesh such as Jatropha, Karanj, Castor and Rubber useful for the design of processing and extraction system of oil from them. Oil content of these seeds were also determined to check their suitability for commercial extraction. Information on the physical properties (weight, length, width, bulk density and moisture content), and mechanical properties (hardness, crushing strength) of the seeds were recorded. Physical and mechanical properties of the seeds will also help to modify the existing mechanical oil expeller used for Brassica. Among the four types of seeds, Rubber seed was the largest in dimension with a length of 21.2 mm followed by Karanj 17.9 mm, Jatropha 17.1 mm and Castor 11.8 mm. The slender ratio of Jatropha, Karanj, Castor and Rubber seeds were found to be 1.8, 1.2, 1.9 and 1.1 respectively. Jatropha and Castor seeds had similar cylindrical shape with rounded tips. Karanj seed was found to be circular and flat. Shape of Rubber seed was rectangular, inflated but slightly flattened thickness. Rubber seed was the heaviest (4.3 g), as its size was also biggest followed by Karanj (1.2 g), Jatropha (0.8 g) and Castor (0.2 g), respectively. Rubber seeds showed the highest hardness (8.6 kg) followed by Jatropha (2.6 kg), Castor (1.9 kg) and Karanj (1.7 kg) respectively. Crushing strength was found to be 121.2, 38.1, 26.6 and 24.1 kg/cm^2 for Rubber, Jatropha, Castor and Karanj seeds respectively. Castor seed yielded the highest amount of oil (67.7%) followed by Rubber (38.9%), Jatropha (32.4%) and Karanj (31.8%) respectively. All the four types of seeds have sufficient percentage of oil content which can be extracted commercially. These oils could be potential sources of biodiesel since the rural poor use these for direct burning. However, chemical properties of these oils should be investigated to check their suitability for transesterification. The percentages of cake obtained from the seeds were 67.6%, 68.8%, 32.3% and 61.0% for Jatropha, Karanj Castor and Rubber seeds, respectively.

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