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Physical and mechanical properties of Paradise Tree seeds (Simarouba glauca DC.)

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Abstract

The aim of this study was to investigate the physical and mechanical properties of Paradise Tree seed for development of postharvest machine. The seeds containing an average moisture content of 67.40% moisture content wet basis were used throughout the study. The physical properties such as; the seed arithmetic mean diameter, geometrical mean diameter and density were evaluate. It was found that the sizes of the seeds were classified by the diameter into three categories which are small, medium and large corresponding to 12.9 ± 0.5, 13.0 ± 0.6 and 13.9 ± 0.6 mm, respectively. The average geometrical mean diameters for small, medium and large sizes were 12.5 ± 0.5, 12.5 ± 0.5 and 13.5 ± 0.6 mm, respectively and the average densities of seeds (small, medium and large) were 446.7 ± 7.1, 427.0 ± 8.2 and 424.2 ± 6.9 kg/m^3 respectively. The angles of repose of Paradise Tree seeds (small, medium and large) were $0.87 \pm 0.04°$, $0.86 \pm 0.03°$ and $0.83 \pm 0.04°$, respectively. The mean coefficients of static friction of seeds on different surfaces which are wood, zinc, steel, stainless steel and rubber sheets were determined. The values for seeds having transverse movement were higher than those having longitudinal movement. The maximum compressive loads (N) on Paradise Tree seeds for all compression speeds (0.83, 3.13, and 7.08 mm/sec) occurred under the condition of compression on three sizes and three different position.

Keywords: Paradise tree, Simarouba glauca DC., Physical properties, Mechanical properties

1. Introduction

Paradise Tree is a medium size evergreen tree. It has a scientific name called "Simarouba glauca DC." in the family of "Oleaceae", same family with Olive oil tree. The Paradise Tree is resistant to various weather conditions. The trunk has a maximum height of about 5-7 meters (Figure 1) and reaches stability in production after 4-5 years when they are ready for harvesting, by April to May. Each mature tree yields about 15-20 kg seeds [1].

Paradise Trees are widely planted in the Central American and Caribbean countries especially in El Salvador, Honduras, Cuba, Nicaragua, Mexico, Haiti and Jamaica [2] In Asia, they have been found to grow a lot in India and Thailand, and were imported as Paradise Trees in 1975. The report on Botany found in Thailand indicated Paradise Tree as a research and experimental trial crop, which can grow and yield in Khon Kaen, Chiang Mai, Nakhon Ratchasima, Chai Nat, Rayong, Mukdahan, Loei, Phetchabun, Ubon Ratchathani and Si Samrong [3].

The various parts of Paradise Tree are beneficial such as roots, stems, leaves, flowers, and fruits, and apart from this, Paradise tree can be of high interest in the oil extracted from the seed. Many researches on Paradise tree seed oil were carried out and it was found that the oil inside the seed contained up to 50-75 % [1] The main composition in the oil is fatty oleic acid about 52.33 %, a good quality oil Corel sterol, which is similar to olive oil and suitable for use as a vegetable oil for human consumption [3] This useful oil can be extracted if an effective method is found and its usage are numerous, for example in the manufacture of cosmetic products and medicines such as painkillers, anti-bacterial or anti-viral/malarial drugs, etc. [1]

The physical characteristics of Paradise Tree seed include the following: a width of about 1.5 cm and a length of 2.5 cm, an oval egg-shaped seed inside which there exists a soft and juicy meat, purple in color, with a hard shell encapsulation and oil inside [4] In order to obtain the oil the seed, the ripe seed is required and the texture have to be dry and mature. Moreover, the seed must be effectively shelled so that the fruit is obtained and processed to extract the oil effectively. In shelling the Paradise Tree seed, a basic tool such as a hand-operated cracker has been used but this method was inconvenient and inefficient, therefore the design and development of a tool or equipment to perform this task efficiently during the process is of great important.

The design and construction of such tool or machine include the study of physical and mechanical properties of Paradise Tree seed in order to obtain the best performance. The aim of this study is, therefore, to investigate the physical properties and the associated mechanical properties of Paradise Tree seed. The consist of the seeds size and shape,

100 unit mass, bulk density, angle of repose, coefficient of friction, and the compressive force exerted on the seed in various conditions of loading.

Figure 1 Paradise Tree (Simarouba glauca DC.)

2. Materials and methods

2.1 Materials

The Paradise Tree seeds were cleaned by sieving to remove other contaminants such as dust, dirt and rock, etc. The seeds were sun-dried or baked for dehumidifying and kept in jute bags to dry under ambient room condition and controlled moisture. The average seed moisture content of 67.40% (w.b.) was used and the size of seeds was sieved through a 1 cm and 1.5 cm sieve to three different seed sizes which are small, medium and large as shown Figures 2 and 3.
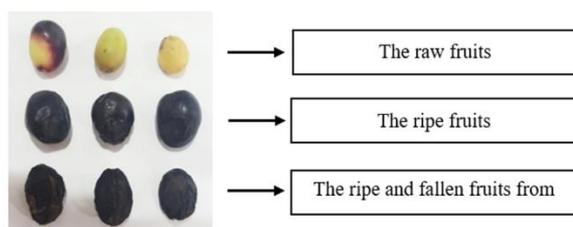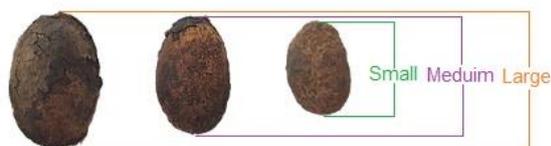

Figure 2 Paradise Tree seeds (Simarouba glauca DC.)

Figure 3 Paradise Tree seeds of small, medium and large sizes

2.2 Physical characteristics of Paradise Tree seeds

2.2.1 Size

The study of size and shape of Paradise Tree seed was conducted by sampling 100 seeds of each size. The measurements of mass per fruit in gram. And the fruit size in millimeter: width (W), length (L), thickness (T) and also the thickness of the shell were performed by using a vernier caliper with an accuracy of 0.01 mm and a digital electronic balance having an accuracy of 0.01 g. as shown Figures 4.

The arithmetic mean diameter (D_a) and geometric mean diameter (D_g) of the seed were calculated by the equations 1 and 2 [5]:

$$D_a = \frac{(L+W+T)}{3} \tag{1}$$

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

The 100 unit mass were determined by randomly selecting 100 seeds in each size then weighing the seed and the average weight 20 samples is also reported.
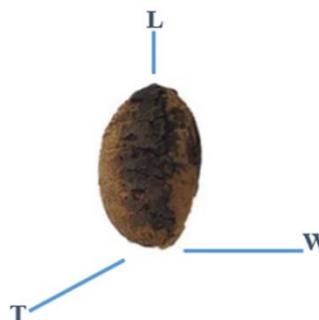

Figure 4 Simulation of Paradise Tree seed in 3D

2.2.2 Bulk Density

The Paradise Tree seeds were placed into a cylindrical container with a volume of 0.5 liters, with materials smoothed/leveled to fit the barrel and weighed by the digital electronic balance having the accuracy of 0.01 g. The samples from three sizes were used in the test of 20 replications. Bulk density was determined using the mass/volume relationship [6] where: ρ was the density (kg/m^3); m was the mass of fruit (kg) and V was the cylindrical container volume (m^3) [7] as following equations:

$$\rho = \frac{m}{v} \tag{3}$$

2.2.3 Coefficient of friction

The coefficients of friction of the Paradise Tree seeds of three sizes were determined using 100 seeds per size. The determinations of the coefficients of friction of the seeds were carried out on five different textured surfaces which are wood, zinc, steel, stainless steel and rubber. Each surface was tested for both the transverse and longitudinal movements of the seeds.

The coefficient of friction (μ) and the material slippery slide (α) were given by the following relationship [8]:

$$\mu = \tan \alpha \tag{4}$$

2.2.4 The angle of repose

The angle of repose was determined by using an open-ended cylinder of volume 0.5 liters and cylinder diameter of 80 mm. The cylinder was slowly raised until a cone was formed on the circular plate. Measurements of the height of the cone from three sizes with 20 samples each were carried out. The angle of repose (θ), height of the cone (H) and diameter of cone (d) was calculated from the following relationship [9]:

$$\theta = \tan^{-1}\left[\frac{2H}{d}\right] \tag{5}$$

2.3 Mechanical property

The compressive force on the seed in three planes: transverse, longitudinal and shell as show in Figure 5 was carried out with three compression speed 0.83, 3.13 and 7.08 mm/second for all three seed sizes. In order to obtain a maximum compression that makes the seed crack under each condition of loading, the cracking behavior of the seed was studied. The compression tests were performed on the LLOYD UNIVERSAL TESTING MACHINE using 50 kN load cell, while the controlling and recording of the results were processed by using the NEXGEN program. Each test was conducted on 20 seeds/size/plane. Then the obtained data was analyzed accordingly to Sudajan, S. and Chusilp, S.[10].
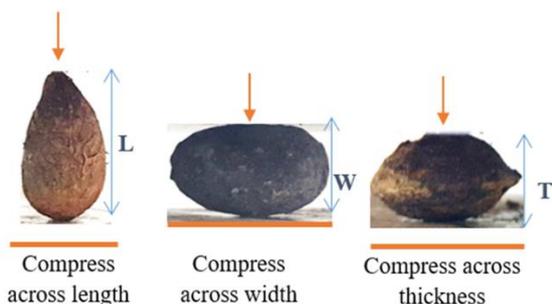

Figure 5 Compression in three planes

3. Results

3.1 Physical characteristics of Paradise Tree seeds

The average width, length, thickness and shell size of small Paradise Tree seeds, were found to be 11.4±0.5, 17.9±1.3, 9.51±0.6 and 1.4±0.2 mm, of medium size 11.5±1.0, 17.9±1.3, 9.5±0.6 and 1.4±0.2 mm and of large size 12.7±0.9, 18.4±1.1, 10.6±0.6 and 1.4±0.3 mm, respectively. It was found that the seed dimensions for small and medium seed were similar, whereas large seed were significantly larger as shown in Figure 6.

The arithmetic mean diameter and geometric mean diameter calculated by using equation (1) and equation (2). It is shown that the average diameters of the arithmetic mean for small, medium and large seeds were 12.9 ± 0.5, 13.0 ± 0.6 and 13.9 ± 0.6 mm, respectively, and the average diameters of the geometrical mean for small, medium and large seeds were 12.5 ± 0.5, 12.5 ± 0.5 and 13.5 ± 0.6 mm respectively as shown in Figure 7.
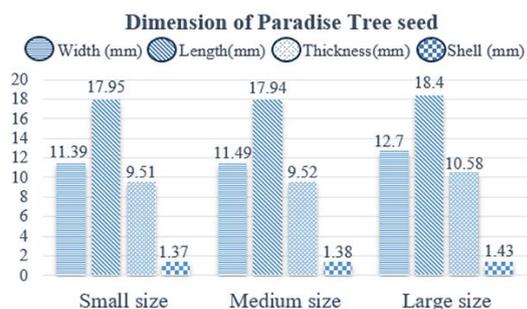

Figure 6 Physical characteristics of seed: width, length, thickness and shell size
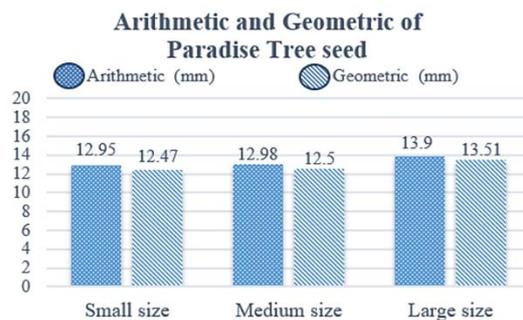

Figure 7 Arithmetic and Geometric mean diameters of three seed sizes

The 100 unit mass was obtained by weighing randomly 100 seed samples for each of the three sizes of the seeds. The average weights from 20 replication for small, medium and large sizes were found to be 70.5 ± 1.3, 70.6 ± 0.9 and 91.3 ± 0.7 g., respectively.

Bulk density is usually one of the most important properties related to transportation and widely calculated for such purpose. It is defined as the mass per unit volume, according to equation (3). The results of the seed bulk density test for three sizes were 446.7 ± 7.1, 427.0 ± 8.2 and 424.2 ± 6.9 kg/m^3, respectively. It can be seen that the density decreased significantly with the size as shown in Figure 8. The coefficients of friction of Paradise Tree seeds in three sizes were examined. For small seeds it was found the best transverse movement is on steel surface at 0.27±0.05 and the best longitudinal movement is on zinc at 0.24±0.04. For medium seeds it was found the best transverse movement is on wood surface at 0.51±0.06 and the best longitudinal movement is on steel at 0.33±0.06. For large seeds it was found the best transverse and longitudinal movements is on zinc with 0.36±0.06 and 0.31±0.05, respectively as Figure 9 and 10.
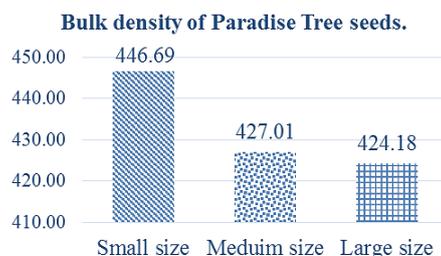

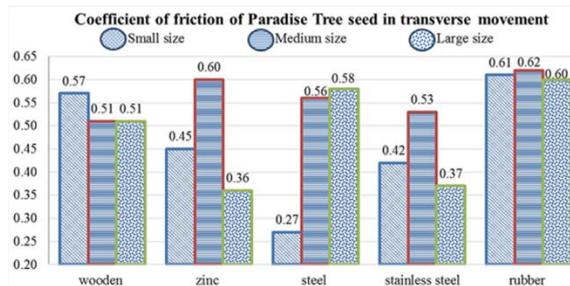**Figure 8** Bulk density of Paradise Tree seeds for three sizes (kg/m^3)

Figure 9 Coefficient of friction of Paradise Tree seed in transverse movement

Table 1 Compressive loads (N) on Paradise Tree seeds

Compression speeds (mm /sec) .	Position in Compression	Maximum load		
		Small Size (N)	Medium Size (N)	Large size (N)
0.83	across width	137.09±54.09	215.82±42.18	247.54±53.25
	across length	230.43±84.76	247.41±60.06	274.23±51.60
	across thickness	232.14±55.98	231.30±55.49	231.30±55.49
3.13	across width	210.21±90.13	158.40±90.13	224.51±40.50
	across length	158.40±77.93	210.01±77.93	272.50±87.28
	across thickness	243.12±110.12	224.38±50.50	222.70±66.69
7.08	across width	152.21±90.14	138.20±54.22	214.28±65.92
	across length	118.46±76.12	229.40±48.95	263.56±93.56
	across thickness	198.09±76.97	210.67±76.39	211.82±45.27
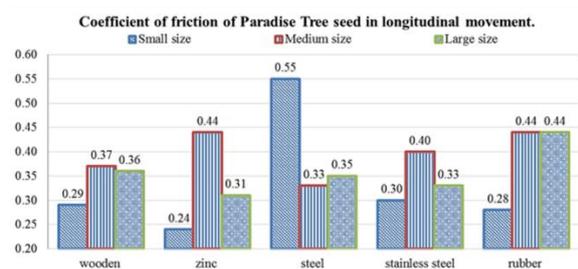
Figure 10 Coefficient of friction of Paradise Tree seed in longitudinal movement

The angle of repose was normally affected by adhesion between the container wall and the seeds. Results for the angles of repose of Paradise Tree seeds, calculated by using equation 5, for seeds of small size, medium size and large size were 0.87 ± 0.04°, 0.86 ± 0.03° and 0.83 ± 0.04 °, respectively.

3.2 Mechanical property

The average maximum compressive loads under three different compression speeds of 0.83, 3.13 and 7.08 mm/sec in three different positions.

The maximum compressive loads of Paradise Tree seeds. For small seeds it was found the maximum compressive loads were 243.1±110.1 N in compression speeds 3.13 mm /sec at across thickness. For medium seeds it was found the maximum compressive loads were 247.4±60.1 N in compression speeds 0.83 mm /sec at across length. For large seeds it was found the maximum compressive loads were 274.2±51.6 N in compression speeds 0.83 mm /sec at across length. As shown in Table 1.

4. Discussion

Paradise Tree seeds used in this study were generally smaller than those found in India [11] whose dimensions could be important in the machine design. The careful consideration of these dimensions would be very useful in the determination of the aperture shape and size relating to the machine design component as proposed by Mohsenin (1980).

The most suitable materials concerning the coefficient of friction of Paradise Tree seeds were determined to be steel and zinc, but stainless steel was also acceptable.

The maximum compressive loads (N) on Paradise Tree seeds for all compression speeds (0.83, 3.13, and 7.08 mm/sec) occurred under the condition of compression on three sizes and three different positions. In the process needs improvement to decrease the quantity of broken kernels.

5. Conclusions

Nowadays, Paradise Tree has a great role as a resource of vegetable oil for human consumption, manufacture of cosmetics, medicinal products and biofuels such as ; biodiesel. The physical characteristics of Paradise Tree seeds such as dimensions, 100-unit mass, density, arithmetic and geometric mean diameters, angle of repose, the coefficient of friction of Paradise Tree seeds and the mechanical properties have been investigated and reported. The seeds are oval shaped; about 17.94-18.40 mm in length, 11.39-12.70 mm in width and 9.51-10.58 mm in thickness, sufficiently strong and not easily broken. The maximum compressive on Paradise Tree seeds it was found to compression speeds used for the design velocity in cracker.

6. Acknowledgements

7. References

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