Effect of moisture content on physical properties of sal

*(Shorea robusta)* seeds

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Abstract

*Shorea robust* commonly known as sal, play an important role in food, non-food industries. It is mainly processed for extraction of its oil. It can be used for cocoa based products and also used in bio-diesel production. This study was conducted to investigate the effect of moisture content (6.38 to 21.95% (d.b.)) on physical properties of sal seeds. Physical properties such as length, width, arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio, surface area, unit seed mass, bulk density, true density, porosity, and coefficient of friction with various surfaces namely, galvanised iron, plastic, ply wood and aluminium sheet were determined. The average dimensions of sal seed was increased with increase in moisture content ranging from 6.38 to 21.95% (d.b.). The unit seed mass was increased from 0.916 to 1.54 g with the increased in moisture content from 6.38 to 21.95% (d.b.). In the same moisture ranges, bulk density, true density and porosity were increased from 349.46 to 371 kg/m³, 807.9 to 963.5 kg/m³ and 56.74 to 62.24%, respectively. The coefficient of friction was increased linearly with increase in sal seed moisture content on four different surfaces namely ply wood, plastic, aluminium and galvanised iron sheet.

Key words: Sal seed, physical properties, moisture content, coefficient of friction
1. Introduction

Sal (Shorea robusta) is one of the important timber and non-timber plants of India. It is known for heavy or tough wood. It is widely distributed in tropical regions of India. Sal forest covers around 10 million hectare in India. The report shows that sal seeds as potential non-timber forest product for enterprise development in India. It is a semi-evergreen tree and grows upto 50 m height. Apart from timber sal plant also play an important role for its seed. Sal seeds are harvested in the month of last week of May upto third week of June [1]. Sal seed consist of 64.4% kernel and 33.6% of shell. Sal seed primarily processed for extraction of its oil. It contain around 34% of oil [2]. It is important role in food, non-food and pharmaceutical industries based industries [3]. It can be used for production of cocoa based products. Recently sal seed identified as a source for vegetable based bio-diesel production [4]. Due to the lack of the technology these seeds are underutilize and very low cost in market.

Various researchers reported that design of post-harvest processing equipment depends on physical and mechanical properties of agricultural products [5-9]. The physical properties of agricultural products are necessary for designing and development of equipment for cleaning, grading, shorting, de-hulling or decorticating, oil extraction, storage and transportation [10], and also for assessing the product quality for the products. For this process, understanding of physical properties of sal seeds play crucial role in development of post-harvest processing equipment. These properties for sal seeds have not been reported in the literatures. Hence the aim of this research was to determine the effect of moisture content on physical properties of sal seed. Various parameters were determined namely, length, width, arithmetic mean diameter, geometric mean diameter, aspect ratio, surface area, bulk density, true density, porosity, angle of repose and coefficient of friction on various surfaces namely, galvanised iron, ply wood, plastic and aluminium sheet in the moisture content range from 6.38 to 21.95 % (d.b).

2. Materials and methods

2.1 Sample

Sal seeds were procured from the local areas of Rourkela, Orissa, India for this investigation. The samples were cleaned manually to remove the immature, infected, dust, stone, dirt, unwanted material and small seeds. The cleaned and graded samples were sundried and packed in air tight aluminium container. Moisture content is a useful information to conduct the experiment and also in the drying process [11]. The initial moisture content of seeds were determined by standard hot air oven method at 105± 1°C for 24 h [12].

2.2 Sample preparation

Sal seeds were conditioned with a calculated amount of water by as per the procedure described by Pradhan et al, (9) and moistened to raise their initial moisture content to desire levels. All the physical properties were determined at moisture range of 6.38%, 10.49%, 13.63%, 17.63% and 21.95% [9, 13, 14].

2.3 Physical properties of sal sample

Samples of one hundred seeds were randomly selected from the bulk of the each conditioned sample. Dimensional properties like length, and width of the sal seeds were measured with a digital Vernier calliper with the accuracy of ±0.01 mm The unit seed mass (g) was measured by using electronic weighing balance (Wensor ISO 9001: 2000 certified, India) with accuracy of ±0.001 g. The average diameter of sample were calculated by using the arithmetic mean diameter, $D_a$ and geometric mean diameter, $D_g$ of seeds were determined standard methods [15-19].

Sphericity, ($\varphi$) seed was calculated based on the isoperimetric properties of the sphere. The higher the sphericity of the seed, the closer is its shape to a sphere [20, 21]. Aspect ratio, ($Ra$) and surface area, ($S$, $mm^2$) of seeds was calculated by standard methods [11, 22].

The bulk density ($\rho_b$), true density ($\rho_t$) and porosity ($\varepsilon$) of the bulk seed was calculated as per standard methods [11, 23]. The coefficient of friction was calculated as the tangent of the angle measured and was determined by method described by other researchers [23-26].
3. Results and discussion

Table 1 shows some dimensional properties of sal seed at its initial moisture content (10.49%, d.b). The average length (major axis) and width (minor axis) of the sal seeds was found to be 24.9±2.6 mm and 12.9±1.01 mm, respectively. The result shows that the length and width of sal seed was lesser than *Jatropha curcas* [27, 28] and higher than the peanut and kernel [29]. Various researcher reported that axial dimensions are very important for determine the aperture size and other machine parameters [28, 30]. The average arithmetic mean diameter and geometric mean diameter were also calculated as 23.6±1.5 mm and 19.3±1.1 mm, respectively.

The principle dimension such as length (*L*) and width (*W*) shows the linear tendency which is increased with increase in the moisture content from 6.38 to 21.95%, d.b (Fig.2). The dimensional axis were increase from 24.5 to 25.12 mm, and 12.76 to 13.61 mm for length and width for sal seeds, respectively. The linear increased in seed dimensions were reported for karingda seeds [31] and squash seeds [7]. The variation of moisture content (*Mc*) and principle dimensions was represented by linear equations as follows:

\[
L = 0.0976Mc + 23.833 \quad (R^2 = 0.958)
\]
\[
W = 0.0558Mc + 12.369 \quad (R^2 = 0.958)
\]

Table 1: Physical properties of sal seed at initial moisture content (10.49%, d.b).

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>N</th>
<th>Mean</th>
<th>Max</th>
<th>Min</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal dimensions, mm</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Length, <em>L</em></td>
<td>100</td>
<td>24.9</td>
<td>33.1</td>
<td>21.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Width, <em>W</em></td>
<td>100</td>
<td>12.9</td>
<td>15.4</td>
<td>10.9</td>
<td>1.01</td>
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<tr>
<td>Average diameter, mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arithmetic mean diameter, <em>Da</em></td>
<td>100</td>
<td>23.6</td>
<td>23.6</td>
<td>16.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Geometric mean diameter, <em>Dg</em></td>
<td>100</td>
<td>19.3</td>
<td>19.3</td>
<td>14</td>
<td>1.1</td>
</tr>
</tbody>
</table>

- N is the number of observation, SD, Standard deviation.

The average diameter was calculated by arithmetic mean diameter (*Da*) and geometric mean diameter (*Dg*) were increased with increase in the moisture content as principal dimensions. The increase in principal dimensions and average diameter could be attributed to the expansion of the seeds as a result of moisture absorption in the intracellular spaces inside the seeds [32]. The relationship between the moisture content (*Mc*) and average diameter of sal seeds was obtained as follows:

\[
Da = 0.00767Mc + 18.101 \quad (R^2 = 0.980)
\]
\[ D_g = 0.0671Mc + 15.35 \quad (R^2 = 0.990) \]

Figure 2: Effect of moisture content (d.b) on dimensions of sal seeds.

The sphericity of sal seed increased from 0.747 to 0.754, when the moisture content increased from 6.38 to 21.95% (d.b). Similar trend was reported for hemp seeds [33] and caper seeds [34]. Researcher reported that grain is spherical when the sphericity value is more than 0.80 and 0.70 [15, 21]. In this experiment sal seed determined as spherical in shape and it helps in calculation of surface area of the sal seeds. The linear equation for sphericity and moisture content \((Mc)\) of sal seed can be formulated to be:

\[ \varphi = 0.0005Mc + 0.7422 \quad (R^2 = 0.850) \]

Aspect ratio \((Ap)\) is the ratio of width and length in percentage which was increased with increase in moisture content. The positive linear relationship between the moisture content and aspect ratio as follows:

\[ Ap = 0.0671Mc + 51.496 \quad (R^2 = 0.9) \]

The variation of surface area \((S)\) with increase in moisture content as shown in fig 3c. The surface area of sal seed increase linearly from 785.42 to 893.16 mm\(^2\) when the moisture content increased from 6.38 to 21.95% (d.b). This property plays an important role to determine the projected area of irregular shaped objects moving in turbulent air stream and helps in cleaner and separator. Similar result has been reported for guar seeds [35]. The relation between surface area and moisture content \((Mc)\) can be expressed mathematically as follows:

\[ \text{Surface area} = 6.879Mc + 737.25 \quad (R^2 = 0.989) \]

Unit seed mass \((g)\) of sal seeds increased linearly from 0.916 to 1.54 g with increase in the moisture content from 6.38 to 21.95% (d.b) shown in fig 3d. The increase in seed mass with increase in seed moisture has been reported for barbunia beans. Various researcher reported that moisture dependent on mass of the agricultural material [37, 38]. The relation between the unit seed mass and moisture content \((Mc)\) represented as:

\[ \text{Unit seed mass} = 0.04Mc + 0.6869 \quad (R^2 = 0.987) \]

The bulk density (kg/m\(^3\)) of sal seeds varied from 349.46 to 371 kg/m\(^3\) and it is increased with the increase in the moisture content (Fig.4). The increase in bulk density with the moisture content is due to absorption of moisture compared to volumetric expansion of sal seeds. True density also increased with the increase in moisture content from 6.38 to 21.95% (d.b) and it might be attributed to the relatively lower true volume compared to the corresponding mass of the sal seed attained due to adsorption of moisture. Similar increasing trend has been reported for sunflower seeds [39]. This property can be used for separate seeds from lighter particles or foreign material. The following linear equation was used to describe the relationship between bulk density and true density with moisture content \((Mc)\).
Bulk density = $1.1153 \text{Mc} + 346.22$ \hspace{1cm} ($R^2 = 0.732$)

True density = $9.4453\text{Mc} + 766.43$ \hspace{1cm} ($R^2 = 0.898$)

It was observed that porosity was increased from 56.74 to 62.24% when the moisture content was increased from 6.38 to 21.95% (d.b) (Fig 4). Similar result was reported for arecant kernels [40]. The relation between moisture content ($M_c$) and porosity was described mathematically as follows:

$$\text{Porosity} = 0.3513 + 54.652$$ \hspace{1cm} ($R^2 = 0.996$)

The coefficient of friction of sal seeds against four different surface, namely aluminium, plastic, ply wood and galvanised iron are presented graphically in fig 5. It was observed that coefficient of friction were increased with increase in moisture content from 6.38 to 21.95% (d.b) for all the contact surfaces. The reason for increased coefficient of friction may be owing to water present in the seed offering a cohesive force on the surface of contact.
Similar trend was observed for popcorn kernels [41]. The highest coefficient of friction was observed for aluminium sheet at 21.95% (d.b) moisture content and lowest for plastic sheet at 6.38% (d.b) moisture content.

![Graph showing variation of bulk density, true density and porosity of sal seed with moisture content (d.b).](image1)

The least coefficient of friction due to the smoother and highly polished surface of the plastic sheet than the other materials. The coefficient of friction affect the design of the post-harvest processing equipment and these four common materials were used for transportation and storage of agricultural materials. The linear equation between the coefficient of friction and moisture content ($M_c$) on aluminium, plastic, ply wood and galvanised sheet as follows:

- Aluminium = $0.0078M_c + 0.2643$ ($R^2 = 0.986$)
- Plastic = $0.0052M_c + 0.2907$ ($R^2 = 0.975$)
- Ply wood = $0.0104M_c + 0.3289$ ($R^2 = 0.856$)
- Galavanised iron = $0.0069M_c + 0.3289$ ($R^2 = 0.726$)

![Graph showing effect of moisture content (d.b) on coefficient of friction of sal seed against various surfaces.](image2)

Figure 4: Variation of bulk density, true density and porosity of sal seed with moisture content (d.b).

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4. Conclusion

The following conclusion was obtained from the investigation on effect of moisture on physical properties of sal seeds in the moisture content ranging from 6.38% to 21.95% (d.b). The average dimensions were increased with the increase in the moisture content. The average dimension such as length, width, arithmetic mean diameter and geometric mean diameter ranged from 24.5 to 25.12, 12.76 to 13.61, 18.63 to 19.86, and 15.82 to 16.87 mm respectively. Sphericity, aspect ratio and surface area were found to increase from 0.747 to 0.754, 52.08 to 53.1% and 785.42 to 893.16 mm$^2$ respectively, in the moisture range of 6.38% to 21.95% (d.b). In the same moisture content bulk density, true density and porosity were increased from 349.46 to 371 kg/m$^3$, 807.9 to 963.5 kg/m$^3$ and 56.74 to 62.24% with the increase in moisture content. The coefficient of friction, depending on friction surface, it was increased linearly with the increase in moisture content, namely aluminium sheet (0.38 to 0.51), plastic (0.29 to 0.43) ply wood (0.31 to 0.43) and galvanised iron (0.33 to 0.41) as moisture content increased from 6.38% to 21.95% (d.b). These properties help to determine the efficiency of agricultural processing machine and also development of post-harvest processing machine.

Reference

1. Patnaik, S., 2015, “Non Timber Forest Product, Enterprise and Forest Governance”. *Center for Peoples Forestry*
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