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Note

Physical properties of fresh mahua

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A b s t r a c t. The physical properties of fresh mahua were evaluated at its initial moisture content. The initial moisture content (d.b.) of fresh mahua flowers was found to be constant at 79.82%. The average arithmetic and geometric mean diameters of fresh mahua having scaly corolla were higher as compared to mahua without scaly corolla. The average value of surface area, 1000 unit mass, densities, angle of repose, terminal velocity and coefficient of friction were higher for mahua with scaly corolla, whereas spericity and aspect ratio were higher in the case of mahua without scaly corolla.

K e y w o r d s: mahua, physical property, moisture content

INTRODUCTION

Mahua (*Madhuca indica* J.F. Gmel. syn. *Madhuca latifolia* Macb.) belonging to the family *Sapotaceae*, is one of those multipurpose forest tree species that provide an answer for the three major Fs *ie* food, fodder and fuel. It is widely distributed in the South Asian countries (Banerji and Mitra, 1996). The tree, known under the name of mahua, produces edible flowers and fruits. Mahua flowers (Fig. 1) are well known for their high reducing sugar and nutrient content (Jayasree *et al.*, 1998). They are edible and used as a sweetener in preparation of many local dishes like halwa, kheer, puri and burfi (Patel and Naik, 2008) in the mahua production belt of India. However, due to the lack of proper scientific investigation and post harvest processing technologies, they are collected and subjected to open yard sun drying till about 80% moisture is lost, before storage (Patel and Naik, 2008). This process results in heavy microbial load and degrades their food value, finally making them suitable only for the liquor distillation units and as cattle feed. This way a precious, organic and easily available source of natural sugar is being under-utilized.

Mahua flowers undergo a series of unit operations before reaching the final step of processing, and the value added products development designs, and fabrication of particular equipments and structures for such unit operations as handling, transport, processing and storage and also for assessing the behaviour of the product quality (Sahay and Singh, 1996), require the knowledge of their physical properties. Physical properties of mahua flowers are essential for the design of equipments for drying, cleaning, grading, storage and value added products. The importance of physical properties for designing postharvest processing equipments has been emphasized earlier (Bagherpour *et al.*, 2010; Pradhan *et al.*, 2009).

The aim of this study was to determine the following physical properties of fresh mahua flowers: moisture content, linear dimensions, arithmetic, and geometric mean diameters, sphericity, aspect ratio, 1 000 unit mass, surface area, true density, bulk density and porosity.

Fig. 1. Inflorescence of mahua.

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MATERIALS AND METHOD

The raw materials used for the present study were collected at the village Rangiatikira, Sambalpur (21°28' 12"N, 83°58'12"E), district of Orissa, India, during March 2005. The fresh flowers were collected early in the morning and cleaned manually to remove all foreign materials and damaged flowers. Weighed amounts of fresh mahua flowers were dried in a hot-air oven at 80°C (Yorco Sales Pvt. Ltd., India) and weighed every time after cooling the samples in a desiccator till constant mass and moisture content was recorded.

The fresh flower samples were divided into 5 lots and 20 samples were selected at random from each lot of flowers to obtain 100 samples for conducting the experiments on dimensions. Hence, measurement of all size and shape indices as well as the flower mass were replicated one hundred times. The flower size, in terms of the three principal axial dimensions, that is length, width and thickness, were measured using a vernier caliper (Mitutoyo, Japan) with an accuracy of 0.02 mm. Two measurements were taken in respect of the length because of the scaly corolla (Fig. 2).

The arithmetic, and geometric mean diameters, bulk and true densities, sphericity, porosity, aspect ratio, surface area of bulk sample were calculated using standard formulas (Burubai *et al*., 2007; Sharifi *et al*., 2007).

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 moveable pointer fixed on a stand having a scale of 0-1 cm precision. The angle of repose, θ, was calculated using the formula:

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

where: H is the height of the cone (cm), D is the diameter of cone (cm). The reported value is the mean of 20 replications.

a

b

Fig. 2. Fresh mahua flowers: a – with scaly corolla, b – without scaly corolla.

The coefficient of friction of mahua flower was found with respect to three structural materials, namely, plywood, mild steel sheet and aluminium, using the inclined plane apparatus as described by Dutta *et al*. (1988) and Pradhan *et al*. (2009). Five replications were made for each sample.

The terminal velocities of mahua flower having scaly corolla and without scaly corolla were measured using an air column. For each test a small sample was dropped into the air stream from the top of the air column, up which air was blown to suspend the material in a hot wire anemometer having the least count of 0.1 m s^{-1}. Five replications were made for each sample.

RESULTS AND DISCUSSION

The results obtained for the physical properties of fresh mahua flowers are presented in Table 1. The length, width and thickness of mahua flowers having scaly corolla were found to be 20.81±1.81, 14.93±1.14 and 13.6±1.22 mm, respectively. Corresponding results for oil bean seeds (Oje and Ugbor, 1991) were 65.4, 41.3 and 13.7 mm, while 7.98, 5.95 and 5.82 mm were reported for gram (Dutta *et al.*, 1988). The fresh mahua flower was thus smaller than oil bean seed but bigger than gram. Specifically, the oil bean seed was approximately three times longer than the fresh mahua flower, approximately two and half times wider, and with about same thickness. Compared with gram, however, the fresh mahua flowers were about two and half times longer, wider and thicker. The importance of these dimensions in determining aperture sizes and other parameters in machine design have been discussed by Mohsenin (1980).

The shape of the flower was determined in terms of its sphericity and aspect ratio. The sphericity was found to be 0.78, which was much higher than the corresponding value of 0.60 reported for oil bean seed (Oje and Ugbor, 1991). However, the value was in the same range as 0.74 reported for gram (Dutta *et al.*, 1988). The high sphericity of the fresh mahua flower was indicative of the tendency of its shape towards a sphere. This result agrees with the investigations by Dutta *et al*. (1988) who considered the grain as spherical when the sphericity value was more than 0.80 and 0.70, respectively. Taken along with the high aspect ratio (which relates the ratio of seed width to length), it may be deduced that the fresh mahua flower will rather roll, like gram, than slide on their flat surfaces like oil bean seed. This tendency to either roll or slide is very important in the design of hoppers. Furthermore, the shape indices indicate that the fresh mahua flower may be treated as an equivalent sphere, like gram, for analytical prediction of its drying behaviour.

It is important to point out that some of the size and shape characteristics of the fresh mahua flower can be modified by trimming the scaly corolla as indicated by the physical parameters determined with the scaly corolla ignored. This trimming may be necessary especially in the adaptation of an existing processing machine and also in taking advantages of the higher sphericity and aspect ratio values.

T a b l e 1. Physical characteristics of fresh mahua flowers

Physical properties	Mean values	
	without scaly corolla*	with scaly corolla
Moisture content (%, d.b.)	79.82 ± 2.31	79.82 ± 2.31
Length (mm)	15.20 ± 1.46	20.81 ± 1.81
Width (mm)	14.93 ± 1.14	14.93 ± 1.14
Thickness (mm)	13.60 ± 1.22	13.60 ± 1.22
Arithmetic mean (mm)	14.58 ± 0.83	16.45 ± 0.91
Geometric mean (mm)	14.54 ± 0.82	16.17 ± 0.89
Sphericity (decimal)	0.95 ± 0.07	0.77 ± 0.06
Aspect ratio (%)	98.25 ± 9.47	71.75 ± 9.08
Surface area (mm^2)	666.38 ± 75.18	821.69 ± 92.17
1 000 unit mass (g)	1720.96 ± 94.49	1844 ± 92.61
Bulk density (kg m^{-3})	517.61 ± 28.90	589.32 ± 22.42
True density (kg m^{-3})	1015.67 ± 11.37	1038.55 ± 12.81
Porosity (%)	49.06 ± 3.46	52.42 ± 4.36
Angle of repose (°)	45.01 ± 2.32	47.1 ± 1.67
Terminal velocity (m s^{-1})	8.91 ± 0.28	9.31 ± 0.35
	Coefficient of friction	
Plywood	0.53 ± 0.12	0.66 ± 0.16
Mild steel sheet	0.42 ± 0.27	0.54 ± 0.07
Aluminium	0.23 ± 0.08	0.36 ± 0.02

*±Standard deviations.

The 1 000 unit mass of fresh mahua without scaly corolla and with scaly corolla were 1 720.96 and 1 844 g, respectively. As expected, this value was much higher than 713 g reported for gram but smaller than the 20 200 g reported for oil bean seed (Dutta *et al.*, 1988; Oje and Ugbor 1991). The surface area of fresh mahua flower was 821.69 mm^2. Surface area affects the resistance to airflow through the bulk material bed and data on this parameter are necessary in designing the drying process.

The fresh mahua flower (without scaly corolla) true density and bulk density were 1 015.67 and 517.61 kg m^{-3}, respectively. These values are lower than the corresponding values of 1 311 and 780 kg m^{-3} reported for gram (Dutta *et al.*, 1988) and 1 578-1 623 and 830-886 kg m^{-3} reported for the pearl millet varieties (Jain and Bal, 1997). The porosity value of fresh mahua flower was 49.06%, which may be useful in the separation and transportation of fresh mahua flowers by hydrodynamic means. The lower porosity or percentage of volume of voids in the fresh mahua flower may be due to the higher sphericity and aspect ratio which ensure a more compact arrangement of the fresh mahua.

The angle of repose of fresh mahua without scaly corolla is 4.44% more than that of mahua having scaly corolla. This is due to the fact that with scaly corolla the sample becomes more resistant to the surface, which causes an increase in the angle of repose. The value of angle of repose for mahua was considerably higher than that of simarouba (Dash *et al.*, 2008) and thevetia (Sahoo *et al.*, 2009). This is because the surface layer of moisture (which is higher than for simarouba and thevetia) surrounding the particle holds the aggregate of mahua together by the surface tension.

The terminal velocity was significantly lower for mahua without scaly corolla than for mahua having scaly corolla at its initial moisture level. This is obvious that the increase in mass due to the presence of the scaly corolla contributed to an increase in the terminal velocity.

It was observed that the coefficient of static friction for fresh mahua having scaly corolla was higher that than that of mahua without scaly corolla for all three surfaces. This suggests that due to the presence of scaly corolla, mahua became rougher than the mahua without scaly corolla. Under all conditions, the maximum friction was offered by plywood, followed by the mild steel and aluminium surfaces. The lowest coefficient of static friction may be owing to the smoother and more polished surface of the aluminium sheet than the other materials used. Plywood also offered the maximum friction for gram, rapeseed (*Brassica napus* L.) and jatropha (Dutta *et al*., 1988; Pradhan *et al*., 2009).

CONCLUSIONS

1. Fresh mahua flowers are nearly spherical in shape and can be used as an excellent source for extraction of sweet juice.

2. The average lengths of fresh mahua flower without scaly corolla and with scaly corolla were 15.20 and 20.81 mm, respectively.

3. The average surface area was 663.38 mm^2 while the sphericity and aspect ratio were 0.95 and 98.25%, respectively, for fresh flowers without scaly corolla. Similarly, mahua with scaly corolla had an average surface area of 821.69 mm^2 while the sphericity and aspect ratio were 0.77 and 71.75%, respectively.

4. The average bulk density was 517.61 kg m^{-3} while the true density was 1 015.67 kg m^{-3}, and the corresponding porosity was 49.06% for mahua without scaly corolla.

5. The angle of repose and terminal velocity of fresh mahua having scaly corolla was higher as compared to mahua without scaly corolla.

6. The coefficient of friction was determined with respect to three different surfaces and it was found that aluminium sheet has the lowest coefficient of friction among all three.

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