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Determination of Properties of Seed, Kernels and Oil of Mahua *(Madhuca indica)* Forest Seed

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Abstract The study was conducted to investigate properties of Mahua seed , kernels and oil. The length, breadth and thickness of Mahua seed and kernels were found to be 25.58, 13.03, 11.11 and 20.69, 11.36, 9.30 mm at moisture of 8.38%. The oil content in Mahua seed kernels was found to be 38.75%. The bulk density, true density, porosity and angle of repose of Mahua seed kernels were found to be 0.99 g/cc, 1.2 g/cc, 17.5 and 33.93. The viscosity of Mahua oil was recorded as 26.27 mm^2/s at 40^0C. This shows that Mahua oil could not be used as sole fuel in diesel engine, because high viscosity of Mahua oil may results in increased droplet size, poor stomization and poor combustion. Combustion properties of Mahua oil i.e. flash and fire point, cloud and pour point were found to be 231.4, 218, 16.2 and 14 4^0C respectively. The calorific value of Mahua oil was found to be 36.44 MJ/kg.

Keywords Mahua seed, Mahua kernels, Mahua oil, Combustion properties, Physical properties.

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Introduction

The two major species of genus Madhuca found in Maharashtra, West Bengal, Orissa, south Indian forests and Sri Lanka. *Madhuca indica* (syn *Bassia latifolia*) and *Madhuca longifolia* (syn *Bassia longifolia)*, family *Sapotaceae*. Madhuca is widely accepted as local name for the fat from both these species. The orange brown pipe flesh berry (2.5-5.0 cm long)contains 1 - 4 shining seeds. Drying and decortications yield kernels 70% by weight [1]. The yield of Mahua seeds varies (5-200 kg/tree) depending upon size and age of the tree. The average yield of sun-dried Mahua seeds is about 1.6 kg/tree. Mahua given seeds after 10 years and it goes up to 60 years, when yield at the age of 10. Recovery of kernel is a village level activity and lack of proper facilities for drying and preservation affects the quality. Kernel contains 20-50% oil depending on expelled by ghani or expeller [2]. The quality of expelled oils depends largely on storage conditions of kernels, which is susceptible to fungus and insect attack. Fresh oil from properly stored seeds is yellow while commercial oils are greenish yellow with disagreeable odour and taste. Free fatty acids of oil from fresh kernels are very less (1-2%) compared to that from stored kernels (30%). In the process of extracting the Mahua oil and derivativities, the kernels undergoes a series of unit operation. Knowledge of the physical properties and their dependence on the moisture content of Mahua seed kernels is essential to facilitate and improve the design of the equipment for harvesting, processing, oil extraction and storage of the kernels [3]. Various

types of cleaning, grading, separation, oil extraction equipment are designed on the basis of the physical properties of the kernels.

Materials and Methods

To study the physical properties fully ripe Mahua seeds were collected from the village. Manually shelled and decorticated Mahua seeds kernel were procured from local market of Gondia district of Maharashtra State. These kernels were cleaned to remove sand, dust, leaves and other contaminants. Different physical properties of Mahua seed and kernels i.e. size, sphericity, angle of repose, bulk density, tree density and weight of thousand seed kernels were carried out.

Determinations of physical properties of Mahua seed/kernels

Oil content : The oil content in Mahua seed kernels was measured with the help of soxhlet apparatus using petroleum ether [4].

Mahua seed/kernel size : Size or equivalent diameter is geometric mean of the three dimensions, viz. length, breadth and thickness which were measured using vernier caliper. Mahua seed/kernel size was calculated from the expression suggested by Moshenin [5].

$$\text{Size} = (L \times B \times T)^{1/3}$$

Sphericity : As suggested by Moshenin [5] the degree of sphericity (Ø) was found out by the expression.

$$Ø = \frac{(a\ b\ c)^{1/3}}{a}$$

Where, $(a\ b\ c)^{1/3}$ = geometric mean diameter, a, b, c = are semi axis of major, medium and minor axis of the seed. The values of sphericity were calculated individually by using the data on geometric mean diameter and the major axis of the kernel.

*Weight of thousand seed/kernels :*Weight of thousand Mahua seed/kernels was determined by using Indian standard method [6–8]. For this purpose well matured healthy Mahua seed kernels were taken. An analytical balance having sensitivity of 0.01 g was used.

*Bulk density :*Bulk density is the ratio of mass to bulk volume of the sample. Density of Mahua seed kernels was measured using a standard measuring cylinder having 500 ml capacity. It was filled up with seed kernels and then the content was weighed [5]. Size of the test sample was taken 500 g.

True density : The ratio of mass of sample to true volume is termed to density of sample. True density of Mahua seed kernels was determined with toluene displacement method. Mahua seed kernels sample about 10 g was submerged in toluene in a measuring cylinder having accuracy of 0.1 ml. The increase of liquid volume was noted as true volume of the sample, which was used to determine the true density of the Mahua seed kernels.

Angle of repose : Angle of repose is important in design of equipment for solid flow and structures for storage of these materials. Angle of repose in defined as when granular material is allowed to flow freely from a point into a pile, the angle which the side of the pile makes with horizontal plane is called angle of repose [8].

The tangent of the angle (tan Ø)

$$(\tan Ø) = \frac{d_1 - d_2}{100} = \frac{d_3}{100}$$

Angle of repose $Ø = \tan^{-1}[(d^3)/100]$

Determinations of properties of oil

Properties of Mahua oil such as moisture content, kinematic viscosity, density, flash and fire point, cloud and pour point and calorific value were determined in laboratory by following standard methods [9-10].

Moisture content: Moisture content of Mahua oil was determined by the oven method. A known quantity of oil was heated at 105^{0}C, and cooled in the desiccators and weighted. The process was repeated till the constant weight was attained.

Table 1. Size, shape and 1000 seed weight of Mahua seeds.

Sl. No.	Length mm	Breadth mm	Thickness mm	Size mm	Sphericity	1000 seed wt g
1	24.50	15.82	8.65	14.96	0.61	1820
2	25.00	11.62	10.9	14.68	0.59	1740
3	26.00	10.61	11.50	14.69	0.57	1691
4	25.80	14.50	11.00	16.02	0.62	1840
5	25.15	13.50	12.15	16.03	0.64	1890
6	25.75	12.20	12.00	15.56	0.60	1710
7	26.12	10.00	9.80	13.67	0.52	1744
8	25.10	12.15	12.00	15.41	0.61	1911
9	27.45	15.00	10.12	16.09	0.58	1860
10	25.00	14.90	13.00	16.92	0.67	1810
Max	27.45	15.00	13.00	16.92	0.67	1911
Min	24.50	10.00	8.65	13.67	0.52	1710
Mean	25.58	13.03	11.11	15.40	0.60	1801.6

$$\text{Moisture content of oil (\%)} = \frac{100\,(P-A)}{P}$$

Where, P = initial weight of sample, g, A = weight of oil sample after heating, g.

Kinematic viscosity: The kinematic viscosity of Mahua oil was determined using Redwood viscometer No. 1. The standard procedure was followed to collect the data for determination of viscosity. A 50 ml volume of Mahua oil was allowed to flow, from a 90 mm height though a standard capillary tube of 46.5 mm tube under its own weight and time of flow in seconds was noted.

Density: Capillary stopper relative density bottle of 50 ml capacity was used to determine the density of Mahua oil. The density of oil was calculated by the following expression:

$$\text{Density (kg/m}^3) = \frac{\text{Mass of oil (kg)}}{\text{Volume of oil, } 1 \times 10^{-3}}$$

Flash and fire point : Flash point is the temperature at which a material gives so much vapour that this vapours when mixed with air forms as ignitable mixture and gives a momentary flash on application of small point test flame. Fire point is the temperature at which the air-vapour mixture burns for at least five seconds when a test flame was introduced. Pensky-Martens apparatus was used to determine flash and fire point of Mahua oil. In this method the sample of Mahua oil was heated at slow, constant rate with centinuous stirring. A small pilot flame was directed into the cup at regular intervals with simultaneous interruption of stirring. The flash point was recorded as the lowest temperature at which application of the test flame ignited the vapour above the oil sample and fire point was recorded as the lowest temperature at which the flame burned for five seconds [11].

Cloud and pour point : The pour point to the lowest temperature expressed as a multiple of 3^0C at which the oil is observed to flow cooled and examined under prescribed conditions. The temperature at which the first wax crystals appear in oil was recorded as cloud point. Cloud and pour point of Mahua oil was determined by using cloud and pour point apparatus. In this method, Mahua oil sample was first heated at 46^0C and then cooled at specified rate and examined at interval of 3^0C for flow characteristics when kept in a pour point apparatus. Ice and common salt mixture was used as cooling agent [11, 12].

*Calorific value :*The gross calorific value of the sample was measured by using CP 500 calorimeter manufactured by Digital Date System Pvt Ltd, South Africa. The sample was filed in gelatin capsule and then it was burnt in the oxygen in bomb calorimeter. The total weight of sample and the capsule was fed to controller and the results including the gross heating value were printed. Knowing the heat and weight value of the capsule, the heat value of the sample was calculated [11, 12].

Table 2. Size, shape 1000 seed weight and oil content of Mahua seeds kernels.

Sl. No.	Length mm	Breadth mm	Thickness mm	Size mm	Sphericity	1000 seed wt g	Oil content %
1	22.34	12.26	11.24	14.55	0.65	1624	40.00
2	22.21	11.14	9.43	13.26	0.59	1590	39.00
3	21.13	10.04	10.00	12.85	0.61	1540	40.50
4	15.07	10.11	7.25	10.33	0.69	1720	41.00
5	18.32	12.26	8.35	12.33	0.67	1650	30.54
6	23.01	11.20	8.50	12.98	0.56	1550	38.00
7	22.11	12.30	9.10	13.52	0.61	1511	37.50
8	19.55	10.20	10.50	12.79	0.65	1623	35.85
9	20.67	11.30	11.01	13.70	0.66	1653	36.15
10	22.50	12.50	7.60	12.88	0.57	1644	40.00
Max	22.50	12.50	11.24	14.55	0.69	1720	41.00
Min	15.07	10.04	7.25	10.33	0.56	1511	35.85
Mean	20.69	11.36	9.30	12.91	0.63	1610.5	38.75

Results and Discussion

Properties of Mahua seed and Mahua seed kernels

Mahua seed from which kernels were obtained was ovate shaped. Matured seed selected was brownish orange and its peel was split when dried Mahua seed contains two kernels. Mahua seed consisted of 75% meat and 25% fruit peel. Mahua seed kernels were sun dried until moisture content reaching 5-7%. Different properties of Mahua seed and kernels procured from local market were determined using standard test procedures. The observations were taken and average values are tabulated in Tables 1, 2 and 3.

The mean dimensions of 10 Mahua seed and kernels within the moisture contain of 8.38% were measured and the length breadth and thickness were found to be 25.58, 13.03, 11.11 and 20.69, 11.36, 9.30 mm respectively [1]. The sphericity of Mahua seed and kernels was found to be 0.60 and 0.63 mm. The 1000 kernel mass of Mahua seed and Mahua seed kernel, were found to be 1801.6 and 1610.5 g. The oil content in Mahua seed kernels was found to be 38.75% as determined by Soxhelt apparatus. The Mahua kernel bulk density and true density were found to be 0.99 and 1.2 g/cc at moisture contain of 8.38%. Porosity was evaluated using mean values of bulk density and true density and found to be 17.5. The value of angle of repose was found 33.93 degree. This is an indication of the Mahua kernel's ability to flow in the machine while oil extraction.

Table 3. Engineering properties of Mahua seed kernels.

Properties	Replications		Mahua seed kernels
Roundness	1		0.41
	2		0.45
	3		0.41
	4		0.35
	5		0.40
		Mean	0.42
Angle of repose degree	1		36.50
	2		40.00
	3		33.00
	4		31.79
	5		28.36
		Mean	33.93
True density g/cc	1		1.20
	2		1.25
	3		1.20
	4		1.15
	5		1.20
		Mean	1.20
Bulk density g/cc	1		1.00
	2		0.98
	3		0.99
	4		0.98
	5		1.00
		Mean	0.99
Porosity %	1		16.00
	2		21.60
	3		17.50
	4		14.78
	5		16.00
		Mean	17.50
Moisture content %	1		8.60
	2		8.40
	3		8.20
	4		8.50
	5		8.20
		Mean	8.38

Table 4. Engineering properties of Mahua seed kernels oil.

Property	Replication		Mahua oil
Moisture contain, %	1		0.12
	2		0.15
	3		0.23
	4		0.21
	5		0.17
		Mean	0.17
Kinematic viscosity	1		28.58
at 45^{0}C, cSt	2		27.63
	3		24.58
	4		24.50
	5		25.55
		Mean	26.27
Density, kg/m3	1		945
	2		960
	3		915
	4		960
	5		945
		Mean	945
Flash point	1		232
^{0}C	2		238
	3		231
	4		231
	5		225
		Mean	231.4
Fire point	1		212
^{0}C	2		210
	3		220
	4		227
	5		221
		Mean	218
Cloud point	1		17
^{0}C	2		14
	3		17
	4		18
	5		15
		Mean	16.2
Pour point	1		14
^{0}C	2		15
	3		15
	4		15
	5		13
		Mean	14.4
Calorific value	1		36.61
MJ/kg	2		36.0
	3		35.65
	4		38.87
	5		35.00
		Mean	36.44

Properties of Mahua oil

The important properties of the Mahua oil i.e. moisture content, viscosity, density and combustion properties like flash point calorific value, cloud and pour point were determined and are shown in Table 4.

The color of extracted oil was greenish yellow and the moisture content in Mahua oil was found to be 0.17% which is very negligible. The viscosity of Mahua oil was recorded as 26.27 mm^2/s at 45^{0}C [3, 8], it is considered as one of the indices for fuel quality. This is an indication that Mahua oil could not be used as sole fuel in diesel engine, because high viscosity of Mahua oil may results in increased droplet size, poor atomization and poor combustion. Combustion properties of Mahua oil i.e. flash and fire point, cloud and pour point were found to be 231.4, 218, 16.2 and 14.4^{0}C respectively [3, 4]. The higher flash point of the Mahua oil makes it safe for transportation and storage. The calorific value of Mahua oil was found to be 36.44 J/kg [4]. As Mahua oil has oxygen in its molecular structure; their calorific value is lower than the diesel.

Conclusions

Based on the result obtained, Mahua seed consisted of 75% meat and 25% fruit peel. Mahua seed kernels were sun dried until moisture content reaching 5-7%. The sphericity of Mahua seed and kernels was found to be 0.60 and 0.63 mm. Porosity was evaluated using mean values of bulk density and true density and found to be 17.5. The value of angle of repose was found 33.93 degree. This is an indication of the Mahua kernel's ability to flow in the machine while oil extraction. The viscosity of Mahua oil was recorded as 26.27mm^2/s at 45^{0}C. Combustion properties of Mahua oil i.e.flash and fire point, cloud and pour point were found to be 231.4, 218, 16.2 and 14.4^{0}C respectively.

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