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Performance Test of Overhead Power Ghani and Screw Expeller Machine for Extracting Mahua (*Madhuca indica*) Seed Kernels into Crude Oil for Preparation of Biodiesel

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Abstract The performance of power ghani and screw expeller was studied and it was found that untreated kernels did not yield oil. Therefore, three treatments i.e. cold water, hot water and steaming were done to study the percentage oil recovery and it was 18.66%, 25.40% in 12 kg batch. Steaming in 30 min showed the maximum oil recovery (28.05%). Performance of screw expeller shows that oil recovery was 38% when kernels were steamed for 30 min than cold water, hot water and steaming treatment of 15 to 20 min respectively.

Keywords Power ghani, Screw expeller, Oil extraction, Mahua seed, Mahua kernels.

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Introduction

Currently due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need to develop alternative energy resources, such as biodiesel fuel. Vegetable oil is a promising alternative because it has several advantages; it is renewable, environs friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. Therefore, in recent years several research been have studied to use vegetable oils as fuel in engines as biodiesel [1, 2]. Various vegetable oils, including palm oil, soybean oil, sunflower oil, rapeseed oil and canola oil have been used to produce biodiesel fuel and lubricants. But due to paucity of edible oils in the country less expensive feedstock containing fatty acids such as inedible oils, animal fats, waste food oil and by products of the refining vegetables oils [3] could be used to reducing the biodiesel production costs. The availability and sustainability of sufficient supplies of less expensive feedstock will be a crucial determinant delivering a competitive biodiesel to the commercials filling stations. Fortunately, inedible vegetable oils, mostly produced by seed-bearing trees and shrubs can provide an alternative. With no competing food uses, this characteristics turns attention to Mahua which grows in warm and humid region for its oleaginous seeds, its flowers and its wood; producing between 20 to

Table 1. Survey results from oil extraction units.

Sl. No.	Particulars	KVIC, Gondia	Jagdamba oil mill Gondia
Part I	General information		
1	Name of industry	Khadi Gramodhyog	Jagdamba oil mill,
2	District	Gondia	Gondia
3	Name of owner	KVIC, Mumbai	Mr S. G. Agrawal
4	Total units	2	1
5	Total No of workers	2	1
6	Nature of final product	Oil & Cake	Oil & Cake
7	Availability of raw materials	Farmers	From market & Farmers
Part II	Oil extraction process schedule		
1	Types of oil Seed extracted	Groundnut, coconut, Mahua Linseed, Seasamum	Soybean, Mahua, Mustard, Linseed, Seasamum Groundnut
2	Method of cleaning of raw material	Manually	Manually
Part III	Process for oil extraction from raw materials		
1	Steaming	Manually	Manually
	i) Steaming Time required, min	30 min	30 min
	ii) Fuel used	Fuel wood	Fuel wood
	iii) Cooling time, min	15	15
	iv) Any other method	Use hot water	Use hot & cold water
2	Capacity	12 kg/batch	25 kg/h

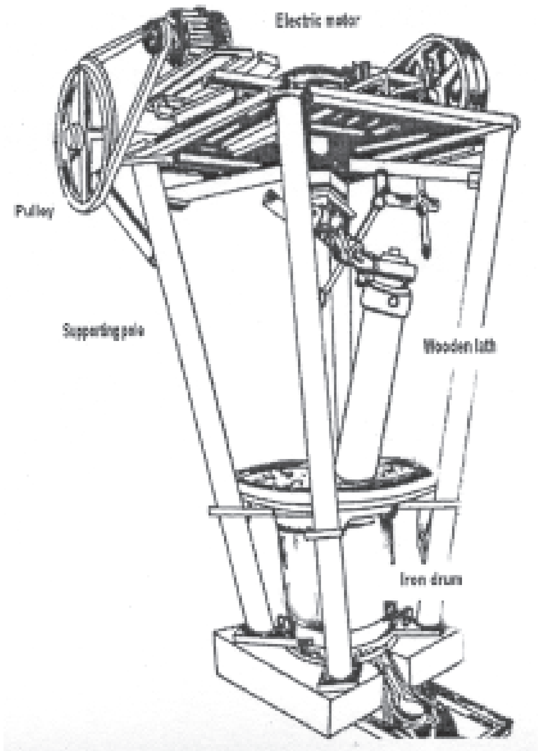

Fig. 1. Cross section of overhead power ghani.

200 kg of seeds annually per tree, depending upon maturity. The Mahua oil is experimented in automobiles as a substitute to diesel either as raw oil or in the form of methyl or ethyl esters. The unrefined oils have rarely been used as combustible in generation of thermal energy. Kernel contains 20–50% oil depending on expelled by ghani or expeller. The expelled cake is solvent extracted to recover residual oil. 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 odor and taste. Free fatty acids of oil from fresh kernels are very less (1–2%) compared to that from stored kernels (30%). Separation of oil from Mahua seed kernels is important processing operation. The process employed has a dired effect on the quality and quantity of protein and oil obtained from oilseed. Basically, two methods are solvent and mechanical oil expression. In mechanical oil expression process, the preconditioned oilseed is passed through a screw where a combination of high temperature and shear is used to crush the oilseed to release the oil. The method is relatively less efficient as it recovers only 70–80% of available oil, depending on the oilseed and pressure employed. Pretreatment and operating conditions determine the efficiency of screw press but each pass can handle much smaller quantity of oilseeds [4]. Oilseed pressing involves very low initial and operating costs compared to the solvent method of oil extraction and relatively free of any polluting or fire hazardous substances. This method is most widely used for oil expression in the developing countries. There is a need to further develop this century old method of oil expression

Table 2. Performance of overhead power ghani with mahua seed kernels.

Treatment: cold water
Location of test-Khadi Gramodhyog, Gondiya.

Test No.	Start time h	Quantity kg	Quantity of water /	Temp Water ºC	Temp Oil ºC	Rpm rpm	No. of labor	Electricity consumption unit (kW)	Oil yield kg	Cake yield kg	Temp of cake ºC	Oil recovery %	Oil recovery (total oil basis) %	End time h	Time required min
1	16.30	12.0	1.5	25.0	32	13	1	2.0	2.1	9.9	44.0	17.50	21.67	19.35	185
2	9.00	12.0	2.0	25.0	34	13	1	2.1	2.3	9.7	43.0	19.16	23.74	12.00	180
3	12.30	12.0	1.8	26.0	33	13	1	2.0	2.3	9.7	43.5	19.16	23.74	15.35	185
4	16.00	12.0	2.0	25.0	34	13	1	2.1	2.2	9.8	44.0	18.33	22.70	19.10	190
5	9.30	12.0	1.5	24.5	34	13	1	2.1	2.3	9.7	43.0	19.16	23.74	12.40	190
Average		12.0	1.76	25.1	33.4	13	1	2.06	2.24	9.76	43.5	18.66	23.12		186

through improving the oil extraction and energy efficiency of existing presses [5].

Materials and Methods

Survey of prevailing oil extraction units

A survey was conducted in and around Gondia and Akola district to identify the technology status and extraction methods adopted. Information regarding the methods of oil extraction, equipments used, its capacity, output, power consumption was collected. The details of oil extraction units selected for the study are given in Table 1.

Extraction of oil from Mahua seed kernels and pretreatments

Oil extraction from Mahua seed kernels was done with existing oil extraction machinery and methods i.e power ghani and oil expeller. The Mahua seed kernels processed in the ghani was not reduced in size prior to their crushing. Whole kernels crushing was tried and pretreatment like cold water treatment, hot water treatment and steaming were carried out to improve the recovery. The Mahua seed kernels cake obtained from ghani was taken for further determination of oil content.

The power ghani

The improved overhead power ghani in KVIC, Gondia unit was selected for the study. Figure 1 shows the cross section of improved ghani. Specifications, of KVIC power ghani are given below.

Power source : 2 hp, 3 phase electric motor, 1440 rpm, Machine rpm13
Dimesion : 1.2 m × 1.12 m × 1.50 m
Capacity : 12–15 kg seed/charge of 50 min
Percentage yield : 40–47% for groundnut, 25–33% for rapeseed/mustard, safflower 48–50% (kernel), seasamum 40–45% and coconut 60–63%
Labor requirement : One

The oil expeller

An expeller at M/s S. G. Agrawal oil mill, Gondia was selected for performance study (Fig. 2). It was consisting of a helical thread (worm assembly) which revolves concentrically within a perforated cylinder (the cage or barrel). The barrel was formed by a series of axially-placed lining bars contained within a robust frame. Oilseeds entered one end of the barrel through the feed inlet and are conveyed by the rotating worm

Table 3. Performance of overhead power ghani with mahua seed kernels.
Treatment: hot water
Location of test-Khadi Gramodhyog, Gondiya.

Test No. and Date	Start time h	Quantity kg	Quantity of water /	Temp Water °C	Temp Oil °C	Rpm rpm	No. of labor	Electricity consumption unit (kW)	Oil yield kg	Cake yield kg	Temp of cake °C	Oil recovery %	Oil recovery (total oil basis) %	End time h	Time required min
1	09.10	12.0	1.5	60	34	13	1	1.8	2.7	9.3	44.0	22.5	27.87	12.00	170
2	12.30	12.0	1.7	70	35	13	1	2.0	2.0	9.0	44.5	25.0	30.96	16.30	180
3	16.00	12.0	1.7	65	35	13	1	2.0	2.9	9.1	44.0	24.16	29.93	18.55	175
4	10.00	12.0	1.8	70	34	13	1	1.9	3.0	9.0	45.0	25.0	30.96	13.00	180
5	13.30	12.0	1.6	65	35	13	1	2.0	3.1	8.9	44.0	25.83	32.00	16.25	175
Average		12.0	1.66	66	34.6	13	1	1.94	2.94	9.06	44.3	25.40	30.34		176

assembly to the discharge end. Three type of pre-treatments i.e. cold water treatment, hot water treatment and steaming were carried out on Mahua seed kernels prior to their crushing to improve the oil recovery. Specifications of the expeller are given below.

Power source	: 15 hp, 3 phase electric motor, 970 rpm, machine rpm 30
Dimensions	: 1.2 m × 1.12 m × 1.50 m
Capacity	: 25 kg seed/charge of 60 min, continuous feeding type
Screw type	: Single screw
Labor requirement	: One

Preparations before operating oil expeller

Before operating oil expeller, 6–8% of water was mixed with dry oil cake and then it was fed into the hopper. Feeding was done slow at first then gradually speed up. Mean while, water was added properly. Care was taken not to feed over dried cake or too quick the feeding [3].

Observations

During the study following observations were recorded during extraction of oil with power ghani and oil expeller.

1. Quantity of seed kernels used per batch/pass for crushing, kg
2. Time duration, h
3. Cold/hot water temperature, °C
4. Quantity of hot water added, ml
5. Man-h required, h
6. Electric energy consumption, kWh
7. Capacity of ghani/expeller, kg/h
8. Quantity of oil recovered, kg
9. Quantity of cake received, kg
10. Temperature of cake, °C

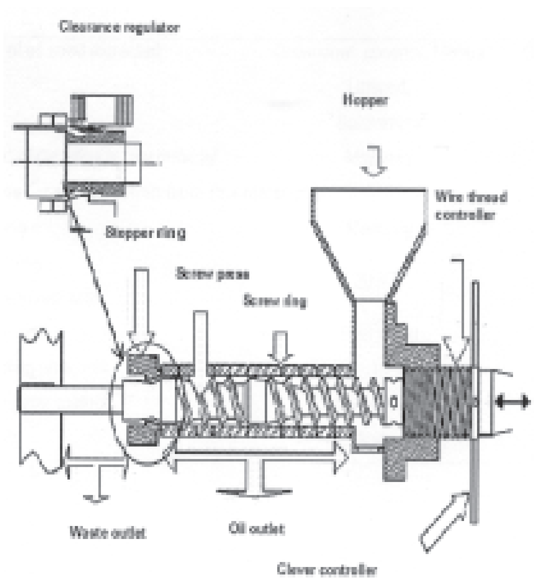

Fig. 2. Cross section of screw type oil expeller.

Table 4. Performance of overhead power ghani with mahua seed kernels.

Treatment: steaming
Location of test-Khadi Gramodhyog, Gondiya.

Test No.	Stea-ming	Start time	Quan-tity	Temp of oil	rpm	No. of labor	Electri-city consum-ption unit	Oil yield	Cake yield	Temp of cake	Oil reco-very	Oil reco-very (total oil basis)	End time	Time requi-red
	Min	h	kg	^{o}C	Rpm		(kW)	kg	kg	^{o}C	%	%	h	min
1	15	09.00	12.0	36.0	13	1	1.80	2.9	9.1	45	24.16	29.93	11.40	160
2	20	12.00	12.0	35.0	13	1	1.60	3.1	8.9	46	25.83	32.00	14.45	165
3	30	15.00	12.0	35.5	13	1	1.50	3.3	8.7	45.5	27.50	34.06	17.20	140
4	30	09.00	12.0	36.0	13	1	1.45	3.4	8.6	46	28.33	35.09	11.15	135
5	30	12.15	12.0	35.5	13	1	1.51	3.4	8.6	45	28.33	35.09	14.20	125
Average			12.0	35.6	13	1	1.48	3.56	8.76	45.5	28.05	34.75		133.3

Results and Discussion

Performance of overhead power ghani for extracting Mahua seed kernels into oil

At KVIC, Gondia there are two improved power oil ghanis Table 2. A ghani is made up of babul wood (*Acacia nilotica*). It consists of iron drums, wooden fotcher, wooden lath and 2 hp three phase electric motor. Revolution of this motor has reduced from 1440 to 13 rpm. The capacity of hopper is 12 kg. The ghani is fitted in concrete mortar. The floor area occupied for these two improved ghanis was 8.0 sqm.

In the first stage untreated whole kernels were tried for extraction of oil. But it was found that untreated kernels did not yield oil. Hence kernels were treated with cold water, hot water and steam . In cold water treatment 2 / water at room temperature (24–26^{o}C) was applied in 12 kg Mahua seed. The percentage oil recovery was found to be 18.66% from Mahua seed containing 38% oil content. The total oil in 12 kg batch was recovered in 3.10 h and the electricity consumption was found to be 2.06 kW (Fig 3).

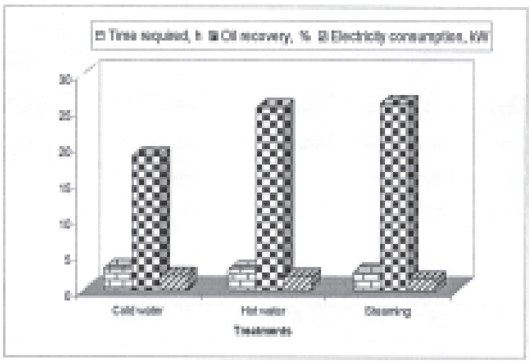

Fig. 3. Performance of overhead power ghani for extracting mahua seed kernels into crude oil.

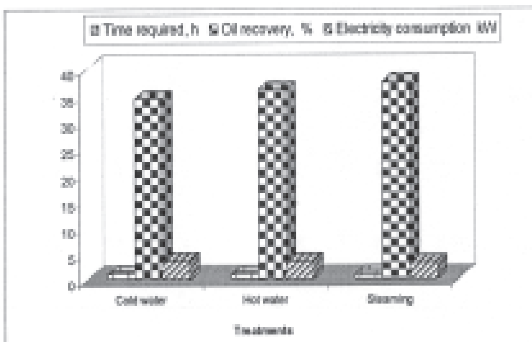

Fig. 4. Performance of screw expeller for extracting mahua seed kernels into crude oil.

Table 5. Performance of screw expeller with mahua seed kernels.

Treatment: cold water
Location of test-Jagdamba oil mill, Gondiya.

Test No.	Start time	Quantity	No. of passes	Quantity of water	Temp Water	Temp Oil	rpm	No. of labor	Electricity consumption units	Oil yield	Cake yield	Temp of cake	Oil recovery	Oil recovery (total oil basis)	End time	Time required
	h	Kg		/	°C	°C	Rpm		kW	kg	kg	°C	%	%	h	min
1	11:00	25.0	I	2.0	25	36.0	30	1	3.5	4.3					12:10	70
			II							3.5						
			III							0.7						
									Total	8.5	16.5	58	34.0	87.74		
2	12:30	25.0	I	1.8	26	36.5	30	1	3.7	4.4					13:35	65
			II							3.4						
			III							0.8						
									Total	8.6	16.4	58	34.4	88.75		
3	14:00	25.0	I	1.9	26	35.0	30	1	3.5	4.3					15:00	60
			II							3.5						
			III							0.9						
									Total	8.7	16.3	57	34.8	89.80		
4	13:05	25.0	I	2.0	25	35.5	30	1	3.6	4.4					14:00	55
			II							3.5						
			III							0.6						
									Total	8.5	16.5	57.5	34.0	87.74		
5	14:15	25.0	I	2.0	26	37.0	30	1	3.6	4.5					15:15	60
			II							3.6						
			III							0.6						
									Total	8.7	16.3	58	34.8	89.80		
Average		25		1.94	25.6	36.0	30	1	3.58	8.6	16.4	57.7	34.4	88.76		62

During hot water treatment Mahua seed kernels were mixed with 1.5 to 2 / of hot water at temperature (60–70°C) and the total oil recovery was found to be 25.40% with electricity consumption of 1.94 kW (Table 3). It showed that the oil recovery was increased than cold water treatment and electricity consumption was also found less. Time required for extracting 12 kg kernels was 2.93 h when seed kernels treated with hot water.

Steaming was done in three stages i.e. 15, 20 and 30 min shown in Table 4. It is seen that the maximum oil recovery at 30 min of steaming was found to be 28.05%. At 15 min and 20 min oil recovery was recorded 24.16 and 25.83% respectively. The electricity consumption was less at 30 min seed treatment i.e. 1.48 kW and at 15 and 20 min treatment were 1.8 and 1.6 kW per batch of 12 kg of Mahua seed kernels respectively. It is clearly seen that the oil recovery increased when the Mahua seed kernels were treated with steam than cold water and hot water. Also electricity consumption was less in comparison to cold and hot water treatments. Time required to extract 12 kg kernels with steam treatment of 30 min, 20 and 15 min was found to be 2.22 h, 2.75 and 2.66 h respectively.

Performance of screw oil expeller for extracting mahua seed kernels into crude oil

Performance of 25 kg hopper capacity screw oil expeller in Jagdamba oil mill, Gondia, was studied. Initially

Table 6. Performance of screw expeller with mahua seed kernels.

Treatment: hot water
Location of test-Jagdamba oil mill, Gondiya.

Test No.	Start time	Quantity	No. of passes	Quantity of water	Temp Water	Temp Oil	Rpm	No. of labor	Electricity consumption unit	Oil yield	Cake yield	Temp of cake	Oil recovery	Oil recovery (total oil basis)	End time	Time required
	h	Kg		/	°C	°C	rpm		kW	kg	kg	°C	%	%	h	min
1	10:00	25.0	I	2.0	70	37.0	30	1	3.50	4.8					11:00	60
			II							3.7						
			III							0.5						
									Total	9.0	16.00	56.0	36.0	92.90		
2	11:15	25.0	I	2.0	65.5	38.0	30	1	3.45	4.7					12:10	55
			II							3.5						
			III							0.7						
									Total	8.9	16.10	56.5	35.6	91.87		
3	12:30	25.0	I	1.9	70	36.0	30	1	3.40	4.5					13:20	50
			II							4.0						
			III							0.6						
									Total	9.1	15.90	57.0	36.4	93.93		
4	14:00	25.0	I	1.9	65	37.5	30	1	3.50	4.7					15:00	60
			II							3.5						
			III							0.8						
									Total	9.0	16.00	57.0	36.0	92.90		
5	15.30	25.0	I	2.0	70	36.5	30	1	3.45	4.5					16:25	55
			II							3.9						
			III							0.7						
									Total	9.1	15.90	56.0	36.4	93.93		
Average		25.0		1.96	68.1	37	30	1	3.46	9.02	15.98	56.5	36.08	93.11		56

untreated whole kernels were tried but it did not yield any oil. It was observed that the screw expeller was blocked during the operation. Hence kernels were treated with cold water, hot water and steaming treatment for judging the performance. In cold water treatment 2 / water at room temperature (25–26°C) was applied in 25 kg Mahua seed shown in Table 5. The percentage oil recovery was found to be 34% from Mahua seed containing 38.75% oil content and time required was 1.03 h. The electricity consumption was found to be 3.58 kW.

During hot water treatment 25 kg Mahua seed kernels were mixed with 2 / of hot water (60–70°C) and the total oil recovery was found to be 36.08% in 0.93 h with electricity consumption of 3.46 kW Table 6. It showed that the oil recovery was increased than cold water treatment and electricity consumption was also found less (Fig. 4).

Steaming was done in three stages i.e. 15, 20 and 30 min shown in Table 7. It is seen that the maximum oil recovery at 30 min of steaming was found to be 38%. At 15 min and 20 min oil recovery was recorded 36.8 and 37.6 % respectively. The electrical energy consumption was less at 30 min seed treatment i.e. 3.06 kW and at 15 and 20 min treatment were 3.2 and 3.1 kW per batch of 25 kg of Mahua seed kernels respectively. It is clearly seen that the oil recovery increased when the Mahua seed kernels were treated with steam than cold water and hot water. Also electric energy consumption was found less in comparison to cold and hot water treatments. Time required to extract 25 kg kernels with steam treatment of 30, 20

Table 7. Performance of screw expeller with mahua seed kernels.

Treatment: steaming
Location of test-Jagdamba oil mill, Gondiya.

Test No.	Staming	Start time	Quantity	No. of passes	Temp of oil	Rpm	No. of labor	Electricity consumption unit	Oil yield	Cake yield	Temp of cake	Oil recovery	Oil recovery (total oil basis)	End time	Time required
	min	h	kg		°C	rpm		(kW)	kg	kg	°C	%	%	h	min
1	15	12:45	25.0	1	38.0	30	1	3.2	5					01:50	65
				II					3.3						
				III					0.9						
								Total	9.2	15.8	58	36.8	94.96		
2	20	14:10	25.0	I	38.5	30	1	3.1	5.2					15:10	60
				II					3.4						
				III					0.8						
								Total	9.4	15.6	59	37.6	97.03		
3	30	15:30	25.0	I	39.0	30	1	3.1	5.3					16:25	55
				II					3.2						
				III					1						
								Total	9.5	15.5	59.5	38.0	98.37		
4	30	17:00	25.0	I	38.0	30	1	3.0	5					17:50	50
				II					3.5						
				III					1						
								Total	9.5	15.5	58	38.0	98.37		
5	30	18:15	25.0	I	39.0	30	1	3.0	4.9					19.05	50
				II					3.6						
				III					1						
								Total	9.5	15.5	59	38	98.37		
Average			25.0		38.5	30	1	3.06	9.42	15.58	58.7	37.68	98.37	56	51.66

and 15 min was found to be 0.86, 1.0 and 1.08 h respectively.

Conclusion

Based on the performance study, in first stage untreated whole kernels were tried for extraction of oil. But it was found that untreated kernels did not yield oil. The total oil in 12 kg batch was recovered in 3.10 h and the electricity consumption was found to be 2.06 kW. Steaming was done in three stages i.e. 15, 20 and 30 min and maximum oil recovery at 30 min of steaming was found to be 28.05%. The percentage oil recovery was found to be 34.4% from Mahua seed containing 38.75% oil content and time required was 1.03 h. The electricity consumption was found to be 3.58 kW. It is clearly seen that the oil recovery increased when the Mahua seed kernels were treated with steam than cold water and hot water. Also electric energy consumption was found less in comparison to cold and hot water treatments. Time required to extract 25 kg kernels with steam treatment of 30, 20 and 15 min was found to be 0.86, 1.0 and 1.08 h respectively.

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