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Optimization of Mechanical Oil Extraction of Jatropha Seeds from Oil Expeller

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ABSTRACT

A study was carried out to optimize the moisture content of Jatropha seeds expelling through a mechanical expeller. A MERADO developed, 1 TPD mustard oil expeller was used for expelling of whole Jatropha seeds. Moisture levels were started from 14 percent with a step size of 3 percent and continued up to the last increment in oil recovery. Oil recovery, specific power consumption and expeller throughput were taken into consideration for observation. Oil recovery was found maximum 21.1 percent at 23 % moisture content and 21.7 percent at 20 % moisture content for hot water sprinkling. However, the expeller efficiencies on these moisture levels were only 57.96 and 59.6 percent. Residual oil in the cake was minimum 15.8 and 15.2 percent in accordance with maximum oil recovery for cold and hot water sprinkling, respectively. Specific power consumption was found minimum at 20 % moisture content for both the treatments. The throughput of the expeller was observed maximum (6.15 kg/h) up to 17 % moisture content and having no remarkable difference among them for both the treatments.

KEYWORDS

Oil recovery, Power consumption, Through-put, Expeller Efficiency.

INTRODUCTION

Jatropha (*Jatropha curcas* L.) is used for various purposes like erosion control, living fence, source of firewood, etc. The bark of *Jatropha curcas* L. is rich in tannin and used for the production of dye. Leaves have been used for the rearing of silkworm and in medicine as an anti-inflammatory substance (Openshaw, 2000; Basha *et al.*, 2009). Seed is used for making insecticide, soap and varnish. Seed cakes are used as fertilizer as well as a solid fuel or in the production of biogas. Due to the depletion of fossil fuels and the greenhouse effect, the application as biofuel is probably the most interesting from both economical and ecological points of views (Beerens, 2007).

One of the most promising renewable and independent energy sources in rural areas is Jatropha oil (Kumar and Sharma, 2008 and Makkar and Becker, 2009). It is non-edible oil. Thus, it will not impair food security issues (Pinzi *et al.*, 2009). As it grows well on dry marginal non-agricultural land, it will not compete with land needed for food production or with nature conservation (Achten *et al.*, 2007; Makkar and Becker, 2009; Pinzi *et al.*, 2009). Jatropha is considered a more sustainable feedstock for energy production than any other food-related crop such as palm, rapeseed, soybean or sunflower (Pinzi *et al.*, 2009).

The physical, mechanical and chemical properties as well as the potential use of extracted oil from J. *curcas* as transesterified oil, or as a blend with diesel has been widely studied (Augustus *et al.*, 2002; Pramanik, 2003; Narayana and Ramesh, 2006; Karaj and Müller, 2010). The calorific value and cetane number of J. *curcas* oil are similar to diesel, but the density and viscosity are much higher (Namasivayam *et al.*, 2007). Various methods for recovering oil from seeds have been investigated (Lim *et al.*, 2010; Qian *et al.*, 2010). The mechanical oil extraction of J. *curcas* was reported as suboptimal due to lack of knowledge about the best operation parameters (Shah *et al.*, 2005). Openshaw (2000) has reported the use of sunflower seed mechanical screw presses for extracting J. *curcas* seed oil as unsuitable due to technical problems and low oil recovery. Beerens (2007) has reported results from using two mechanical screw presses: a mechanical cylinder press (BT50) and a strainer press (Sayyar *et al.*, 2009). Maximum oil recovery was reported to be 79% for BT50 screw press and 87% for Sayyar strainer press after dual passing.

Seed conditioning processes, i.e. grading, drying, cleaning, and further moisture addition, before mechanical oil extraction from the oilseeds, have been found useful for better oil expelling. Among all the parameters, moisture is the most effective parameter for the expelling. Decreasing the moisture content from 7.8 to 2.3 percent was found to increase the proportion of oil extracted from 31.4 to 49.6 percent. The effect of moisture level on extraction efficiency may be related to the mucilage development in the outer epidermal cells. Addition of water results in swelling of mucilage, which in turn may produce a cushioning effect leading to reduced rupturing of the seed coat and internal tissue. The cumulative impact of all these results in the hurdled flow of oil from cotyledon tissue.

Concerning the optimization of oil extraction efficiency, neither the influence of different settings of the screw press nor the resulting dependent factors were reported in other studies. Therefore, this study was aiming to analyze different

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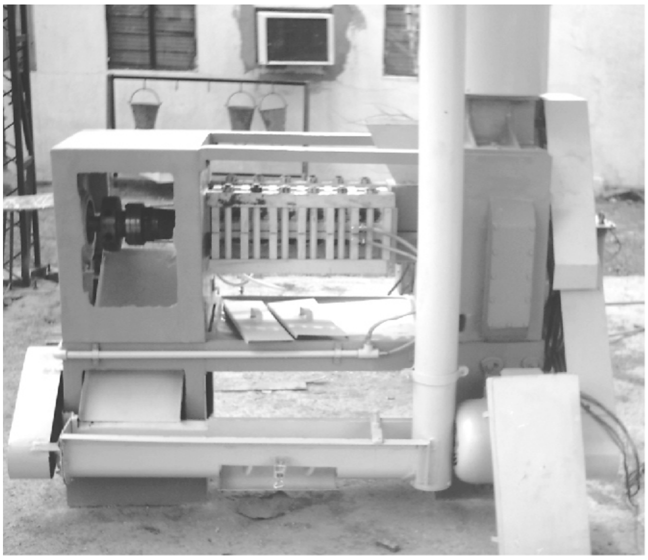
designed variables such as screw press, press cylinder, nozzle size and rotational speed to optimize the mechanical oil extraction of J. *curcas* seeds by increasing the efficiency of oil recovery with a mechanical cylinder screw press.

MATERIALS AND METHOD

Experiments were conducted at Mechanical Engineering Research and Development Organisation (MERADO), Ludhiana on a 1 TPD (Tonne Per Day) mustard oil expeller (Fig. 1) developed by MERADO. The expeller was electric motor driven (5 hp) having a water-cooled extraction chamber. The conditioning of the expeller was done on 2-3 kg seeds before each experiment. The seeds (Fig. 2) were of commercial-grade having 10 percent overall impurities. The impurities included seeds of other crops, crop residues and some debris. The initial moisture content of seed was 7 percent and around 36 percent oil content. The seed contained approximately 42 percent kernel. The physical analysis of the seed is given in Table 1.



(a) Front View

(b) Isometric View

Fig. 1: Commercial oil expeller

Fig. 2: Jatropha seeds

Table 1: Physical properties of Jatropha seed

Parameter	Seed	Kernel	Hull
Dimensions, cm			
a. Length	1.778	-	-
b. Width	1.108	-	-
c. Thickness	0.861	-	-
Geometric mean diameter, cm	1.192	-	-
Sphericity	0.670	-	-
Moisture content, % (wb)	7.286	7.054	7.517
Oil content, % (dry weight basis)	36.496	61.189	-
Angle of repose, degree	18.849	19.158	-
Angle of internal friction, degree	23.015	25.041	-
Bulk density, g/cc	0.407	0.412	-
True density, g/cc	0.669	0.673	-
Porosity, %	39.197	38.725	-
1000 grain weight, g	581.364	402.400	-

Treatments and observations

Water was sprinkled to increase the moisture content of seeds. The sprinkling of hot and cold water was done on whole Jatropha seeds (10 kg) in an open tray and left for approximately 5 minutes. For hot water sprinkling, the water temperature was more than 80 ^{0}C. The initial moisture level was decided to take 14 percent. The calculated amount of water was mixed in seed to increase moisture content in the step of 3 percent (wb) until a decrease in oil recovery was observed. Oil recovery, cake temperature, cake thickness, residual oil content in cake, the initial temperature of seed after treatment, time requirement, and seed and cake moisture content were observed. Measurement and calculation procedure for each parameter is described below:

The moisture content of seed and cake was determined according to IS: 3579–1966 and was calculated by the formula

$$\text{Moisture, \% (w/w)} = \frac{100\,w}{W} \quad \text{......... (1)}$$

Where,

w = loss in weight in g of the material upon drying, and
W = weight in g of the material taken for the test.

Oil recovery during the expelling of samples was measured by collecting oil output in the tray. Oil recovery percentage was calculated based on total material fed into the hopper.

Oil content of seed and cake samples were measured by using Gerhart make Soxtherm works on the principle of solvent extraction using the standard technique. Following relation was used to calculate oil content

$$RO = \frac{w}{w_2 - u_1} \times 100 \qquad ....(2)$$

where,

RO = residual oil content, g/cc

w = weight of oil, g

w_2 = final weight of flask with sample, g

w_1 = initial weight of flask, g

The power requirement was measured by a power meter that directly gives the power consumption in kW. The least count of the power meter was 0.01, with a maximum capacity of 9999.99 kW without tare. It was fitted to the control panel of the expeller. Power readings were noted down at the start and end of each pass.

A screw gauge was used to measure cake thickness having the least count of 0.01 mm for the first 5.0 centimetres. When the operating condition was normalized, the pass samples of the cake were taken from the outlet and measured.

RESULTS AND DISCUSSION

Available Jatropha seeds were found to have 36.4 percent (db) oil content and 7 percent moisture content. Additional water required to be added is given in Table 2. During experiments, key parameter was oil recovery. Expected moisture content, observed moisture content and cake thickness of final pressing are given in Table 3.

Table 2: Additional amount water requirement for different moisture levels

Expected moisture content, % (wb)	Water to be added (g)
10	340
14	820
17	1210
20	1630
23	2080
26	2570

Table 3: Expected moisture content, observed moisture content and cake thickness

Expected moisture content, %	14	17	20	23	26	14	17	20	23
Observed moisture content, %	13.67	16.50	20.50	23.17	25.67	14.17	17.00	20.17	23.00
Cake thickness, mm	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5

Oil recovery

In water sprinkling experiments oil recovery was 14.18, 14.90, 17.86, 21.10 and 18.67 percent and 15.52, 16.21, 21.70 and 17.16 percent on 14, 17, 20, 23 and 26 percent moisture content with cold and hot water, respectively. It is clear from Fig. 3 that the highest recovery for cold and hot water sprinkling is 21.10 and 21.70 percent at 23 and 20 percent moisture content (wb), respectively.

The expeller efficiency was only 57.96 and 59.61 percent with cold and hot water sprinkling, respectively. The oil recovery at low moisture content may be due to insufficient moisture in the meal, which leads to rapid compaction. Higher oil recovery with hot water sprinkling than cold water sprinkling may be due to better moisture penetration in the thick woody seed coat. The second pass was challenging to operate with higher moisture content due to the improper machine running, further leading to the higher duration of the operation. Opposite trends were found for the residual oil in finally pressed oil cake. This was found to be 15.8 and 15.2 percent for cold and hot water sprinkling, respectively.

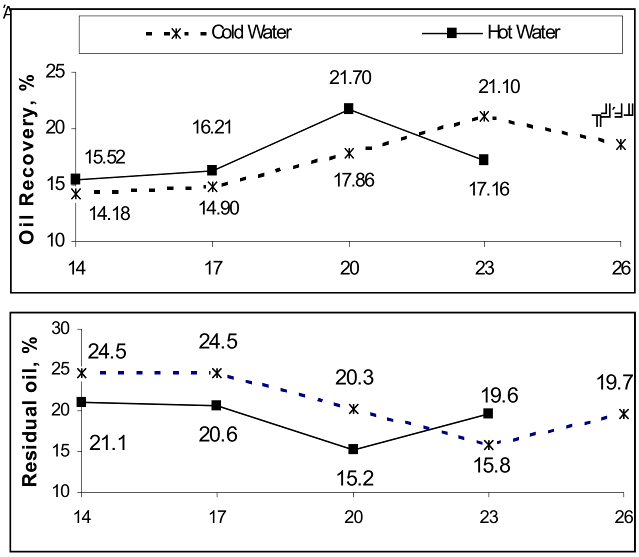


Fig. 3: Oil recovery and residual oil power consumption, residual oil and machine capacity for different experiments on Jatropha oil expelling

Specific power consumption

The values of power consumption were taken for a seed sample of 10 kg and converted into the specific power consumption of Jatropha seed as shown in Fig 4. Minimum values of specific power consumption were found as 0.22 and 0.20 kW/kg for cold and hot water sprinkling. Coldwater sprinkling was found to be 1.19 percent increased power-consuming than hot water sprinkling. In Fig. 4 increasing values of power consumption towards the ends of the graph showing abnormal machine operation due to loss or excess moisture content because moisture plays a vital role in the grip of the worm and cage on the material and material compressibility, which further adds to the oil recovery and machine throughput.

Throughput

The original throughput of the machine was around 40 kg/h

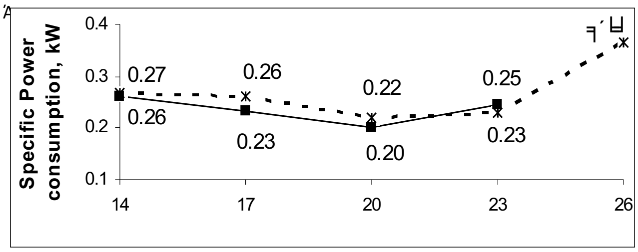


Fig. 4: Oil recovery and residual oil power consumption, residual oil and machine capacity for different experiments on Jatropha oil expelling

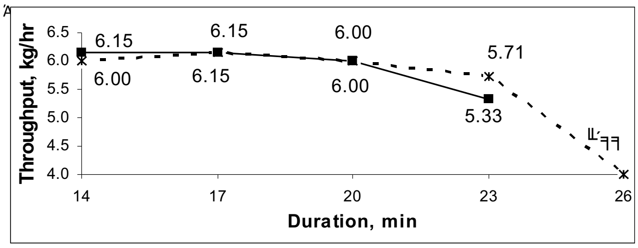


Fig. 5: Machine throughput capacity for different experiments on Jatropha oil expelling

(1tonne per day). Operated with Jatropha the throughput of the expeller was found to be drastically reduced (Fig. 5). For the cold water sprinkling maximum and minimum throughput was found as 6.15 kg/h and 4.0 kg/h at 17 and 26 percent moisture content, respectively. But, for hot water sprinkling, it was maximum from 14–17 percent moisture content and minimum at 23 percent moisture content. The extrapolation of the graph for hot water sprinkling may show the value of throughput at 26 percent moisture content, which, obviously be much less than the value observed for cold water sprinkling. From the throughput point of view, moisture content from 14 to 20 percent is better and no further increment in moisture is advisable. However, the maximum throughput with cold and hot water sprinkling is only 15 percent of the original expeller throughput. With an increase in moisture content reducing throughput may be due to the reduction of worm grip on the material inside.

CONCLUSION

It may be concluded that oil recovery of Jatropha seeds by increasing moisture content increases up to 21.10 percent for cold water sprinkling at 23 % moisture content and up to 21.70 percent for hot water sprinkling at 20 % moisture content. Expeller efficiency was found 57.96 and 59.61 percent with cold and hot water sprinkling. Residual oil in the final cake was found minimum 15.8 and 15.2 percent for cold and hot water sprinkling, respectively. The trend of the residual oil was exactly the reverse of oil recovery. Specific power consumption was found minimum as 0.22 and 0.20 kW/kg at 20 percent moisture content for both cold and hot water sprinkling. An increase and decrease in moisture content than 20 percent resulted in increased specific power consumption. Maximum power consumption was found for cold water sprinkling at 23 percent moisture content. Throughput for both cold and hot water sprinkling was almost the same up to moisture level of 20 percent and after that, it drastically decreased. Maximum throughput was observed at 14-17 percent moisture content for hot water sprinkling and 14 percent for cold water sprinkling.

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