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Optimization of mechanical extraction of *Jatropha curcas* seeds

Reduction of world fossil fuel reserves and increase of CO_2 emissions are calling for appropriate alternative fuels. In this context, vegetable oils show several advantages – they are renewable, environmental friendly and are produced easily in rural areas. In the recent years systematic efforts have been made by several research groups for using vegetable oils as fuel in engines. Jatropha curcas is such a plant which might be used as alternative fuel and since it is a non-edible vegetable oil it is not in direct competition with food supply.

Keywords

Expeller, mechanical press, oil extraction, *Jatropha curcas*

Abstract

Landtechnik 64 (2009), no. 3, pp. 164 - 167, 3 figures, 4 tables, 12 references

Fig. 1

Jatropha curcas fruits and seeds

Jatropha curcas L. is a drought-resistant shrub/tree belonging to the family Euphorbiaceae [1, 2]. Cultivated in Central and South America, Jatropha was distributed by Portuguese seafarers in Southeast Asia, India and Africa [3]. Propagated by cuttings, is widely planted as a hedge to protect fields from browsing animals. The plant and its seeds are non edible (toxic) to animal and humans; toxicity of seeds is mainly due to the presence of curcine and deterpine [2, 4].

The distribution of Jatropha shows that its introduction has been most successful in drier regions of the tropics. It grows on well-drained soils with good aeration and is well adapted to marginal soils with low nutrient content [2].

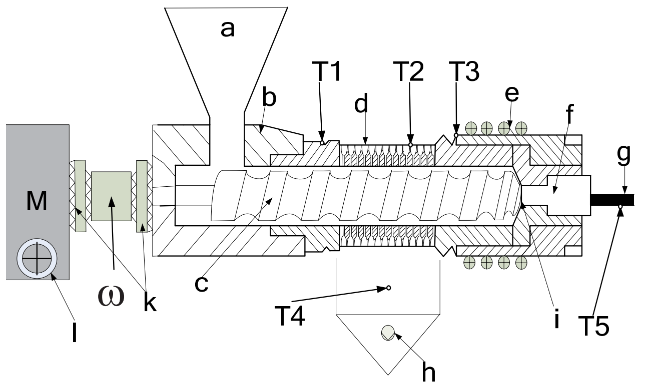
Jatropha can be utilized for different purposes, it can be used for erosion control, recreation, fire wood, grown as a live fence; the bark is rich in tannin and produces a dark blue dye. Leaves have been used for rearing of silkworm, in dyeing and in medicine as anti-inflammatory substance. Seeds have been used as insecticide, soap, and varnish production. Seed cakes have been used as fertilizer, solid fuel, or in biogas production. Non toxic varieties or detoxified press cake has been used as fodder for animal [1, 5]. Despite all various purposes, the application as fuel is probably the most interesting one for both economical and ecological point of view [6].

Four basic methods for extracting vegetable oils from seeds, nuts and fruits have been progressed [8]. The first method was the basic wet process in which the oil-bearing material was boiled in water leading to a partial separation of oil, which was skimmed. The second was the cage-type press in which pressure was put on a stationary mass by levers, screw jacks or hydraulic cylinders and the vegetable oil flowed from the compressed mass to collecting rings below. Both these methods are more or less out of date. The third method is the mechanical screw press and the fourth is solvent extraction [6, 8].

Mechanical pressing and solvent extraction are the most commonly used methods for commercial oil extraction. Screw pressing is used for oil recovery up to 90-95 %, while solvent extraction is capable of extracting 99 % [6, 9].

The potential use of extracted oil from Jatropha as transesterified oil (biodiesel), or as a blend with diesel have been studied [1, 10-12]. The calorific value and cetane number of Jatropha oil are similar to diesel, but the density and viscosity are much higher [13]. In small scale oil pressing units, undesirable residues from plant materials are found in the crude oil. These impurities lead to depositions during combustion in stoves or engines and reduce lifetime and service intervals significantly. Consequently, the contamination of the crude oil by these

Fig. 2



Mechanical screw press for oil extraction and installed sensor, (a) feeding hopper, (b) housing, (c) screw press, (d) oil outlet holes, (e) heating, (f) nozzle, (g) press cake outlet, (i) cohesion zone, (h) oil collector, (k) coupling, (l) speed alternator, (M) motor, (T1-T5) temperature sensors, (T5) temperature sensor (IR), (ω) rotational speed

unwanted impurities should be avoided during production. The objective of this study was:

- optimization of oil-pressing with respect to oil quality
- generating a standard for Jatropha oil for the use in plant oil stoves
- developing process steps for cleaning Jatropha crude oil.

Material and Method

For this study, dried Jatropha seeds (mc 9 % db) were imported from India. The place of seed's origin was characterized by an annual precipitation of 1000-1200 mm and a temperature range of 15-35 °C. Jatropha plantation was 11-12 years old and its yields were 7500 kg/ha/a. Seeds were harvested manually during November-December 2007 (harvest season) and stored in jute bags in a warehouse facility in temperature range of 14-30 °C. Jatropha seeds were cleaned with a pneumatic air/sieve separator to remove impurities and then stored on ambient temperature.

The experiments were carried out with mechanical screw press (German screw press type - Komet D85-1G), maximal capacity of material input was 25 kg/h and the screw press was powered by a 3.0 kW electrical motor (**figure 2**).

The screw press was modified and different sensors were installed for measuring parameters such as oil recovery, temperature and rotational velocity (rpm). The temperature was measured on five positions (T1-T5) as demonstrated in **figure 2**. Oil extraction was weighted after each experiment at oil collection point. Screw speed was adjusted between 0 and 600 rpm by a variable speed alternator. The screw size and nozzle size were not varying in these experiments (**figure 3** and **table 1**). The effect of the independent variables such as screw speed and press cylinder on oil recovery was compared. The variable tested parameter were the rotational speed (ω) and press cylinder hole size (P_1 and P_1.5), see **table 2**.

There were used 10 kg Jatropha seeds for each experiment. After pressing a sample from the press cake was analyzed on oil content with Soxhlet extraction according to DGF standards [15]. The raw oil recovered was taken for further analyses. Kinematic viscosity and total contamination were analysed using German Standard protocols (DIN). The sensors data were collected with a data acquisition unit (hp 34970A) and then transferred for further statistical analyses with OriginLab-8 software.

Results

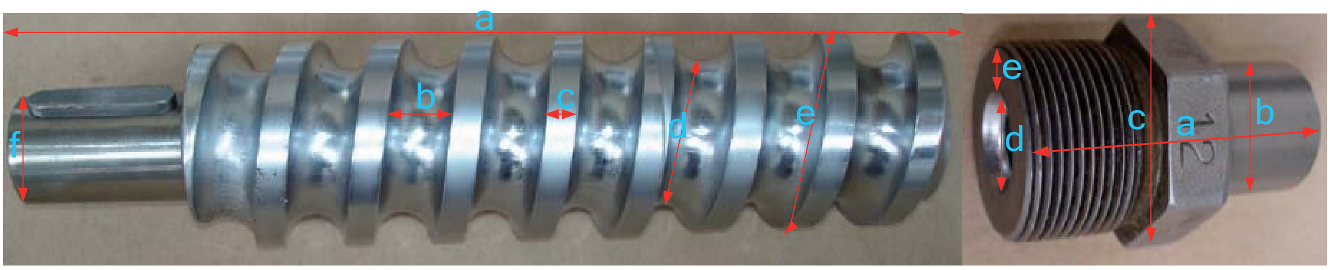
Properties of Jatropha's oil extraction. Table 3 shows the temperature generated during the pressing process on five different positions while varying the rotational speed and press cylinder holes. The rotational speed was increased from 220 rpm to 365 rpm, on experiment $P\_1\,\omega_{220}$ to $P\_1\,\omega_{365}$ and from 230 rpm to 365 rpm on experiments $P\_1.5\,\omega_{230}$ to

Tab. 1

Screw press and nozzle size dimensions

Mechanical screw press	Size dimensions (mm)	Nozzle	Size dimensions (mm)
Length (a)	253	Length (a)	50
Choke between worm shaft (b)	16	Outlet diameter (b)	19
Worm shaft (c)	8	Nozzle diameter (c)	32
Choke ring (d)	41	Compression size (d)	12
Worm shaft diameter (e)	56	Nozzle wall (e)	9
Axial worm (f)	30		

Fig. 3



Screw press and nozzle size dimensions, see table 1

P_1.5 ω_{365}. The temperatures at the starting point (T1) were increased with the increase of the rotational speed for both press cylinders (P_1 and P_1.5). The press cylinder with 1 mm holes was generating more temperature than the press cylinder with 1.5 mm holes. This was because the friction on the press cylinder with 1 mm holes was higher as results of higher restriction. The temperatures at oil outlet (T2) were increased with the increase of rotational speed. The press cylinder with 1.5 mm holes was showing higher temperature than the press cylinder with 1 mm holes. At compression zone (T3) was recorded the higher temperature generated in the screw press (see also **figure 2**).

Influences on oil temperature. The temperatures were increased with the increase of the rotational speed on the experiments P_1.5 ω_{230}, P_1.5 ω_{295} and P_1.5 ω_{365}. The experiments P_1 ω_{220}, P_1 ω_{260} and P_1 ω_{365} were showing first an increase of the temperature and then a decrease. Oil temperatures (T4) on the oil collector (**figure 2**) were increased with the increase of rotational speed for both press cylinders (P_1 and P_1.5). The highest temperatures were recorded on experiment P_1.5 ω_{295} and P_1.5 ω_{365}, respectively 85.8 °C and 97.2 °C. It was noticed that the standard deviation of oil temperatures sensor was high. This was due to sensor positioning to ambient temperatures. The highest press cake temperatures (T5) were recorded on experiment P_1 ω 260 and P_1.5 ω_{295} respectively 106.1 °C and 87.9 °C. According **table 4** the highest oil recovery was recorded at experiment P_1.5 ω_{230} with 3.2 kg oil per 10 kg of pressed seeds. With the increase of rotational speed on the press cylinder with holes P = 1 mm from level ω = 220 rpm to level ω = 365 rpm the time for pressing 10 kg of Jatropha seeds were decreased from 156 min to 90 min. The oil recovery was decreased from 3.2 kg/10 kg seeds to 3.1 kg/10 kg seeds and the oil content in press cake was increased from 7.85 % to 9.26 % oil content. The increase of rotational speed on the press cylinder P = 1.5 mm from level ω = 230 rpm to level ω = 365 rpm the time necessary for pressing 10 kg seeds were decreased, respectively 147 min to 95 min. On the other side oil recovery was decreased and the oil content in press cake was increased from 7.96 % to 8.92 % oil content.

The results show that kinematic viscosity is decreasing with the increase of rotational speed for both press cylinders (P_1.5 mm and P_1 mm), see **table 4**. The highest kinematic viscosity was recorded on the experiment P_1.5 ω_{230} (84.20 mm²/s) and the lowest on experiment P_1 ω_{365} (42.20 mm²/s). Total pollution is of high importance because the presence of larger particles in the oil could cause deterioration of the engines and plug filters. The highest value of total pollution was recorded on experiment P_1 ω_{220} and the lowest on experiment P_1 ω_{365}. This indicates that total pollution might be optimized by using different parameters on the screw press.

Tab. 2

Variable tested parameters

Nr.	Experiment name	Press cylinder hole size (mm)	ω rotational speed min^{-1}
1	P_1 ω_{220}	1	220
2	P_1 ω_{260}	1	260
3	P_1 ω_{365}	1	365
4	P_1.5 ω_{230}	1.5	230
5	P_1.5 ω_{295}	1.5	295
6	P_1.5 ω_{365}	1.5	365

Conclusion

The optimization of oil-pressing with respect to oil quality for direct use in plant oil stoves as combustion fuel was analyzed, following conclusion were determined. Temperature behaviour on the screw press strictly depends on the rotational speed of the screw press and press cylinder restriction size. Oil recovery depends on the rotational speed of screw press (rpm) and the size of the press cylinder holes. The chemical properties of Jatropha oil are varying with the change of pressing setups (rotational speed, press cylinder). The optimum operation of the mechanical press could be indentified by analyzing the time, oil recovery, oil content on press cake and chemical properties such as; kinematic viscosity and total pollution. The recommended operation is the following setup: (P_1 ω_{260}), press cylinder holes P = 1 mm and rotational speed 260 rpm. Further studies have to improve the oil quality according to international standards.

Tab. 3

Verlocity and temperature behaviour at different points on the screw press

Experiment name	T1 Start point (°C)	T2 Oil outlet (°C)	T3 Compression zone (°C)	T4 Oil recovery point (°C)	T5 Press cake (°C)
P_1 ω_{220}	50.8 ±1.0	80.6 ±0.9	106.5 ±0.9	77.3 ±6.9	83.3 ±2.0
P_1 ω_{260}	51.9 ±3.5	80.2 ±2.2	115.7 ±0.7	81.0 ±5.8	106.1 ±2.3
P_1 ω_{365}	54.1 ±0.7	82.9 ±0.7	108.8 ±0.8	81.8 ±6.1	84.6 ±3.9
P_1,5 ω_{230}	48.4 ±0.9	83.8 ±0.5	108.8 ±0.5	72.0 ±6.2	73.1 ±9.2
P_1,5 ω_{295}	51.6 ±0.6	86.2 ±0.9	111.1 ±0.9	85.8 ±4.3	87.9 ±3.1
P_1,5 ω_{365}	53.7 ±0.6	87.6 ±0.9	111.4 ±0.5	97.2 ±8.5	85.0 ±7.3

Tab. 4

Oil pressing experiment from jatropha seeds (9 % moisture content)

Experiment Name	Time (min)	Oil recovered (kg)	Press cake (kg)	Oil content in press cake (%)	Kinematic viscosity (mm^2/s 20 °C)	Total Pollution (mg/kg)
P_1 ω_{220}	156	3.2	6.58	7.85	82.4 ±0.06	2999 ±5.2
P_1 ω_{260}	130	3.1	6.66	7.95	47.8 ±0.10	411.6 ±4.0
P_1 ω_{365}	90	3.1	6.56	9.26	42.2 ±0.00	401.6 ±1.5
P_1.5 ω_{230}	147	3.2	6.56	7.96	84.2 ±0.10	540.0 ±2.0
P_1.5 ω_{295}	115	3.2	6.52	8.33	47.9 ±0.10	655.3 ±12.0
P_1.5 ω_{365}	95	3.2	6.58	8.92	42.8 ±0.00	1344 ±10.8

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