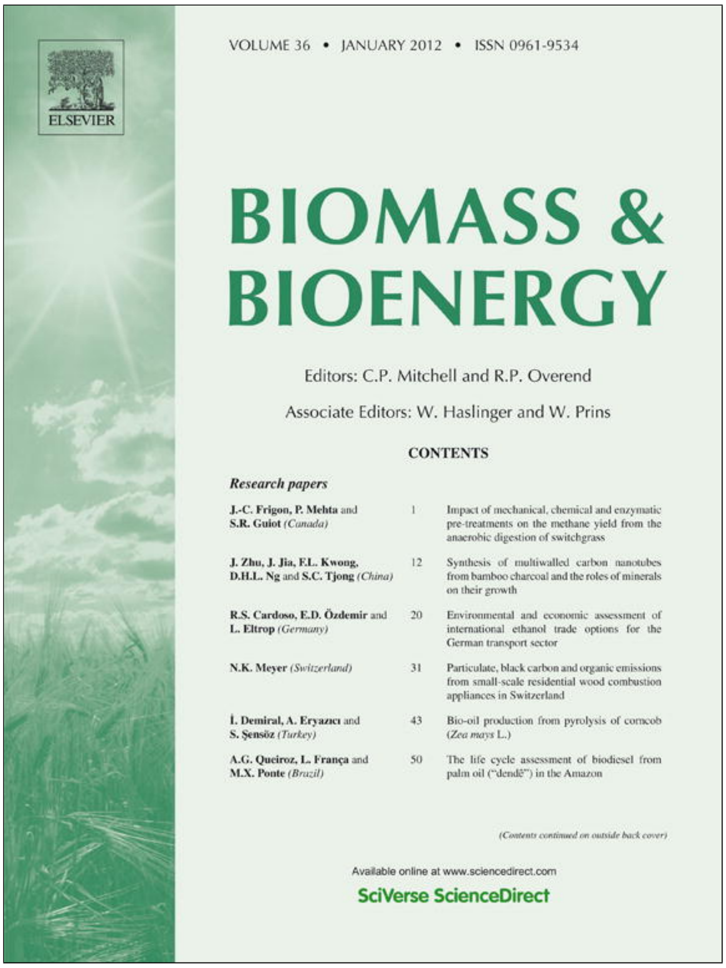

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Yield and physicochemical properties of mechanically extracted crude *Jatropha curcas* L oil

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ABSTRACT

Knowledge on physical properties and their dependence on moisture content of *Jatropha curcas* L seeds are essential to improve the design of equipment for harvesting, processing and storage of the seeds. The objective of this experiment is to find the effect of mechanical extraction method to the physicochemical properties of the extracted oil. The result is expected to be valuable as basic data for designing the equipments and process related to the extraction of oil from the seed of Jatropha. The oil extraction was performed using a specially designed laboratory scale mechanical extractor, and the yield was calibrated with soxhlet apparatus using hexane as the solvent to obtain its extraction efficiency. The experiment was conducted in factorial arrangement, with four types of sample (seeds, kernel, crushed seeds, and crushed kernel), four extraction temperature (ambient, 50 °C, 60 °C and 80 °C), and three preheating time (600 s, 1200 s, and 2400 s), and analyzed with Duncan Multiple Range Test (DMRT). The results show that crushing the kernel of Jatropha before extracting the oil mechanically will give higher oil yield and higher extraction efficiency. Higher temperature and longer preheating time also increase the oil yield. However, the maximum applicable temperature for mechanical extraction is 60 °C, since the viscosity and free fatty acid content of the extracted oil will increase if the extraction temperature increased above the temperature.

1. Introduction

The inedible nature of *Jatropha curcas* L oil without detoxification is one of its attractive points to be used as alternative source of energy or fuel. Jatropha is a multipurpose bush/small tree belonging to the family of Euphorbiaceae, but now thrives in many parts of the tropics and sub-tropics in Asia and Africa. Extracted oil from Jatropha seed can be used as feedstock for biodiesel production by transesterification process, or used directly either for low rotation diesel engine or for direct burning [1]. In either way of utilization, the yield and properties of the extracted oil are very important, and needs to be well understood. Oil extraction from Jatropha seed using aqueous enzyme with best operational condition was reported to give maximum oil yield of 74% [2]. Proper extraction in terms of equipment design and procedures is inevitable to obtain the high quality of the Jatropha seed oil. Another study concluded that the key determinant to the development of Jatropha is the costs of soap production and efficiency with which oil is extracted from the seeds for

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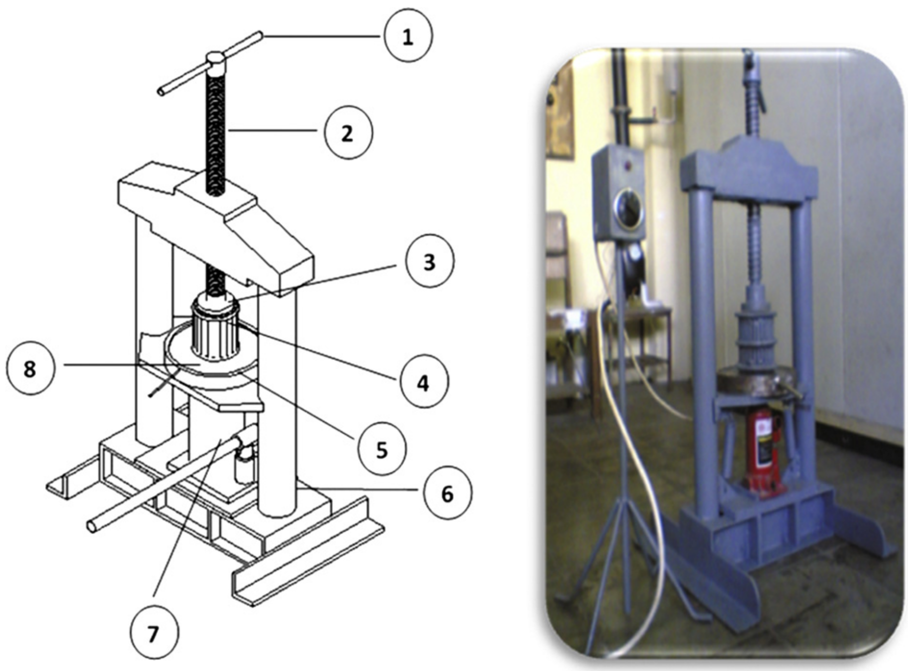

Fig. 1 – Experimental expeller for mechanical extraction of Jatropha oil (1: steering handle; 2: driving screw; 3: pressing disk; 4: pressing chamber; 5: bearing; 6: frame; 7: hydraulic jack; 8: thermostat).

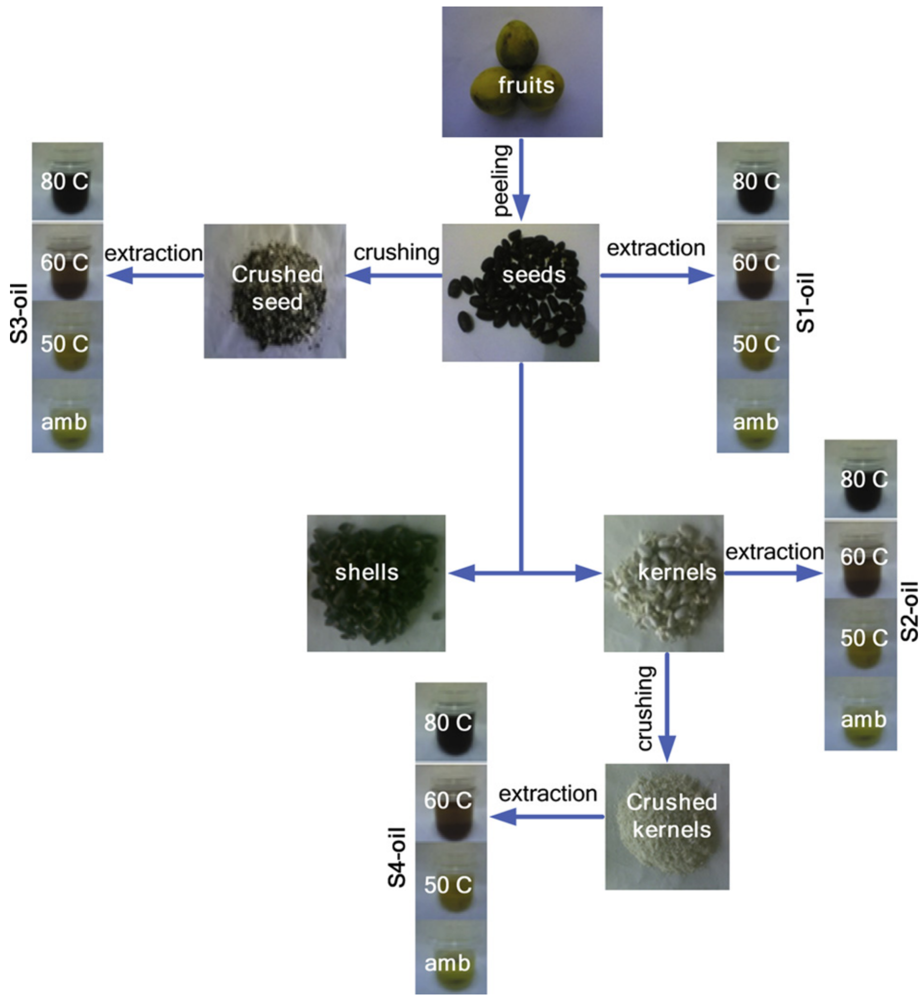

Fig. 2 – Schematic diagram of the experimental treatment.

Table 1 – Effect of sample condition, extraction temperature, and preheating time to oil yield and extraction efficiency.

Treatments	Oil yield (% mass fraction)	Extraction efficiency (%)
Type of samples		
1. Seeds	20.5[d]	55.6[c]
2. *kernel*	36.1[c]	72.0[b]
3. Crushed seeds	25.5[b]	69.1[b]
4. Crushed kernel	41.2[a]	82.3[a]
Significance	*	*
Temperatures (°C)		
1. ambient	22.3[c]	49.5[c]
2. 50	30.8[b]	70.2[b]
3. 60	34.6[a]	78.4[a]
4. 80	35.6[a]	80.9[a]
Significance	*	
Preheating time (s)		
1. 600	28.7[c]	65.2[c]
2. 1200	30.5[b]	69.2[b]
3. 2400	33.2[a]	74.8[a]
Significance	*	
Interaction		
Samples vs. temperatures	*	*
Samples vs. preheating	*	*
Temperatures vs. preheating	*	*
Samples vs. temperatures vs. preheating	NS	NS

*Significant at $P \leq 0.05$.
Mean for each treatments followed by the same letter (a, b, c and d) at the same columns are significantly different at $p \leq 0.05$ with *Duncan Multiple Range Test (DMRT)*.

biodiesel production [3]. That conclusion was derived after an evaluation on multipurpose oil seed from Jatropha. It is clear that knowledge of physical properties of the seed and their dependence on its processing condition is essential to improve the design of equipment for extracting the oil from the seeds with optimum quantity and quality.

Many researchers had studied the characteristics and composition of seed oil from Jatropha. Those studies range from measurement of various physical and mechanical characteristic of Jatropha seed [4], moisture content of the seed [5], density, kinematic viscosity, and crushing strength of the fruit and seed [6,7], to the drying and pretreatment for oil extraction from the seed [8]. Those studies indicated that the processing conditions resulted in different oil yield, oleic acid content, acid value and viscosity. Major fatty acids in the seed oil were oleic acid, linoleic acid, palmitic acid and the stearic acid, which constitutes of 21.6% saturated, 45.4% mono unsaturated and 33.0% polyunsaturated fatty acids [9]. They reported that free fatty acid content of Jatropha seed oil they used for their experiment was 2.23% ± 0.02%. Various ways of oil extraction from the seed was also explored in order to obtain the highest yield of the extraction process, such as using ultrasonication and aqueous enzyme [10]. However, those experiments have not yet considering the proper condition of the seeds during mechanical extraction of the crude oil and the condition required for the mechanical extraction process.

The objective of this experiment is to find the effect of mechanical extraction method to the yield and psycho-chemical properties of the extracted oil. The result is expected to be valuable as basic data for designing the

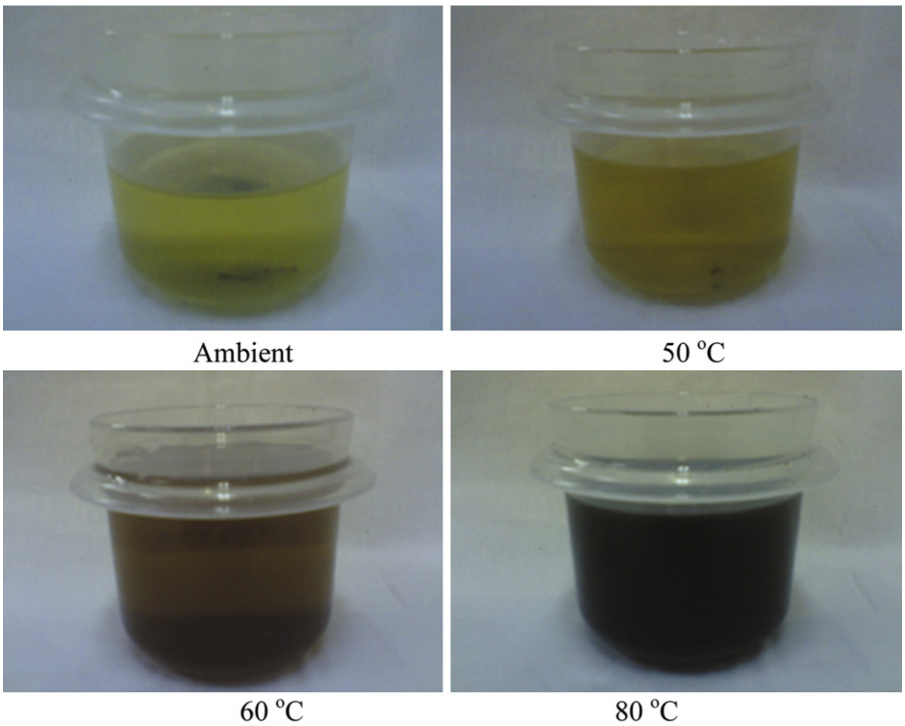

Fig. 3 – Effect of extraction temperature to the color of the extracted oil by mechanical extraction.

equipments and process related to the extraction of Jatropha seed oil.

2. Material and methods

Wet Jatropha fruits were obtained from local farmer in Malingping, Banten District of Indonesia, with geographic coordinate of 6° 7′ 12″ S; 106° 9′ 1″ E. The seeds were hand-picked and grouped into 8 level of maturity according to its skin color. Seed with maturity level 4, which was at the age of 41 days after date of bloom, was used for the mechanical extraction in this experiment and to evaluate the physicochemical properties of the extracted oil. Preliminary study [11] showed that this level of maturity has the highest oil content compared to other maturity level. The seed was sun dried to a final mass fraction water content of arround 6% and stored at room temperature before used as sample for the experiments. The crude oil was extracted from the seeds using a laboratory scale mechanical extractor (Fig. 1) and compared to the chemical extraction, using the soxhlet technique (hexane solvent), for calibration in terms of extraction efficiency.

The experiment was conducted in factorial arrangement (Fig. 2), with four types of sample (seeds, kernel, crushed seeds, and crushed kernel), four extraction temperatures (ambient, 50 °C, 60 °C and 80 °C), and three preheating time (600 s, 1200 s, and 2400 s). Preheating time is the duration of the sample kept at the required temperature, i.e. the extraction temperature, before it was pressed for the oil extraction. Extraction temperature is the temperature of the seed during extraction by heating the pressing disk using a spiral type electric heater. A thermostat was used to control the seed temperature constant at the predetermined level during the preheating and extraction process, and thermocouples were used to measure the temperature.

Data obtained from the experiment was the extraction yield and the physicochemical properties of the oil, i.e. viscosity, calorific value, and free fatty acid content. Color of the extracted oil was measured with Tintometer Model F, pipette Mohr. Viscosity of the extracted oil was measured with kinematic viscosity meter (model VT-01 RION Co. Ltd.) at room temperature. Calorific value of the oil was measured using Adiabatic Bomb Calorimeter (OSK) and Beckman thermometers. Free fatty acid content was analyzed with AOAC Official Method 940.28.

Table 2 – The effect of preheating time and extraction temperature to the color of extracted Jatropha oil.

Type of sample	Preheating time (s)	Extraction Temp. (°C)	Lovibond scale	
			Red	Yellow
Seed	600	50	0.0	0.9
		60	0.0	0.6
	1200	50	3.0	8.8
		60	10.8	30.0
Crushed seed	600	50	0.5	6.0
		60	1.0	5.0
	1200	50	2.0	8.5
		60	3.1	20.0

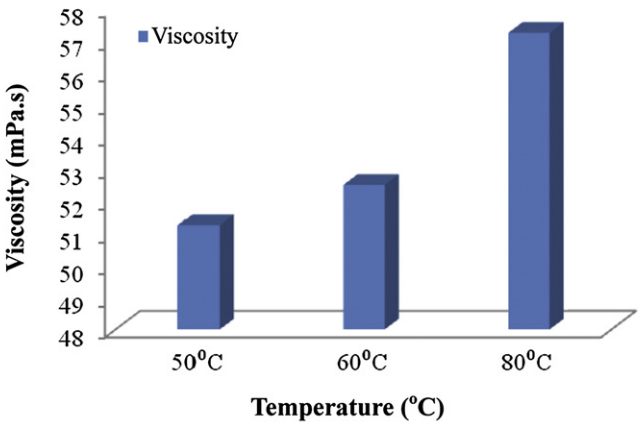

Fig. 4 – Effect of extraction temperatures to oil viscosity by mechanical extraction.

3. Results and discussion

3.1. Oil yield and extraction efficiency

The results of Duncan Multiple Range Test (DMRT) analysis on the experimental data is shown in Table 1. The results showed that the sample condition (seed, kernel, crushed seed and crushed kernel), extraction temperature, and preheating time, respectively gave significant effect to the oil yield. Oil yield is the percentage of extracted oil out of the sample weight. Higher oil yield from crushed samples (either seed or kernel) could be due to the larger sample's surface area, which facilitate easier way for the oil to come out of the solid sample, while also providing more uniform temperature throughout the samples. Higher extraction temperature and longer preheating time also give higher oil yield, even though the oil yield increment at higher temperature was smaller.

The experimental results also showed that extraction efficiency, which represents the mass ratio of extractable oil by the mechanical method to the one by soxhlet apparatus, was significantly affected only by the sample's condition. The result indicates that crushing the seed before applying the mechanical pressing can extract more than 80% mass fraction

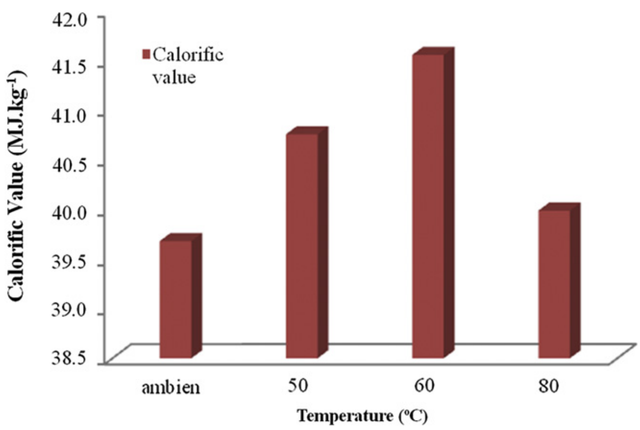

Fig. 5 – Effect of extraction temperatures to the calorific value of Jatropha oil by mechanical extraction.

Table 3 – The effect of preheating time and extraction temperature to the mass fraction FFA content of the extracted Jatropha oil.

Type of sample	Preheating time (min)	Extraction temperature (°C)	Mass fraction FFA content (%)
Seed	10	50	0.4
		60	0.7
	20	50	0.7
		60	1.1
Crushed seed	10	50	0.4
		60	0.6
	20	50	0.8
		60	1.1

of the extractable oil by soxhlet method. Soxhlet method could be regarded as the most ideal extraction method since it can extract 95%–98% mass fraction of the available oil in the Jatropha seed [1]. Extraction temperature gave no significant effect to the extraction efficiency; however increasing the temperature from ambient to 50 °C can increase the efficiency from 49.5% to 70.2%. Interaction between two out of three parameters was significant, but interaction among all of the three parameters was not significant at $p \leq 0.05$ by the DMRT.

4. Effect of extraction temperature to the physicochemical properties

While giving a significant effect to the oil yield, the extraction temperature shows impact also to the oil quality. Fig. 3 shows the change of color of the extracted oil as affected by the extraction temperature. Extraction temperature can affect the chemical characteristic of the extracted oil by hydrolysis and oxidation, which will influence its physicochemical properties. The Lovibond scale depicted in Table 2 shows that crushing the seed before extraction, longer preheating time and higher extracting temperature yields in darker color of the extracted oil. The darker color of the oil extracted at higher temperature is supposed to be caused by oxidation during the extraction process.

The effect of extraction temperatures to the oil viscosity is shown in Fig. 4. The oil viscosity is higher if extracted at higher temperature. The abrupt change of the viscosity was especially occurred if the extraction temperature was above 60 °C. Other researcher found that pretreatment of the Jatropha kernel by drying at 80 °C air temperature before extraction gives higher oil yield but with relatively the same viscosity [8].

A specific phenomenon was observed in the calorific value of the extracted oil (Fig. 5). Increasing the extraction temperature up to 60 °C resulted in the increase of calorific value. However, calorific value of the oil decreased when the extraction temperature elevated to 80 °C, which need further study to investigate whether the decrease due temperature induced property changes in the oil or simply an experimental error. Accordingly, this study indicated that maximum temperature applicable for mechanical extraction of Jatropha oil is 60 °C, in order to maintain the quality of the extracted oil.

The effect of sample type (seed and crushed seed), preheating time, and extraction temperature to the free fatty acid (FFA) content of the crude jatropha oil is shown in Table 3. The FFA content was in the range of 0.4%–1.1%. The table shows that higher extraction temperature with longer preheating time at the predetermined temperature clearly gave ways to the higher FFA content, even though type of the sample (seed or crushed seed) gave no significant effect to the FFA content. Higher FFA content of the Jatropha oil extracted at higher temperature and longer preheating time is in line with the color change as describe above, and regarded as related to physicochemical changes due to hydrolysis and oxidation induced by the temperature during the preheating and extraction period.

Furthermore, the effect of maturity of the Jatropha fruits to the FFA content and yield is shown in Fig. 6. Even though fruit's maturity clearly affected the extraction yield, it gave no influence to the FFA content. Accordingly, this study indicates

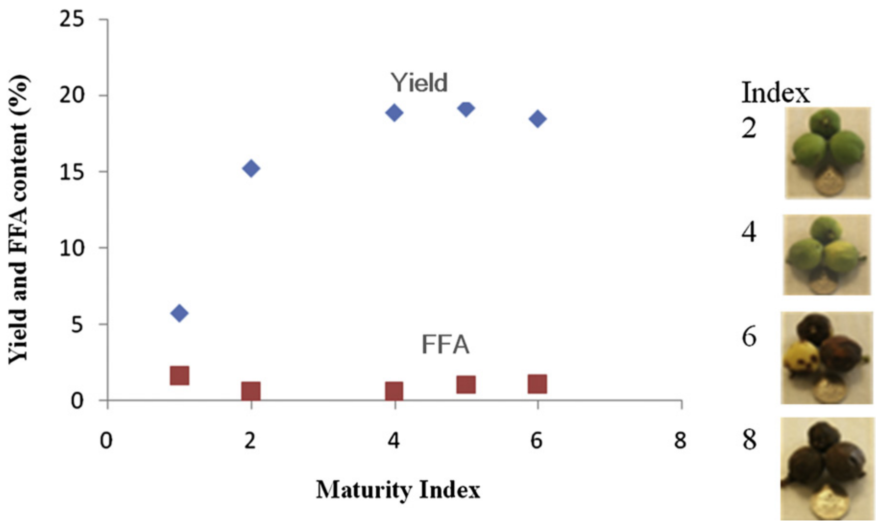

Fig. 6 – The effect of maturity level of Jatropha fruits (at mass fraction water content > 40%) to the oil yield and mass fraction of free fatty acid content.

that FFA content of Jatropha crude oil more affected by the processing than by the maturity of the fruits.

5. Conclusion

The experiment shows that crushing the kernel of Jatropha before extracting the oil mechanically will give higher oil yield and higher extraction efficiency. Higher temperature and longer preheating time also increase the oil yield. This study indicated that the maximum applicable temperature for mechanical extraction of Jatropha oil is 60 °C. Increasing the extraction temperature will result in increasing free fatty acid value.

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