Effects of the Revolution Speed on Yield of Crude Jatropha Oil from the Jatropha Squeezing Machine

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Abstract

The performance of jatropha squeezing machine was evaluated at National Agricultural Machinery Center (NAMC), Kasetsart University, Kamphaeng Saen Campus, Thailand during 2011-2012. This model of jatropha squeezing machine was designed and fabricated by National Metal and Materials Technology Center (MTEC), Thailand. The trial was conducted using three revolution speeds at 13.3, 20 and 30 rpm, respectively. Dried jatropha seed samples have been prepared with 10 kg of each with three replications. Significant variables of the experiment were discussed. The performance of the squeezing machine has been proved to be unsatisfactory done at high revolution speed, resulted in high oil content left in jatropha seedcake. On the other hand, the capacity of the machine increased under high revolution speed due to the typical design of the squeezing machine, and the significant variable of this specific experiment.

Key words: evaluation, jatropha, screw, squeezing machine and performance

Introduction

In general, biomass can be used as raw materials for food, feed, chemicals, materials, and energy which is now substantially used in biomass power plants in Thailand. Biofuel utilization is expected to be a beneficial effect on the environment, economy, and society. Besides, reducing the use of fossil fuels and the emission from their combustion, biofuel production should enable a village to supply its own energy needs and provide local energy security, while at the same time creating job opportunities for the villagers. In Thailand, several food crops e.g. palm oil, sugar cane, and cassava, have been used as energy crops. However, the use of food crops to produce biofuels can cause problems due to the possible competition between the productions of food versus fuel. To overcome this circumstance, the potential of biofuel production from non-edible crops, especially Jatropha (Jatropha curcas L.) has been investigated.

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Jatropha curcas L. is a perennial plant belonging to Euphorbiaceae family and gaining more attention for biodiesel production. This plant can be grown in low to high annual rainfall either in the farms as a commercial crop or on the boundaries as a hedge. In addition, jatropha seed meal that can serve as a highly nutritious and economic protein supplement in animal feeds after detoxification process from (Kumar and Sharma, 2008). However, Makkar et at., 1997 found that jatropha kernel meal from non-toxic Mexico varieties had as good protein quality as those from toxic varieties and thus could be a potential source of oil for biodiesel and good quality protein for livestock. To extract oil from jatropha seed, mechanical approach is generally practiced.

Mechanical pressing includes different types such as hydraulic press, squeezing machine and rolling press. These methods for oil extraction are preferable in terms of safety feature and environmental friendly. Squeezing machine can be subdivided into two main types, namely the ‘strainer press’ and the ‘cylinder-hole press’. They differ mainly in screw geometry, oil outlet and press cake restriction. For the strainer press type the screw rotates in a cage lined with hardened steel bars, resembling a strainer. Spacers placed between the steel bars allow the oil outlet as the pressure on the feed material increases. The gaps between the bars form an adjustable oil outlet, allowing the pressure to be optimized for different input materials. With the cylinder-hole press, the oil is pushed out through holes drilled in the cylinder tube. Increasing pressure forces the press cake through a circular nozzle at the end of the cylinder. In order to avoid blocking of the press, the area around the nozzle (press head) is usually preheated before operation which decreases the viscosity of the paste inside the press. When squeeze the rapeseed, the temperature of the oil should not increase above 40°C that might lead to high phosphor content in the extruded oil. High phosphor content is an undesirable fuel property as it can cause deposits and clogging in the engines. To prevent the oil from reaching 40°C, the temperature near the die, which is the location where the maximum temperature occurs, should be in the range of maximum temperature at 60 to 80°C. On the other hand, the cake outlet temperature is too low and the solid content in the oil becomes unacceptable (Ferchau, 2000).

Some researchers have reported that the parameters used before and during operation will affect oil squeezing process. They are heating time, heating temperature, moisture content, particle size and applied pressure (Ajibola et al., 2000; Olayanju et al., 2006; Mwithiga and Moriasi, 2007). The purpose of this specific study is to examine the effect of the revolution speed of the jatropha squeezing machine on the production of crude jatropha oil yield and the temperature in the squeezing house. The results from this study can be used for further modification of this specific jatropha squeezing machine.

Materials and methods

Raw material

The samples of jatropha seeds (Fig.1) were sieved to remove dust, stone and other foreign matters. The samples were then kept in plastic bags and stored at room temperature until processing. Each plastic bag contained 10 kg of jatropha seeds. Before testing, samples of jatropha seeds were analyzed for oil and moisture content as shown in Table 1 in the laboratory.

Table 1. Oil and moisture contents of Jatropaha seeds

Properties	Method	Results (%)
Total fat and oil (g/100g%wt)	Acid hydrolysis, Petroleum either extraction	28.63
Moisture content (%d.b.)	Grinding and oven dried at 103±1°C	7.67

Figure.1 Dried jatropha seeds before removal of foreign matters

Oil extraction procedure

Physical treatment of squeezing machine with combination of the revolution speed

The squeezing machine used in this study was carefully fabricated by National Metal and Materials Technology Center (MTEC) and Thai Machinery Association, Thailand. The machine was designed to have specific cold pressing system with a single conveyor screw to squeeze the oil from jatropha seeds Fig. 2(a). The machine operates with a very gentle mechanical press that does not involve in mixing and tearing the seeds. The diameter of the shaft screw is 70 mm with one stage compression as shown in Fig. 2(b).

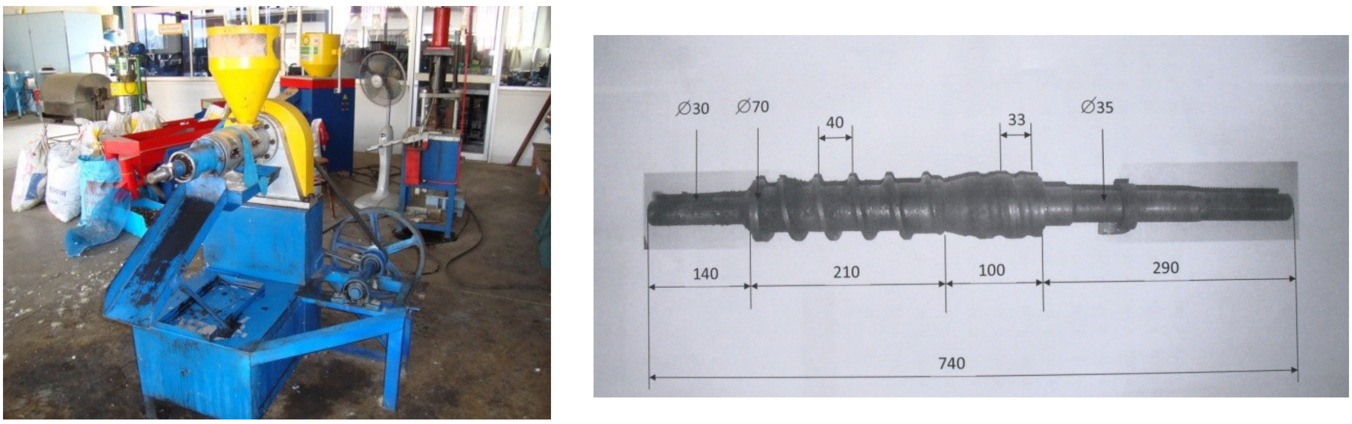
Each combined treatment from jatropha seeds was filled into seed hopper and pressed by the machine with the revolution speeds of 13.3, 20 and 30 rpm with three replications. The extracted oil was placed in dark glass bottles and stored away from light in chiller (4°C) to allow settle down of the foreign matter. After 48 hours, the oil was filtered to remove the fine particles and weighed to calculate percentage of the average oil yield using the following formula:

$$\text{Average oil yield} = m_o / m_s \times 100 \quad (1)$$

Where: mo is the average weight of oil extracted, ms is the average weight of the sample.

Oil extraction experiment at different revolution speeds

The combinations of parameters used to pro-



(a) (b)

Figure 2. Squeezing machine in tested; (a) jatropha squeezing machine, (b) designed of shaft screw

duce optimum oil yield from the jatropha squeezing machine has been obtained. The samples were then extracted using the combinations of the revolution speed at 13.3, 20 and 30 rpm with three replications. A digital data logger (YOKOKAWA DC 100) with four rods type T thermocouple was used to measure the temperature along the press head. A thermocouple was placed into the small bowl to measure the extracted oil temperature after the operation of the machine. The revolution speed of the shaft screw was adjusted by using the variable low speed mortar. Speed revolution meter (ONOSOKI) was used to monitor the revolution speed of the machine in this specific experiment. Then, jatropha seeds of each replication were fed into the hopper for evaluating the squeezing machine as presented in Fig. 3. The efficiency of the jatropha squeezing machine can be described as the relationship between the speed revolution and the production of crude jatropha oil. The relationship formula can be described as follow:

$$Y = AX2 + BX + C \qquad (2)$$

Where Y is the percentage amount of crude jatropha oil; X is the revolution speed and A, B, C are the constant values.

The measurement of the temperature inside the squeezing house seemed to be very important in further development by using applied heating temperature. The increasing in temperature can be described as a function of the operating time. The prediction equation between both parameters can be expressed as follow:

$$y = ax + b \qquad (3)$$

Where y is the average temperature inside the squeezing house; x is the operating time; a and b are the constant values

(a) (b)

Figure. 3 Experiment of the machine: (a) installation of the thermocouple, (b) machine in operation

RESULTS AND DISCUSION

Oil extraction experiment at different revolution speeds

Upon extraction of the oil, the seedcakes were determined for kept total fat and oil as shown in Table 2. The results of oil yield, oil in cake and the extraction efficiency were evaluated and presented in Fig. 4.

The results from Fig.4 showed that the extraction efficiency of the squeezing machine decreased when the significant variables of the revolution speed of the machine increased. The average oil in cake was increased when increasing the revolution speed, while lower revolution speed produced more crude jatropha oil.

These results indicated that under lower speed revolution, the duration of the expression allowed the oil to flow easily through the slit along the barrel of the machine. This result was supported by Singh et al., 1990 who stated that the oil contained inside the cells of oilseed in different places together with other components such as protein, globoids and nucleus would come out in the form of oil globules after being compressed by the shaft screw and nozzle under high pressure to break the cell wall. Khan and Hanna (1983) stated that during the operation, the pressure breaks cell wall of the seed and release mores oil. According to Singh and Bagale (2000), the diameter of the shaft screw also involved in the compression for the production of oil yield, while the pitch, helix angle of the screw and barrel diameter were kept constant. Significant variables that influenced of the production of the oil yield include the diameter of shaft screw, nozzle size, and revolution speed of the squeezing machine.

Harmanto et al., 2009, found that using the revolution speed of 45 rpm and nozzle size of 6 mm have the highest oil yield of jatropha seeds. Their re-

Item	Method	Results (%)
Oil in cake from 13.3 rpm		12.24
Oil in cake from 20 rpm	Acid hydrolysis, Petroleum either extraction	13.23
Oil in cake from 30 rpm		15.56

Table 2. Analysis results of total fat and oil in cake obtain from different revolution speeds

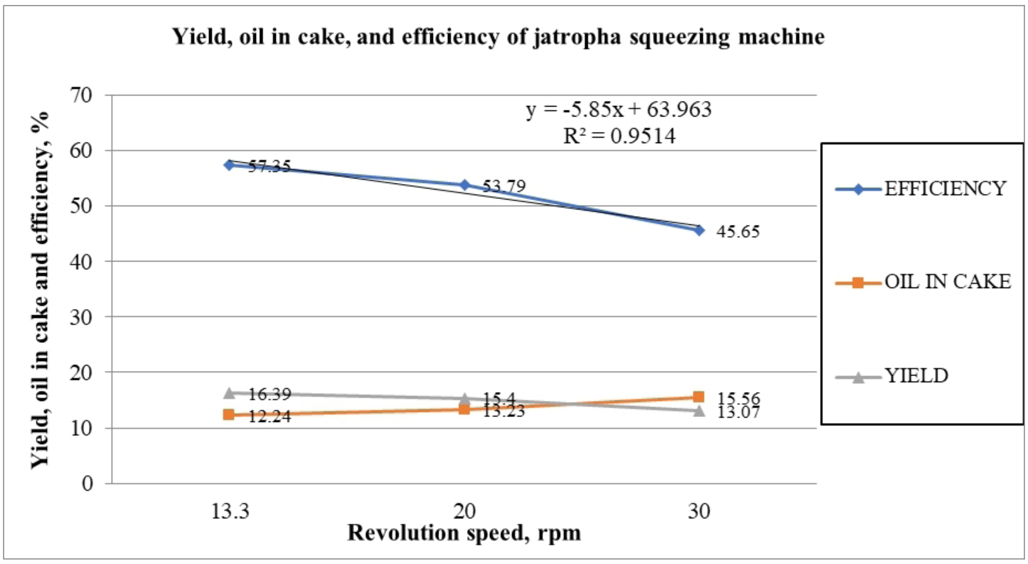


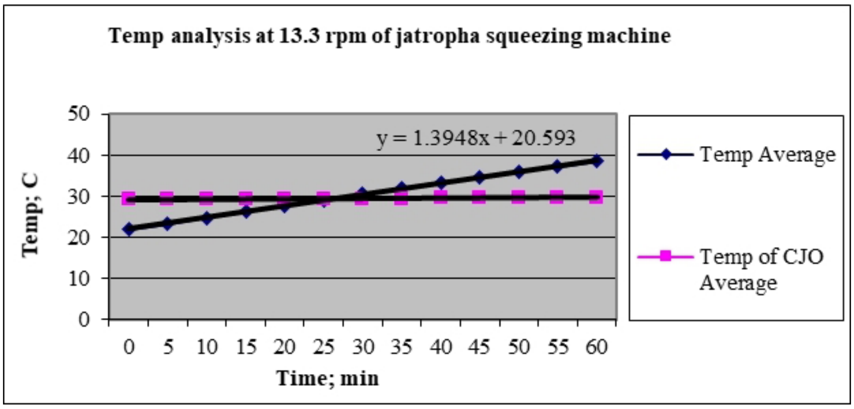
Figure 4. Oil yield, oil in cake and the efficiency of the squeezing machine at different revolution speed

sults indicated that the oil yield decreased with the increase in nozzle size and revolution speed.

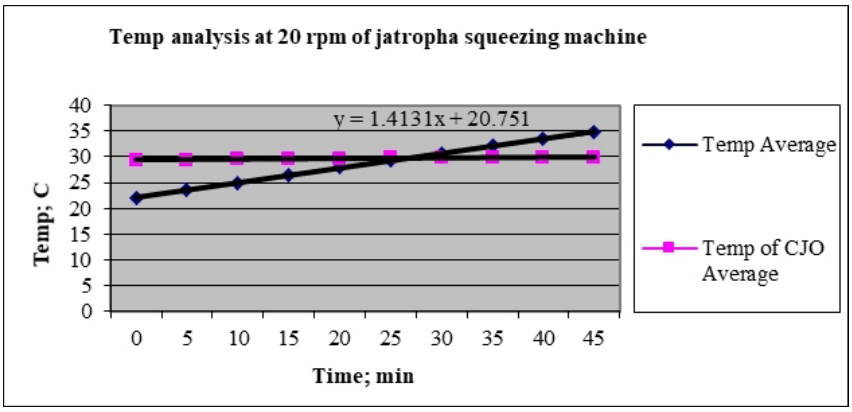
Base on the results, the best revolution speed to be used for highest of oil yield is at 13.3 rpm. This might be close to the theoretical design of the specific jatropha squeezing machine. The prediction equation between the speed revolution and the production of crude jatropha oil can be given as follow:

$$Y = -5.85X+ 63.963 \qquad (R2 = 0.9514)$$

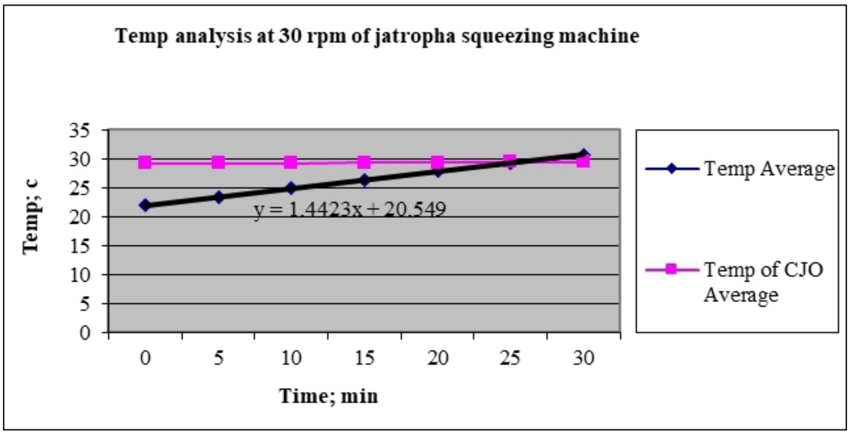
The temperatures measured from the thermocouples in the squeezing house are given in Fig. 5. The results shown that the significant variable of the speed revolution have the effect on the temperature in the squeezing house.



(a)



(b)



(c)

Fig. 5 Average temperature in the squeezing house (a) at 13.3 rpm; (b) at 20 rpm; (c) at 30 rpm

Although, this results showed us significant effect on the percentage of oil yield but modification of the squeezing machine needed some information to adapt the morphological design. The prediction equations containing the revolution speed and the temperature inside the squeezing house can be given as follow:

$$Y = 1.3948X + 20.593 \quad \text{(for 13.3 rpm)}$$

$$Y = 1.4131X + 20.754 \quad \text{(for 20 rpm)}$$

$$Y = 1.4423X + 20.549 \quad \text{(for 30 rpm)}$$

The research results should that the temperature increases with the increasing revolution speed of the implement. These speeds might be too high for the optimum pressure and led to reduction of time required for the operation, which might increase the heat as the results of higher collision and friction among the seeds and the seed with the shaft screw. These results were supported by Felycia et al., 2008 who reported that increasing the heating temperature decreased the oil yield of neem seeds. Also Yasuf K. A. et al., 2017 said that the extraction efficiency of the squeezingf machine increases with increase in temperature but tends to decrease as the temperature increased beyond 100°C.

Conclusion

This research was conducted to determine the effect of revolution speed of the squeezing machine on oil yield of jatropha seeds, as well as the effect of the revolution speed on increasing rates of the temperature inside the squeezing house. The research results showed that the speed of 13.3 rpm gave the highest crude oil. The percentage of oil yield decreased with increasing of the revolution speed. The temperature in the squeezing house also increased with the increasing speed. With this specific design of the jatropha squeezing machine, the optimum pressure of the expression and duration allow the oil flow through the slit along the barrel of the machine. More variables of this experiment such as variable pitch of the squeezing machine and heating temperature will be determined for further modification of the squeezing machine. Two steps compression with the optimum nozzle diameter will be designed under higher speed for further development of the squeezing machine.

Acknowledgements

The authors would like to express their gratitude to Kasetsart University, Research and Development Institute, Thailand for financing of this project, to the staff members of National Agricultural Machinery Center, Kasetsart University for accommodation of this research study. Special thanks to National Metal and Materials Technology Center (MTEC) and Thai Machinery Association for allowing us to set the experiment using the jatropha squeezing machine.

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