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PRODUCTION OF BIODIESEL FROM JATROPHA FRUIT (Jatropha Curcas)

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ABSTRACT

The energy crisis has led to rising petroleum prices. To address this issue, alternative fuels need to be sought. This study aims to utilize oil from the Jatropha plant (*Jatropha curcas*) to produce biodiesel through a transesterification reaction. The research was conducted using Jatropha oil-to-methanol ratios of 1:3, 1:4, and 1:5, with transesterification reaction times of 2 hours, 2.5 hours, and 3 hours. The results showed that the optimum volume of methyl ester from the transesterification reaction was achieved with a 1:4 ratio and a reaction time of about 2 hours.

Keywords: Biodiesel, Jatropha plant, transesterification reaction

1. INTRODUCTION

The energy crisis has triggered an increase in fuel prices. The main fuel sources today are derived from gas and petroleum, which are non-renewable resources. Therefore, it is time to focus on developing alternative, environmentally friendly fuel sources, such as plant-based fuels, commonly known as biodiesel.

Indonesia, as a tropical country, has abundant natural plant resources. One of these is the Jatropha plant (*Jatropha curcas*). Jatropha oil can be used to produce biodiesel as an alternative fuel source. Its use dates back to the 1940s as fuel for war machinery. However, with the rising trend of fossil fuel consumption, the use of Jatropha oil as fuel has been largely forgotten.

Classification and Morphology of Jatropha

The Jatropha plant belongs to the Euphorbiaceae family, which also includes rubber and cassava. It falls under the division Spermatophyte, subdivision Angiospermae, class Dicotyledoneae, order Euphorbiales, family Euphorbiaceae, genus *Jatropha*, and species *Jatropha curcas L.*

It is a shrub that grows between 1-7 meters in height, with irregular branching, a woody cylindrical stem, and sap that oozes when injured. Due to its very low essential fatty acid content, Jatropha oil differs from other vegetable oils. The physical and chemical properties of Jatropha oil are shown in Table 1.

Table 1. Physical and Chemical Properties of Jatropha Oil

Characteristic	Value
Viscositase (gradner-hol), 20°C	U-V (6,3 – 8)
Bobot Jeis, 20/20 º	0,957 – 0,963
Bilangan Asam	0,4 4,0
Number of Lamination	176 – 181
Iod Number (wijs)	82 – 88
Color (appearance)	Clear
Gardner Color (max)	No darker than 3
Indek Bias, n25d	1,477 -1,478
Solubility in Akohol	Clear (not cloudy)
Flash Point (Tag close cup)	230 ºC
Flame Point (Cleveland open cup)	285 ºC
Antognition Temperature	449 ºC
Fire Point	322 ºC
Boiling Point	Dec

Source: Bailey,A.E (1950)

Biodiesel

Biodiesel is an oil-based fuel derived from vegetable or animal oils. The quality standards for biodiesel fuel can be seen in Table 2.

Raw materials for vegetable oil in Indonesia for the manufacture of biodiesel are so abundant. The backbone is palm oil. However, palm oil is an *edible oil (fat*) so the stability of biodiesel supply will be disrupted if the demand for food oil increases. Therefore, there needs to be a substitute in the form of non-edible oil (*fat*). An alternative option is the hedge castor plant (*Jatropha curcas*). Jatro Pagar was chosen as a raw material for biodiesel because it currently has no economic value and grows wild, can grow on critical land, does not require a lot of water and fertilizer, and is easy to maintain. Castor plants can generally be harvested after they are six to eight months old. However, it is only able to produce optimal fruit at the age of five.

The process of making biodiesel from castor oil is carried out through several stages. The first stage is steaming of castor seeds. The goal is to release enzymes that are not needed, which can reduce the quality of castor oil. The second stage is the process of extracting jatropha seeds using methanol solvents. In order to form biodiesel, a NaOH catalyst is added to the extraction process to encourage the transesterification reaction. The final stage is the purification process of the obtained biodiesel oil.

The chemical structure of castor oil consists of triglycerides with straight (unbranched) fatty acid chains, with or without double bonds like other vegetable oils. The chemical structure of castor oil is shown in Figure 1.

The structure of castor oil (*Jatropha curcas*) is very different from that of castor oil of *the type Ricinus Communis (Castrol Oil)* which has hydroxyl branches. The chemical structure of Castor Oil *Ricinus communis* is shown in Figure 2. This difference in structure causes the use of the two oils to be very different. Castor oil of *the Ricinus Communis* type is more suitable for application as a lubricant than as a fuel.

Table 2. ASTM Standards for Biodiesel Fuel**

Paramaeter Test	Analyze Method ASTM	Value	Unit
Specific Gravity	D1298	0,86-0,90	g/cm^3
Gross Heating Value	D2382	17.65 min	Btu/lb
Cloud Point	D2500	Report to customer	F
Pour Point	D97	28 max	F
Flash Point	D93	100 min	°C
Kinematic Viscosity	D445	1,9-6,0	CSt
Water and Sediment	D2709	0,05 max	% Vol
Copper Strip Corrosion	D130	No. 3b max	Deg. of Corrosion
Sulfur	D2622	0,05max	% mass
Carbon Residue	D4530	0,05 max	% mass
Cetane Number	D613	40 min	-
Sulfated Ash	D482	0,02 max	% mas
Neutralization / Acid	D664	0,08 max	mg/gr
Methanol	GC	0,02 max	% mass
Free Glycerol	GC	0,02 max	% mass
Total Glycerol	GC	0,24 max	% mass
Oil Ester	GC	97,50 max	% mas

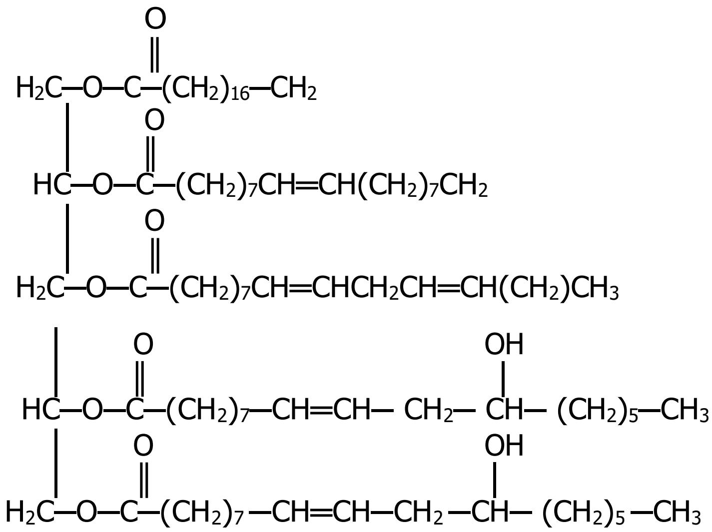


Figure 2. Chemical Structure of Castor *Oil Ricinus communis*

Economically, castor plants can be used in all parts, starting from leaves, fruits, bark, sap, and stems. Leaves can be extracted into silkworm feed and herbal medicines, stem bark can be extracted into tannins or simply used as local fuel to then produce fertilizer, sap can be extracted into fuel. Likewise, the stem part can be used for firewood.

The greatest potential of the jatropha plant is in the fruit consisting of seeds and shells (skin). On the seeds there is a seed core and a seed shell. The seed core is the basic material for making biodiesel, a source of energy to replace diesel. After going through the milking process, from the seed core will produce milk meal, which is then extracted. The results are in the form of jatropha oil and extraction meal.

The average seed size is 18 x 11 x 9 mm, weighs 0.62 grams, and consists of 58.1% kernel seeds in the form of flesh (*kernel*) and 41.9% skin. The bark contains only 0.8% ether extract. The oil content (triglycerides) in the seed core is equivalent to 55% or 33% of the total weight of the seed. The fatty acids that make up castor oil consist of 22.7% saturated acid and 77.3% unsaturated acid. The fatty acid content of oils consists of 17.0% palmic acid, 5.6% stearic acid, 37.1% oleic acid, and 40.2% linoleic acid (*Stegar and van Loon*, 1941). Castor oil is a clear liquid in color and does not become cloudy even if stored for a long time.

Alcohol Solvents and Catalysts

To make biodiesel, the esters in vegetable oils need to be separated from the glycerol. These esters are the basic ingredients that make up biodiesel. During the transesterification process, the glycerol component of vegetable oil is replaced by alcohol. The most common alcohol used for the transesterification process is methanol because its reaction power is higher when compared to other alcohols, besides that it is also cheap.

The process of methanolysis of alkaline bilytic can be carried out at room temperature and will produce more than 80% esters shortly after the reaction takes place. The separation of esters and glycerol takes place quickly and perfectly.

To obtain high biodiesel conversion, a catalyst is added to the trans-esterification reaction process. The catalyst that may be used for methyl ester is Sodium Hydroxide (NaOH) which is also called caustic soda or Potassium Hydroxide (KOH), both of which can be in the form of powders, granules or pellets.

The extraction time or transesterification reaction in the previous study lasted for 2-3 hours at atmospheric pressure and reaction temperature of 60-70oC (M,Robert,.......). To obtain the optimum yield, variations in temperature and duration of the reaction can be performed. This study aims to obtain the optimal conditions of the biodiesel manufacturing operation process through the transesterification process.

2. RESEARCH METHODS

Research on the production of biodiesel from castor oil was carried out using the extraction method. In the extraction process, the steaming of castor seeds and the transesterification reaction occur simultaneously. Once biodiesel is formed, phase separation and purification are carried out.

The treatment procedure for the research is as follows:

Steaming Stage

Two or two kilograms of jatropha fruit (Jatropha curcas) are steamed for an hour and a half, then crushed with a blender. The result is squeezed to produce oil. Steaming is carried out in the temperature range of 100 $^{oC.}$

Transesterification Stage

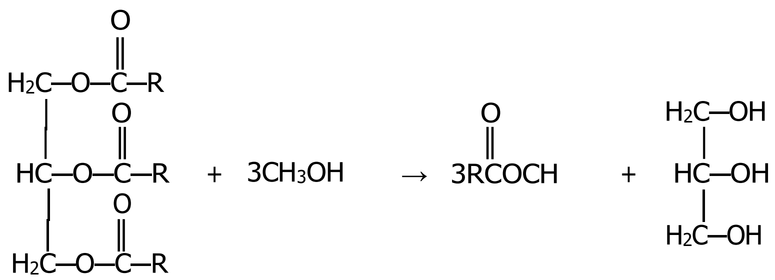
The production of biodiesel oil (Methyl Ester) is formed through a chemical process called a transesterification reaction. In the transesterification reaction, castor oil will react with methanol to form methyl ester and glycerol. Glycerol is widely used in the pharmaceutical, cosmetic, toothpaste and paint industries. The transesterification reaction will be able to proceed well if it is assisted by an alkaline catalyst. In this study, the catalyst used was Sodium Hydroxide. The process of methyl ester formation through the transesterification reaction is shown in Figure 3.

Phase Separation

Once the extraction time or transesterification reaction is reached, the reaction mixture is left to sit until phase separation occurs. The ester phase is deanted from the equilibrium mixture. Methyl Ester is obtained in the upper layer, while the by-product, namely glycerol, will be found in the bottom *layer*.

Trial Treatment

The study was conducted at a reaction temperature of 60oC, the ratio of castor oil to solvent was varied in the ratio of 1:3, 1:4 and 1:5, while the operation time was selected 2 hours, 2.5 hours and 3 hours. The weight of the catalyst is set at 2% of the weight of the solvent, the speed of stirring and the concentration of methanol 89% is made fixed. The response variable measured was the percentage of product weight (yield) of Methyl Ester (Crude Methyl Ester) and the characteristic test was carried out at the maximum yield obtained. The measurements of biodiesel characteristics carried out include flash *point* using the ASTM 93 method, *kinematic viscosity* using the ASTM 1796 method and specific gravity and moisture content using the AOAC method, 1995.



Tryglyceride + Methanol → Methyl Ester + Glycerine

Figure 3. Castor Oil Transesterification Reaction Into Biodiesel

3. RESULTS AND DISCUSSION

Steaming Results

Steaming a number of peeled castor fruits (*Jatropha curcas*) for an hour and a half, then crushed with a blender and squeezed, produces castor oil. The steaming temperature is around 100 oC. The amount of castor oil produced is shown in Figure 4.

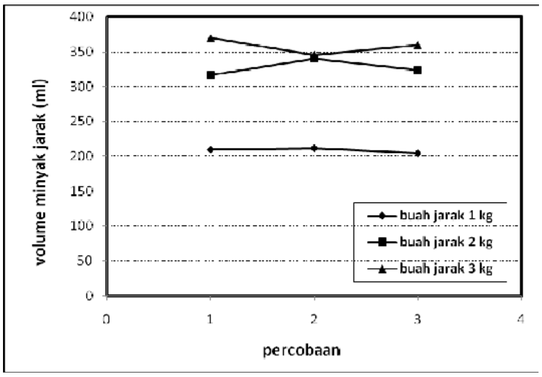


Figure 4. Volume of Castor Oil

From Figure 4, it can be seen that the volume of castor oil obtained from steaming is not directly proportional. This difference is due to the age difference between young and old jatropha seeds. For the age of young castor or young seeds, the volume of oil produced from the pressing is not much and the color is also a bit whitish or a little cloudy. This is likely because the sap content in young castor seeds is still large. Meanwhile, the volume of castor oil produced by the old seed pressing process is more when compared to the castor oil produced by young seeds, besides that it is also clear yellow.

Results of Trans-esterification Reaction

Biodiesel oil (Methyl Ester) is formed from the result of a transesterification reaction between castor oil and alcohol with the help of an alkaline catalyst. The alcohol used in this study was methanol (CH3OH) 89%. The catalyst used is sodium hydroxide (NaOH). The volumes of methyl esters obtained at various ratios of castor oil to ethanol are shown in Figure 5.

From Figure 5, it can be seen that the volume of methyl ester produced for each ratio and the same operating time tends to increase, meaning that the higher the ratio between castor oil and solvent, the higher the methyl ester produced. The optimum ratio obtained in this study is in the ratio of castor oil to solvent 1:4, due to the increase in the volume of methyl ester (percentage) obtained from the ratio of 1:3 to 1:4 ratio rather than the ratio of 1:4 to 1:5.

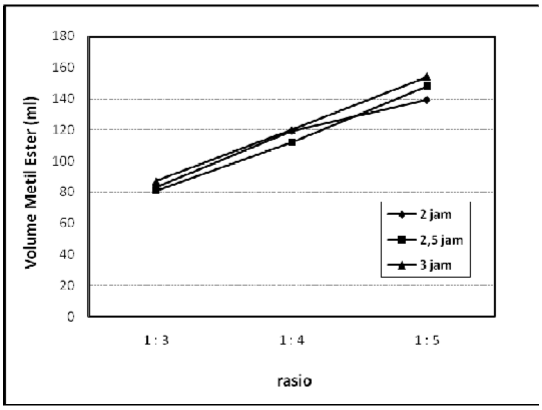


Figure 5. Graph of the Effect of Ratio on Methyl Ester Volume

From Figure 5, it can also be seen the effect of reaction time on the methyl ester produced, that the longer the reaction time, the volume of methyl ester produced also increases. The optimum reaction time obtained from this study is 3 hours.

Results of Physical Properties Analysis of Methyl Ester

The physical properties of methyl esters analyzed include flash point, density and viscosity. The results of the analysis are shown in Table 3.

Table 3. Results of Physical Properties Analysis of Methyl Ester

Ratio	Reaction Time (jam)	Flash Point (^{o}C)	Density (gr/cm3)	Viscosity (poise)
1:3	2	175	0,8988	2,17
	2,5	182	0,8892	1,68
	3	170	0,8968	1,94
1:4	2	150	0,8936	2,20
	2,5	172	0,8888	1,65
	3	165	0,8976	1,96
1:5	2	160	0,8956	2,00
	2,5	165	0,8916	1,65
	3	170	0,8984	1,99

From Table 3 we can see either for each ratio or for all reaction times we can say that almost all of the parameters are close to the standard range set for biodiesel. The minimum value obtained from the flash point test results is 150oC at a ratio of 1:4 for a reaction time of two hours, while the maximum value of the flash point is 175oC at a ratio of 1:3 with the same reaction time, which is for two hours. Based on these data, it can be determined that the optimal time for the best transesterification reaction from the results of this study is 2 (two) hours.

CONCLUSION

From this research, there are several conclusions that will be explained both in terms of the volume of castor oil produced from pressing and from the volume of methyl ester formed as a result of the transesterification reaction, which are as follows:

1. The volume of castor oil obtained from the pressing process is not the same even though the amount of raw materials is the same, this is due to the age factor of the plant. In other words, the volume of castor oil produced by younger castor plants is less and the color is slightly cloudy with whitish spurs than older castor plants which are yellow.
2. From the results of this study for the ratio and time made, the optimum volume of methyl ester that occurs from the results of the transesterification reaction is in a ratio of 1:4 and the reaction time is about 2 (two) hours.

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