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Simulation of Rice Bran Oil Transesterification Process for Biodiesel Production

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ABSTRACT
World energy demand continues to increase rapidly. Meanwhile the non-renewable sources of energy keep decreasing. To overcome this situation, many studies to produce energy from renewable source has been developed and tested. From many available options, biodiesel is one of renewable energy that has been researched and implemented. To produce biodiesel the most common feedstock is vegetable oil. In Indonesia, there are many plants that have potential to produce vegetable oil. The waste of abundant plant that have potential to be used to produced biodiesel is rice bran. The rice bran oil composition is around 20%-wt. Fatty acid in form of triglycerides and free fatty acids (FFA) are the most substances that make-up vegetable oil. Each of vegetable oil has different fatty acid composition. For rice bran oil, the dominant fatty acids are oleic acid, linoleic acid, and palmitic acid. Biodiesel can be produced via transesterification of vegetable oil with glycerol as by-product. Generally, in transesterification process vegetable oil is reacted with alcohol and base as catalyst. Aspen Hysys was used to simulate the process of biodiesel production rice bran oil. In the simulation the rice bran oil is assumed as triolein (43.1%), trilinolein (33.2%), tripalmitin (18.8%), and oleic acid (4.9%) as FFA. The transesterification reactor operating conditions was set at 65C and 1 bar. The reaction conversion was assumed to be 100% and with oil to methanol mole ratio 1:6. The process continued with recovery of excess methanol and glycerol separation. Simulation result that from 110 L/h rice bran oil can be converted into 114 L/h crude biodiesel and 8.3 L/h glycerol as by-product. Around 99.5 % of excess methanol can be recovered.

Keywords: *biodiesel, rice bran oil, transesterification, simulation*

1. INTRODUCTION

Non-renewable resources of energy keep on decreasing, meanwhile the energy demand continues to increase rapidly. The production of alternative fuel from renewable resource to meet this energy demand is a. There have been many studies about energy production from renewable sources to overcome this problem. Biomass is one of the most abundance renewable material than can be converted to energy. Biodiesel is one of alternative form of energy that rapidly produced and developed. Biomass in form of vegetable oil is the most common raw material for biodiesel production.
Indonesia is a country with high biodiversity. This biodiversity makes Indonesia rich in biomass as a source of vegetable oil that can be converted into biodiesel. One of the most productive plants in Indonesia is rice. From the waste produced by rice mills, large amounts of rice bran can be obtained. Rice bran a coproduct of rice milling can be an option for a low-cost feedstock for biodiesel production. The oil content in rice bran ranges from 10-26% which can be influenced by the variety, milling process, and other agroclimatic conditions [1]. There has been a lot of research done on production of biodiesel from rice bran oil (RBO) [2]–[4].

Industrial grade of RBO is non-edible oil because the high level of free fatty acids (FFA) content, so its utilization for biodiesel will not disrupt the supply for food purposes. Vegetable oil mostly compost of fatty acids in form of triglycerides and FFA. Each of vegetable oil has different fatty acids composition, saturated and unsaturated. The dominant fatty acids composition of RBO oil are oleic acid, linoleic acid, and palmitic acid (Table 1) [3],[5],[6].

Table 1 Main fatty acid composition of RBO

No	Fatty Acids	Percentage %		
		[3]	[5]	[6]
1	Oleic Acid	43.4	41	42.5
2	Linoleic Acid	37.9	38	39.1
3	Palmitic Acid	18.7	16	15.0

Previous studies has simulated glycerol production as by-product biodiesel production from corn oil [7]. Another work about biodiesel production via hydrodeoxygenation that produced propane as by-product then converted to propylene [8]. The Simulation of Jatropha Curcas seed oil utilization for biodiesel production result with high purity biodiesel (> 99.65%) and glycerol (95.3%) as by-product [9]. Other study use waste cooking oil as raw material for simulation of biodiesel production [10]. To understand and get overview of the process and product specification for biodiesel production from rice bran oil the process simulation is required.

2. METHODS

Aspen Hysys used to simulate the biodiesel production process from rice bran oil. the process is designed based on the following assumptions. The process includes esterification and transesterification reaction to convert rice bran oil to biodiesel and glycerol as by-product. The conversion rate of rice bran oil was assumed to be 100%. The amount of heat loss on all process equipment was ignored. The heat exchanger pressure drop was set 1.5 psi. The number of pressure loss due to fluid flow along the pipe was ignored. The RBO triglycerides were represented with triolein and both trilinolein and tripalmitin as hypothetical components, for FFA was used oleic acid. The composition of RBO can be seen in Table 2

Table 2 Feed Rice Bran Oil simulation compositions

No	Fatty Acids	Percentage %
1	Triolein	43.1
2	Trilinolein	33.2
3	Tripalmitin	18.8
4	Oleic Acid (FFA)	4.9

2.1 *General description of esterification process*

For vegetable oil with FFA more than 2%, the oil needs to undergo esterification. In esterification process FFA reacted with alcohol, to produce biodiesel (fatty acid alkyl ester) and water. In this reaction acid substance such as sulfuric acid is commonly utilize as homogeneous catalyst. The using of strong acid as catalyst has many drawbacks because its corrosivity, need to wash several times to remove from the products, and waste produced. Heterogenous catalyst based on silica zirconia can be used to eliminate the use of this strong acid catalyst [11]. The esterification reaction as below.

$$\text{FFA + alcohol} \xrightarrow{\text{acid}} \text{Biodiesel + Water} \quad (1)$$

2.2 *General description of transesterification process*

The universal process to produce biodiesel from vegetable oil is the transesterification process. The reaction of triglycerides in vegetable oils with alcohols (methanol) and alkaline/acid catalysts, to produce short-chain fatty acid esters (biodiesel) and by-product in form of glycerol, is called Transesterification reaction. Commonly, the transesterification process has a relatively low operating condition, temperature, and pressure of 60-70°C and atmospheric. The application of catalysts in the transesterification process is crucial. Sodium hydroxide was frequently used as a catalyst for this process [5]. Metal oxide utilization as a catalyst in transesterification reaction to produce biodiesel is also extensively researched [2],[4].

$$\text{Triglyceride + alcohol} \xrightarrow{\text{base}} \text{Biodiesel + Glycerol} \quad (2)$$

2.3 *General description of biodiesel separation process*

The transesterification process conducted in excess methanol system. To be able to use methanol economically the unreacted methanol needs to separate from the product stream. The separation consists of three steps excess methanol recovery stage one, glycerol removal, excess methanol recovery stage two. The flash distillation can be used to for methanol recovery stage 1. Before feeding the product stream into the flash column, the product heated to around 80°C, so that most of the methanol exit from the top of the column and then recycled. To separate glycerol many technologies can be used. Generally Membrane can be potential alternative to separate glycerol from biodiesel [12]. After glycerol removal the process continued with excess methanol recovery stage 2. For this step distillation can be used as separation method [13]. The distillation product consists of distillate which is rich with methanol and the bottom product is crude biodiesel. The distillate then recycled to the feed tank and used for the next production. High Voltage Electrolysis can also be used to remove glycerol from biodiesel [14].

3. RESULTS

The process flow diagram of simulated process shown in Figure 1. The process compost of esterification, transesterification, excess methanol recovery, and glycerol separation.

3.1 *Esterification and Transesterification process*

The process started with RBO (110 L/h) and methanol as raw material. The RBO composition was simulated as triolein (43.1%), trilinolein (33.2%), tripalmitin (18.8%), and oleic acid (4.9%) as FFA. Because of the high FFA content of RBO, esterification process was needed before transesterification. The RBO to methanol molar ratio was set 1:6. For Both esterification (CRV-100) and transesterification (CRV-101) conversion reactor was chosen to simulate the processes. Both reactors operating condition was set to 65°C and atmospheric with FFA and triglycerides conversion 100%. The reactor output stream was mostly consisting of the excess methanol, glycerol, and biodiesel. The product then continued to flow into separation stages, methanol recovery and glycerol separation process to obtain biodiesel.

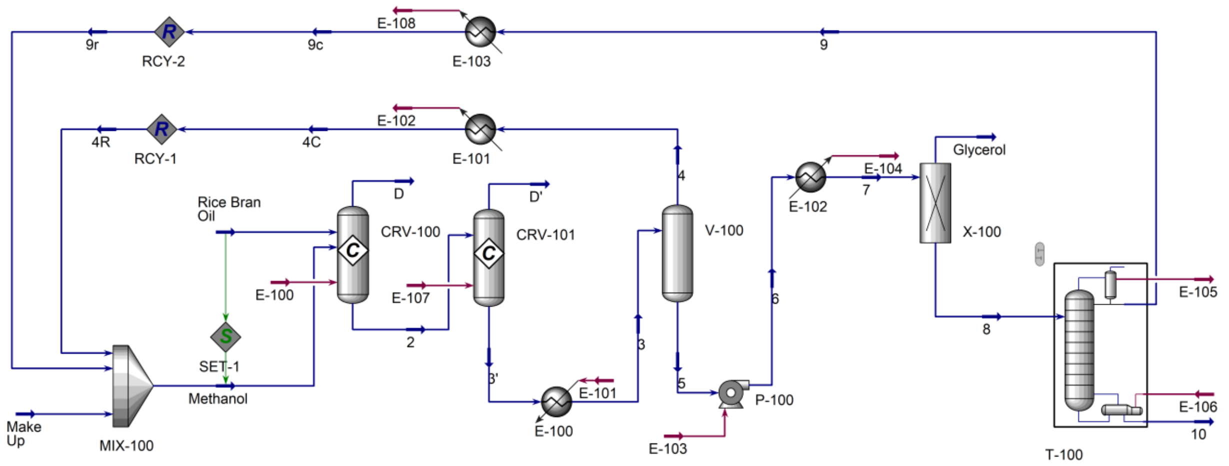

Figure 1 Simulation Process Flow Diagram

3.2 Biodiesel Separation process

Following the completion of transesterification process, to evaporate most of excessed methanol products stream exit from the reactor was heated to 80°C. Two phases product stream then separated using flash distillation (V-100). In this stage the excess methanol recovery achieved was around 64,7%. The process continued with glycerol separation, one of technology that can be used for this operation is membrane [12]. The stream was pumped and cooled into 5.5 bar and 25C before entering the membrane (X-100). The membrane output is glycerol (8.3 L/h) with high purity that reach 99 % and mixture of biodiesel and methanol. The permeate then flowed to second methanol recovery, multi-staged distillation (T-100) is chosen to perform this operation. From multi-stage distillation around 29.4% of excess methanol can be obtained. The total of unreacted methanol that can obtained from product mixture was 99.5%. After separation process, the crude biodiesel produced was around 114 L/h. The simulation product properties comparison to Lin et.al study [5] and Sinha and Agarwal study of biodiesel production from rice bran oil conducted at 55°C and oil to alcohol molar ratio 1:9 [15] shown in Table 3. The density of simulation result is similar with both studies, but the viscosity is much lower.

Table 3 Product Fuels Properties

Property	Simulation Result	RBO Diesel [5]	ROME [15]
Specific gravity @ 30°C	0.874	0.884	0.877
Viscosiy (cSt) @ 40°C	2.00	4.12	5.29

3.3 Rice Bran Feedstock Estimation

The oil content in rice bran ranges from 10-26% [1]. Then, it was assumed the average oil content of rice bran around 18%, so to produce 110 L/h RBO (density 0.92 kg/L) was needed 562 kg/h of rice bran.

3.4 Utility Consumption

The utility consumption for the biodiesel production from RBO based on simulated process is shown in Table 4. The utility consists of electricity, heating utility, and cooling utility. Electricity was needed for powering pump P-100. The heating utility can be supply using steam and for cooling utility, water already sufficient to use in this process.

Table 4 Utility Consumption

Type	**Equipment**	**Consumption (kW)**	**Total (kW)**
Electricity	E-103	0.222	0.222
Heating utility	E-100	3.197	25.031
	E-101	3.554	
	E-106	18.280	
Cooling utility	E-102	1.557	18.909
	E-104	4.922	
	E-105	4.545	
	E-107	7.590	
	E-108	0.295	

4. CONCLUSION

Based on simulation result, with RBO feed of 110 L/h and excess methanol can be produced around 114 L/h crude biodiesel and 8.3 L/h glycerol. From the two stage of methanol process recovery was achieved that around 99.5% of excessed methanol can be recovered. The crude biodiesel still needs further purification to be able to fulfil specifications according to standard.

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