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Research Article

Enhancing Ethyl Oleate Purity and Energy Efficiency in the Biodiesel Production Process Through Distillation Design Modifications

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Abstract

The growing demand for renewable energy sources has driven research into more efficient biodiesel production methods. This study focuses on enhancing the purity and energy efficiency of ethyl oleate in biodiesel production through the transesterification of triolein using ethanol and sodium hydroxide. Two process designs were compared: a base process and a modified process incorporating the removal of the initial mixer, adjustment of distillation flow rates, and addition of a second distillation column. The modified process resulted in a higher ethyl oleate purity of 99.03% compared to 89.98% in the base case. Furthermore, energy savings increased to 57.66% and carbon emissions were reduced by 57.65%, demonstrating improved environmental performance. These findings suggest that process redesign can significantly improve biodiesel production quality and sustainability. However, further research is needed to assess economic feasibility using tools such as the Aspen Process Economic Analyzer (APEA) for potential industrial-scale implementation.

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Keywords: Biodiesel; triolein transesterification; energy efficiency; product purity; carbon emissions; process simulation; Aspen HYSYS

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1. Introduction

The need for energy continues to increase along with population growth and industrial development. Meanwhile, the availability of fossil energy sources is increasingly depleted and needs to be reviewed by considering their limited availability and their impact on the environment [1]. The transportation sector contributes 23% of global CO_2 emissions, with fossil diesel as the main contributor [2]. Therefore, developing biodiesel as an alternative renewable energy is a strategic solution, especially considering the low hazardous emissions from biodiesel compared to conventional diesel.

Biodiesel as a renewable alternative to fossil diesel has become a major focus, especially in vegetable oil-producing countries such as Indonesia. Chemically, biodiesel is included in the monoalkyl ester or methyl ester group with a carbon chain length of 12-20. This distinguishes it from petroleum diesel (solar), whose main component is hydrocarbons [3]. The opportunity to utilize palm oil as a raw material for biodiesel is auspicious in Indonesia, considering Indonesia's position as the world's largest producer of CPO (Crude Palm Oil). However, using palm oil for biodiesel can cause problems because palm oil is one of the food sources. Therefore, vegetable oil can be used as an alternative solution for biodiesel raw materials [4].

One of the main components in vegetable oil is triglycerides, which are composed of glycerol and three fatty acids. Triolein, a triglyceride

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consisting of three oleic acids, is the dominant compound in cooking oil due to its high oleic acid content [5]. The vegetable oil used must have a low free fatty acid (FFA) content (<1%); if more, then pretreatment is necessary because it will result in low efficiency performance. the alternative feedstocks include waste cooking oils [6].

In biodiesel production, triolein is the main target of the transesterification reaction, which converts it into methyl ester (biodiesel) and glycerol. This compound attracts attention as a raw material for biodiesel research because it has an unsaturated structure that can increase fluidity at low temperatures. Meanwhile, the chemical properties of triolein are well defined, which allows controlled optimization of the biodiesel production process [7]. Transesterification of triglycerides with homogeneous acid or base catalyst requires neutralization and recovery from the reactor products. Increased purification and recovery steps can, eventually, affect product costs and the market.

This study explores the design of a biodiesel plant using simulation, focusing on increasing energy efficiency and enhancing the purity of the acetone product. The study results show that implementing sustainable design at every stage of the process can be a solution to overcome this challenge. Moreover, efforts to optimize energy efficiency in the industrial sector are essential, aligning with the industry's key objectives.

2. Method

Aspen HYSYS V14 can be used to model the biodiesel production process from triolein transesterification, and the corresponding process flow diagram is shown in Figure 1. Through the application of mass and energy balances, phase considerations, and chemical equilibrium relationships, this simulation model can predict

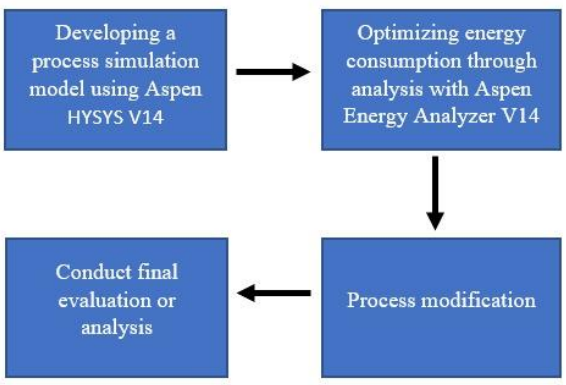

Figure 1. Basic process flow diagram of DME production via methanol dehydration [1].

the process response of a plant. For physical calculations, real-time operating conditions, and rigorous equipment models that closely replicate actual plant processes, Aspen HYSYS provides an accurate and comprehensive thermodynamic foundation. To meet market demands, the process equipment modeled in HYSYS includes a complete library of unit operation models, encompassing distillation, reactors, heat transfer operations, rotating equipment, controllers, and logic operations. This is done in both steady-state and dynamic environments [8]. According to industry standards, this simulation model can improve the purity of ethyl oleate products and reduce energy consumption. The biodiesel production process can be found in the literature [9]. Furthermore, to meet market demand, an optimal process design is needed to improve the purity of biodiesel from the triolein transesterification process. The objective of the first stage, conceptual design, is to identify the optimal process flow. Alternative designs are selected based on economic feasibility, environmental constraints, and utility efficiency. This stage involves process calculations, flow diagrams, equipment sizing, cost analysis, and energy requirement estimations [10].

To determine if the modified biodiesel production method outperforms the original one, the study considered several key factors. The primary measures of improvement were the purity of the final product, how efficiently energy was used, and the process's impact on the environment. Modification of the biodiesel manufacturing process is done to increase the biodiesel production yield while reducing energy requirements. In this modification, the mixer for mixing triolein with Ethanol and NaOH is removed from the system, then the triolein flow is directly entered into the first mixer, and a distillation column is added after the product. In the first Distillation Tower, the average distillation rate is reduced from 3.1 kgmole/h to 1,787 kgmole/h to increase the mass of the bottom product and reduce energy consumption in the condenser and reboiler of the distillation column. The second distillation column is used to increase the purity of ethyl oleate and separate glycerol. These changes are intended to maximize biodiesel production while reducing energy consumption in the system.

In the simulation of a CSTR reactor using Aspen HYSYS to produce biodiesel from triolein transesterification, a power law model was used to describe the reaction speed. The reaction is based on molar concentration, and occurs in the liquid phase. A CSTR is assumed to be perfectly mixed, meaning the composition and temperature are uniform throughout the reactor and equal to the outlet conditions. This means the reaction rate

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is proportional to a power of the concentration of one or more reactants. This model is expressed as: $-r_A = kC_A^a C_B^b$, where $-r_A$ is the rate of disappearance of reactant A, C_A and C_B are the concentrations of reactants A and B, respectively, and a and b are the reaction orders. The rate constant k is temperature-dependent and follows the Arrhenius equation:

$$k = A \cdot \exp\left(\frac{-E}{(R \cdot T)}\right) \cdot T^b \quad (1)$$

With the following parameters: A = 1.9647 × 10^{-5} gmol/cm³.s, E = 34.209 kJ/mol, b = 1.0, R = 8.314 J/mol.K, and T = 322 K. Using the Arrhenius equation at an operating temperature of 49 °C (322.15 K), the following reaction rate constants were obtained: $k = 1.80 \times 10^{-8} \frac{gmol}{cm^3}.s$; where, A is the pre-exponential factor, E is the activation energy, R is the universal gas constant, and T is the temperature.

A conceptual process simulation model was created specifically for biodiesel production from triolein transesterification. During the plant process, the Aspen Energy Analyzer V14 was used to assess energy consumption. Aspen HYSYS was used to optimize energy efficiency and study heat transfer and conversion in biodiesel production. bThe in-depth simulation includes measurement operations that demonstrate the real-life industrial process of the plant.

3. Results and Discussion

3.1. Process Description and Simulation

The concepts described in the literature form the basis for biodiesel production with triolein transesterification [9]. Figures 2 and 3 show an industrial-scale biodiesel plant designed to produce ethyl oleate and glycerol as the main products. The reactor used is a CSTR reactor operating at 45 ℃ with a pressure of 1 atm. The NRTL thermodynamic model was selected to account for the various phases that may occur in this process.

Biodiesel production is done through a transesterification reaction where triglycerides react with primary alcohols such as ethanol. The results of the reaction are esters and glycerin or also known as glycerol. This reaction takes place in three reversible reaction stages, where each stage converts one triglyceride fatty acid chain into esters [11]. The reactor output product, as a liquid mixture, is then reheated before being fed into the distillation column. At the distillation stage, separation is carried out based on the components' boiling points [12]. Ethyl oleate, as the main product with a boiling point of 573.15 K at a pressure of 0.1 MPa [13], is separated from the ethanol, which has a boiling point of 351.47 K at a pressure of 0.1 MPa in the distillation column [14]. The top product of the distillation column is pure ethanol with high purity are returned to the initial stage of the process for recycling. In contrast, the bottom product contains of ethyl oleate is cooled and become the product.

This process was simulated using Aspen HYSYS 14 software to model the material and energy flows in the system, as shown in Figure 3. The NRTL equation was chosen because it can calculate multiple phases. At the initial stage, the raw material mixture is fed into the mixer unit (MIX-100). Next, the flow is heated in the first heater (E-100) to raise its temperature to 49 °C before entering the CSTR reactor (CSTR-100). The transesterification reaction occurs at 49 °C and 1 atm pressure in the reactor. This reactor produces a liquid mixture of ethyl oleate, glycerol, and residual ethanol. The liquid mixture then undergoes a heating process.

The liquid mixture is heated using a heater (E-101). Next, the liquid mixture flows to the distillation column (T-100) for separation at a temperature of 80 °C and a pressure of 0.3 atm. The bottom distillation product, ethyl oleate and glycerol, is shown in the stream product, with a composition of ethyl oleate 1052.0819 kg/h. The remaining ethanol, along with a small amount of water, is returned to the mixing unit (MIX-102) as a recycle stream. The simulation results are shown in Table 1.

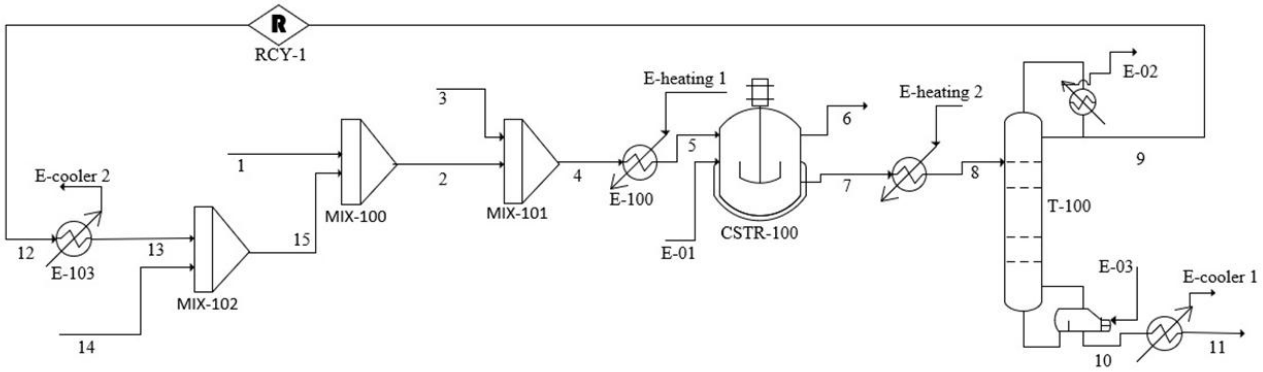

Figure 2. Basic (unmodified) process flow diagram for ethyl oleate production [9].

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3.2. Thermodynamics and Operating Conditions Consideration

From a thermodynamic point of view, based on the enthalpy value of the formation reaction, it is exothermic and reversible. Table 2 shows the values of ($\Delta H°_f$) and ($\Delta G°_f$) of each component at 298 K [15].

Reaction:

$$C_{57}H_{104}O_{6(l)} + 3C_2H_5OH_{(l)} \rightarrow 3C_{20}H_{38}O_{2(l)} + C_3H_8O_{(l)} \quad (2)$$

$$\Delta H_{r°} = \Delta H_{f°produk} - \Delta H_{f°reaktan} \quad (3)$$

$\Delta H_{r°} = (\Delta H_f° \ C_{20}H_{38}O_2 + \Delta H_f° \ C_3H_8O) - (\Delta H_f° \ C_{57}H_{104}O_6 + \Delta H_f° \ C_2H_5OH)$

$\Delta H_{r°} = ((3\times-656.19) + -582.8) - (-1807.7 + (3\times-234.96))$

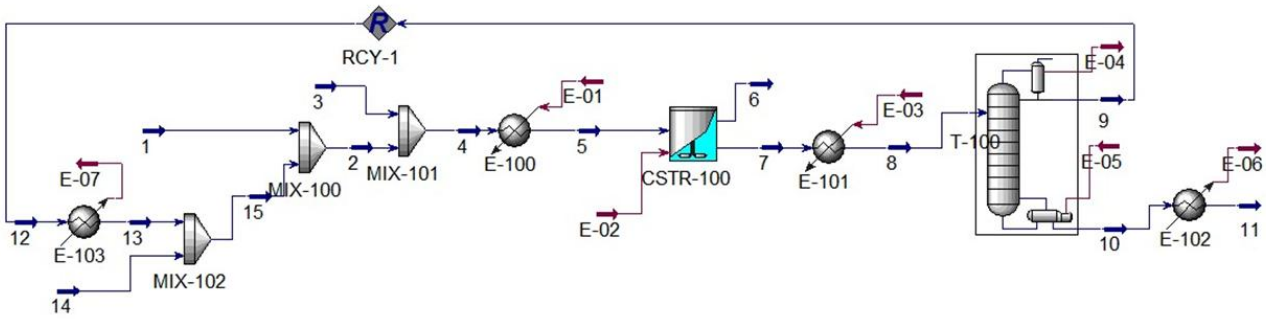

Figure 3. Aspen HYSYS simulation model for the basic (unmodified) biodiesel production process.

Table 1. Mass and energy balances for the basic (unmodified) biodiesel production process.

		Material Stream							
		1	2	3	4	5	6	7	8
Vapour Fraction	-	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
Temperature	C	60.00	26.38	45.00	38.91	48.30	-26.26	-26.26	80.00
Pressure	atm	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Molar Flow	kgmole/h	0.2542	6.811	1.129	7.941	7.941	0.0000	7.941	7.941
Mass Flow	kg/h	10.00	310.0	1000	1310	1310	0.0000	1310	1310
Liquid Volume Flow	m^3/h	5.671e-3	0.3822	1.092	1.474	1.474	0.0000	1.492	1.492
Heat Flow	kJ/h	-2.131e+4	-1.846e+6	-2.146e+6	-3.991e+6	-3.961e+6	0.0000	-3.961e+6	-3.675e+6
		9	10	11	12	13	14	15	
Vapour Fraction	-	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	1.000	
Temperature	C	50.57	178.1	60.00	50.57	25.00	25.00	25.00	
Pressure	atm	0.300	0.300	0.300	0.300	1.000	1.000	1.000	
Molar Flow	kgmole/h	3.100	4.841	4.841	3.100	3.100	3.457	6.557	
Mass Flow	kg/h	140.7	1169	1169	140.7	140.7	159.3	300.0	
Liquid Volume Flow	m^3/h	0.1764	1.316	1.316	0.1765	0.1765	0.2001	0.3766	
Heat Flow	kJ/h	-8.507e+5	-2.574e+6	-2.887e+6	-8.507e+5	-8.628e+5	-9.615e+5	-1.824e+6	

	Compositions							
	1	2	3	4	5	6	7	8
Mole Frac (Triolein)	0.0000	0.0000	1.0000	0.1422	0.1422	0.0000	0.0000	0.0000
Mole Frac (NaOH)	0.9700	0.0362	0.0000	0.0311	0.0311	0.0000	0.0311	0.0311
Mole Frac (Ethanol)	0.0000	0.9518	0.0000	0.8164	0.8164	0.9870	0.3897	0.3897
Mole Frac (H_2O)	0.0300	0.0120	0.0000	0.0103	0.0103	0.0130	0.0103	0.0103
Mole Frac (Glycerol)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1422	0.1422
Mole Frac (Ethyl Oleat_1*)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4267	0.4267
	9	10	11	12	13	14	15	
Mole Frac (Triolein)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Mole Frac (NaOH)	0.0000	0.0510	0.0000	0.0510	0.0000	0.0000	0.0000	
Mole Frac (Ethanol)	0.9757	0.0145	0.0145	0.9761	0.9761	1.0000	0.9887	
Mole Frac (H_2O)	0.0243	0.0013	0.0013	0.0239	0.0239	0.0000	0.0113	
Mole Frac (Glycerol)	0.0000	0.2333	0.2333	0.0000	0.0000	0.0000	0.0000	
Mole Frac (Ethyl Oleat_1*)	0.0000	0.6999	0.6999	0.0000	0.0000	0.0000	0.0000	

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$$\Delta H_{r^\circ} = -38.79\frac{kJ}{mol} = -38790\frac{J}{mol}$$

The reaction that occurs is exothermic because the enthalpy value of the reaction is negative, so the reaction emitting heat:

$$\Delta G_{298k} = \Delta G_{f^\circ produk} - \Delta G_{f^\circ reaktan} \quad (4)$$

$$\Delta G_{298k} = \left(\Delta G_{f^\circ 3C_{20}H_{38}O_2} + \Delta G_{f^\circ C_3H_8O}\right) - \left(\Delta G_{f^\circ C_{57}H_{104}O_6} + \Delta G_{f^\circ 3C_2H_5OH}\right)\Delta G_{298k}$$

$$= \left((3 \times -112.46) + -447.07\right) - (-263.83 + (3 \times -167.85))$$

$$\Delta G_{298k} = -17.07\frac{kJ}{mol} = -17070\frac{J}{mol}$$

Based on the Van't Hoff equation [16]:

$$\ln K = \frac{-\Delta G_{298k}}{RT_{298}} \quad (5)$$

$$\ln K = \frac{-(-17070)\frac{J}{mol}}{8.314\frac{J}{mol.k} \times 298k}$$

$$K_{298k} = 9.82 \times 10^2$$

Table 2. Gibs value ($\Delta G_f°$) and standard enthalpy ($\Delta H_f°$).

Component	($\Delta H_f°$) (kJ/mol)	($\Delta G_f°$) (kJ/mol)
C_2H_5OH	-234.96	-167.85
$C_{57}H_{104}O_6$	-1807.7	-263.83
$C_{20}H_{38}O_2$	-656.19	-112.46
C_3H_8O	-582.8	-447.07

To determine the value of K at an operating temperature of 49 °C (322 K), it can be done in the following way:

$$\ln\left(\frac{K_{322K}}{K_{298K}}\right) = \frac{-\Delta H_{r^\circ}}{R}\left(\frac{1}{T_{322}} - \frac{1}{T_{298}}\right) \quad (6)$$

So that, $K_{322K} = 3.0571411 \times 10^2$.

The value of the reaction equilibrium constant at 49 °C (322 K) is more than one, so the reaction is reversible.

3.3. Increased Product Purity by Process Modification

In general, biodiesel production through this process can still improve efficiency and purity. Integration of distillate rate is an important aspect in reducing residuals in the product and optimizing utility design in the system to achieve better energy efficiency. This study was conducted using Aspen Energy Analyzer, where the required data were obtained through Aspen HYSYS. Process modifications were made to develop a more efficient biodiesel production process design that produces high purity, as shown in Figures 4 and 5.

The design modification of the biodiesel process involves the same initial steps as the basic process system. The differences and innovations in this process are found in the mixer for mixing triolein with Ethanol and NaOH was removed from the system, the distillate rate at the first distillation column, and the addition of a distillation column after the product. In the first

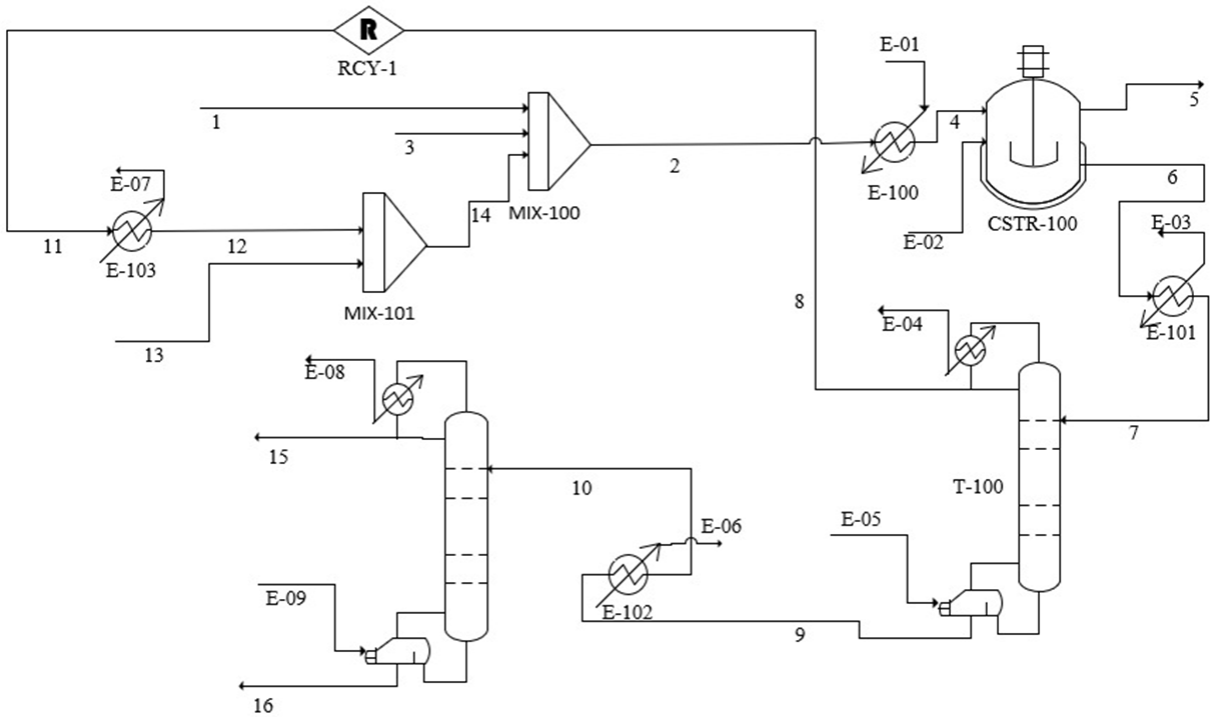

Figure 4. Modified process flow diagram for acetone production.

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Distillation Tower, the distillation rate was lowered from 3.1 kgmole/h to 1.787 kgmole/h to reduce the energy consumption in the condenser and reboiler of the distillation column. The second distillation column is used to increase the purity of ethyl oleate and separate glycerol. These changes aim to maximize biodiesel production while reducing energy consumption in the system [17]. The final product of this process is represented in stream "ethyl oleate", with an ethyl oleate mass of 1029.9094 kg/hour. The simulation results are shown in Table 3.

This process design modification integrates the concept of higher product purity compared with the previous biodiesel process design. In addition, the biodiesel product's purity is higher than that of the basic process system. The next chapter will discuss further comparison of the process design in terms of energy and purity.

3.4. Product Purity Analysis

The quality of the biodiesel product serves as an indicator for both the plant and the overall quality of the product produced. A higher level of purity in the product indicates superior quality, both for the product itself and the factory [18]. To determine the percentage of purity in the two simulation processes, the calculation is carried out using the Equation below [19]:

$$\%Purity = \frac{mass\ of\ ethyl\ oleate\ product}{total\ product\ mass} \times 100\% \qquad (7)$$

The mass of ethyl oleate and the mass of the total product were obtained from Aspen HYSYS simulation data. Table 4 interprets the data for the total product mass in the basic process design.

Based on these calculations, ethyl oleate produced using the basic process system has a purity of 89.98%. The purity of ethyl oleate in the modified process was also calculated using the same method to compare with the modified process. Table 5 shows the mass of ethyl oleate product obtained from the modified process. Based on the purity data between the basic biodiesel production process system and the modified biodiesel production process (Table 6), it can be seen that ethyl oleate with the modified process has a higher purity of 99.03%, with a difference of 9.05% between the two processes.

3.5. Analysis of Energy Used in Utilities

Using the Aspen Energy Analyzer simulation, energy demand data were obtained for the basic biodiesel production process system and the modified biodiesel production process. Furthermore, a comparison of the energy requirements for each process is shown in Figure 6 and Figure 7. Data analysis from Figures 6 and 7 shows that the energy requirements for the basic process system are higher than those for the modified process. This can be seen from the more excellent value of energy requirements in the basic process system compared to the modified process. Regarding energy, the modified process system is much more efficient, with energy savings of 57.66%, compared to the basic process system, which had 26.70%. In addition, the modified process reduced carbon emissions by

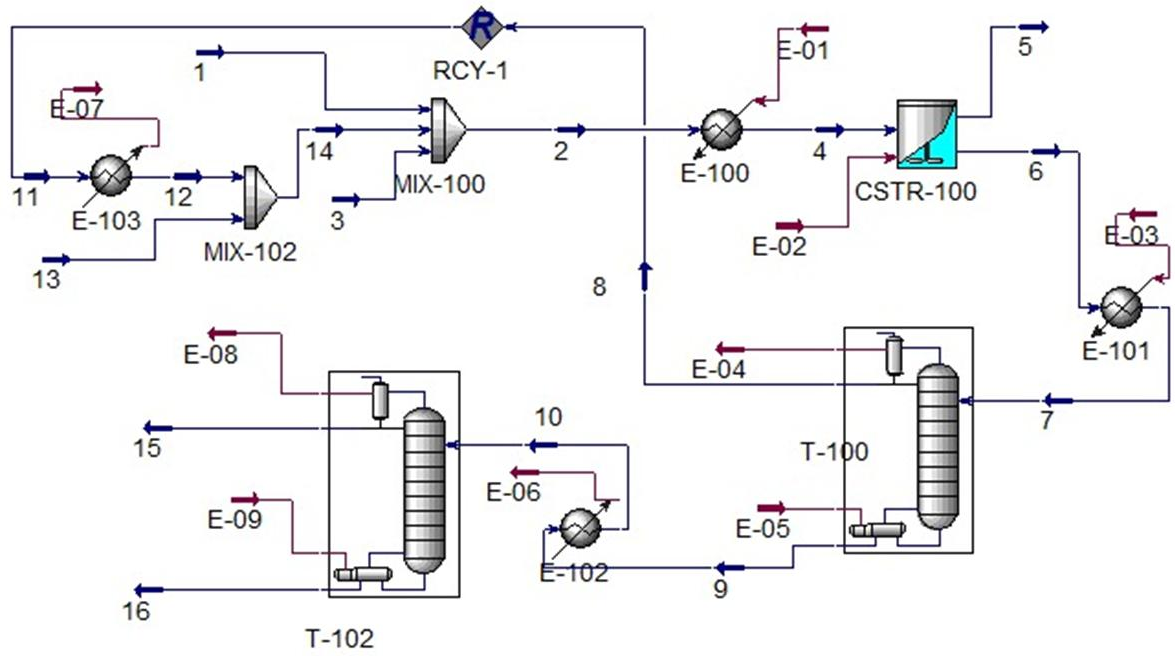

Figure 5. Aspen HYSYS simulation model for the modified biodiesel production (Figure 4).

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Table 3. Mass and energy balances of the modified biodiesel production process (Figure 4).

		Material Stream							
		1	2	3	4	5	6	7	8
Vapour Fraction	-	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
Temperature	C	60.00	39.89	45.00	49.28	-31.87	-31.87	80.00	50.55
Pressure	atm	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.3000
Molar Flow	kgmole/h	0.2542	6.587	1.129	6.587	0.0000	6.587	6.587	1.787
Mass Flow	kg/h	10.00	1247	1000	1247	0.0000	1247	1247	79.63
Liquid Volume Flow	m^3/h	5.671e-3	1.395	1.092	1.395	0.0000	1.413	1.413	9.960e-2
Heat Flow	kJ/h	-2.131e+4	-3.615e+6	-2.146e+6	-3.587e+6	0.0000	-3.587e-6	-3.331e+6	-4.908e+5
		9	10	11	12	13	14	15	16
Vapour Fraction	-	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	1.000	0.0000
Temperature	C	213.1	60.00	50.55	25.00	25.00	25.00	159.7	285.1
Pressure	atm	0.3000	0.3000	0.3000	1.000	1.000	1.000	0.3000	0.3000
Molar Flow	kgmole/h	4.800	4.800	1.787	1.787	3.417	5.203	1.234	3.566
Mass Flow	kg/h	1167	1167	79.59	79.59	157.4	237.0	127.3	1040
Liquid Volume Flow	m^3/h	1.314	1.314	9.955e-2	9.955e-2	0.1977	0.2973	0.1098	1.204
Heat Flow	kJ/h	-2.459e+6	-2.875e+6	-4.908e+6	-4.977e+5	-9.503e+5	-1.448e+5	-7.742e+5	-1.502e+6

	Compositions							
	1	2	3	4	5	6	7	8
Mole Frac (Triolein)	0.0000	0.1715	1.0000	0.1715	0.0000	0.0000	0.0000	0.0000
Mole Frac (NaOH)	0.9700	0.0374	0.0000	0.0374	0.0000	0.0375	0.0375	0.0000
Mole Frac (Ethanol)	0.0000	0.7752	0.0000	0.7752	0.9549	0.2608	0.2608	0.9464
Mole Frac (H_2O)	0.0300	0.0159	0.0000	0.0159	0.0451	0.0159	0.0159	0.0536
Mole Frac (Glycerol)	0.0000	0.0000	0.0000	0.0000	0.0000	0.1714	0.1714	0.0000
Mole Frac (Ethyl Oleat_1*)	0.0000	0.0000	0.0000	0.0000	0.0000	0.5143	0.5143	0.0000
	9	10	11	12	13	14	15	16
Mole Frac (Triolein)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mole Frac (NaOH)	0.0514	0.0514	0.0000	0.0000	0.0000	0.0000	0.0000	0.0692
Mole Frac (Ethanol)	0.0056	0.0056	0.9455	0.9455	1.0000	0.9813	0.0218	0.0000
Mole Frac (H_2O)	0.0019	0.0019	0.0545	0.0545	0.0000	0.0187	0.0074	0.0000
Mole Frac (Glycerol)	0.2353	0.2353	0.0000	0.0000	0.0000	0.0000	0.9130	0.0008
Mole Frac (Ethyl Oleat_1*)	0.7058	0.7058	0.0000	0.0000	0.0000	0.0000	0.0578	0.9300

Table 4. Composition of the basic process system product.

Composition	Mass flow (kg/h)
Sodium Hydroxide	9.8704
Ethyl Oleate	1052.0819
Glycerol	104.0103
Ethanol	3.2245
Water	0.1165
Total product	1169.3035

Table 5. Composition of the modification process system product.

Composition	Mass flow (kg/h)
Sodium Hydroxide	9.8704
Ethyl Oleate	1029.9250
Glycerol	0.2545
Total product	1040.0498

Table 6. Comparison of ethyl oleate purity between basic and modified process flow diagrams.

Purity of Ethyl Oleate base process system production (%)	Purity of Ethyl Oleate production with modification process (%)
89.98	99.03
Residual	0.97

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57.65%, better than the basic process, which had 26.69%. Thus, the modified process can be considered more environmentally friendly than the basic process system.

4. Conclusion

In summary, modifying the biodiesel production process by removing the initial mixer, changing the rate of distillate removal, and adding a second distillation column has resulted in notable enhancements in both energy savings and product quality. The updated method reduces energy consumption by approximately 57.66%, compared to the original process, which used considerably more utilities. This decrease in energy use also leads to a reduction of about 57.65% in carbon emissions, supporting better environmental sustainability. Also, the purity of ethyl oleate improved dramatically, reaching 99.03% from 89.98% in the original setup, reflecting a major boost in product quality. These findings suggest that the revised process is more energy-efficient, environmentally sustainable, and capable of producing biodiesel with higher purity. However, the study did not perform a comprehensive economic analysis. To determine the financial feasibility and potential for industrial scale-up, further evaluation using tools like Aspen Process Economic Analyzer (APEA) is recommended.

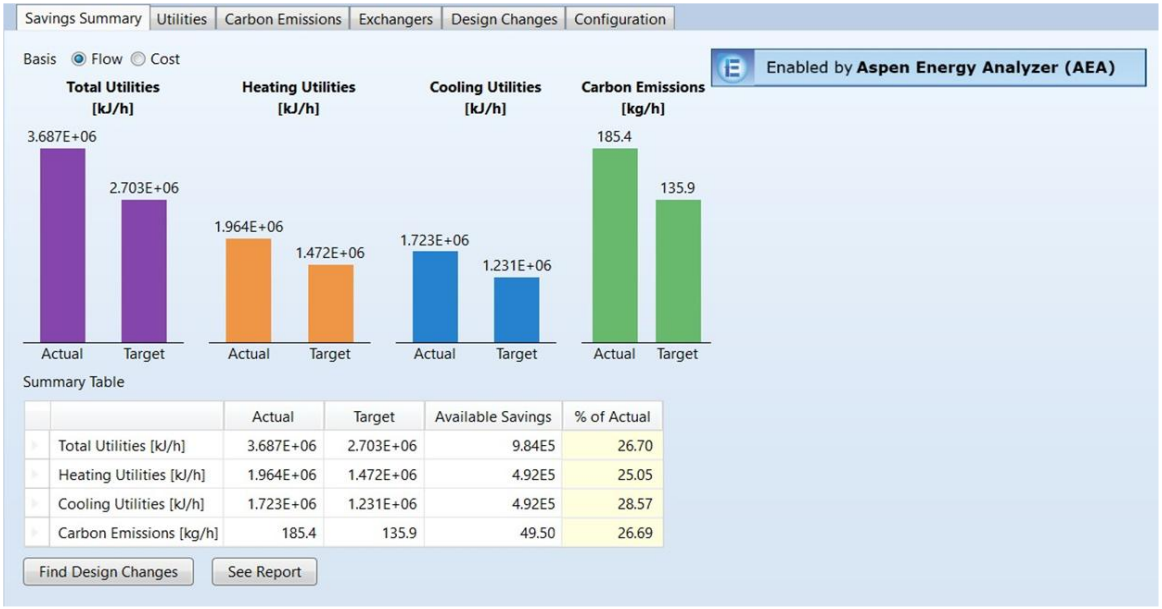

Figure 6. Energy requirements in the basic process system.

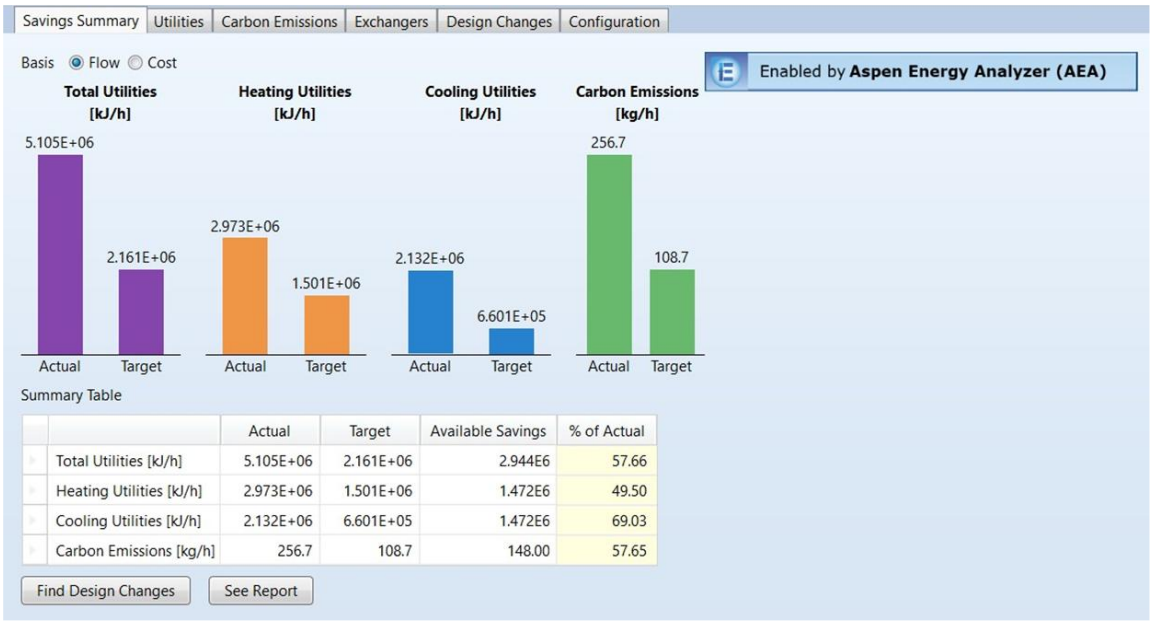

Figure 7. Energy requirement in the modified process.

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CRediT Author Statement

Authors contributions: L. Gabriaty was responsible for writing, review and editing, editing revision, and conducting literature searches for theoretical foundations. M. Rizki contributed to writing, review and editing, editing revision, and conducting literature searches for theoretical foundations. N. F. Rosyda handled conceptualization, formal analysis, investigation, methodology, software development, visualization, data curation, validation, project administration, and supervision. Finally, T. H. Kusuma focused on conceptualization, formal analysis, investigation, methodology, software development, visualization, data curation, validation, project administration, supervision, and writing the original draft. All authors have read and agreed to the published version of the manuscript.

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