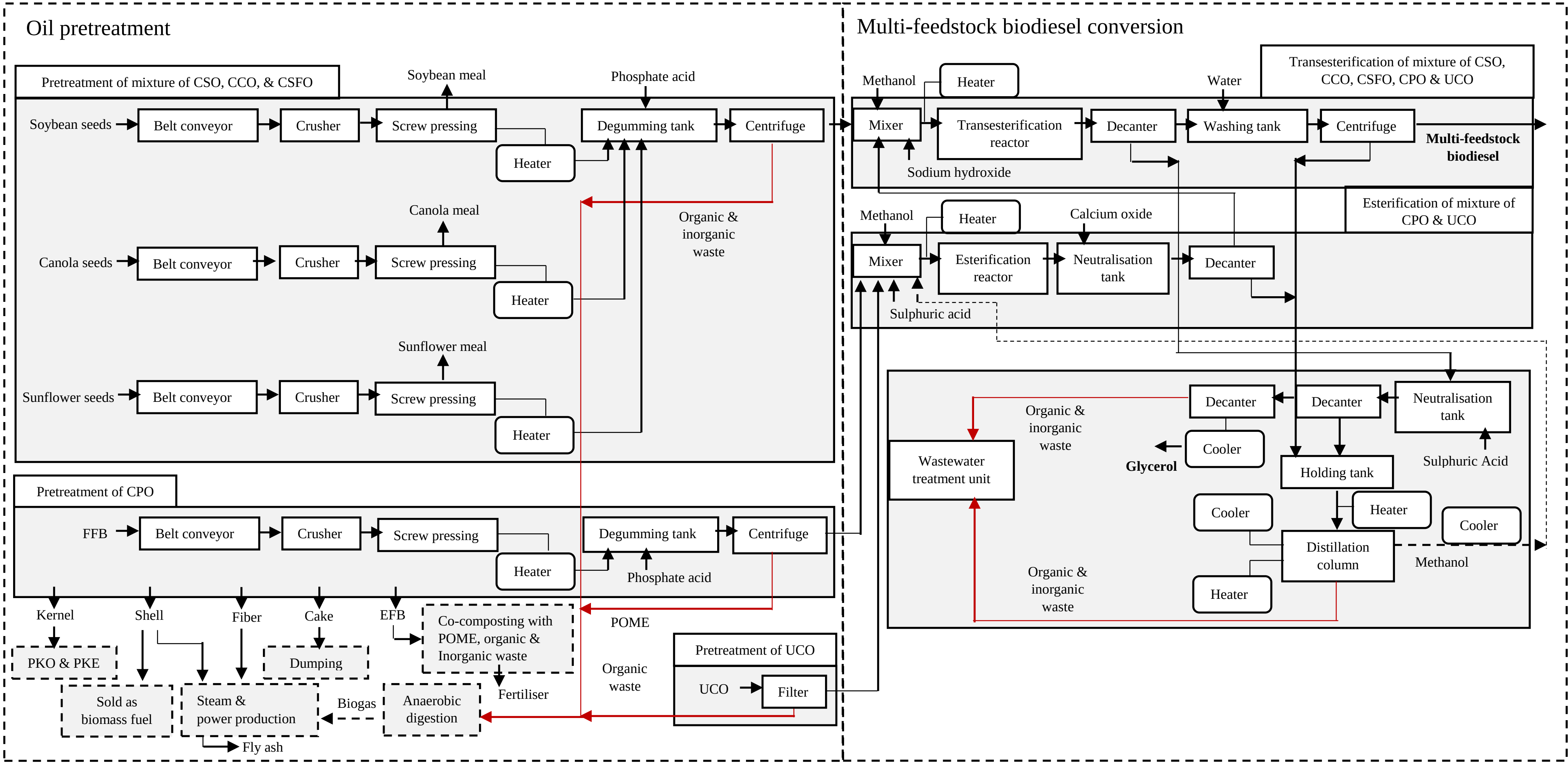
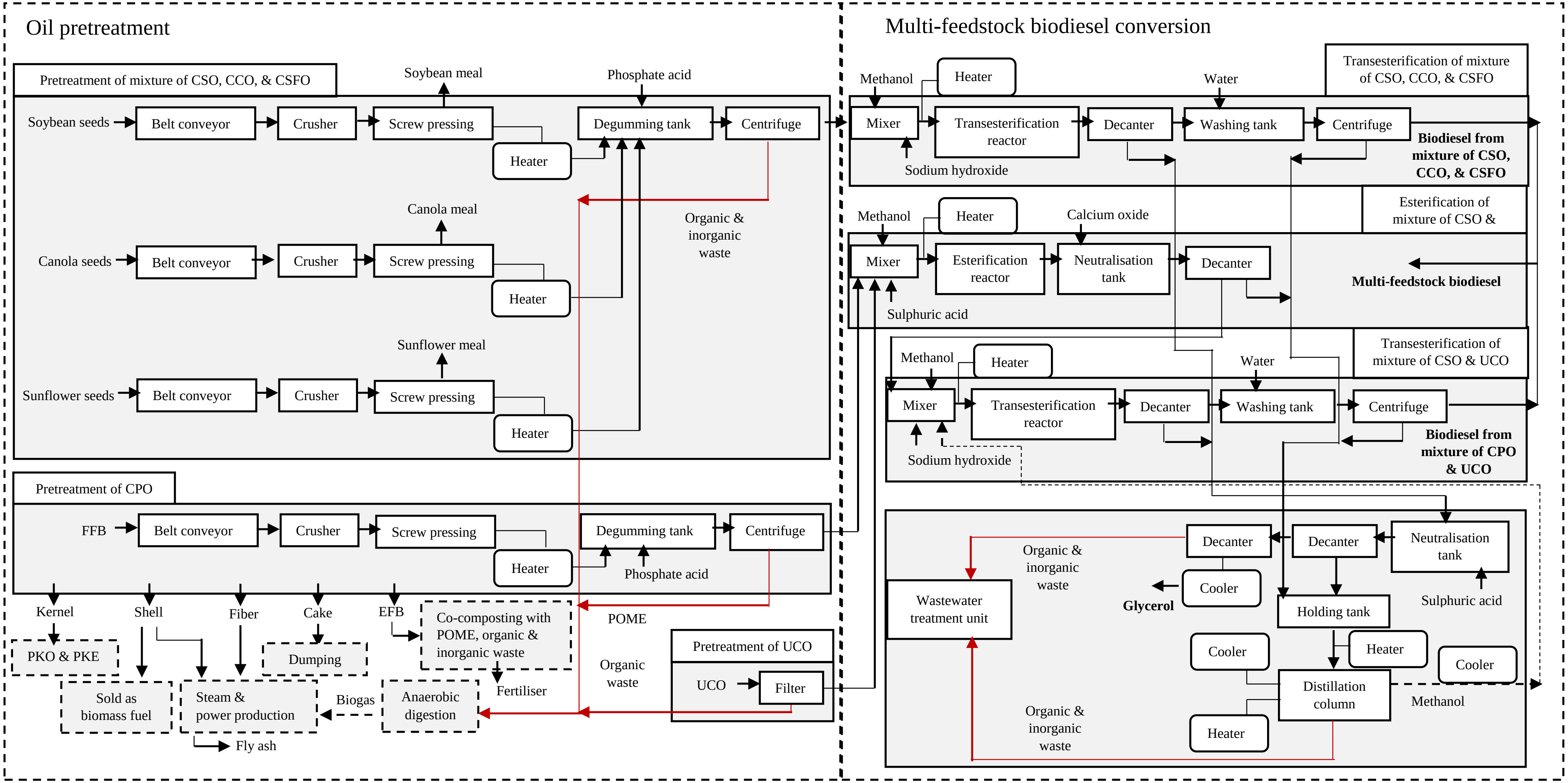
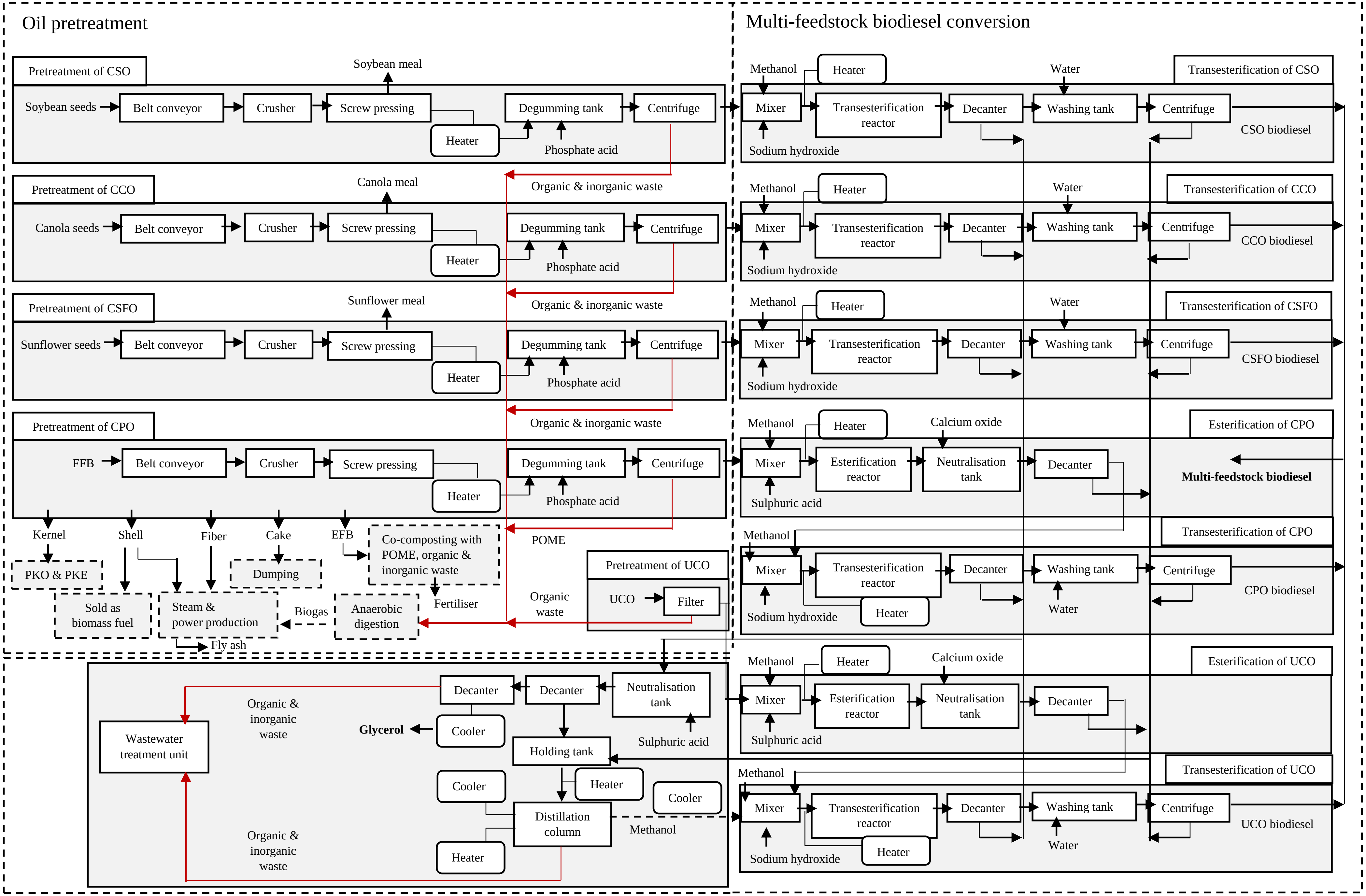
Appendixes



Appendix 1. Preliminary design of multi-feedstock biodiesel plant scenario 1



Appendix 2. Preliminary design of multi-feedstock biodiesel plant scenario 2



Appendix 3. Preliminary design of multi-feedstock biodiesel plant

Appendix 4. Inventory data of preliminary design of multi-feedstock biodiesel plant scenario 1

			Scenario 1							
			Oil pretreatment					Multi-feedstock biodiesel conversion (scenario 1)		
Categories	Parameter	Unit	Pretreatment of a mixture of CSO, CCO, & CSFO	Pretreatment of CPO	Steam & power production	Anaerobic digestion	Pretreatment of UCO	Esterification of a mixture of CPO & UCO	Transesterification of a mixture of CSO, CCO, CSFO, CPO & UCO	Wastewater treatment unit
Input material and energy	Soybean seeds	T/hour	1.2	-	-	-	-	-	-	-
	Canola seeds	T/hour	0.5	-	-	-	-	-	-	-
	Sunflower seeds	T/hour	0.6	-	-	-	-	-	-	-
	Steam	kJ/hour	$25x10^3$	$12x10^3$	-	-	-	$16x10^3$	$54x10^4$	-
	Electricity	kWh	11.2	6.71	-	-	0.75	58.5	62.9	20
	H_3PO_4	kg/hour	9.27	4.46	-	-	-	-	-	-
	FFB	T/hour	-	1.1	-	-	-	-	-	-
	UCO	T/hour	-	-	-	-	0.2	-	-	-
	H_2SO_4	kg/hour	-	-	-	-	-	0.24	-	-
	Methanol	kg/hour	-	-	-	-	-	89.2	250	-
	CaO	kg/hour	-	-	-	-	-	0.13	-	-
	NaOH	kg/hour	-	-	-	-	-	-	13.8	-
	Water	kg/hour	-	-	-	-	-	-	255	-
Output product and co-product	A mixture of CSO, CCO, & CSFO	kg/hour	665	-	-	-	-	-	665	-
	Soybean meal	kg/hour	918	-	-	-	-	-	-	-
	Canola meal	kg/hour	291	-	-	-	-	-	-	-
	Sunflower meal	kg/hour	337	-	-	-	-	-	-	-
	CPO	kg/hour	-	257	-	-	-	257	-	-
	Cake	kg/hour	-	57.8	-	-	-	-	-	-
	Kernel	kg/hour	-	82.5	-	-	-	-	-	-
	Shell	kg/hour	-	82.5	82.5	-	-	-	-	-
	Fiber	kg/hour	-	193	193	-	-	-	-	-
	Empty fruit bunches	kg/hour	-	330	-		-	-	-	-
	Fly ash	kg/hour	-	-	66.1		-	-	-	-
	POME	kg/hour	-	118	-	118	-	-	-	-
	UCO	kg/hour	-	-	-	-	199	199	-	

			Scenario 1							
			Oil pretreatment					Multi-feedstock biodiesel conversion (scenario 1)		
Categories	Parameter	Unit	Pretreatment of a mixture of CSO, CCO, & CSFO	Pretreatment of CPO	Steam & power production	Anaerobic digestion	Pretreatment of UCO	Esterification of a mixture of CPO & UCO	Transesterification of a mixture of CSO, CCO, CSFO, CPO & UCO	Wastewater treatment unit
Emissions	Esterified oil from a mixture of CPO & UCO	kg/hour	-	-	-	-	-	514	514	-
	Multi-feedstock biodiesel	T/hour	-	-	-	-	-	-	1	-
	Glycerol	kg/hour	-	-	-	-	-	-	104	-
	Water emissions:									-
	Organic waste	kg/hour	54.8	-	-	-	38.9	-	432	432
	Inorganic waste	kg/hour	12.8	-	-	-	-	-	4.12	4.12
	Organic waste from pretreatment of a mixture of CSO, CCO, & CSFO	kg/hour	-	-	-	54.8	-	-	-	-
	Inorganic waste from pretreatment of a mixture of CSO, CCO, & CSFO	kg/hour	-	-	-	12.8	-	-	-	-
	Organic waste from pretreatment of UCO	kg/hour	-	-	-	38.9	-	-	-	-

Appendix 5. Inventory data of preliminary design of multi-feedstock biodiesel plant scenario 2

			Scenario 2								
			Oil pretreatment					Multi-feedstock biodiesel conversion (scenario 2)			
Categories	Parameter	Unit	Pretreatment of a mixture of CSO, CCO, & CSFO	Pretreatment of CPO	Steam & power production	Anaerobic digestion	Pretreatment of UCO	Transesterification of a mixture of CSO, CCO, & CSFO	Esterification of a mixture of CPO & UCO	Transesterification of a mixture of CPO & UCO	Wastewater treatment unit
Input material and energy	Soybean seeds	T/hour	1.2	-	-	-	-	-	-	-	-
	Canola seeds	T/hour	0.5	-	-	-	-	-	-	-	-
	Sunflower seeds	T/hour	0.6	-	-	-	-	-	-	-	-
	Steam	kJ/hour	$25x10^3$	$12x10^3$	-	-	-	$12x10^3$	$16x10^3$	$61x10^4$	-
	Electricity	kWh	11.2	6.71	-	-	0.75	56.2	58.5	62.9	20
	H_3PO_4	kg/hour	9.27	4.46	-	-	-	-	-	-	-
	FFB	T/hour	-	1.1	-	-	-	-	-	-	-
	UCO	T/hour	-	-	-	-	0.2	-	-	-	-
	H_2SO_4	kg/hour	-	-	-	-	-	-	0.24	-	-
	Methanol	kg/hour	-	-	-	-	-	150	89.2	150	-
	CaO	kg/hour	-	-	-	-	-	-	0.13	-	-
	NaOH	kg/hour	-	-	-	-	-	8.85	-	4.91	-
	Water	kg/hour	-	-	-	-	-	154	-	101	-
Output product and co-product	A mixture of CSO, CCO, & CSFO	kg/hour	665	-	-	-	-	665	-	-	-
	Biodiesel from a mixture of CSO, CCO, & CSFO	kg/hour	-	-	-	-	-	603	-		-
	Soybean meal	kg/hour	918	-	-	-	-	-	-	-	-
	Canola meal	kg/hour	291	-	-	-	-	-	-	-	-
	Sunflower meal	kg/hour	337	-	-	-	-	-	-	-	-
	CPO	kg/hour	-	257	-	-	-	-	257	-	-
	Cake	kg/hour	-	57.8	-	-	-	-	-	-	-
	Kernel	kg/hour	-	82.5	-	-	-	-	-	-	-
	Shell	kg/hour	-	82.5	82.5	-	-	-	-	-	-
	Fiber	kg/hour	-	193	193	-	-	-	-	-	-
	Empty fruit bunches	kg/hour	-	330	-		-	-	-	-	-
	Fly ash	kg/hour	-	-	66.1		-	-	-	-	-
	POME	kg/hour	-	118	-	118	-	-	-	-	-

Categories	Parameter	Unit	Scenario 2								
			Oil pretreatment					Multi-feedstock biodiesel conversion (scenario 2)			
			Pretreatment of a mixture of CSO, CCO, & CSFO	Pretreatment of CPO	Steam & power production	Anaerobic digestion	Pretreatment of UCO	Transesterification of a mixture of CSO, CCO, & CSFO	Esterification of a mixture of CPO & UCO	Transesterification of a mixture of CPO & UCO	Wastewater treatment unit
Emissions	UCO	kg/hour	-	-	-	-	199	-	199		-
	Esterified oil from a mixture of CPO & UCO	kg/hour	-	-	-	-	-	-	514	514	-
	Biodiesel from a mixture of CPO & UCO	kg/hour	-	-	-	-	-	-	-	397	-
	Multi-feedstock biodiesel	T/hour	-	-	-	-	-	-	-	-	-
	Glycerol	kg/hour	-	-	-	-	-	65.7	-	38.5	-
	Water emissions:										
	Organic waste	kg/hour	54.8	-	-	-	38.9	246	-	186	432
	Inorganic waste	kg/hour	12.8	-	-	-	-	2.28	-	1.84	4.12
	Organic waste from pretreatment of a mixture of CSO, CCO, & CSFO	kg/hour	-	-	-	54.8	-	-	-	-	-
	Inorganic waste from pretreatment of a mixture of CSO, CCO, & CSFO	kg/hour	-	-	-	12.8	-	-	-	-	-
	Organic waste from pretreatment of UCO	kg/hour	-	-	-	38.9	-	-	-	-	-

Appendix 6. Inventory data of preliminary design of multi-feedstock biodiesel plant scenario 2

Categories	Parameter	Unit	Scenario 3														
			Oil pretreatment							Multi-feedstock biodiesel conversion (scenario 3)							
			Pretreatment of CSO	Pretreatment of CCO	Pretreatment of CSFO	Pretreatment of CPO	Steam & power production	Anaerobic digestion	Pretreatment of UCO	Esterification of CPO	Esterification of UCO	Transesterification of CSO	Transesterification of CCO	Transesterification of CSFO	Transesterification of CPO	Transesterification of UCO	Wastewater treatment unit
Input material and energy	Soybean seeds	T/hour	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Canola seeds	T/hour	-	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sunflower seeds	T/hour	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-
	Steam	kJ/hour	$89x10^2$	$81x10^2$	$81x10^2$	$12x10^3$	-	-	-	$59x10^2$	$65x10^2$	$84x10^2$	$72x10^2$	$72x10^2$	$91x10^2$	$68x10^4$	
	Electricity	kWh	6.71	6.71	6.71	6.71	-	-	0.75	58.5	58.5	56.2	56.2	56.2	56.2	62.9	20
	H_3PO_4	kg/hour	4.82	2.15	2.30	4.46	-	-	-	-	-	-	-	-	-	-	-
	FFB	T/hour	-	-	-	1.1	-	-	-	-	-	-	-	-	-	-	-
	UCO	T/hour	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-	-
	H_2SO_4	kg/hour	-	-	-	-	-	-	-	0.21	0.04	-	-	-	-	-	-
	Methanol	kg/hour	-	-	-	-	-	-	-	75.6	13.6	70	70	70	70	70	
	CaO	kg/hour	-	-	-	-	-	-	-	0.11	0.02	-	-	-	-	-	-
	NaOH	kg/hour	-	-	-	-	-	-	-	-	-	3.26	2.97	2.62	2.94	1.97	-
	Water	kg/hour	-	-	-	-	-	-	-	-	-	51.1	49.7	53.1	56.8	44.4	-
Output product and co-product	Soybean meal	kg/hour	918	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CSO	kg/hour	223	-	-	-	-	-	-	-	-	223	-	-	-	-	-
	Canola meal	kg/hour	-	291	-	-	-	-	-	-	-	-	-	-	-	-	-
	CCO	kg/hour	-	215	-	-	-	-	-	-	-	-	215	-	-	-	-
	Sunflower meal	kg/hour	-	-	337	-	-	-	-	-	-	-	-	-	-	-	-
	CSFO	kg/hour	-	-	227	-	-	-	-	-	-	-	-	227	-	-	-
	CPO	kg/hour	-	-	-	257	-	-	-	257	-	-	-	-	-	-	-
	Cake	kg/hour	-	-	-	57.8	-	-	-	-	-	-	-	-	-	-	-
	Kernel	kg/hour	-	-	-	82.5	-	--	-	-	-	-	-	-	-	-	-
	Shell	kg/hour	-	-	-	82.5	82.5	-	-	-	-	-	-	-	-	-	-
	Fiber	kg/hour	-	-	-	193	193	-	-	-	-	-	-	-	-	-	-
	Empty fruit bunches	kg/hour	-	-	-	330	-	-	-	-	-	-	-	-	-	-	-
	Fly ash	kg/hour	-	-	-	-	66.1	-	-	-	-	-	-	-	-	-	-
	POME	kg/hour	-	-	-	118	-	118	-	-	-	-	-	-	-	-	-
	UCO	kg/hour	-	-	-	-	-	-	199	-	199	-	-	-	-	-	-

Categories	Parameter	Unit	Scenario 3														
			Oil pretreatment							Multi-feedstock biodiesel conversion (scenario 3)							
			Pretreatment of CSO	Pretreatment of CCO	Pretreatment of CSFO	Pretreatment of CPO	Steam & power production	Anaerobic digestion	Pretreatment of UCO	Esterification of CPO	Esterification of UCO	Transesterification of CSO	Transesterification of CCO	Transesterification of CSFO	Transesterification of CPO	Transesterification of UCO	Wastewater treatment unit
	Esterified oil from CPO	kg/hour	-	-	-	-	-	-	-	313	-	-	-	-	313	-	-
	Esterified oil from UCO	kg/hour	-	-	-	-	-	-	-	-	201	-	-	-	-	201	-
	CSO biodiesel	kg/hour	-	-	-	-	-	-	-	-	-	200	-	-	-	-	-
	CCO biodiesel	kg/hour	-	-	-	-	-	-	-	-	-		195	-	-	-	-
	CSFO biodiesel	kg/hour	-	-	-	-	-	-	-	-	-	-	-	208	-	-	-
	CPO biodiesel	kg/hour	-	-	-	-	-	-	-	-	-	-	-	-	223	-	-
	UCO biodiesel	kg/hour	-	-	-	-	-	-	-	-	-	-	-	-	-	174	-
	Glycerol	kg/hour	-	-	-	-	-	-	-	-	-	22.3	21.4	22	20.9	17.6	-
Emissions	Water emissions:																
	Organic waste	kg/hour	26.7	14.3	13.9	-	-	-	38.9	-	-	82.3	79.8	84.2	105	81	432
	Inorganic waste	kg/hour	7.23	2.69	2.87	-	-	-	-	-	-	0.76	0.76	0.76	1.04	0.81	4.12
	Organic waste from pretreatment of CSO	kg/hour	-	-	-	-	-	26.7	-	-	-	-	-	-	-	-	-
	Inorganic waste from pretreatment of CSO	kg/hour	-	-	-	-	-	7.23	-	-	-	-	-	-	-	-	-
	Organic waste from pretreatment of CCO	kg/hour	-	-	-	-	-	14.3	-	-	-	-	-	-	-	-	-
	Inorganic waste from pretreatment of CCO	kg/hour	-	-	-	-	-	2.69	-	-	-	-	-	-	-	-	-

Categories	Parameter	Unit	Scenario 3														
			Oil pretreatment							Multi-feedstock biodiesel conversion (scenario 3)							
			Pretreatment of CSO	Pretreatment of CCO	Pretreatment of CSFO	Pretreatment of CPO	Steam & power production	Anaerobic digestion	Pretreatment of UCO	Esterification of CPO	Esterification of UCO	Transesterification of CSO	Transesterification of CCO	Transesterification of CSFO	Transesterification of CPO	Transesterification of UCO	Wastewater treatment unit
	Organic waste from pretreatment of CSFO	kg/hour	-	-	-	-	-	13.9	-	-	-	-	-	-	-	-	-
	Inorganic waste from pretreatment of CSFO	kg/hour	-	-	-	-	-	2.87	-	-	-	-	-	-	-	-	-
	Organic waste from pretreatment of UCO	kg/hour	-	-	-	-	-	38.9	-	-	-	-	-	-	-	-	-

Scientific Mechanism of the Occurrence of Environmental Impacts

Scientific mechanisms of compounds and activities in the life cycle of biodiesel production that have an impact on the environment.

1. The formation of N_2O from the use of urea which has an impact on global warming potential

The use of urea fertiliser can cause N_2O gas emissions through the nitrification and denitrification processes. Nitrification is the process of converting ammonium to nitrate through 2 stages of biological oxidation, namely:

Change of ammonium to nitrite, the reaction:

$$2NH_4^+ + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2^- + 4H^+ + 2H_2O \qquad (1)$$

Change of nitrite to nitrate, the reaction:

$$2NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2NO_3^- \qquad (2)$$

Denitrification is the process of reduction of nitrate to nitrogen gas (Reece et al. 2014). Nitrate (NO_3^-), which is used as an alternative electron acceptor in anaerobic respiration, is reduced to nitrogen gases such as (N_2, NO, or N_2O) (Madigan et al. 2012). The reaction is as follows:

$$2NO_3^- \xrightarrow{\text{Pseudomonas}} 2NO_2 \rightarrow 2NO \rightarrow \mathbf{N_2O} \rightarrow N_2 \qquad (3)$$

The global warming potential (GWP) caused by N_2O gas is 298 times larger than that of CO_2 (IPCC 2006; Siangjaeo et al. 2011).

2. Global warming potential due to carbon emissions

The activities of the biodiesel industry and power plants, such as steam power plants, urea plants, methanol plants and so on, are still using coal as fuel which can emit fossil CO_2, sulfur dioxide (SO_2), and nitrogen oxides (NO_x) (Figure 1) (Silalertruksa & Gheewala, 2012; Wahyono et al., 2019). Transportation such as trucks in the biodiesel industry also contributes to high CO_2 emissions (Figure 1) because it uses diesel fuel (Siregar et al., 2015; Wahyono et al., 2019).

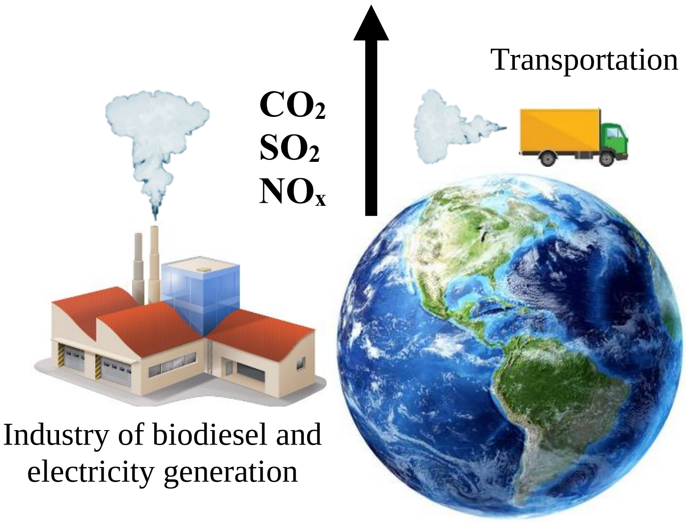


Figure 1. CO_2 emissions from biodiesel production, electricity generation, and transportation

CO_2 emissions will be released into the air and eventually in the earth's atmosphere. The CO_2 in the atmosphere layer will reflect the sun's infrared radiation back to the earth. The sun's infrared rays that are reflected back to the earth will cause the earth's temperature to increase and eventually cause global warming (Soden, 2005). Illustration of the process of global warming is shown in Figure 2.

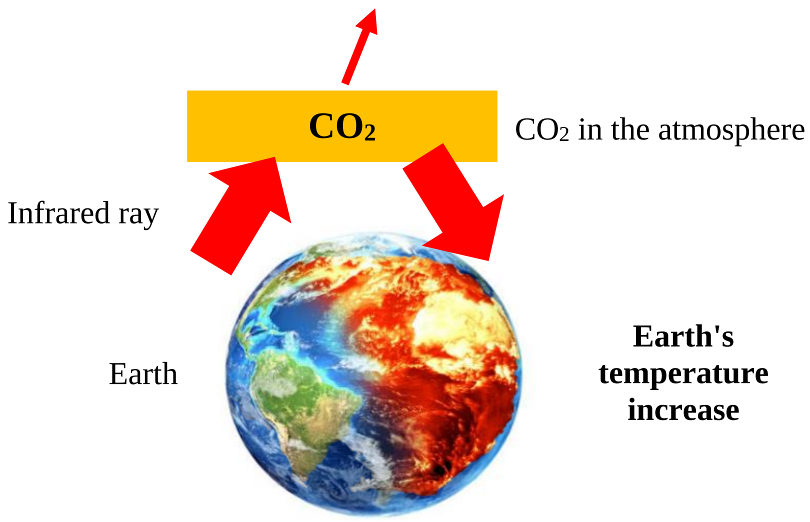


Figure 2. The process of global warming potential

3. Eutrophication due to the use of urea and phosphate fertilisers

Eutrophication due to the use of urea and phosphate fertilisers shown in Figure 3.

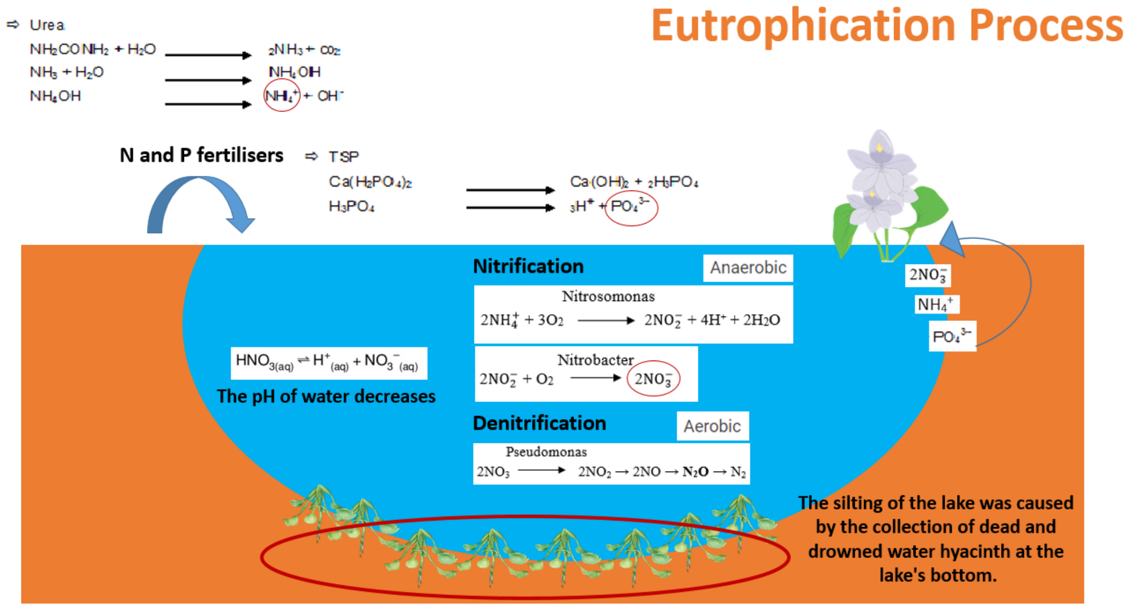


Figure 3. Eutrophication due to the use of urea and phosphate fertilisers

When it rains, the residual urea and phosphate fertilisers not absorbed by oil palm trees will be transported away by surface water flows and entering the lake, marking the beginning of eutrophication. The lake has excessive amounts of nitrogen and phosphorus, which act as fertilisers for water hyacinth, algae, and microalgae (Figure 3).

4. Acidification and ecotoxicity occur due to acid rain

Acidification and ecotoxicity occur due to acid rain shown in Figure 4.

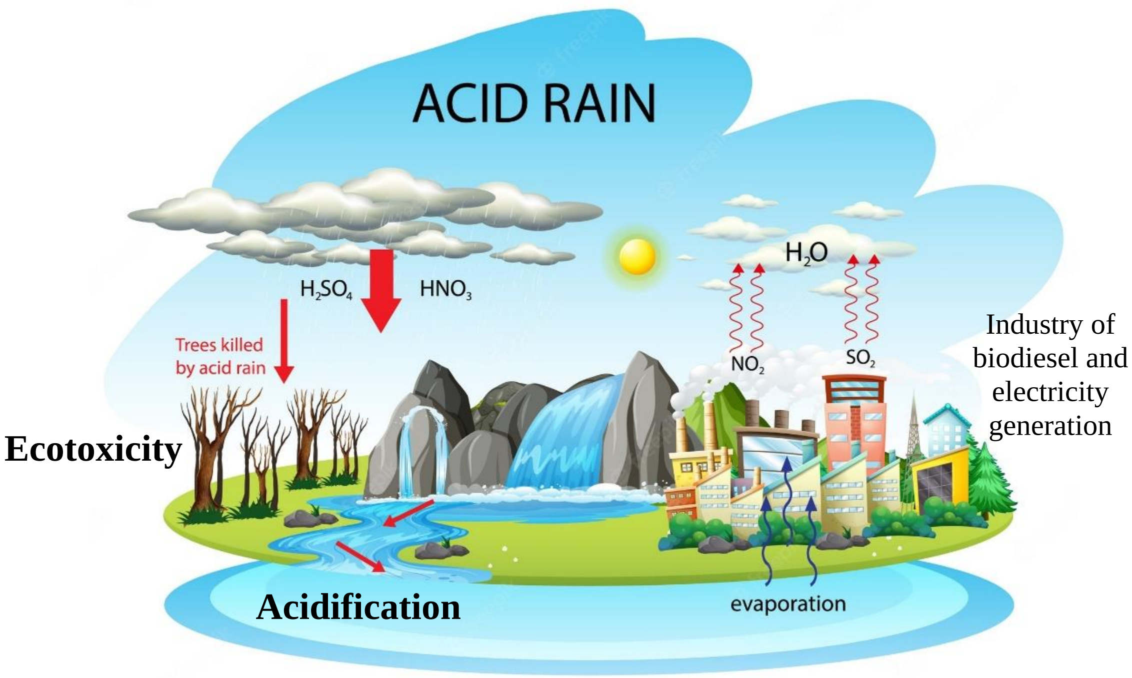


Figure 4. Acidification and ecotoxicity occur due to acid rain

NO_2 and SO_2 emissions will ascend into the air and environment as a result of coal burning in electricity generation. NO_2 and SO_2 chemicals react with precipitation to generate H_2SO4 and HNO_3 when it rains. H_2SO_4 and HNO_3 precipitate with rainfall on terrestrial, freshwater, and marine. As a consequence, it will result in the acidification of terrestrial, freshwater, and marine, as well as ecotoxicity in terrestrial, freshwater, and marine (Figure 4).

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Summary

Effective biodiesel storage has proven to be an issue, with the Indonesian government investing billions of Indonesian rupiahs (IDR) to address. As a result, it is critical to explore how different storage strategies impact the quality of biodiesel. The goal of this research was to see how storage at room temperature in the dark affects the quality of palm oil biodiesel (POB) and canola oil biodiesel (COB). POB and COB were kept for 12 months in airtight containers at 22 °C in the dark. The findings revealed that POB was substantially more damaged than COB. This study discovered increases in density (POB by 51.52 kg/m^3 and COB by 17.52 kg/m^3), kinematic viscosity (POB by 0.67 mm^2/s and COB by 0.32 mm^2/s), and kinematic viscosity (POB by 0.67 mm^2/s and COB by 0.32 mm^2/s), acid value (POB by 0.27 mg-KOH/g and COB by 0.25 mg-KOH/g), total glycerol (POB by 0.58 %-mass and COB by 0.60 %-mass), and peroxide value (POB by 48 meq-O_2/kg and COB by 54 meq-O_2/kg), however fatty acid methyl esters decreased (POB by 7.11 %-mass and COB by 9.36 %-mass). The findings of gas chromatography-mass spectrometry for POB and COB revealed decreases in 9-octadecenoic acid methyl ester and 9,12-octadecadienoic acid (Z,Z)-methyl ester and increases in 9-octadecenoic acid and 9,12-octadecadienoic acid (Z,Z)-methyl ester (Z,Z). As indicated by the findings of this study, the storage of biodiesel in a closed container at 22 °C in the dark may reduce biodiesel oxidation, particularly, the negligible development of ketone and aldehyde groups in the biodiesel oxidation process during storage, based on FTIR measurements.

If not handled appropriately, the production of palm oil biodiesel in Indonesia has the potential to damage the environment. As a result, we performed a life cycle assessment (LCA) research on the production of palm oil biodiesel to evaluate Indonesia's environmental performance. Using an LCA methodology, we examined environmental indicators such as the carbon footprint, as well as the impact on human health, ecosystem diversity, and resource availability

in the production of palm oil biodiesel. In this investigation, one ton of biodiesel used as the functional unit. The palm oil biodiesel production life cycle consists of three processing units: oil palm plantation, palm oil production, and biodiesel synthesis. The oil palm plantation was discovered to be the processing unit with the largest environmental effect. The environmental benefits, namely the usage of phosphate, generated 62.30 % of the total environmental benefit of the CO_2 uptake from the oil palm plantation processing unit (73.40 %). The entire human health damage caused by the palm oil biodiesel production life cycle was 0.00563 DALY, whereas the total environmental diversity degradation was 2.69×10^{-5} species•yr. Finally, we determined that the oil palm plantation processing unit was the largest contributor to the carbon footprint, human health damage, and ecological diversity damage, whereas the biodiesel production processing unit caused the most damage to resource availability.

This study was carried out to produce biodiesel from a mixture of five different oils, namely palm oil, used cooking oil, soybean oil, canola oil, and sunflower oil, using transesterification at varying mole ratios of oil:methanol. The oils were combined in a total volume of 300 mL, using the same amount of each oil. The transesterification of blended oils was carried out at 60°C for 1 hour, with the oil:methanol mole ratios adjusted at 1:3, 1:6, 1:9, 1:12, and 1:15. The results showed that mole ratios of 1:6 produced the best yield of 92.99% with a conversion of 99.58% mass. According to the gas chromatography-mass spectrometry (GCMS) data, all mole variants had a methyl ester percentage of greater than 98 percent area. For all variants, the FTIR analysis found peaks indicating the existence of a methyl ester functional group and its long-chain (–R). The methyl ester concentration, density, acid value, and total glycerol test parameters all satisfied ASTM D 6751, EN 14214, and SNI 7182–2015 quality requirements. As a result of this research, multi-feedstock biodiesel appropriate for industrial-scale applications was successfully created.

Future industrialization is possible for the existing laboratory-scale synthesis of biodiesel from numerous feedstocks. Therefore, the energy balance of biodiesel synthesis from many feedstocks must be examined. This research compares the energy balance of palm oil biodiesel production in Indonesia to that of multi-feedstock biodiesel production. According to the energy balance analysis, the biodiesel multi-feedstock plant is operationally viable. Multi-feedstock biodiesel's renewability is 2.62 whereas palm oil biodiesel's is 5.27. The energy content and demand of multi-feedstock biodiesel (and its co-products) are much lower than palm oil biodiesel (and its co-products). Multi-feedstock biodiesel has less energy than palm oil biodiesel, 86,159 MJ against 110,350 MJ, respectively. The energy requirements for the manufacturing of biodiesel from several feedstocks and biodiesel from palm oil are $35x10^3$ MJ and $23x10^3$ MJ, respectively. Energy requirements, both fossil and biomass, are due to plantation activities, such as the application of fertilisers. Multiple crop plantations use more energy than single crop plantations because they need more fertilisers. It is not recommended to generate biodiesel from sunflower, canola, and soybean since its energy balance is not superior than palm oil biodiesel.

The production of biodiesel from multiple feedstocks, which is now being done on a laboratory scale, has the potential to be scaled up to an industrial size in the future. As a result, research on the environmental effect of multi-feedstock biodiesel production is required. This study compares the environmental performance of simulated multi-feedstock biodiesel production to palm oil biodiesel production in Indonesia. In general, the environmental effect of multi-feedstock biodiesel production is greater during the planting stage than palm oil biodiesel production. The conversion of scrubland to various crop plantations (soybean, canola, sunflower, and oil palm) resulted in a contribution of 9.89 tCO_2 GHG emissions per tonne of biodiesel generated, but the conversion to exclusively oil palm plantation resulted in a value of -3.43 tCO_2. Many environmental consequences, such as ecotoxicity, eutrophication, acidification, and global warming, are associated with plantation operations, notably fertiliser usage. Multiple crop farming is more damaging to the environment than oil palm agriculture alone since it requires more fertiliser. It is not suggested utilising soybean, canola, and sunflower to produce multi-feedstock biodiesel since it has a larger environmental impact than palm oil biodiesel.

Investigating the environmental damage of multi-feedstock biodiesel production is necessary. This study compares the environmental performance of simulated multi-feedstock biodiesel production to palm oil biodiesel production in Indonesia. In general, multi-feedstock biodiesel production causes more environmental impact during the planting stage than palm oil biodiesel production. Plantation operations, notably the use of fertilisers, cause environmental damage to human health, ecosystem variety, and resource availability. Multiple crop farming is more damaging to the environment than oil palm agriculture alone since it requires more fertiliser. The cost of multi-feedstock biodiesel is 126 $. The availability of resources for multi-feedstock biodiesel is more than that of palm oil biodiesel, which was 79.7 $. It is not suggested utilising soybean, canola, or sunflower to make multi-feedstock biodiesel since it has a larger environmental damage than palm oil biodiesel.

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List of Publications

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LIFE CYCLE ASSESSMENT

LCA

$$CS = (SOC + C_{VEG}) \times A$$

$$SOC = (SOC_{ST} + F_{LU} + F_{MG} + F_I)$$

$$E_{LUC} = \left(\frac{CS_R - CS_A}{T}\right) \times 3.664 + \left(\frac{E_{fire,Non-CO_2}}{T}\right)$$

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