Producing Biodiesel from Waste Cooking Oil in Saudi Arabia: Process Design and Cost Study

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ABSTRACT

This project provides an overview of a biodiesel production unit designed to convert waste cooking oil into biodiesel, utilizing Aspen HYSYS software within the context of Saudi Arabia. The initiative addresses the increasing demand for sustainable and eco-friendly fuel sources in the region. The design incorporates process simulation, equipment selection, and operational optimization to ensure the efficient and environmentally responsible production of biodiesel. Special attention is given to the unique challenges and opportunities the Saudi Arabian context presents, emphasizing the potential of waste cooking oil recycling and local biodiesel production to contribute to a more sustainable energy landscape.

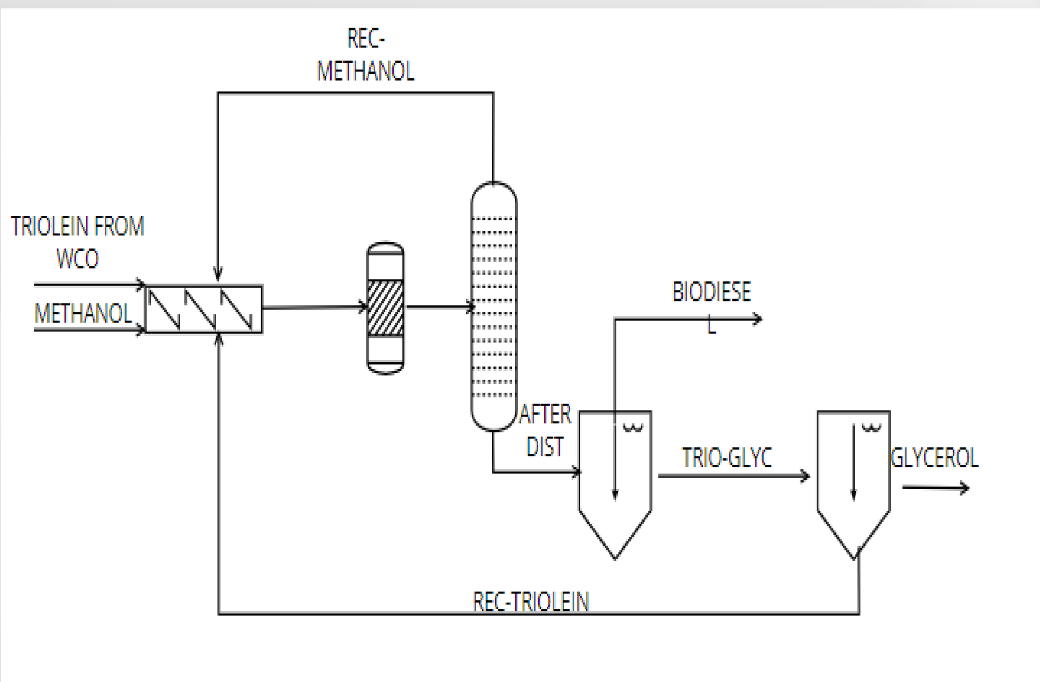
In this study, Aspen HYSYS and Aspen Plus were employed to design a biodiesel production unit to achieve an optimal configuration. The selected unit, which includes a triolein separator before the biodiesel reactor, was identified as the optimal choice due to its smaller reactor size and reduced number of trays in distillation columns. Notably, the design using Aspen HYSYS outperformed Aspen Plus's conversion efficiency.

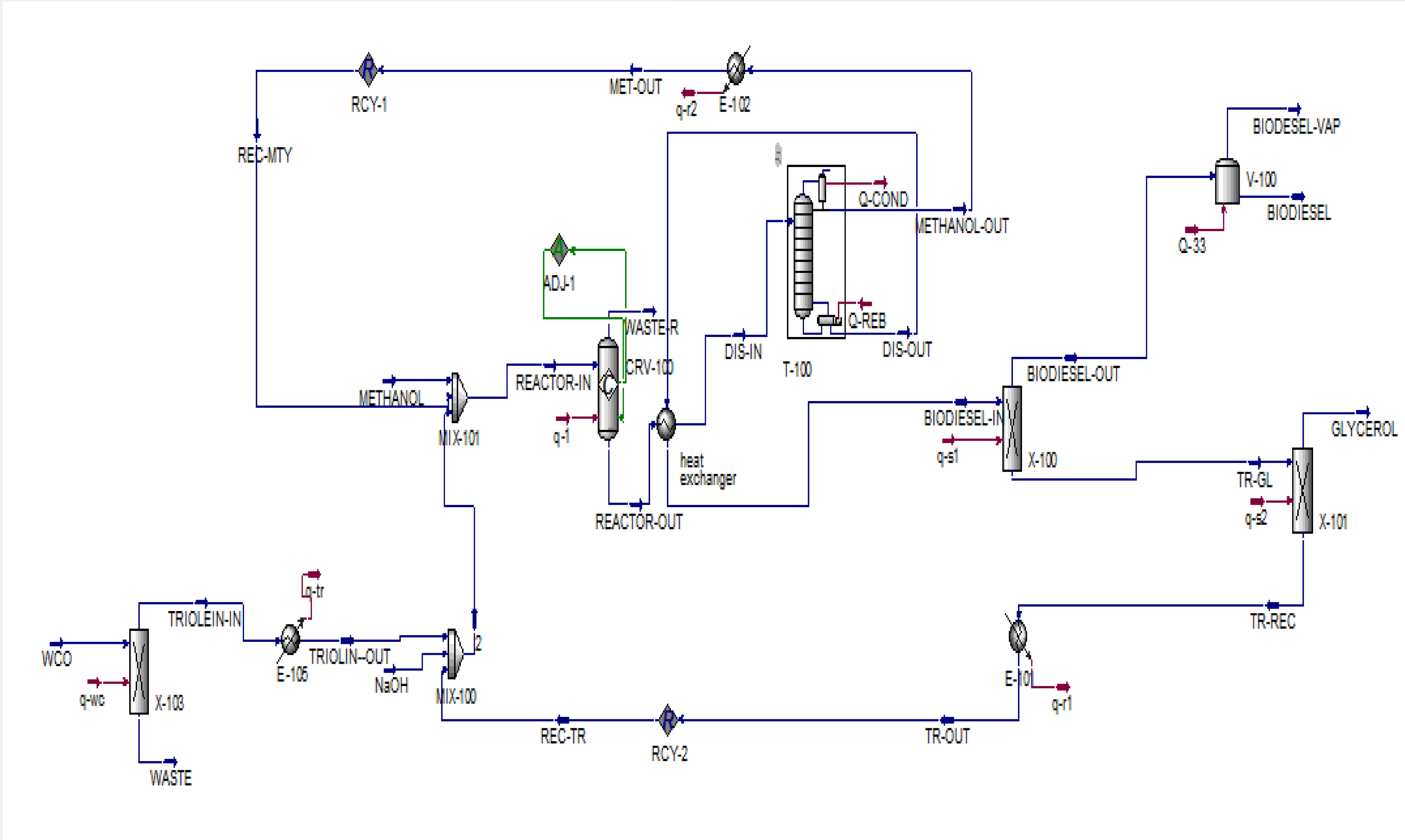
The project aims to produce 21,024 tons of biodiesel annually from waste cooking oil. The document provides insights into biodiesel's historical production and consumption globally and in Saudi Arabia. It also details the physical and chemical properties of biodiesel. The process simulation was conducted using Aspen HYSYS, focusing on three main units: the reactor, heat exchanger, and distillation tower. A capital cost estimate for the project is approximately 138.75 million Saudi riyals, with an estimated project lifespan of 12 years.

PROBLEM STATEMENT

There are many ways to produce biodiesel using several techniques, including modern technologies and old technologies. The goal of the graduation project is to design a processing unit to produce biodiesel from cooking oils, as well as to benefit from the amount of cooking oil waste present in the Kingdom of Saudi Arabia, the methods of disposal of which are complex and harmful to the environment. Its use in the production of biodiesel is beneficial to the environment and economically feasible. In the first part of the project A literature review will be conducted to collect data about the history of biodiesel, its importance, uses, production capacity, and consumption around the world and in the Kingdom of Saudi Arabia. By-products and raw materials will be collected. The different technologies used in production, biodiesel will be studied, and then the most appropriate technology will be chosen. The second part of the project will start with simulation of the process using ASPEN HYSYS and ASPEN PLUS.

PROCESS BLOCK DIAGRAM





PROCESS DESCRIPTION

First, the waste cooking oil was entered at 25℃ and a pressure of 100 KPa and the molar flow rate 46.12 kmol/hr into the splitter to separate the triolein from the rest of the materials resulting from the waste cooking oil. It came out with a temperature of 614℃ and a pressure of 120 Kpa. After that, it cooled to 25℃ with a pressure difference of 20 KPa. After that, it introduced into the mixture so that could benefit from it. After our process, this return from after the final separation process was then introduced into another mixture containing methanol with molar flow rate 11.53 kmol/hr to be mixed to produce biodiesel after the reaction. After that, it introduced to the Conversion Reactor to produce biodiesel. produced biodiesel at a temperature of 65℃ and a pressure of 100 KPa, but it does contain other materials with biodiesel.

Stoichiometric Equation for reaction taking place:

$$C_{57}H_{104}O_6 + 3CH_3OH \rightarrow 3C_{19}H_{36}O_2 + C_3H_8O_3$$

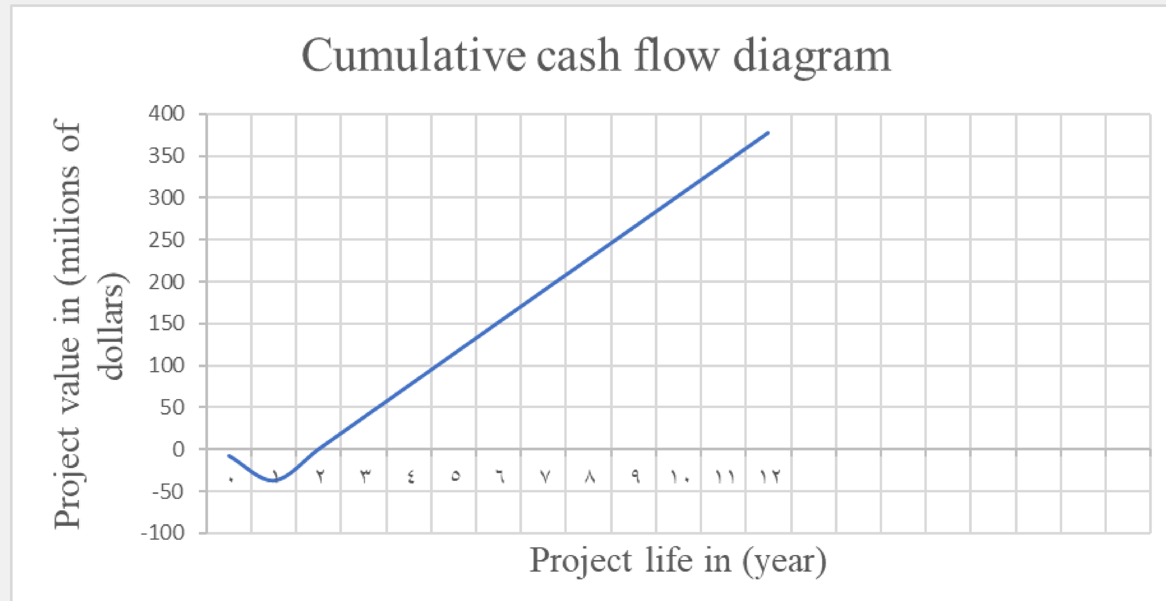
(Triolein) (Methanol) (Biodiesel) (Glycerol)

The biodiesel must be separate it from other materials. After that, separated the methanol from the biodiesel and returned the methanol to the mixer before the reactor so that could benefit from it. In the lower stream there is biodiesel, Triolein, and glycerol. separated the biodiesel from the two materials and the triolein is removed from the glycerol and return the triolein to the mixer so that it can be used. And the biodiesel will be introduced inside a tank and cooled it to 25℃ and pressure 101.3 KPa and the molar flow rate is 8.093 kmol/hr .

ECONOMIC STUDY

Equipment Type	Equipment Code	Purchasing Cost ($)
	E-701	99,300
	E-702	99,300
Heat Exchanger	E-703	9,930
	E-704	124,000
Reactor	R-701	304,000
	V-701	24,100
	V-702	19,300
	V-703	16,100
Vessel	V-704	16,100
	V-801	16,100
	V-802	24,800
	V-803	24,100
Tower	T-801	51,300
Total capital cost		893,700

Product	Price ($/kg)	Production (kg/y)	Revenue ($/Y)
Biodiesel	3	21,024,000	63,072,000
Glycrol	0.5	2,487,840	1,243,920
	Total		64,315,920



CONCLUSION

In this study, the use of Aspen HYSYS and Aspen Plus proved effective in designing an optimized biodiesel production unit. The configuration featuring a triolein separator ahead of the biodiesel reactor emerged as the optimal choice, offering advantages such as a compact reactor size and a reduced number of trays in the distillation columns. Notably, the design using Aspen HYSYS demonstrated superior conversion efficiency when compared to Aspen Plus. This research underscores the significance of software selection in the optimization of biodiesel production processes. The plan in the GP2 phase involves the design of reactors, distillation columns, and heat exchangers. Economic aspects of the project will be calculated, and potential challenges will be identified. For the reactor design, the values for volume are specified as 13.08 m^3, with a space time of 3.57; additional values are detailed in Table 6.2. The design of heat exchangers and distillation column rooms adheres to relevant standards and codes. Subsequent steps include a comprehensive review of the economic study for the entire plant. The annual utility cost is estimated at 550,000 SAR, with an annual raw materials cost of 47.650 million SAR. The initial plant startup cost is projected at 75 million SAR, while the land cost is 30 million SAR, and the capital cost is 12.63 million SAR.

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