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CASTOR OIL CONVERSION TO BIODIESEL: A PROCESS SIMULATION STUDY

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ABSTRACT

The aim of this study is to highlights the importance to shift from the use of traditional fossil fuels to biodiesel as a clean energy source. A simulation study has been conducted using ASPEN HYSIS software for the biodiesel production form castor oil. The simulation was run and the properties of the produced biodiesel were highlighted. The optimum conditions resulted in 88 % conversion.

Keywords: biodiesel, castor oil, simulation, yield, transesterification.

1. INTRODUCTION

The global economy and socio-economic development are intensively depending on the energy sector. The use of energy in the world is increasing overtime. Every year, the rate of energy is increasing 23%; the main cause of this increase is the overpopulation. The main source of energy is the fossil fuel as the Energy Information Administration (EIA) mentioned with86.4% of primary energy used in the world gets from fossil fuel (EIA 2019). This main source of energy is one of dangerous sources that led to air pollution and greenhouse gas emissions. Different combustion products are being released to our atmosphere such as volatile organic components (VOCs), carbon monoxide (CO), nitrogen oxide (NO_X) and particulate matter (PM). The Ozone which is the main component of smog is produced within the presence of NO_X and VOC_s combined with any source of heat. The CO_2 produced by the combustion of fossil fuel is equal to 21.3 billion tones/year, after the need of natural process, the rest equals to 10.65 billion tones CO_2 in the atmosphere air(Prasad and Dhanya 2011). The second main source of energy is coal, whose combustion produces Sulphur dioxide (SO_2) which affect the local pollution. The methane emissions are caused by the biomass combustion which emits 40% of gross carbon dioxide and 38% of tropospheric Ozone(Olivier and Peters 2020). There are many natural problems inflicted by these emissions such as the global warming. On the other hand, there are another natural issues such as deforestation and water scarcity due to the overpopulation that are also affected by these emissions.

In the recent years, a holistic thinking to reduce the air pollution by switching from the fossil fuels to other clean energy sources(Al-Akraa, Mohammad *et al*. 2011, Al-Akraa, Mohammad *et al*. 2012, Al-Akraa, Mohammad *et al*. 2015, Al-Akraa, Mohammad *et al*. 2015, Al-Akraa, Mohammad *et al*. 2015, Al-Akraa, Mohammad *et al*. 2015, Al-Akraa, Mohammad *et al*. 2015, Mohammad, El-Nagar *et al*. 2015, Al-Akraa 2017, Al-Akraa, Mohammad *et al*. 2017, Al-Akraa, Asal *et al*. 2018, Al-Akraa, Asal *et al*. 2018, Al-Akraa, Mohammad *et al*. 2018, Mohammad, Al-Akraa *et al*. 2018, Al-Akraa, Asal *et al*. 2019, Al-Akraa, Asal *et al*. 2019, Al-Akraa, Asal *et al*. 2019, Al-Akraa, Ohsaka *et al*. 2019, Asal, Al-Akraa *et al*. 2019, Asal, Al-Akraa *et al*. 2019, Abdulhalim, Asal *et al*. 2020, Abuzaied, Asal *et al*. 2020, Al-Akraa, Al-Qodami *et al*. 2020, Al-Akraa, Al-Qodami *et al*. 2020, Al-Akraa and Mohammad 2020, Al-Akraa, Salama *et al*. 2021, Al-Qodami, Alalawy *et al*. 2021, Ali, Asal *et al*. 2021, Asal, Mohammad *et al.* 2021). Biofuel is also an alternative for fossil fuels and is considered as a friendly fuel to the nature in limiting the air emissions and improving the air quality. The biofuel is derived from biomass, for example wood residual, forest residual, agriculture products, industrial and urban residues. It involves mainly bioethanol, biodiesel, and biogas and bio hydrogen. (Dhanya 2011).

The formulation of biodiesel yield is obtained from the literature data and hence utilized in Aspen HYSYS process simulation. Aspen HYSYS is a process modeling tool that is used for optimizing, conceptual designing, planning, managing, and monitoring the performance of production, processing, refining, and separating industries. It is a main section of Aspen Tech's aspen ONE® Engineering applications. It has a massive application for chemical engineers in process simulation. It was recognized as a very instinctive and simple process simulator used in gas and oil refining industries. It has very spontaneous proficiencies that include high cooperative flow diagram for navigating and structuring processes through great simulations.

Simulating the technical process is important for designing, analyzing, developing, and optimizing the process. It is mostly applied in chemical plants and power stations. Simulating a process serves as a model-based representation of physical, chemical, and biological unit operations. Simulating a process is used to illustrate the ultimate effects of alternate conditions and followed actions.

2. EXPERIMENTAL PART

ASPEN HYSYS version 10 was used to simulate the production of biodiesel by the transesterification process (Equations 1-3) (Keera, El Sabagh *et al.* 2018):

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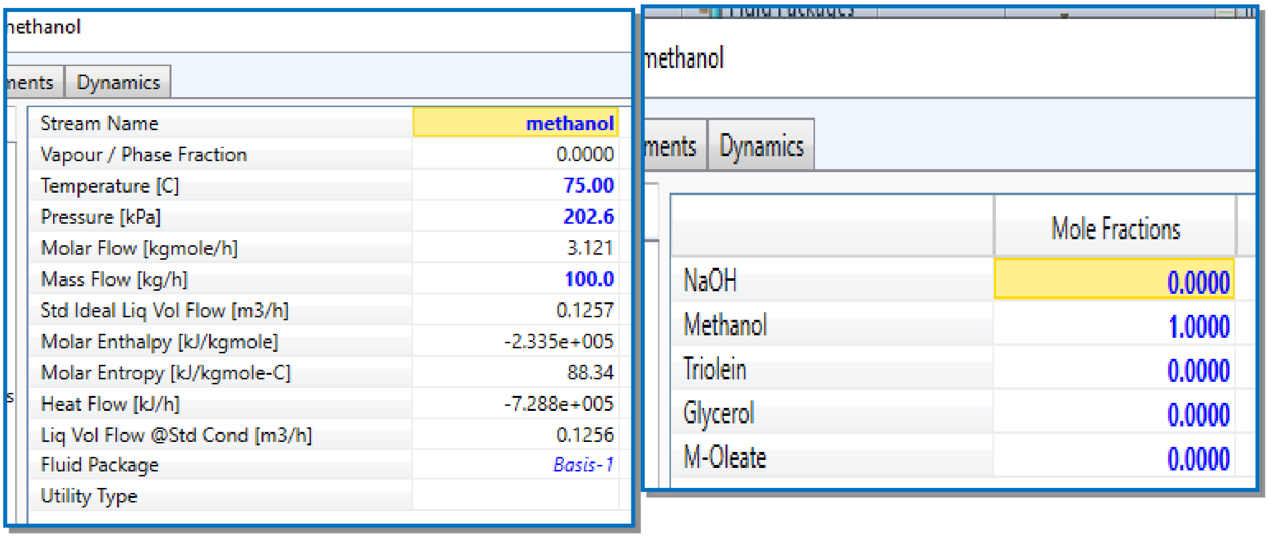
$$TGs + ROH \xleftrightarrow{catalyst} DGs + RCO_2R \qquad (1)$$

$$DGs + ROH \xleftrightarrow{catalyst} MGs + RCO_2R \qquad (2)$$

$$MGs + ROH \xleftrightarrow{catalyst} RCO_2R\ (ester) + \text{Glycerol} \qquad (3)$$

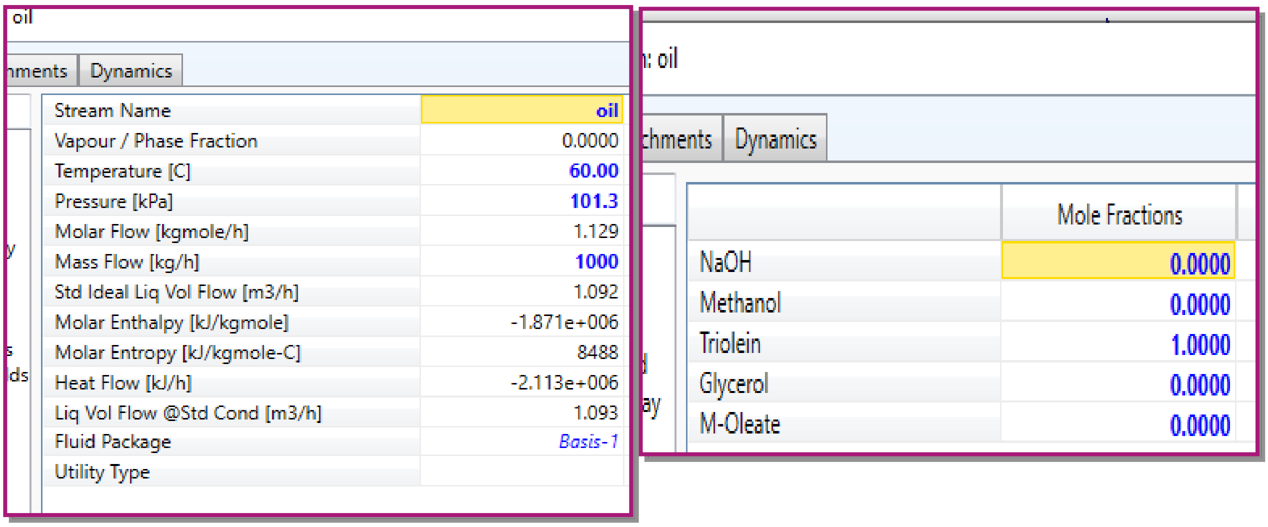
The input design, conditions, compositions and material streams, respectively, for the methanol and the oil are shown in Figure-1 and Figure-2.



Stream Name	methanol
Vapour / Phase Fraction	0.0000
Temperature [C]	75.00
Pressure [kPa]	202.6
Molar Flow [kgmole/h]	3.121
Mass Flow [kg/h]	100.0
Std Ideal Liq Vol Flow [m3/h]	0.1257
Molar Enthalpy [kJ/kgmole]	-2.335e+005
Molar Entropy [kJ/kgmole-C]	88.34
Heat Flow [kJ/h]	-7.288e+005
Liq Vol Flow @Std Cond [m3/h]	0.1256
Fluid Package	Basis-1
Utility Type	

	Mole Fractions
NaOH	0.0000
Methanol	1.0000
Triolein	0.0000
Glycerol	0.0000
M-Oleate	0.0000

Figure-1. The input conditions, compositions and material streams for methanol.



Stream Name	oil
Vapour / Phase Fraction	0.0000
Temperature [C]	60.00
Pressure [kPa]	101.3
Molar Flow [kgmole/h]	1.129
Mass Flow [kg/h]	1000
Std Ideal Liq Vol Flow [m3/h]	1.092
Molar Enthalpy [kJ/kgmole]	-1.871e+006
Molar Entropy [kJ/kgmole-C]	8488
Heat Flow [kJ/h]	-2.113e+006
Liq Vol Flow @Std Cond [m3/h]	1.093
Fluid Package	Basis-1
Utility Type	

	Mole Fractions
NaOH	0.0000
Methanol	0.0000
Triolein	1.0000
Glycerol	0.0000
M-Oleate	0.0000

Figure-2. The input conditions, compositions and material streams for the oil.

3. RESULTS AND DISCUSSIONS

The formulation of biodiesel yield is obtaining from literature data and hence utilized in Aspen Hysys process simulation. The process in Hysys is composed of two streams; one of the oil and the other one is the methanol enters to a Continuously Stirred Tank Reactor (CSTR) where the transesterification reaction takes place, then the vapor stream and the liquid one pass through a total condenser distillation to separate the oil used (Triolein) from the biodiesel (Methyl-Oleate) and the glycerol. The top stream which contains the biodiesel and glycerol enters to the settling tanks which separate the glycerol from the biodiesel due to the difference in their densities. Figure-3 shows the biodiesel production simulation process and Figure-4 shows the output compositions and materials streams for the biodiesel.

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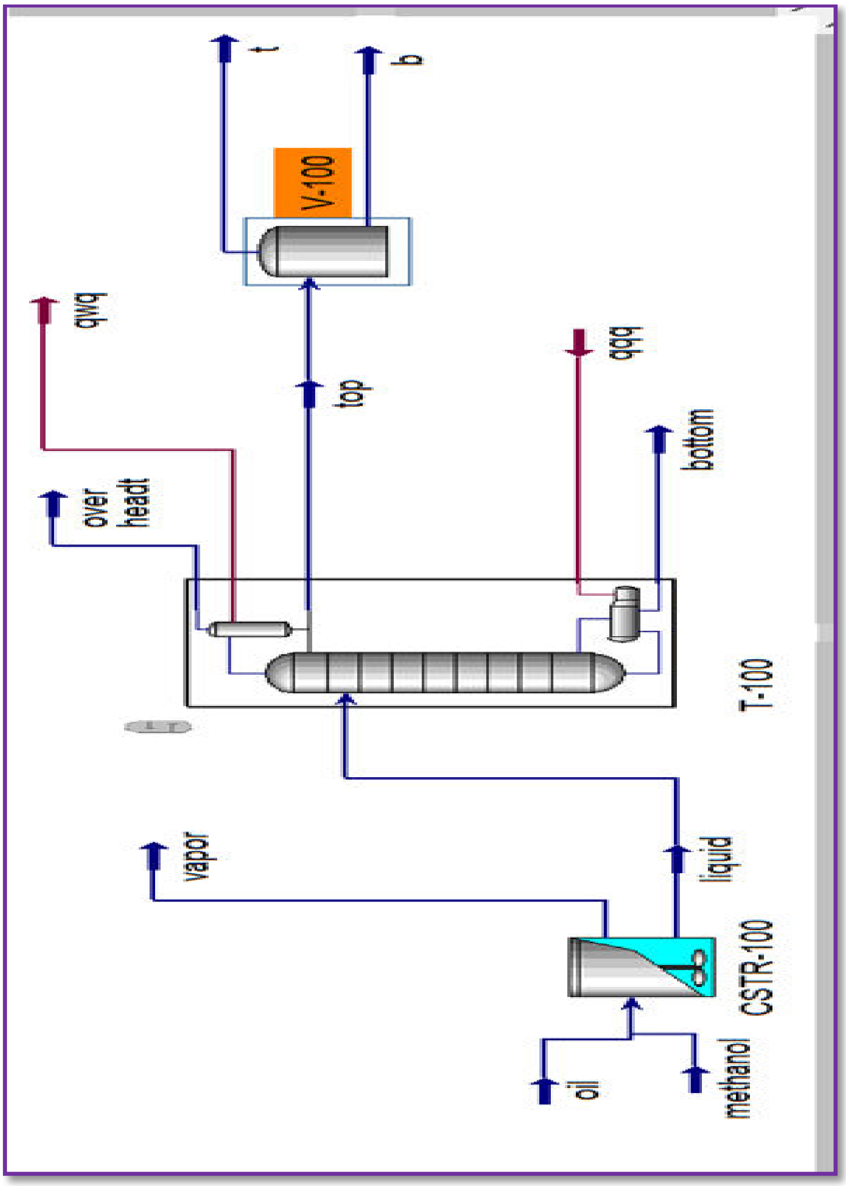

Figure-3. The simulated biodiesel production process.

Stream Name	b
Vapour / Phase Fraction	0.0000
Temperature [C]	304.1
Pressure [kPa]	101.3
Molar Flow [kgmole/h]	0.8213
Mass Flow [kg/h]	223.6
Std Ideal Liq Vol Flow [m3/h]	0.2520
Molar Enthalpy [kJ/kgmole]	-5.364e+005
Molar Entropy [kJ/kgmole-C]	779.5
Heat Flow [kJ/h]	-4.405e+005
Liq Vol Flow @Std Cond [m3/h]	0.2414
Fluid Package	Basis-1
Utility Type	

	Mole Fractions
NaOH	0.0000
Methanol	0.0024
Triolein	0.0000
Glycerol	0.1156
M-Oleate	0.8820

Figure-4. The output conditions, compositions and material streams for the produced biodiesel.

4. CONCLUSIONS

To decrease pollutant emissions to atmosphere, biodiesel can be used instead of the traditional fossil fuels. This study aimed to simulate the biodiesel production process from castor oil using Aspen Hysys software.The optimum case with the highest conversion (88 %) was demonstrated.

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