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Original Research Article

Automation of the Two Stage Biodiesel Production Process

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Abstract

The control of the biodiesel production plays an important role on achieving the production standard of the biodiesel. The quality of the produced biodiesel depends on the raw materials, alcohol and catalyst selections and process and storage conditions. The control of the biodiesel production not only enables to achieve high quality biodiesel but also maintains the continuity of the product quality.

In this work, an automation system for a two stage biodiesel production is designed and realized. A PLC (Programming Logic Control) based system is used for this purpose. The designed and realized biodiesel production facility enables to produce biodiesel using either a single stage or a two stage process. The quality of the biodiesels separately produced using a single stage and a two stage process are analyzed and compared. The analysis results show that a two stage biodiesel production process gives better results compared to the single stage in fuel density, viscosity and flash point.

Keywords: Automation, PLC, Biodiesel, Two stage

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1. Introduction

Due the continuous increase in CO₂ production which causes the global warming necessitates to use environment friendly fuels. Biodiesel is an example of those environment friendly fuels. Many biomass studies have been conducted on biodiesel [1-5]. It is produced using chemical methods from the used or unused plant or animal originated oils [6].

Biodiesel properties must adhere with the international biodiesel standard specifications such as the American Standards for Testing Materials (ASTM 6751-3) or the European Union (EN14214) for biodiesel fuel. These biodiesel properties can be improved by five methods: pyrolysis, dilution with blending, micro-emulsion, and trans-esterification and super critical method. Transesterification is regarded as the best method among the other approaches due to its low cost and simplicity. The properties of produced biodiesel are characterized by physicochemical properties [7, 8].

Transesterification method is a widely used technique to produce fuels from vegetable oils. In this method, raw materials, catalyst, alcohol, temperature, process time affect the properties of the produced biodiesel. In order to increase the quality of the biodiesel, two stage production processes are becoming more common [9, 10].

Rapeseed oil is chosen for this study as it is very rich for its fatty acid components. In order to produce biodiesel from the rapeseed

oil, a PLC controlled production facility is designed and realized, and first a single stage, then a two stage biodiesel productions are performed using the transesterification method. The biodiesel produced using the single and two stage methods are compared according to fuel properties such as density, viscosity, flash point, cloud point, pour point, freezing point, Cold Filter Plugging Point (CFPP), copper strip corrosion, calorific value, and water content.

It is advantageous to produce the biodiesel in an automated way as automation will provide the production of the fuel in desired amounts and according to the standards. Moreover, automation will add benefits such as maintaining the fuel quality, minimizing the man power during the production, the ability to interfere to the production process at any level, the ability to increase the fuel production capacity, minimizing the maintenance costs, and minimizing the total fuel production costs [11]. The produced biodiesel should be competitive with the petro diesel in order to be accepted as an alternative fuel. The biodiesel produced in a proper way provides similar performance against the petro diesel in fuel quality.

2. Experimental Study

The process to produce the biodiesel from vegetable oils is categorized in four main steps as reaction, decomposition, rinsing and drying. In this study, the reaction step could be performed in two stages with a production facility shown in Figure 1.



Fig. 1 The production facility used to produce the biodiesel

In Figure 2, the first stage of the two stage process is schematically shown. In this stage, first the raw oil is introduced to the reactor. In the reactor, this raw oil is heated up to 55 °C. Meanwhile, methanol whose amount is 20% of the amount of the raw oil, and Sodium Hydroxide whose amount is 0.45% of the amount of the raw oil, are introduced to the Methoxide tank. 66% of the solution in the Methoxide tank is then introduced to the reactor after the temperature of the raw oil in the reactor stabilizes at 55 °C. This solution in the reactor is then stirred for 50 minutes at 55 °C. Then, the temperature of the solution is increased up to 65 °C, which is the boiling temperature of the alcohol. This step takes 10 minutes. The alcohol is thrown away from the reactor with the help of the Heat Exchanger. With the help of this step, 15-20% of the alcohol which enters the reaction is regained. Then, the solution in the reactor is kept still. The glycerine is separated due to the density difference. Finally, this glycerine is taken away from the reactor.

The second stage of the two stage process, which is schematically shown in Figure 3, starts with heating the solution in the reactor again up to 55 °C. Then, the remaining 34% of the initial solution in the Methoxide tank is introduced to the reactor. This solution in the reactor is stirred at 55 °C for 50 minutes. After the stirring, the temperature of the solution is increased to 65 °C to regain the alcohol. Then, the solution in the reactor is transferred to the waiting and rinsing tank, and kept still for 8 hours. After this period, the biodiesel and the glycerine are separated because of the density difference, and glycerine is taken away from the tank.

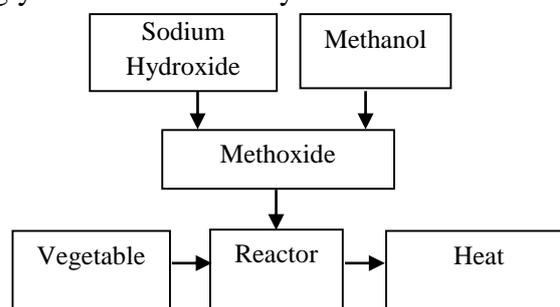


Fig. 2. The schematic view of the first stage of the two stage biodiesel production process

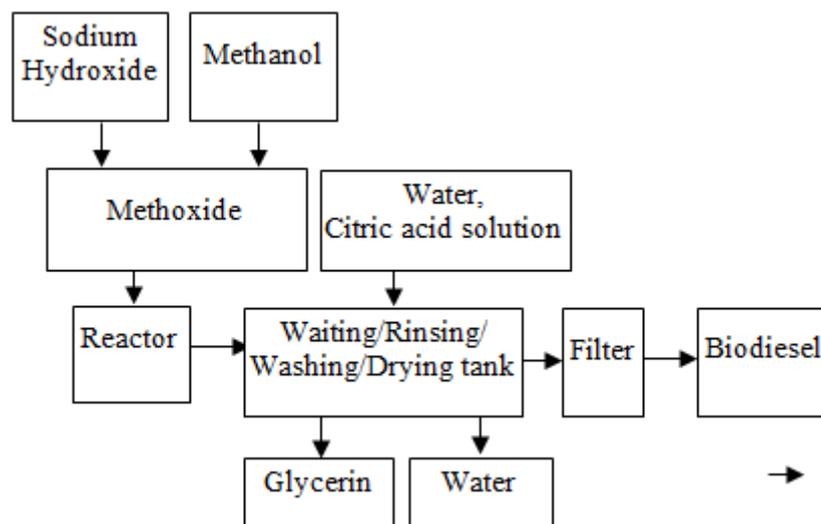


Fig. 3. The schematic view of the second stage of the process.

In order to remove the remaining alcohol and particles, the biodiesel is rinsed with water-citric acid solution. For this rinsing step, first the biodiesel in the waiting and rinsing tank is heated up to 60 °C. Then water having 0.3% citric acid is introduced to the tank. The amount of water introduced to the tank is kept 20% of the amount of biodiesel inside the

tank. The rinsing is performed using the fogging method. After the rinsing, the solution is kept still for 2 hours. After the waiting period, the biodiesel and water can be separated due to the density difference. The water which lowers down is taken away from the tank. After this step, the biodiesel is heated up to 85°C under the vacuum

conditions and dried. This step takes 60 minutes. After that, biodiesel is kept still till its temperature is decreased down to 50 °C. Finally, this biodiesel is passed through a 5 micron filter.

3. The Details of the Automated System

Figure 4 provides a schematic view of the PLC and surrounding elements and their connections which are used in the automation of the biodiesel production.

In order to realize the above mentioned process steps, PLC based system is used for the automation and an operator panel is used to provide the data for the biodiesel production. Moreover, pressure sensors are used to detect the pressure in the tanks, PT 100 resistive sensors are used to detect the

temperature of the materials in the tanks, solenoid pump and valves are used to transfer the materials between tanks, and mixers are used to stir the materials in the tanks. Table 1 shows every control element used for each tank. (“□” shows that that element is used, “-” shows that that element is not used).

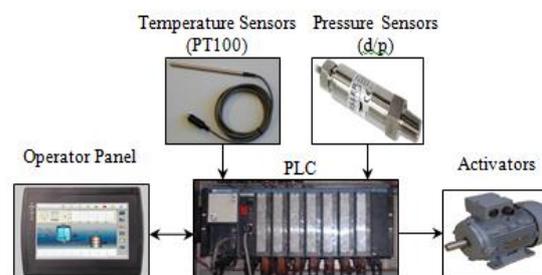


Fig. 4. PLC and surrounding elements and their connections which are used in the automation of the biodiesel production

Table 1. The Control Elements used in Biodiesel Production

Reactor	Pressure sensor (d/p)	Temperature sensor (PT 100)	Mixer (M)	Pump (P)	Solenoid valve	Heat Element
Raw Material	*	-	-	*	*	-
Reactor	*	*	*	*	*	*
Methanol Tank	*	-	-	-	*	-
Sodium Hydroxide Tank	*	-	-	-	*	-
Methoxide Tank	*	-	-	-	*	-
Recreation Tank	*	*	*	*	*	*

The level of the liquid in a tank is determined from the data obtained from the pressure sensor located at the bottom of the tank. Equation 3.1 show the expression of the pressure at the bottom of the tank which is caused by the liquid in the tank.

$$P_T = \rho \cdot g \cdot h \cdot 10^{-5} \quad (3.1)$$

where P_T is the pressure of the liquid at the bottom of the tank (bar), ρ is the density of the oil (kg/m^3), g is the gravitational acceleration (m/s^2), and h is the level of the oil in the tank (m). The mass of the liquid in the tank can be found using the Equation 3.2

$$Q = A \cdot h \cdot \rho \quad (3.2)$$

where Q is the mass of the liquid (kg), A is the cross sectional area of the tank (m^2), h is the level of the oil in the tank (m).

The data obtained from the pressure sensors are also used to determine the amount of oil required during the automated process or the amount of catalyst to be transferred to the reactor tank. The amount of oil or catalyst to

be transferred to the reactor tank can be found by estimating the pressure difference at the bottom of the tank before and after the transfer. Equation 3.3 can be used for this purpose. This equation is derived from Equation 3.1 and Equation 3.2 by replacing the h parameter.

$$P_T = g \cdot Q / A \quad (3.3)$$

For each tank, g/A ratio is calculated to obtain the amount of the liquid in the tank by checking the data the pressure sensor provides ($Q = P_T / (g/A)$), or the data the pressure sensor should provide in order to reach the amount of liquid to be transferred to the tank ($P_T = g \cdot Q / A$). The resolution error of the amount of the liquid transferred in the tanks is calculated using Equation 3.4

$$\varepsilon = P_T / (2^n - 1) \quad (3.4)$$

where ε is the resolution error of the pressure sensor read by the PLC and n is the analog input bit number of the PLC. The ladder diagram of the program code which the

pressure at the bottom of the tank using the data from the pressure sensor can be written as below (Figure 5). Figure 5 shows the process box representation of this calculation where Wxab is the word address of pressure sensors connected to the PLC, Wrb is the internal word address of the PLC, A is the maximum measurement level of the pressure sensor, and Wrc is the pressure of the liquid at the bottom of the tank [12].

$$WRa = Wxab$$

$$WRb = WRa * A$$

Fig. 5. The ladder diagram program determining the amount of the liquid to be transferred to the tank

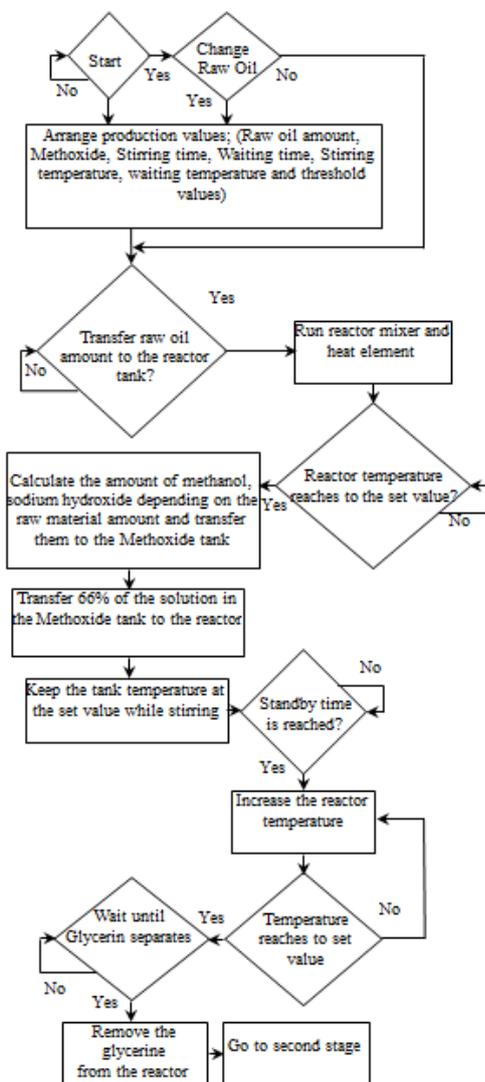


Figure 6. Automation flow diagram of first stage for production of biodiesel

Figure 6 and Figure 7 show the process flow of the first and the second stages of the PLC

programs for the two stage biodiesel production process developed in this study.

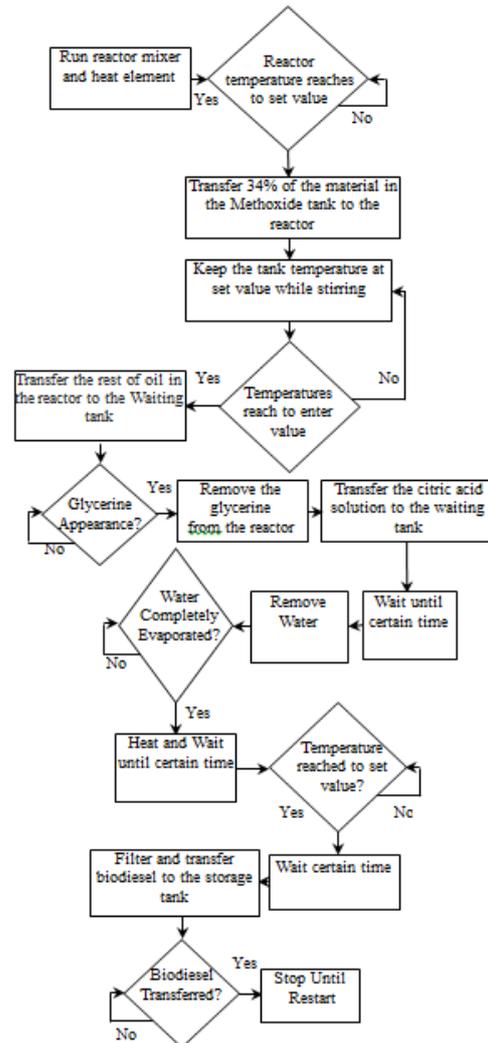


Fig. 7. Automation flow diagram of second stage for production of biodiesel

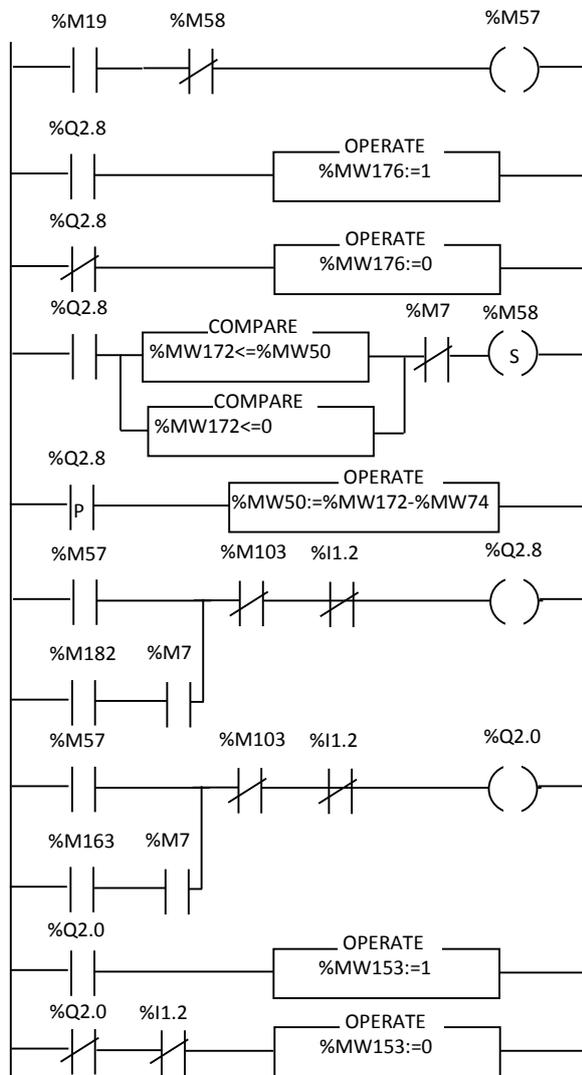
Ladder programming language is used to program the PLC for this biodiesel production. A sample Ladder code for transferring the raw oil to the reactor tank is provided in Figure 8.

4. Result and Discussion

In the developed production plant, biodiesels are produced using the single stage and two stage processes with four replications and the resulted biodiesels are compared with respect to their fuel properties using the average values. Table 2 provides the results of this comparison of single stage and two stage biodiesels.

It can be seen from Table 2 that the two stage biodiesel is better than the single stage

biodiesel in Density, Kinematic viscosity, Flash point, Calorific Value, Water Content properties. The two stage biodiesel production will be preferred by the commercial biodiesel production plants in order to realize higher quality biodiesel.



At Program; MW72 : Crude oil intake

MW172 : Crude oil level

Fig. 8. A sample Ladder code for transferring the raw oil to the reactor tank

In order to provide engine guaranty and to widespread the biodiesel usage, high quality biodiesel production should be maintained. Automated processes provide high quality biodiesel by continuously controlling the process and quality. Moreover due to the high quality fuel, any possible problem that will harm the engine is prevented.

Table 2. Fuel Properties Biodiesel Obtained from Rapeseed Oil

Fuel Properties	Diesel Fuel	Rapeseed Oil Biodiesel Stage 1	Rapeseed Oil Biodiesel Stage 2	Test Methods
Density, kg/m ³ at 15 °C	839	889,2	896,0	EN 14103 ASTM D 1298
Kinematic viscosity, mm ² /s at 40 °C	2,9	5,9	5,5	EN ISO 3104 ASTM D 445
Flash point, °C	65	140	160	EN ISO 3679 ASTM D 93
Cloud point, °C	- 12	- 5	- 5	EN 23015 ASTM D 2500
Pour point, °C	- 31	- 7	- 7	ISO 3016 ASTM D 97
Freezing point, °C	- 38	- 8	- 8	ISO 1041 ASTM D-4539
CFPP, °C Cold Filter Plugging Point	- 7	- 4	- 5	ASTM D 6331
Copper Strip Corrosion (3 h at 50 °C)	1a	1a	1a	EN ISO 2160 ASTM D 130
Calorific Value (kj / kg)	46580	40423	41288	DIN 51900
Water Content (mg / kg)	29	163,96	84,384	EN ISO 12937

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5. References

- [1] Sağlam B, Küçük Ö, Bilgili E, Durmaz BD, Baysal İ. Estimating fuel biomass of some shrub species (maquis) in Turkey. Turk J Agric For 2008; 32: 349-356.
- [2] Yücesu HS, Altın R, Çetinkaya S. Experimental investigation of vegetable oil usage as alternative fuel in diesel engines. Turkish J Eng Env Sci 2001; 25: 39-49.
- [3] Ergenç AT, Yüksek L, Özener O. Performance, emission, and heat release analyses of a direct injection diesel engine running on diesel and soybean ester blends. Turkish J Eng Env Sci 2013; 37: 23-32.

- [4] Sadeghinezhad E, Kazi SN, Badarudin A, Oon CS, Zubir MNM, Mehrali M. A comprehensive review of bio-diesel as alternative fuel for compression ignition engines. *Renewable and Sustainable Energy Reviews* 2013; 28: 410-424.
- [5] Avinash A, Subramaniam D, Murugesan A. Bio-diesel a global scenario. *Renewable and Sustainable Energy Reviews* 2014; 28: 410-424.
- [6] Oğuz H, Öğüt H, Eryilmaz T. Investigation of biodiesel production, quality and performance in Turkey. *Energy Sources Part A Recovery, Utilization and Environmental Effects* 2007; 29: 1529–1535.
- [7] Atabani AE, Silitonga AS, Badruddin IA, Mahlia TMI, Masjuki HH, Mekhilef S. A comprehensive review on biodiesel as an alternative energy resource and its characteristics. *Renewable and Sustainable Energy Reviews* 2012; 16: 2070–2093.
- [8] Helwani Z, Aziz N, Bakar MZA, Mukhtar H, Kim J, Othman MR. Conversion of jatropha curcas oil into biodiesel using re-crystallized hydrotalcite. *Energy Conversion and Management* 2013; 73: 128-134.
- [9] Kusdiana D, Saka, S. Two-step preparation for catalyst-free biodiesel fuel production. *Applied Biochemistry and Biotechnology* 2004; 115: 781-791.
- [10] Saka S, Kusdiana D, Minami E. Non catalytic biodiesel fuel production with supercritical methanol technologies. *Journal of Scientific and Industrial Research* 2006; 65: 420-425
- [11] Özcan M, Oğuz H, Öğüt H. Application of automation system in biodiesel production 4. *International Advanced Technologies Symposium*; 28-30 September 2005; Selçuk University, Turkey: pp. 487- 491.
- [12] Özcan M, Özkan AO. *Automation Systems PLC Applications*. Turkey, Istanbul, TURKEY: Atlas, 2004.