Biomechanism and Bioenergy Research 1(2), 65-68

Investigating the Effects of Some Operating Parameters Affecting Biodiesel Production from Used Vegetable Oil

Farshad Tavakoli Moghadam, Seyed Ahmad Ataei*, Aram Namjo

Department of Chemical Engineering, Faculty of Engineering, Shahid Bahonar University of Kerman, Kerman, Iran

INFO

ORIGINAL RESEARCH PAPER

KEYWORDS

Biodiesel; Screening, Transesterification; Experimental design; Placket Burman design.

Received: ***11 November 2022***

Revised: ***03 December 2022***

Accepted: ***30 December 2022***

Available Online: ***31 December 2022***

ABSTRACT

Currently, the main source of energy used all over the world are fossil fuels. Due to their non-renewable nature as well as the environmental problems caused by their use, the need for an alternative energy source is felt. Biodiesel is a biodegradable, non-toxic and environmentally friendly substance. This substance is produced from vegetable oils and animal fats in different ways. Using the Transesterification method to produce biodiesel has advantages such as low cost, high reaction speed and better quality than other methods. In this research, the effect of factors such as temperature, stirring speed, methanol-to-oil ratio, and catalyst weight percentage on biodiesel production was investigated with the help of experimental design using Minitab software version 19. The quality of the produced product was compared with international standards by measuring some of its characteristics. The esterification reaction was carried out by methanol in the presence of sodium hydroxide catalyst. Based on the "Placket Burman" design (PBD), the influencing factors including the ratio of methanol to oil and the weight percentage of the catalyst were identified. Considering that the temperature and stirring speed do not have much effect on the process, there is no need to adjust the process temperature to reduce the production cost, and the mixing speed can be used with less energy consumption.

INTRODUCTION

In recent years, the increase in demand for energy as well as the acceleration of global warming has become a great concern and challenge in the world. The non-renewability of fossil fuels, the increase in the price of these fuels due to the reduction of available reserves and on the other hand the pollution caused by their consumption has made the need for a new source of energy especially in the field of transportation an important matter. According to the reports of international organizations, until 2030, the amount of energy needed will increase by 53% (Sigar *et al.*, 2008). In recent years, many investments and studies have been used in the field of finding suitable alternatives for fossil fuels such as solar, wind, geothermal, etc. Among biofuels, biodiesel and bioethanol are known as the most desirable alternative fuels. Biodiesel refers to a wide range of fuels that are prepared from various vegetable oils and animal fats and are used as an alternative fuel for diesel engines (Morris *et al.*, 2003). In fact, biodiesel is a combination of mono alkyl esters and long chain fatty acids resulting from the reaction of an alcohol with renewable lipid materials. This substance is biodegradable, non-toxic and environmentally friendly (Canakci and Van Gerpen, 2001). One of the differences between biodiesel and diesel is the amount of oxygen in it. Oxygen in biodiesel is 11% by weight, while this amount is zero for diesel. This causes biodiesel to have a more complete combustion than diesel, and as a result, emits a lower percentage of carbon in suspended particles and pollutants such as carbon monoxide and unburned hydrocarbons in suspended materials. Also, the absence of sulfur compounds is another reason for the compatibility of biodiesel with the environment. If clean biodiesel is used, the emission of carbon monoxide will decrease to 46.7%, the emission of particles to 66.7%, and the emission of unburned hydrocarbons will decrease to 45.2% (Caruana, 1992).

The amount of edible oil waste is high. About 15 million tons of vegetable oil waste is produced in the world every year, which causes many environmental and economic problems. Waste edible oils contain toxic and harmful substances and cannot be reused in the food industry. But if it is possible to reuse them to produce useful materials such as biodiesel, in addition to solving the environmental problems related to them, renewable fuel can be produced using cheap raw materials (Fangfang *et al.*, 2021). There are various methods such as blending, cracking, micro emulsion, pyrolysis and Transesterification to convert these oils into biodiesel. The Transesterification method is one of the most suitable methods for producing biodiesel. The advantages of this method compared to other methods include high reaction speed, insensitivity of the process to the used feed, carrying out the reaction in abnormal conditions, high conversion and better quality (Wang *et al.*, 2006).

The Transesterification process is considered as a very efficient and also low-cost process for biodiesel production. In this process,

* Corresponding Author. Email Address: ataei@uk.ac.ir
DOI: 10.22103/BBR.2022.20528.1029

during a chemical reaction between triglyceride and an alcohol in the presence of a catalyst, methyl ester (biodiesel) and glycerol are produced, which is shown in Fig.1 of this reaction (Sundar and Dharmendirakumar, 2022)

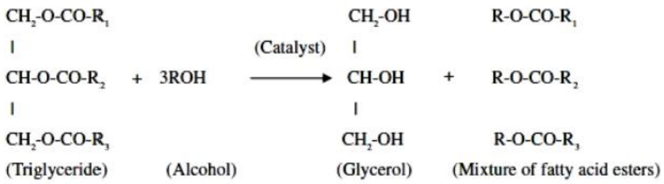

Fig 1. Simple example of Transesterification reaction (Knothe *et al.*, 2015)

In this research, the effective parameters on the production of biodiesel from restaurant frying waste oils were screened and identified by Transesterification method. Screening was done using version 19 of mini tab software by Placket Burman method by selecting parameters of reaction temperature, stirring speed, molar ratio of methanol to oil and weight percentage of catalyst. Methanol was used as alcohol and potassium hydroxide as catalyst due to its special physical characteristics and low cost.

MATERIALS AND METHODS

The used oil was obtained from the restaurants of Kerman city, Kerman, Iran. To prepare the materials for the Transesterification reaction, based on the standards specified in the test plan, sodium hydroxide was added to methanol as a catalyst and stirred at the designed speed and duration. After the completion of the reaction between the alcohol and the catalyst to separate the glycerol, the contents of the reaction vessel were transferred to a decanter. In this separation, the lower phase (darker phase) is glycerol and the upper phase is biodiesel with other impurities. Fig. 2 shows the two-phase separation.

Fig 2. Separation of glycerol from biodiesel

After removing the glycerol from the sample, to remove the alcohol from the biodiesel, the sample was rotated for 40 min at a temperature of 65 °C to evaporate the alcohol in it. Evaporated methanol can be recovered by condensing. In the next step, in order to remove the produced soap and excess catalyst from the produced biodiesel suspension, the sample was washed three times with warm distilled water (60 °C) until clear water finally comes out and the excess particles in it are also removed. The use of hot water prevents the formation of fatty acid deposits and also reduces the formation of emulsion (Ghobadian *et al.*, 2006). The clarity of the waste water resulting from washing is a good measure to complete the need for washing. Usually, twice the volume of biodiesel is added to that water for each wash. After making sure that all the impurities are washed away, the water in the solution should be removed. To separate and evaporate the water in biodiesel, the sample was placed at 100 °C for 15 min (Hashemi, 2014). If the color of the biodiesel becomes cloudy after cooling, it indicates that one of the washing or dewatering steps was not done correctly and these steps should be repeated.

Selection of effective parameters

Many factors are involved in the biodiesel production process. In order to achieve the highest efficiency, the necessary conditions must be provided for the highest amount of biodiesel production. These factors include temperature, stirring speed, methanol-to-oil ratio, and catalyst percentage. To determine the influencing parameters on the efficiency of biodiesel production, a series of experiments was designed with the Placket Burman method using statistical software Minitab version 19. According to previous studies, the levels of the parameters are considered in two levels, high and low, and are reported in Table 1. All experiments were performed with an initial volume of 100 ml of oil at an optimal time of 90 min (based on previous studies) (Athar *et al.*, 2022). Then, the steps of biodiesel production were performed for all the experiments in the same way, and at the end, the efficiency of biodiesel production was obtained as a response in each case, and the most effective factors were identified.

Table 1- Parameters and levels of screening test design

Parameters	Low level (-1)	High level (+1)
Temperature (°C)	30	50
Stirring speed (RPM)	100	300
The ratio of methanol to oil (v/v)	1:3	1:9
Catalyst percentage (%)	0.5	1.5

Biodiesel properties

The physical characteristics and quantitative and qualitative properties of the produced biodiesel, including flash point, cloud point, amount of water in the fuel, viscosity, amount of residual carbon, and methyl ester content, were investigated and compared with the American standard (ASTM).

RESULTS AND DISCUSSION

Physical and chemical properties of primary waste oil

The physical and chemical properties of the tested waste oil are listed in Table 2.

Table 2. Physical and chemical properties of waste oil

Characteristic	Value
Density	0.906 g/cm^3
Kinematic viscosity	26.75 mm^2/s
Acidity number	0.43 mg KOH/g Oil
Acidity	0.215
Mean of Molecular weight of Triglycerides	885 g/mole
Molecular weight of Oil	2655 g/mole

Parameters affecting biodiesel production

To check the effective parameters of biodiesel production, different modes of experiments designed by Minitab software were conducted with the conditions stated in the materials and methods section. Then the efficiency of biodiesel production was calculated in each case. The design of the experiments and the results obtained from the Berman platelet design are reported in Table 3. The results expressed are the average of three replicates.

Table 3. Test plan and biodiesel production efficiency

Test number	Block	Temperature(°c)	Mixer speed (rpm)	Methanol to oil ratio	Catalyst percentage	Biodiesel production efficiency
1	1	30	300	1:3	0.5	60.83
2	1	50	300	1:9	0.5	86.78
3	1	50	300	1:3	1.5	88.35
4	1	50	100	1:9	1.5	94.76
5	1	30	100	1:3	0.5	63.02
6	1	50	100	1:3	0.5	59.80
7	1	30	100	1:3	1.5	74.75
8	1	50	300	1:3	1.5	75.89
9	1	30	100	1:9	1.5	93.47
10	1	30	300	1:9	0.5	84.71
11	1	30	300	1:9	1.5	92.19
12	1	50	100	1:9	0.5	81.97

Table 4- Analysis of variance of the results of screening tests

Source	DF	SS	MS	F-Value	P-Value
Model	4	1661.08	415.27	21.40	0.001
Linear	4	1661.08	415.27	21.40	0.001
T	1	28.77	28.77	1.48	0.263
RPM	1	36.68	36.68	1.89	0.212
M/O	1	1031.19	1031.19	53.13	0.000
Cat.	1	564.44	564.44	29.08	0.001
Error	7	135.86	19.41		
Lack-of-Fit	6	58.24	9.71	0.13	0.970
Pure Error	1	77.63	77.63		
Total	11	1796.95			

Analysis of variance related to screening tests is shown in Table 4. According to the P-Value values mentioned in the analysis of variance table (Table 4), the model with a P-Value < 0.05 indicates the fact that at least one of the selected parameters has a significantly effect on the process. The effective parameters in this experiment were methanol to oil ratio and catalyst percentage (with P-Value < 0.05). Fig. 3 is the Pareto diagram of the experimental design, which, in addition to confirming the effect of the stated parameters, shows the order of their importance. According to this Fig., it is clear that the ratio of methanol to oil has the highest effect in the tests. Catalyst percentage was obtained as the next effective parameter. Other parameters do not have much effect on the response rate

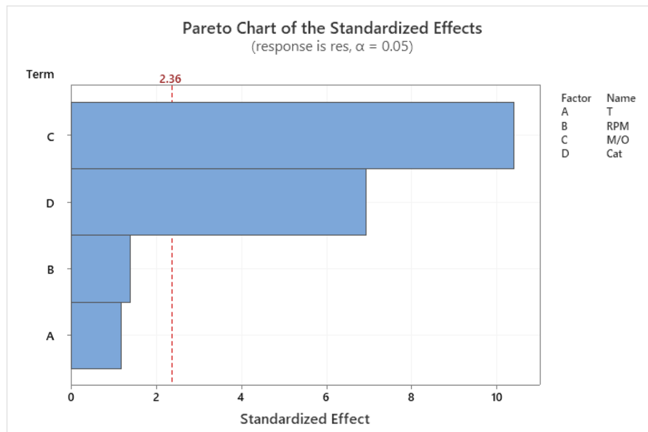

Fig 3. Comparing the importance of the parameters and displaying the influential and non-influential parameters in the screening test

Measured properties of produced biodiesel

Some important properties related to the produced biodiesel were measured.

The density, cloud point, pour point, kinematic viscosity, and flash point of produced biodiesel are shown in Table 5.

Table 5- Some properties of produced biodiesel

Characteristic	Value	Limits ASTM	Standard ASTM
Density (g/cm^{3})	0.829	0.820-0.892	D1298
Kinematic Viscosity (at 40°C) (mm^2/s)	4.88	4.2 to 4.9	D445
Kinematic Viscosity (at 100°C)(mm^2/s)	1.8519	1.72 to 6	D445
Acid value (mg KOH/g Oil)	0.57	0.4 to 0.6	D664
Cloud point (°C)	4	1 to 3	D2500
Flashpoint (°C)	138	103 to 162	D93

CONCLUSIONS

There is a large amount of waste cooking oil everywhere, and its use does not require the cultivation of various plant seeds, and as a result, there is no problem of lack of land to plant and use them directly. Also, by using these oils, the problem of disposing and entering these wastes into the environment is reduced. The Transesterification method is a suitable method for reducing the viscosity of oils and producing biodiesel, which is the most suitable method for producing biodiesel due to its simplicity, the greater similarity of the product to diesel fuel and higher efficiency. The purpose of this research was to investigate the influencing factors on the biodiesel production process from cooking oil waste. For this purpose, restaurant oil waste was prepared. Factors affecting this process were identified by Berman's platelet method with Minitab version 19 software. The viscosity of the oil in the biodiesel production process decreased significantly. In the production of biodiesel from edible oil waste, the parameters of methanol-to-oil ratio and catalyst weight percentage were identified as influencing factors. The use of sodium hydroxide as a catalyst, in addition to the reasonable price, causes a high speed of the Transesterification reaction. The properties of the produced biodiesel showed that it complies with global standards in terms of physical and chemical properties, and it can be used as a clean and environmentally friendly fuel. According to the results of the experimental design, the temperature and stirring speed did not have much effect on the process, so there is no need to adjust the process temperature to reduce the production cost, and the mixing speed can be used with less energy consumption.

REFERENCES

Athar, M, Imdad, S, Zaidi, S, Yusuf, M, Kamyab, H, Klemeš, JJ and Chelliapan, S (2022). Biodiesel production by single-step acid-catalysed transesterification of Jatropha oil under microwave heating with modelling and optimisation using response surface methodology. *Fuel,* 322**,** 124205.

Canakci, M and Van Gerpen, J (2001). Biodiesel production from oils and fats with high free fatty acids. *Transactions of the ASAE,* 44**,** 1429.

Caruana, C (1992). Pollution control drives new interest in biodiesel. *Chemical engineering progress (USA)*.

Fangfang, F, Alagumalai, A and Mahian, O (2021). Sustainable biodiesel production from waste cooking oil: ANN modeling and environmental factor assessment. *Sustainable Energy Technologies and Assessments,* 46**,** 101265.

Ghobadian, B, Khatamifar, M and Rahimi, H (2006). Biodiesel fuel production using transesterification of waste vegetable oils. *The journal of engine research,* 8**,** 80288-7.

Hashemi, A (2014). design, construction and evaluation of a biodiesel production reactor from waste kitchen oil. master's thesis, Faculty of Agricultural Engineering, Sari University of Agricultural Sciences and Natural Resources.

Knothe, G, Krahl, J and Van Gerpen, J (2015). *The biodiesel handbook,* Elsevier.

Morris, R, Mansell, G, Jia, Y and Wilson, G 2003. Impact of Biodiesel Fuels on Air Quality and Human Health: Task 2 Report; The Impact of Biodiesel Fuels on Ozone Concentrations. National Renewable Energy Lab.(NREL), Golden, CO (United States).

Sigar, C, Soni, S, Mathur, J and Sharma, D (2008). Performance and emission characteristics of vegetable oil as diesel fuel extender. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects,* 31**,** 139-148.

Sundar, AM and Dharmendirakumar, M (2022). Biodiesel production and comparison using commercial lipase and chemical catalyst from Cassia auriculata oil. *Journal of the Indian Chemical Society,* 99**,** 100265.

Wang, Y, Ou, S, Liu, P, Xue, F and Tang, S (2006). Comparison of two different processes to synthesize biodiesel by waste cooking oil. *Journal of Molecular Catalysis A: Chemical,* 252**,** 107-112.