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Optimization of hydrodynamic cavitations reactor efficiency for biodiesel production by response surface methods (Case study: Sunflower oil)

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Introduction

Biofuels are considered as one of the largest sources of renewable fuels or replacement of fossil fuels. Combustion of plant-based fuels is the indirect use of solar energy. Biofuels significantly have less pollution than other fossil fuels and can easily generate from residual plant material. Waste and residues of foods and wastewater can also be a good source for biofuel production.

Transesterification method (one of biodiesel production methods) is the most common forms to produce mono-alkyl esters from vegetable oil and animal fats. The procedure aims are reduction the oil viscosity during the reaction between triglycerides and alcohol in the presence of a catalyst or without it. In this study, the method of transesterification with alkaline catalysts is used that it is the most common and most commercial biodiesel production method.

In this study, configurations of made hydrodynamic cavitation reactor were studied to measure biodiesel fuel quality and enhanced device performance with optimum condition. The Design Expert software and response surface methodology were used to get this purpose.

Materials and Methods

Transesterification method was used in this study. The procedure aims were reduction of the oil viscosity during the reaction between triglycerides and alcohol in the presence of a catalyst or without it. Materials needed in the production of biodiesel transesterification method include: vegetable oil, alcohol and catalysts. The used oil in the production of biodiesel was sunflower oil, which was used 0.6 liters per each test in the production process base on titration method. Methanol with purity of 99.8 percent and the molar ratio of 6:1 to oil was used based on titration equation and according to the results of other researchers. The used catalyst in continuous production process was high-purity sodium hydroxide (99%) that it is one of alkaline catalysts. Weight of hydroxide was 1% of the used oil weight in the reaction.

Response surface methodology: Three important settings of reactor were considered to optimize reactor performance, which include: inlet flow to reactor, reactor rotational speed and the fluid cycle time in the system. Each set was considered at three levels. The factorial design was used to the analysis without any repeat, there will be 27 situations that because of the cost of analysis per sample by GC, practically not possible to do it. Therefore, response surface methodology was used by Design Expert software. In the other words, after defining the number of variables and their boundaries, software determined the number of necessary tests and the value of the relevant variables.

Results and Discussion

Three parameters include the inlet flow to reactor, reactor rotational speed and the fluid cycle time in the system were considered as input variables and performance of reactor as outcome in analyzing of extracted data from the reactor and GC by Design Expert software. The results of tests and optimization by software indicated that in 3.51 minutes as retention time of the raw material of biodiesel fuel in the system, the method of transesterification reaction had more than 88% Methyl ester and this represents an improvement in reaction time of biodiesel production. This method has very low retention time rather than biodiesel fuel production in conventional batch reactors that it takes 20 minutes to more than one hour.

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Conclusions

According to the researches, efficiency of biodiesel fuel production in hydrodynamic cavitation reactors is higher than ultrasonic reactors so in this study, the settings of hydrodynamic reactor were investigated so that the settings were optimized in production of biodiesel fuel. Sunflower oil was used in this research. The molar ratio of Methanol to oil was 6 to 1 and sodium hydroxide as a catalyst was used. Three important settings of reactor were considered which include: inlet flow to reactor, reactor rotational speed and the fluid cycle time in the system. The results were analyzed by gas chromatography. The results showed that at 8447 rpm of reactor speed, inlet flow of reactor at 0.86 liters per minute and 1.02 minute of circulation time, the best performance of reactor were created. The flash point, kinematic viscosity and density of biodiesel in this study were 172 ° C, 2.4 square millimeters per second and 861 kg per cubic meter, respectively. Maximum and minimum performances of hydrodynamic cavitation reactor in biodiesel production were 6.19 and 1.13 mg kJ^{-1}, respectively.

Keywords: Biodiesel, Optimization, RSM, Transesterification

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