Optimization of Biodiesel Production from Trap Grease of Hospital Cafeteria Using Response Surface Methodology

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Abstract :

Trap grease from a hospital cafeteria with high free fatty acid was used as raw material to produce biodiesel. Response surface methodology (RSM) was applied to optimize the free fatty acid content in esterification step, after that the transesterification was further reacted in the follow step for lab scale biodiesel production. The optimization in esterification step was base on five levels, three variable central composition design (CCD). Three factors in esterification step for obtaining the percentage of free fatty acid content less than 2% (H_2SO_4 catalyst concentration, 0.16-1.84% w/v), reaction time (9.6-110.4 min) and methanol to oil ratio (0.16-1.84 v/v)) were investigated. After that both steps conditions (esterification+transesterification) from lab scale experiment were up scale to community scale experiment (150 liter/batch). The biodiesel obtained at optimization in lab scale and community scale experiment were determined the properties compare with community biodiesel standard. The result showed both trap grease biodiesel from lab scale and community scale to meet the community biodiesel standard and can be used as a qualified fuel for diesel engines.

Introduction:

Trap grease is waste oil for the feed stock of biodiesel product, that is intercepted in the grease trap of restaurants or cafeteria to prevent from entering the sewage system. Common contaminants include solids, phosphorus and sulfur which are in the trap grease. Trap grease contains a mixture of glyceride (fats) and free fatty acid (FFA), can be make into biodiesel with special process considerations. So, the production of biodiesel from trap grease is one approach not only lower biodiesel production cost but also reduce environmental problem, too.

In this study, we generate biodiesel from trap grease of one big hospital cafeteria in Thailand via two-step catalyzed processes in laboratory scale. The esterification step is studied to optimize condition by Response surface methodology (RSM). FFA content in trap grease is reduced less than 2% (w/w) in the esterification step. Tranesterification in the second step produce fatty acid methyl esters (FAME) or biodiesel that study follow the condition of Park *et. al.*. After that, both optimum conditions of esterification and transesterification from laboratory scale were extended to community scale production with the reactor capacity of 150 liters/batch. The fuel quality of both biodiesel analyzed by ASTM and EN standard methods for comparison with community biodiesel standard of Thailand.

Methodology :

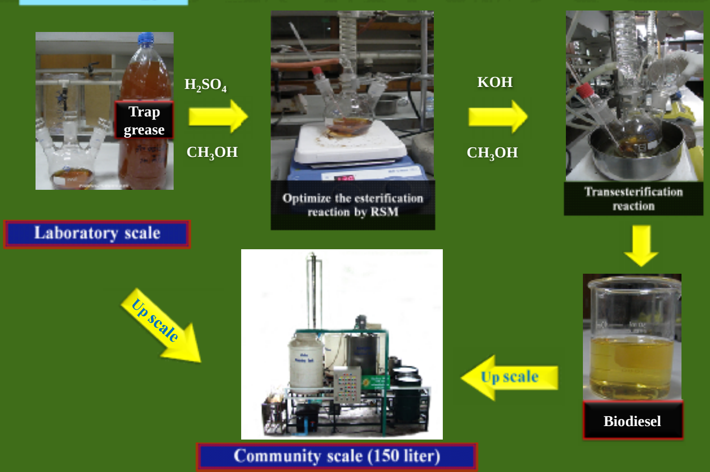

Fig. 1 Experimention on laboratory and community biodiesel scale

A five-level-three-factor central composite design (CCD) was employed in this study, requiring 20 experiments. The independent variables to optimize FFA were H_2SO_4 catalyst concentration (C), methyl alcohol-to-Trap grease ratio (M) and reaction time (T). The actual and coded levels of the independent variables are given in table 1.

Table 1 Range of independent variables for central composite design

Variables	Symbols	Code levels[a]				
		-1.68 (-α)	-1	0	+1	+1.68 (+α)
Methanol to trap grease ratio (v/v)	M	0.16	0.5	1	1.5	1.84
H_2SO_4 concentration (% w/v)	C	0.16	0.5	1	1.5	1.84
Reaction time (min)	T	9.6	30	60	90	110.4

Results and Discussion :

Model fitting and ANOVA

The quadratic polynomial model for percentage FFA content to predict the predicted values were obtained from the model fitting technique using SPSS software version 12 and correlated to the observed value. From the software, the quadratic polynomial is given below:

$$\text{FFA content (\%)} = -40.467 - 61.233M - 16.428C - 0.382T + 48.706M2 + 9.542C2 + 0.005T2 + 2.820MC + 0.038MT + 0.057CT - 13.288M3\ 2.765C3 - 2.19E\text{-}5T3 - 0.024MCT$$

Effect of parameters

From the Fig. 2(a), acid catalyst amount (C) and time (T), (b) methanol-to-trap grease ratio (M) and time and (c) methanol-to-trap grease ratio and acid catalyst amount, their mutual interaction on the FFA of trap grease for esterification step. From the Fig.2 (b) and (c) indicated that methanol-to-trap grease ratio was higher effect than other parameters. The optimum value was 0.9-1.0 % of acid value, 30-60 min. of reaction time and 1.7-1.8 ml of methanol per ml oil trap grease that reduced FFA to lower than 2% wt.

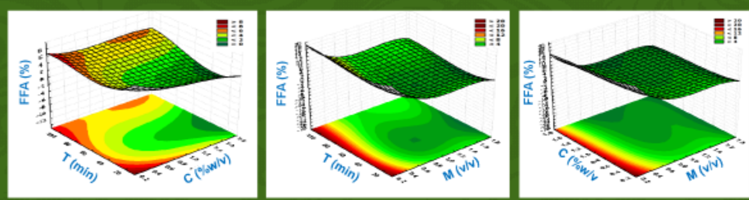

Fig. 2 Response surface plots representing the effect factors on FFA predicted from the quadratic polynomial model.

Optimization of esterification step

Optimization of esterification step of trap grease was predicted using optimization function of the SPSS Software. The optimize condition was selected at 1.7 (v/v) methanol-to-trap grease ratio, 0.9 % H_2SO_4 of acid catalyst for 30 min of reaction time which could reduced FFA to 1.84%.

Transesterification step and biodiesel properties

After the esterification step, trap grease with low FFA content was used as raw material for tranesterification step. The properties showed in table2, they were almost met in fuel quality methyl ester which followed ASTM D 6751 and EN 14105standard methods for community biodiesel of Thailand.

Table 2 The physical and chemical properties of trap grease methyl ester from community biodiesel scale

Properties	Unit	Trap grease biodiesel		ASTM D6751	EN 14105
		Lab scale	Community scale		
Density @15°C	kg/m^3	867.3	872.4	860-900	-
Viscosity @ 40°C	cSt	4.64	5.42	1.90-6.00	-
Flash point	°C	145	172	120 min	-
Acid value	mg KOH/g	0.26	0.43	0.80 max	-
Total glycerin	%wt.	0.19	0.21	-	1.50max

Conclusions :

RSM method can be used to optimize biodiesel in laboratory scale and extent the optimum condition to community scale with correctly and efficiently. Trap grease biodiesel from community scale has a qualified fuel for diesel engines.

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Reference :

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