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Optimisation of Biodiesel Production from Waste Margarine Oil Using Response Surface Methodology

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INTRODUCTION & AIM

Biodiesel is a biodegradable, non-toxic fuel derived from organic sources. Using waste margarine, which often ends up as landfill waste, not only provides an eco-friendly energy solution but also addresses waste management issues.^[1]



To produce biodiesel at a lower cost requires using cheap feedstock, such as waste cooking oil ^[2] and waste margarine oil.^[1] Waste oils are about 2–3 times cheaper than virgin vegetable oil.^[3]

RESULTS & DISCUSSION



Figure 1: Transesterification reaction

Closed to 5 tons per month of waste oil is produced in butter and margarine manufacturing plants, which are mainly disposed of and can be used as a low-cost feedstock for biodiesel production.^[1] Catalysts used in biodiesel production are classified as homogeneous, heterogeneous and enzymatic.^[4]

The kinetics of the transesterification process is performed by examining variables such as time, temperature, the methanol-to-oil ratio and catalyst loading.^[5]

This study aims at optimising biodiesel production from waste margarine oil using central composite design (CCD) response surface methodology (RSM) for process optimisation and performing kinetics.

METHOD

The waste margarine was sourced from a local margarine manufacturing plant. Potassium hydroxide (85%) was used as a catalyst for the transesterification, with Methanol (99.5%), Phenolphthalein which was used as an indicator, were sourced from ACE (Associate Chemical

Enterprises)



Lab scale reactor as shown in Figure 1 was used for the transesterification. The methanol-to-oil molar ratio and catalyst ratio, reaction time, and temperature were varied according to the experimental design. When the reaction time elapsed, the mixture was emptied into a separating funnel, separating the biodiesel and the glycerol layers into two layers. Biodiesel was quantified and yield as calculated as per Equation (1).

 $TG + 3M \stackrel{KOH}{\longleftrightarrow} G + 3M$ (2)

 $[TG] = [TG_o](1 - X) (5)$

 $X = 1 - \frac{[TG]}{[TG_0]}$

 $r = -\frac{d[TG]}{dt} = k[TG] \quad (3)$

(4)

Figure 3: The 3-D surface plots of Biodiesel yield using the 4 process parameters

Analysis of variance (ANOVA) was used to evaluate the effect of process variables. As shown in Table 2, the methanol-to-oil ratio has more impact on the transesterification reaction. Using numerical optimisation, the optimum yield was obtained at a 9 mol ratio of 0.9 wt. % catalyst ratio, 60-minute reaction time, and 50 °C reaction temperature, with 89.09% yield.

Table 2. ANOVA for Quadratic model

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	Figure 4. nl			Figure		0/T

The *Ea*, was determined by the rate at which the *k* constant changes with temperature as shown in Figure 4, calculated using Equation 9. The significant linearity between *lnk* and 1,000/T over the 303-333K (30-60°C) is shown in Figure 5. The approximate activation energy of 62,41 kJ.mol⁻¹ was obtained

Figure 2: Experimental setup

The reaction kinetics was studied by following the equations as shown in equation 2-8.

Table 1: Experimental Design

Input		Level				$\frac{dX}{dt} = k(1 - X)$	(6)
Variables	-2	-1	0	+1	+2	$-\ln(1 - X) = k_1 t$	(7)
Methanol/Oil (wt. %)	3	6	9	12	15	$- m(1 - \lambda) - \kappa_1 \iota$	(7)
Catalyst ratio (wt. %)	0.2	0.6	0.9	1.2	1.5	$lnk = lnA - \frac{Ea}{RT}$	(8)
Time (min)	30	45	60	75	90	-Ea	
Temperature (°C)	30	40	50	60	70	$k = Ae^{\left[\frac{Ea}{RT}\right]}$	(9)

The biodiesel was then washed with distilled water at 60°C; this was done to ensure that any traces of methanol and KOH were 3 times washed off from the biodiesel. The washed biodiesel was then dried using a heating plate at 105°C for 1 h until no trace of water was observed.

Biodiesel yield = $\frac{Mass \ of \ biodiesel}{Mass \ of \ Oil}$

(1)

CONCLUSION

A numerical optimum yield of 94.024% was obtained at a 9.6 mol ratio of 0.96 wt. % catalyst ratio, reaction time of 63 min, 52 °C and a low standard error of 0.576 %. ANOVA showed that the methanol to oil ratio had the highest influence on the biodiesel yield, followed by the catalyst ratio, and reaction time had the least impact after temperature. The kinetics study performed to obtain the activation energy was 62.41 kJ/mol. It was concluded that biodiesel could be produced using waste margarine oil as a cost-effective feedstock optimised by RSM.

FUTURE WORK / REFERENCES

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