Application of response surface methodology to optimize the treatment process of high conversion of free fatty acids using (1R)-(-)-camphor-10-sulfonic acid and iron(III) sulphate

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Abstract This study investigates biodiesel production from acidic crude palm oil using one homogeneous catalyst, (1R)-(-)-camphor-10-

sulfonic acid (10-CSA), and one heterogeneous catalyst, iron(III) sulphate, focusing on their catalytic activity, recyclability, and process optimisation by using response surface methodology. Optimal conditions were identified by utilising a Box-Behnken factorial design. For 10-CSA, the optimised conditions yielded a free fatty acid (FFA) reduction to 0.43 wt.%, with a catalyst dosage of 1.5 wt.% (investigated range: 1.0-2.0 wt.%), methanol-to-oil molar ratio of 12.67:1 (investigated range: 10 to 14:1), reaction temperature of 59.6 degrees C (investigated range: 50 to 65 degrees C), and reaction time of 33.1 min (investigated range: 30 to 40 min). For iron(III) sulphate, the optimised conditions led to FFA reduction to 1.04 wt.%, with a catalyst dosage of 3.14 wt.% (investigated range: 2.5 to 3.5 wt.%), methanol-to-oil molar ratio of 12:1 (investigated range: 10 to 14:1), reaction temperature of 60 degrees C (investigated range: 55 to 70 degrees C), and reaction time of 178.6 min (investigated range: 150 to 180 min). Results of the ANOVA analysis confirmed the significance of key factors for both catalysts ($p < 0.05$), with R-2 values of 0.937 for 10-CSA and 0.916 for iron(III) sulphate, indicating strong model fits. The mean relative percent deviation (MRPD) was <5 % for both models, demonstrating high predictive accuracy. The lack of fit was found to be insignificant ($p > 0.05$), confirming the adequacy of the models. Both catalysts achieved high FFA conversions of 95.2 % for 10-CSA and 88.2 % for iron(III) sulphate, which meets the EN 14214 and ASTM D6751 standards. Notably, 10-CSA exhibited superior catalytic activity and recyclability, highlighting its potential for industrial-scale biodiesel production. This study offers practical insights into optimising esterification processes for biodiesel production from acidic crude palm oil.

Keywords

Author Keywords: Acidic crude palm oil; biodiesel; esterification; homogeneous acid catalyst; heterogeneous acidic catalyst

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