Chemical Engineering Journal 214 (2013) 157–164

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Process optimization and kinetic study for biodiesel production from non-edible sea mango (*Cerbera odollam*) oil using response surface methodology

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HIGHLIGHTS

- ▶ Process optimization and kinetics study on the transesterification of sea mango oil.
- ▶ Reaction temperature was the most significant variable.
- ▶ Significant interaction effect between reaction temperature and amount of catalyst.
- ▶ Significant interaction effect between reaction time and amount of catalyst.
- ▶ Order of reaction = 1.1, E = 36.03 kJ mol^{-1}, A = 5.56 × 10^{2} min^{-1}.

ARTICLE INFO

Article history:
Received 27 July 2012
Received in revised form 25 October 2012
Accepted 27 October 2012
Available online 2 November 2012

Keywords:
Cerbera odollam (sea mango)
Fatty acid methyl esters (FAME)
Heterogeneous transesterification
Response surface methodology (RSM)
Sulfated zirconia

ABSTRACT

This paper presents the process optimization and kinetic study for the heterogeneous transesterification of non-edible sea mango (*Cerbera odollam*) oil using response surface methodology central composite design (RSMCCD). The four transesterification process variables studied are; reaction temperature (333–453 K), reaction time (1–5 h), molar ratio of oil to methanol (1:6–1:14) and amount of sulfated zirconia catalyst (2–10 g* g^{-1}) (catalyst/oil). From this study, it was found that reaction temperature gave the most significant effect on the conversion of sea mango oil to fatty acid methyl esters (FAME), followed by reaction time. There were also significant interaction effects between reaction temperature and amount of catalyst, and between reaction time and amount of catalyst. Based on the optimized condition, highest conversion of 97.5% was predicted using the following variables; reaction temperature = 423 K, reaction time = 3 h, molar ratio of oil to methanol = 1:12 and amount of catalyst = 8 g* g^{-1}. Experimental verification on the predicted optimum condition gave an actual conversion of 94.1%. The small error between the predicted and actual optimum conversion (3.5%) indicated that the model was valid and accurate in representing the actual experimental values and also in predicting conversion at any condition within the range studied. The developed kinetics model suggested a 1.1th order reaction with activation energy of 36.03 kJ mol^{-1} and frequency factor of 5.56 × 10^{2} min^{-1}.

1. Introduction

In biodiesel production, studies regarding conversion of edible oils such as palm oil [1–3], soybean oil [4–7], rapeseed oil [8], sunflower oil [9] and coconut oil [2,10] into fatty acid alkyl esters (biodiesel) have been very common. Edible oils are abundantly available in the market; hence they are extensively used as viable feedstock for biodiesel production. Some of these oils, for example palm oil, are also cheap, making them economically feasible as feedstock. However, the utilization of edible oils in the production of biodiesel has created controversy as edible oils are converted to fuel while hunger and famine are still rampant around the globe. Due to this issue, some researchers have begun to study alternative oil sources (feedstock) particularly non-edible oils to replace the edible oils. There are a few non-edible oils that have been identified so far, including waste cooking oil [11–14], Jatropha curcas oil [15–17], croton oil [18], rocket seed oil [19] and algae oil [20–23].

Sea mango (*Cerbera odollam*) is relatively new and unknown for many among these non-edible oils. There are a few studies on sea mango but most of them are focused on its toxicity or poisonous properties. Currently there is no other published report regarding

Abbreviations: ANOVA, analysis of variance; CCD, central composite design; *DF*, dilution factor; DOE, design of experiment; FAME, fatty acid methyl esters; FFA, free fatty acids; IS, internal standard; MeOH, methanol; RSM, response surface methodology; TG, triglycerides.

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http://dx.doi.org/10.1016/j.cej.2012.10.048