Journal of Environmental Chemical Engineering 13 (2025) 115186

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

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

Elucidating the clinker-based catalyst deactivation for biodiesel production in a continuous microwave-assisted reactor

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ARTICLE INFO

Keywords:
Biodiesel
Catalysis
Renewable energy
Biofuel
Catalyst deactivation

ABSTRACT

A clinker-based catalyst (CBC) was synthesized by incipient wetness impregnation with potassium hydroxide (10 wt%), then calcined at 700 °C. XRD and EDX analyses revealed that CaO (66.61 wt%) and Ca (34.63 wt%) are the primary constituents of the CBC, with the main crystalline phases identified as $Ca_2Al_{0.67}Mn_{0.33}FeO_5$ (monoclinic) and Ca_3SiO_5 (orthorhombic). This catalyst was effectively employed for the transesterification of waste cooking oil (WCO) in a continuous microwave-assisted reactor (CMAR), achieving a fatty acid methyl ester (FAME) yield of over 92.8 % under optimal conditions: a methanol to oil molar ratio of 12:1, a catalyst concentration of 5 wt% (catalyst/oil), and a reaction temperature of 65 °C. Moisture in CBC can reduce its performance by over 36 %. The catalyst was recovered and reused four times with minimal loss of activity. Analysis of the reused catalyst indicated that the reduction in catalytic performance was due to leaching, catalyst poisoning, and a decrease in surface area and porosity. Due to its reusability, the clinker-based catalyst has the potential to replace homogeneous catalysts, thereby reducing biodiesel production costs.

1. Introduction

Biodiesel, also known as fatty acid alkyl esters, is a renewable alternative to petroleum-based diesel fuel. Its advantages as a replacement for petrodiesel include the absence of aromatics and sulfur compounds, a high cetane number, a high flash point, and lower emissions of hydrocarbons and CO_x [1–3]. However, despite these benefits, biodiesel production often faces challenges due to the limited availability of inexpensive non-food feedstock and high production costs [4–6].

Biodiesel is often produced using feedstocks such as rapeseed oil, castor oil, Jatropha oil, sunflower, palm oil, rubber seed oil, animal fat, and waste cooking oil (WCO) among others. However, producing biodiesel from edible oils such as those from oil palm, groundnut, sunflower, rapeseed, corn, and soybean, which are also used for food, has sparked a food vs. fuel argument. Non-food crops like Jatropha and castor require specific farmland, which reduces the amount of arable land available for food production and increasing costs of biodiesel production [7]. Consequently, growing non-food crops for biodiesel may not be the optimal solution.

WCO is known as a practical alternate feedstock for biodiesel production due to its ready availability, unlike vegetable oils such as Jatropha oil that must first be extracted. In fact, approximately one billion liters of WCO are available annually, which could meet 10 % of Malaysia's diesel demand [8]. Awareness campaigns by non-governmental organizations have highlighted the environmental issues associated with WCO disposal through drainage or landfill. Additionally, using recycled cooking oil for cooking is strongly discouraged as it may pose significant health risks [9]. Repeated heating of oil can lead to the formation of trans fats [10], aldehydes [11], and free radicals, which are linked to heart disease, stroke, diabetes,

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https://doi.org/10.1016/j.jece.2024.115186
Received 25 September 2024; Received in revised form 24 November 2024; Accepted 19 December 2024
Available online 20 December 2024