Renewable Energy 229 (2024) 120750

Contents lists available at ScienceDirect

Renewable Energy

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

Transesterification of used cooking oil by palm lignocellulosic biomass magnetic biochar catalyst: Optimization and kinetic analysis

Mohd Nurfirdaus Bin Mohiddin [a], Yie Hua Tan [a,b,*], Jibrail Kansedo [a], Nabisab Mujawar Mubarak [b,c], Yen San Chan [a], Mohammad Khalid [d,e], Keat Teong Lee [f]

[a] Department of Chemical and Energy Engineering, Faculty of Engineering and Science, Curtin University Malaysia, CDT 250, 98009, Miri, Sarawak, Malaysia
[b] Petroleum and Chemical Engineering, Faculty of Engineering, Universiti Teknologi Brunei, Gadong BE1410, Brunei Darussalam
[c] Department of Chemistry, School of Chemical Engineering and Physical Sciences, Lovely Professional University, Jalandhar, Punjab, India
[d] Sunway Centre for Electrochemical Energy and Sustainable Technology (SCEEST), School of Engineering and Technology, Sunway University, No. 5, Jalan Universiti, Bandar Sunway, 47500 Selangor Darul Ehsan, Malaysia
[e] University Centre for Research and Development, Chandigarh University, Mohali, Punjab, 140413, India
[f] Low Carbon Economy (LCE) Research Group, School of Chemical Engineering, Universiti Sains Malaysia, 14300, Nibong Tebal, Pulau Pinang, Malaysia

ARTICLE INFO

Keywords:
Transesterification
Palm lignocellulosic biomass
Magnetic catalyst
Optimization
Kinetic study
Biochar

ABSTRACT

Biodiesel has recently gained popularity as an alternative biofuel to substitute fossil fuel. Utilization of magnetic biochar catalyst (MBC) in biodiesel production can enhance the catalyst separation process. In this research, MBC was synthesized from oil palm waste such as palm kernel shell (PKS), oil palm frond (OFP), and empty fruit bunch (EFB). Biodiesel production parameters were studied using the Central Composite Design-based Response Surface Method. Based on the characterization results, EFB is the most suitable palm lignocellulosic biomass for MBC synthesis. The MBC has a BET surface area of 44.42 $m^2\ g^{-1}$, an average acid density value of 3.85 mmol g^{-1}, and a σ_s value of 3.19 $Am^2\ kg^{-1}$. MBC synthesis is at its optimal by using 1.5 M $FeCl_3{\cdot}6H_2O$ solution, 800 °C carbonization temperature, and 2.5 M H_2SO_4. The optimized transesterification parameters are: catalyst loading of 10.25 wt%, methanol to oil molar ratio of 28, 70 °C, and 8 h gave a maximum fatty acid methyl ester yield of 91.50 %. After five cycles, the yield dropped to 67.37 %. Biodiesel production is reported to be the pseudo-irreversible first-order kinetic with an activation energy of 29.20 kJ mol^{-1}. The physicochemical characterization showed the biodiesel has met the ASTM D6751 standard.

1. Introduction

Since the world's population is expanding and energy demand is rising, the world's current fossil fuel consumption is gradually rising [1]. Our housing and transportation are both heavily reliant on petroleum [2]. In terms of lowering our reliance on fossil fuels, biofuel - biodiesel is one of the most well-liked and promising alternative energies. Biodiesel is a great option for a substitute energy source because of its ecologically favorable features [3]. Compared to petroleum diesel, biodiesel emits cleaner exhaust emissions that are comprised of less soot, hydrocarbon, and carbon monoxide (CO) [4,5]. Due to its biodegradability and lower toxicity exhaust gas emission, biodiesel has emerged as one of the most popular biofuels for the transportation industry [6,7].

Biodiesel production can be either a catalytic or non-catalytic reaction. Non-catalytic biodiesel production usually requires a longer reaction period and higher reaction temperature and pressure than a catalytic biodiesel production reaction [8]. Homogeneous catalysts, heterogeneous catalysts, and enzyme catalysts are the three primary categories used to make biodiesel [9]. The most practical and effective way to produce biodiesel is through homogeneously catalyzed transesterification [10]. There are, however, a few problems with it. Homogeneous catalysts are very difficult to recover once a reaction has taken place. Most typical homogeneous catalysts are not biodegradable, which has led to disposal issues with the catalysts and by-products [11]. A homogeneous catalyst cannot be reused in this context. To get over these obstacles, a heterogeneous catalyst is used [12]. Heterogeneous catalysis has received a lot of attention since it is simpler to isolate and recycle for further uses [11]. The heterogeneous catalyst has the potential to be made from a renewable source, such as materials left over from industrial processes [13,14]. Activated carbon [15], biochar [16], biomass

* Corresponding author. Petroleum and Chemical Engineering, Faculty of Engineering, Universiti Teknologi Brunei, Gadong, BE1410 Brunei Darussalam.
E-mail addresses: yiehua.tan@utb.edu.bn, tanyiehua@curtin.edu.my (Y.H. Tan).

https://doi.org/10.1016/j.renene.2024.120750
Received 12 November 2023; Received in revised form 24 April 2024; Accepted 31 May 2024
Available online 31 May 2024