Bioresource Technology 125 (2012) 158–164

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

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

Development and characterisation of novel heterogeneous palm oil mill boiler ash-based catalysts for biodiesel production

Wilson Wei Sheng Ho [a], Hoon Kiat Ng [a], Suyin Gan [b,*]

[a] Department of Mechanical, Materials and Manufacturing Engineering, The University of Nottingham Malaysia Campus, Jalan Broga, 43500 Semenyih, Selangor Darul Ehsan, Malaysia
[b] Department of Chemical and Environmental Engineering, The University of Nottingham Malaysia Campus, Jalan Broga, 43500 Semenyih, Selangor Darul Ehsan, Malaysia

HIGHLIGHTS

- Novel heterogeneous palm oil mill boiler ash-based catalysts were developed.
- The optimum catalyst is 15 wt% calcined $CaCO_3$ at 800 °C loaded onto fly ash.
- Fly ash exhibited fine morphology size (<5 μm) and high surface area (1.719 m^2/g).
- Maximum crude palm oil conversion of 94.48% is achieved using the novel catalyst.

ARTICLE INFO

Article history:
Received 26 June 2012
Received in revised form 23 August 2012
Accepted 25 August 2012
Available online 1 September 2012

Keywords:
Palm oil mill boiler ash
Heterogeneous catalyst
Transesterification
Crude palm oil
Biodiesel

ABSTRACT

Novel heterogeneous catalysts from calcium oxide (CaO)/calcined calcium carbonate ($CaCO_3$) loaded onto different palm oil mill boiler ashes were synthesised and used in the transesterification of crude palm oil (CPO) with methanol to yield biodiesel. Catalyst preparation parameters including the type of ash support, the weight percentage of CaO and calcined $CaCO_3$ loadings, as well as the calcination temperature of $CaCO_3$ were optimised. The catalyst prepared by loading of 15 wt% calcined $CaCO_3$ at a fixed temperature of 800 °C on fly ash exhibited a maximum oil conversion of 94.48%. Thermogravimetric analysis (TGA) revealed that the $CaCO_3$ was transformed into CaO at 770 °C and interacted well with the ash support, whereas rich CaO, Al_2O_3 and SiO_2 were identified in the composition using X-ray diffraction (XRD). The fine morphology size (<5 μm) and high surface area (1.719 m^2/g) of the fly ash-based catalyst rendered it the highest catalytic activity.

1. Introduction

Increasing worldwide energy demands in addition to depleting fossil fuel reserves have necessitated the search for alternative renewable fuels (Basha et al., 2009; Demirbas, 2007). Amongst the promising alternatives fuels is biodiesel, a suitable replacement for petroleum diesel because of its relatively lower cost, compatibility with existing diesel infrastructure and availability of production technology (Ng et al., 2010a, 2010b). Moreover, biodiesel has been demonstrated to have potential to reduce pollutant emissions in both engines and oil burners (Ng and Gan, 2010; Ng et al., 2011, 2012).

Biodiesel is produced through transesterification in which triacylglycerides of an oil or fat are converted into lower molecular weight fatty acid monoalkyl esters using methanol in the presence of a basic or acidic catalyst (Boro et al., 2012). The main hurdle in the commercialisation of biodiesel is the cost of raw feedstocks. One way to reduce the cost of biodiesel production is to employ cheaper feedstocks such as waste cooking oils (Enweremadu and Mbarawa, 2009; Lam et al., 2010; Math et al., 2010) or crude palm oil (CPO) instead of neat or refined vegetable oils (Lou et al., 2008). However, such a process is challenging due to the presence of considerable undesirable components especially free fatty acids (FFAs) and water (Aijaz and Flora, 2010; Gan et al., 2010). The use of homogenous base catalysts for the transesterification of such feedstocks suffers from saponification whereby the catalyst reacts with FFAs to form large amounts of unwanted soap as by-product which inhibits the separation of biodiesel, glycerin and wash water (Helwani et al., 2009). This ultimately reduces the yield of biodiesel substantially (Lou et al., 2008). On the other hand, homogenous acid catalysts are not sensitive to FFAs but they are difficult to recycle and result in slower reaction rates as well as environmental and corrosion problems. Both these homogeneous catalysts are not reused hence they must be neutralised and discarded as aqueous salt waste streams (Helwani et al., 2009). Due to the problems associated with the use of homogenous catalysts, there has been an

* Corresponding author. Tel.: +60 3 8924 8162; fax: +60 3 8924 8017.
E-mail address: suyin.gan@nottingham.edu.my (S. Gan).

0960-8524/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2012.08.099