Applied Catalysis A: General 433–434 (2012) 170–178

Contents lists available at SciVerse ScienceDirect

Applied Catalysis A: General

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

Liquid hydrocarbon fuels from jatropha oil through catalytic cracking technology using AlMCM-41/ZSM-5 composite catalysts

G. Ramya, R. Sudhakar, J. Amala Infant Joice, R. Ramakrishnan, T. Sivakumar*

Catalysis Laboratory, Department of Chemical Engineering, A.C. Tech, Anna University, Chennai 600025, India

ARTICLE INFO

Article history:
Received 26 December 2011
Received in revised form 2 May 2012
Accepted 12 May 2012
Available online 18 May 2012

Keywords:
Composite catalyst
Green gasoline
Vegetable oil
Cracking
Bioliquid fuels, Porous materials

ABSTRACT

Biofuels, the hydrocarbons less than C_{18}, produced by catalytic cracking of nonedible vegetable oils are the potential source to battle energy demand and pollution. Among the non edible oils, jatropha is the apt candidate for the production of biofuel. Jatropha oil can be cracked catalytically over solid acid catalysts to yield liquid fuels with superior characteristics. We present here the hydrothermal syntheses of a microporous solid acid catalyst (HZSM-5 with Si/Al = 14), mesoporous materials (AlMCM-41) with varying Si/Al ratios (Si/Al = 18, 41, 72 and 95) and composite catalyst comprising HZSM-5 (as core) and varying coating percentages (5, 10 and 20%) of AlMCM-41 (as shell). All the synthesized catalysts were characterized by using XRD, BET N_2 sorption studies, ICP, TPD and SEM techniques. Herein we report the catalytic activities of all the synthesized catalysts towards the cracking of jatropha oil obtained at the optimized conditions of temperature – 400 °C, WHSV – 4.6 h^{-1} and reaction time – 1 h. Of all the mesoporous catalysts with varying Si/Al ratios, AlMCM-41 (Si/Al = 18) was found to be the most active catalyst as it converted 65% of jatropha oil yielding 39% of bioliquid fuel with 47% and 36% selectivities towards green diesel and green gasoline respectively. In the core–shell architecture of the composite catalyst, different % coatings of the best active mesoporous material (AlMCM-41, Si/Al = 18) over the best active microporous material (ZSM-5, Si/Al = 14) were done. AlMCM-41/ZSM-5 (25, 15, 10) showed remarkable performance in the conversion of jatropha oil (99%) yielding 70% of bioliquid fuel with very high selectivity (61%) towards green gasoline.

1. Introduction

The extensive use of fossil fuels to satisfy the majority of our energy needs has a negative impact on the environment. The levels of toxic gases such as NO_X and SO_X, photochemical oxidants, lead, particulate matter, etc., in the atmosphere are very high and alarming [1–3]. Finite nature of fossil fuels stimulates the interest among the researchers to look out for alternative fuels [4]. Hence a good alternative fuel should be in correlation with sustainable development, energy conservation, efficiency and more importantly environmental preservation [5–7]. Vegetable oils are the best alternative sources from which an environmentally benign fuel can be derived [8]. Although the research on alternative fuels emerged in 1900 itself by Rudolf Diesel's test on his engine with peanut oil it was not successful due to engine related problems [9]. There have been several methods reported for the production of biofuel through transesterification (biodiesel), pyrolysis (lower hydrocarbons) and catalytic cracking (engine friendly hydrocarbons) [10–13]. The biodiesel, mono-alkyl esters of long chain fatty acid produced from transesterification of vegetable oils needs high reaction time and requires higher molar ratio of methanol to oil and hence it is not cost effective. Moreover biodiesel can be used in diesel engine only. In addition, biodiesel has to blended with fossil fuels and cannot be used as such [14–16]. Biodiesel is not economically attractive because it requires blending with petrol or diesel and it also does not burn cleanly as it forms gums on engines. Pyrolysis, which is a direct thermal decomposition method, operates at a very high temperature (700–1000 °C) and yields mostly gaseous products containing straight chain hydrocarbon fuels [12]. Among various biofuels that can be obtained by different methods, biofuels obtained through catalytic cracking from nonedible vegetable oils outshine other biofuels due to their (i) ease to use in engines as such, (ii) sustainable and non-polluting nature (no sulphur and nitrogen containing compounds) and (iii) low cost of production. Catalytic cracking of vegetable oils also has an edge over other processes as it requires lower operating temperature (<450 °C) and low catalyst to oil ratio. The biofuel obtained through catalytic cracking also shows very high selectivity towards gasoline fraction and burns cleanly.

* Corresponding author. Tel.: +91 44 22359193; fax: +91 44 22352642.
E-mail addresses: tssivakumar@yahoo.com, sivakumar@annauniv.edu (T. Sivakumar).

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http://dx.doi.org/10.1016/j.apcata.2012.05.011