RINGKASAN

Biodiesel merupakan salah satu alternatif energi terbarukan yang berpotensi menggantikan bahan bakar fosil. Katalis berbasis CaO umumnya hanya bertahan hingga 5 siklus daur ulang, sedangkan dukungan Fe_3O_4 dapat meningkatkan kemudahan pemisahan dan stabilitas katalis. Penelitian ini memanfaatkan limbah cangkang telur ayam sebagai sumber CaO dan pasir besi Sungai Batanghari sebagai sumber Fe_3O_4 untuk sintesis katalis heterogen CaO/Fe_3O_4 melalui metode dry milling. Hasil XRF menunjukkan kandungan CaO pada cangkang telur 96,70% dan Fe_3O_4 pada pasir besi 61,20%. Analisis XRD mengidentifikasi struktur rhombohedral cangkang telur ayam (29,99 nm) dan struktur kubik CaO, Fe_3O_4, serta CaO/Fe_3O_4 (26,34 nm; 4,52 nm; 17,32 nm). FTIR mengkonfirmasi ikatan Ca–O dan Fe–O dengan pergeseran bilangan gelombang pada komposit. FESEM-EDX memperlihatkan morfologi homogen CaO (160,19 nm), agregasi Fe_3O_4 (95,55 nm), serta aglomerasi pada CF 3 (74,36 nm) dengan kandungan Ca 29,80% dan Fe 21,99%. Uji CO_2-TPD menunjukkan CF 3 memiliki situs basa tertinggi (3,9586 mmol/g). BET menunjukkan luas permukaan CaO (72,93 m^2/g), Fe_3O_4 (105,7 m^2/g), dan CF 3 (26,60 m^2/g) dengan struktur mesopori (2-50 nm). VSM menunjukkan sifat superparamagnetik dengan Ms Fe_3O_4 (40,60 emu/g) dan CF 3 (11,50 emu/g). Minyak biji bunga matahari sebagai bahan baku dominan mengandung asam oleat (32,46%). Kondisi optimum reaksi transesterifikasi diperoleh pada katalis CF 3, 3 wt.% katalis, rasio molar metanol:minyak 12:1, dan suhu 65 °C, dengan yield biodiesel 88,42% didominasi metil ester asam 9-oktadekanoat (Z). Katalis CF 3 dapat digunakan hingga 4 kali siklus dengan sifat superparamagnetik (Ms 11,50 emu/g). Analisis biodiesel (B100) menunjukkan warna (1,5), bilangan asam (0,365 mg KOH/g), viskositas 40 °C (2,9125 cSt), densitas 40 °C (876,6 kg/m^3), kadar ester metil (88,90%), dan kadar air (400 ppm). Seluruh parameter memenuhi standar SK Dirjen EBTKE No. 189/2019 kecuali kadar air.

Kata Kunci: *Nanokomposit CaO/Fe_3O_4, Transesterifikasi, Ultrasonik, Biodiesel.*

SUMMARY

Biodiesel is one of the renewable energy alternatives that has the potential to replace fossil fuels. CaO-based catalysts generally only last up to 5 recycling cycles, while Fe_3O_4 support can improve catalyst separation and stability. This study utilizes chicken eggshell waste as a source of CaO and Batanghari River iron sand as a source of Fe_3O_4 for the synthesis of CaO/Fe_3O_4 heterogeneous catalysts through the dry milling method. XRF results show that the CaO content in eggshells is 96.70% and the Fe_3O_4 content in iron sand is 61.20%. XRD analysis identified the rhombohedral structure of chicken eggshells (29.99 nm) and the cubic structures of CaO, Fe_3O_4, and CaO/Fe_3O_4 (26.34 nm; 4.52 nm; 17.32 nm). FTIR confirmed the Ca–O and Fe–O bonds with wavelength shifts in the composite. FESEM-EDX showed the homogeneous morphology of CaO (160.19 nm), Fe_3O_4 aggregation (95.55 nm), and agglomeration in CF 3 (74.36 nm) with Ca content of 29.80% and Fe content of 21.99%. The CO_2-TPD test showed that CF 3 had the highest base site (3.9586 mmol/g). BET showed the surface area of CaO (72.93 m^2/g), Fe_3O_4 (105.7 m^2/g), and CF 3 (26.60 m^2/g) with a mesoporous structure (2-50 nm). VSM showed superparamagnetic properties with Ms Fe_3O_4 (40.60 emu/g) and CF 3 (11.50 emu/g). Sunflower seed oil as the dominant raw material contained oleic acid (32.46%). The optimum transesterification reaction conditions were obtained with CF 3 catalyst, 3 wt.% catalyst, methanol:oil molar ratio of 12:1, and temperature of 65 °C, with a biodiesel yield of 88.42% dominated by 9-octadecanoic acid methyl ester (Z). The CF 3 catalyst can be used up to 4 cycles with superparamagnetic properties (Ms 11.50 emu/g). Analysis of biodiesel (B100) showed color (1.5), acid number (0.365 mg KOH/g), viscosity at 40 °C (2.9125 cSt), density at 40 °C (876.6 kg/m^3), methyl ester content (88.90%), and water content (400 ppm). All parameters meet the standards of SK Dirjen EBTKE No. 189/2019 except for water content.

Keywords: CaO/Fe_3O_4 nanocomposite, Transesterification, Ultrasonic, Biodiesel.