

Valorization of Waste Cooking Oil into Fuels: Exploring Co-Mo/CNT and Zeolite Catalysts for Enhanced Hydrocarbon Production

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PURPOSE OF THE ABSTRACT

The use of vegetable oil in cooking is common worldwide, raising concerns about the proper disposal of waste cooking oil (WCO) to prevent environmental impacts. WCO valorization has gained attention for biofuel production due to its composition, suitable for deoxygenation, isomerization, and cracking reactions [1]. Conventional sulfide Co-Mo/ γ -Al₂O₃ catalysts are commonly used for upgrading petrochemical derivatives but require continuous sulfur supply to avoid deactivation [2]. Non-sulfide catalysts, such as carbon nanotubes (CNT)-based catalysts, offer a sustainable alternative with strong thermal stability and the ability to process complex feedstocks without sulfur resupply. Although CNT offer several advantages, they lack the necessary acidity to efficiently produce hydrocarbons in specific fuel ranges, even after undergoing oxidation treatment, as reported elsewhere [3]. An alternative to address this limitation is adding acidic materials like zeolites. In this context, this work focused on assessing WCO conversion using different catalytic systems of CNT-based catalyst and zeolite. First, Co-Mo/CNT (2.5 wt.% Co and 10.5 wt.% Mo) was prepared by incipient wetness impregnation method, dried at 110 °C overnight, and subsequently thermally treated with N₂ followed by a reduction under H₂ at the same temperature (600 °C). An ammonium type ZSM-5 was calcined at 600 °C for 3 h to obtain the acid form (H-ZSM-5). The catalysts were characterized by nitrogen adsorption at -196 °C, X-ray diffraction (XRD) and inductively coupled plasma-optical emission spectroscopy. The catalytic experiments were performed in a 100 mL batch reactor at 325 °C, 70 bar of H₂ (at 25 °C), 1000 rpm, 0.25 g of catalyst and 2.5 g of WCO in 25 g of n-decane, for 3 h. Liquid and gas samples were analyzed by gas chromatography (GC) with a flame ionization detector (FID) and GC-FID/thermal conductivity detector, respectively. The carbon content of the WCO used was determined by elemental analysis. Overall, four experiments were conducted: (a) Co-Mo/CNT; (b) Co-Mo/CNT and H-ZSM-5 (physical mixture, 1:1 proportion); (c) H-ZSM-5 and (d) benchmarking Co-Mo/Al₂O₃ (pre-reduced at 600 °C). The Co-Mo/CNT and H-ZSM-5 catalysts exhibited specific surface areas of 198 and 352 m² g⁻¹, with total pore volumes of 1.51 and 0.99 cm³ g⁻¹,

respectively. While the CNT catalyst showed no microporosity, the zeolite presented a micropore volume of 0.16 cm³ g⁻¹. XRD analysis confirmed the high crystallinity of H-ZSM-5 (Si and Al oxides), as well as the presence of MoO₂ and CoMo alloys in the Co-Mo/CNT. The Co and Mo loadings matched the nominal values, and no additional metals were detected in the zeolite. According to the catalytic experiments, a higher selectivity to C17-C18 hydrocarbons (55 mol.%) was achieved using Co-Mo/CNT. As expected, when the zeolite was incorporated into the system, an increase in the cracking reactions was observed, leading to selectivities of 70, 20, and 10 mol.% for hydrocarbons in the C5–C7, C8–C16, and C17–C18 ranges, respectively. In contrast, the reaction performed solely with H-ZSM-5 produced hydrocarbons primarily within the C1–C16 range. The commercial catalyst, under the applied conditions, was insufficient to achieve complete deoxygenation of the reaction intermediates.

Acknowledgments

This work was supported by national funds through FCT/MCTES (PIDDAC): LSRE-LCM, UIDB/50020/2020 (DOI:10.54499/UIDB/50020/2020) and UIDP/50020/2020 (DOI:10.54499/UIDP/50020/2020); and ALiCE, LA/P/0045/2020 (DOI:10.54499/LA/P/0045/2020). The authors thank the financial support from the I+D+i projects PID2020-115053RB-I00 and PID2023-147514OB-I00, funded by Spanish Ministry of Science and Innovation (MCIN/AEI/10.13039/501100011033). K.K.F. acknowledges her Ph.D. scholarship (2022.12949.BD) from FCT. C.D.S is grateful for the Juan de la Cierva fellowship (JDC2022-048765-I) funded by MICIU/AEI /10.13039/501100011033 and by FSE+.

FIGURES

FIGURE 1

FIGURE 2

KEYWORDS

Waste cooking oil valorization | Carbon nanotubes | Zeolite | Liquid Fuels

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