Optimization and characterization of mesoporous sulfonated carbon catalyst and its application in modelling and optimization of acetin production

ABSTRACT

In this study, an optimized mesoporous sulfonated carbon (OMSC) catalyst derived from palm kernel shell biomass was developed using template carbonization and subsequent sulfonation under different temperatures and time conditions. The OMSC catalyst was characterized using acid-base titration, elemental analysis, XRD, Raman, FTIR, XPS, TPD-NH3, TGA-DTA, SEM, and N2 adsorption–desorption analysis to reveal its properties. Results proved that the OMSC catalyst is mesoporous and amorphous in structure with improved textural, acidic, and thermal properties. Both FTIR and XPS confirmed the presence of -SO3H, -OH, and -COOH functional groups on the surface of the catalyst. The OMSC catalyst was found to be efficient in catalyzing glycerol conversion to acetin via an acetylation reaction with acetic acid within a short period of 3 h. Response surface methodology (RSM), based on a two-level, three-factor, face-centered central composite design, was used to optimize the reaction conditions. The results showed that the optimized temperature, glycerol-to-acetic acid mole ratio, and catalyst load were 126 °C, 1:10.4, and 0.45 g, respectively. Under these optimum conditions, 97% glycerol conversion (GC) and selectivities of 4.9, 27.8, and 66.5% monoacetin (MA), diacetin (DA), and triacetin (TA), respectively, were achieved and found to be close to the predicted values. Statistical analysis showed that the regression model, as well as the model terms, were significant with the predicted R2 in reasonable agreement with the adjusted R2 (<0.2). The OMSC catalyst maintained excellent performance in GC for the five reaction cycles. The selectivity to TA, the most valuable product, was not stable until the fourth cycle, attributable to the leaching of the acid sites.

Keyword: Mesoporous; Carbon; Sulfonation; Acetin; Modeling; Optimization