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Production of biogasoline and biojet fuel from castor oil using nano-nickel catalyst supported on carbon dots

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ABSTRACT

Bio-energy resources become more interesting as alternative to produce energy and can attract investors depending on their availability as feedstock, production cost and sustainability of conversion of biomass into biofuels. This study addressed the challenges raised by the heavy reliance on petroleum fuel in South Africa, which has resulted to the crisis of energy security, greenhouse gas emissions, and heavy foreign exchange spent on imported oil. This study focuses on the production of biojet and biogasoline fuel from castor oil using hydrocracking process on a nano-nickel catalyst supported on carbon dots (C dots).

Castor oil was extracted from castor seeds obtained from Selokong Sa Dimelang (SSD) plantation using solvent extraction. The castor oil extraction parameters were optimised using RSM by varying extraction temperature, extraction time, and seed/solvent ratio to obtain maximum oil that can be extracted. The maximum oil yield obtained from SSD castor seeds was 44.8 wt. % at optimal extraction parameters of 63.3^{o}C, 3.6 h, and 0.03 g/ml of extraction temperature, extraction time and seed/solvent ratio, respectively. The compounds identified by GC/MS in the extracted oil were oleic acid, palmitic acid, undercylenic acid, methyl ricinoleate, behenic acid,tridecylenic acid and 13-hexyloxacyclotridec-10-en-2-one. The acid value, saponification value, iodine value, specific gravity, viscosity of the castor oil were determined to be 1.22, 178, 85, 0.952, and 6.6 respectively, and were found to be within ASTM standard specification values.

Different Ni/C dots catalysts were synthesized with varying Ni-loadings from 5 wt. % to 25 wt. % and calcination temperatures from 350°C to 750°C. The catalysts were characterised using AAS, TGA, BET, SEM, TEM, XRD, and FT-IR spectroscopy. 5 wt. % Ni-loading catalyst calcined at 350^{o}C showed highest thermal stability, highest BET surface area of 71.69 m^2/g, and the particles were less agglomerated compared to the catalyst produced with different Ni-loadings and calcination temperatures.

The effect of Ni-loading, calcination temperature, extraction time extraction temperature, and catalyst/oil ratio on the production of biojet and biogasoline fuel was studied. The maximum production yield of biojet was obtained to be 56 wt. % at 5 wt. % Ni-loading catalyst calcined at 350^{o}C, reaction temperature of 250^{o}C, reaction time of 1.5 h, and catalyst/oil ratio of 0.005 g/ml and the maximum production yield of biogasoline was obtained to be 36 wt. % at 5wt. % Ni-loading catalyst calcined 350^{o}C, reaction time of 350^{o}C, reaction time of 1.5 h, and catalyst/

oil ratio of 0.003 g/ml. The overall order of the reaction for the biojet and biogasoline production was investigated according to 0 to 4^{th} order and but did not fit to any reaction order for the forward reaction. Then reverse process yield of biofuel reduced was assumed. Second order rate plots best fitted both biojet and biogasoline production for the reverse reaction. The rate constant (k) was obtained from the slope of the plots. The rate constants for biojet production from 0.5-1.5 h and 1.5-2.5 h were 0.0326 and 0.007, respectively. The rate constants for biogasoline production from 0.5-1.5 h and 1.5-2.5 h were 0.0294 and 0.0206, respectively. RSM from Design Expert version 11.0.4 software was used to determine the optimum process conditions for the hydrocracking of castor oil. The optimal reaction temperature, reaction time, and catalyst/oil ratio were 350^{o}C, 1.5 h, and 0.002 g/ml and produced the maximum production of 50.51 wt. % and 33.57 wt. % of biojet and biogasoline fuel, respectively.