SINTESIS, KARAKTERISASI, DAN APLIKASI KATALIS NI/Z UNTUK *HYDROTREATMENT* MINYAK SAWIT MENJADI BIOAVTUR

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INTISARI

Penelitian ini difokuskan pada pengembangan sintesis katalis Ni/ZSM-5 untuk proses *hydrotreatment* minyak sawit dengan variasi susunan katalis dalam reaktor untuk menghasilkan bioavtur. Tujuan penelitian ini antara lain mempelajari pengaruh metode sintesis katalis nikel teremban ZSM-5 (Ni/Z) melalui *spry-dry impregnation* serta pemanasan konvensional dan *microwave* terhadap karakter katalis, mengevaluasi pengaruh konfigurasi susunan katalis tunggal dan ganda dalam reaktor, dan stabilitas katalis. Katalis disintesis melalui metode *spray-dry impregnation* menggunakan prekursor logam $NiNO_3.6H_2O$ dan ZSM-5 sebagai material pendukung. Karakterisasi katalis dilakukan dengan FTIR, XRD, SAA, SEM-EDX, XRF, XPS, NH_3-TPD, TEM, dan TGA. Uji aktivitas, selektivitas, dan stabilitas katalis untuk *hydrotreatment* minyak sawit dilakukan menggunakan variasi susunan katalis Ni/ZSM-5 dengan menggunakan reaktor *semi-batch* pada tekanan atmosferik pada temperatur 400-550 °C. Produk cair yang dihasilkan diuji dengan GCMS dan FTIR serta akan dilakukan pengujian dengan distilasi fraksinasi serta pengujian produk menggunakan standar ASTM.

Hasil penelitian menunjukkan bahwa katalis nikel teremban ZSM-5 dengan pemanasan konvensional (Ni/Z A) dan katalis nikel teremban ZSM-5 dengan pemanasan *microwave* (Ni/Z MW) menunjukkan kristalinitas masing-masing sebesar 77,42 dan 74,66%; rerata ukuran kristal sebesar 18,79 dan 15,95 nm; luas permukaan spesifik sebesar 218,74 dan 238,81 $m^2\ g^{-1}$; volume pori total sebesar 0,20 dan 0,21 $cm^3\ g^{-1}$, rerata jari-jari pori sebesar 1,85 dan 1,79 nm dengan kandungan logam Ni sebesar 3,39 dan 7,03% yang terdeteksi dengan SEM-EDX serta 3,85 dan 4,22% dengan XRF; keasaman total sebesar 1,817 dan 1,810 mmol g^{-1}. Analisis XPS menunjukkan bahwa bilangan oksidasi Ni adalah 0 dan +2. Katalis Ni/Z MW susun ganda menunjukkan *yield* tertinggi fraksi bioavtur sebesar 38,07% pada temperatur reaksi 400–475 °C. Uji stabilitas katalis menunjukkan bahwa Ni/Z MW susun ganda menunjukkan kinerja yang menjanjikan setelah lima siklus reaksi menghasilkan *yield* bioavtur fraksi I dan II masing-masing sebesar 30,8 dan 22,1%. Titik beku produk bioavtur dari susunan katalis Ni/Z MW fraksi I dan II masing-masing sebesar -47,01 dan -53,19 °C.

Kata kunci: bioavtur, *hydrotreatment*, katalis, *microwave,* minyak sawit.

SYNTHESIS, CHARACTERIZATION, AND APPLICATION OF NI/ZSM-5 CATALYST FOR HYDROTREATMENT OF PALM OIL INTO BIOAVTUR

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ABSTRACT

This research focuses on the development of Ni/ZSM-5 catalyst synthesis for the hydrotreatment of palm oil to produce bio-aviation fuel, investigating various catalyst arrangements within the reactor. The objectives of this study include: examining the influence of synthesis methods for Ni-impregnated ZSM-5 (Ni/Z) catalysts—via spray-dry impregnation with conventional and microwave heating on catalyst characteristics; evaluating the effect of single and dual-bed catalyst configurations in the reactor; and assessing catalyst stability. The catalysts were synthesized via the spray-dry impregnation method using $Ni(NO_3)_2 \cdot 6H_2O$ as the metal precursor and ZSM-5 as the support material. Catalyst characterization was performed using FTIR, XRD, SAA, SEM-EDX, XRF, XPS, NH_3-TPD, TEM, and TGA. The activity, selectivity, and stability of the catalysts for palm oil hydrotreatment were tested using various Ni/ZSM-5 arrangements in a semi-batch reactor under atmospheric pressure at temperatures ranging from 400–550 °C. The resulting liquid product was analyzed by GCMS and FTIR and will be further tested by fractional distillation and product evaluation according to ASTM standards.

The results showed that the conventionally heated (Ni/Z A) and microwave-heated (Ni/Z MW) Ni-impregnated ZSM-5 catalysts exhibited crystallinities of 77.42% and 74.66%; average crystal sizes of 18.79 and 15.95 nm; specific surface areas of 218.74 and 238.81 m^2/g; total pore volumes of 0.20 and 0.21 cm^3/g; and average pore radii of 1.85 and 1.79 nm, respectively. The Ni metal content detected by SEM-EDX was 3.39% and 7.03%, and by XRF was 3.85% and 4.22%. The total acidity was 1.817 and 1.810 mmol/g. XPS analysis indicated that the oxidation states of Ni were 0 and +2. The dual-bed configuration of the Ni/Z MW catalyst showed the highest bioavtur fraction yield of 38.07% at a reaction temperature of 400–475 °C. The stability test demonstrated that the dual-bed Ni/Z MW catalyst exhibited promising performance after five reaction cycles, yielding bio-aviation fuel fractions I and II at 30.8% and 22.1%, respectively. The freezing points of the bio-aviation fuel products from the Ni/Z MW catalyst in fractions I and II were -47.01 °C and -53.19 °C, respectively.

Keywords: bioavtur, catalyst, hydrotreatment, microwave, palm oil.