

PENGARUH URUTAN IMPREGNASI NIKEL DAN MOLIBDENUM PADA SILIKA MESOPORI DARI LIMBAH DAUN SALAK TERCETAK EKSTRAK BIJI LERAK TERHADAP AKTIVITAS DAN SELEKTIVITAS HYDROTREATING MINYAK NYAMPLUNG MENJADI BIOAVTUR

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INTISARI

Pengembangan bioavtur berbasis bahan baku nonpangan dan katalis ramah lingkungan menjadi salah satu strategi penting dalam mendukung transisi energi berkelanjutan pada sektor penerbangan. Penelitian ini telah berhasil mensintesis katalis Ni–Mo terimpregnasi pada silika mesopori dari biomassa daun salak tercetak dengan ekstrak biji lerak untuk proses *hydrotreating* minyak nyamplung menjadi bioavtur berbantuan *microwave*. Pendekatan *green chemistry* diterapkan melalui pemanfaatan limbah biomassa sebagai sumber silika, penggunaan ekstrak biji lerak sebagai *template* alami pengganti surfaktan sintetik, penggunaan minyak nyamplung sebagai umpan *non-edible*, serta penerapan metode *ultrasound-assisted impregnation* dan *hydrotreating* berbantuan *microwave* yang lebih efisien energi. Penelitian ini bertujuan mengevaluasi pengaruh urutan impregnasi logam terhadap karakteristik fisikokimia dan performa katalitik material Ni–Mo/MS, Mo–Ni/MS, dan NiMo/MS dalam produksi bioavtur dari minyak nyamplung.

Karakterisasi material dilakukan menggunakan FTIR, XRD, FESEM–EDX Mapping, SAA, NH₃-TPD, dan TEM-SAED. Aktivitas katalitik diuji melalui proses *hydrotreating* minyak nyamplung menggunakan reaktor *microwave*, kemudian produk cair dianalisis menggunakan GC–MS. Hasil penelitian menunjukkan bahwa urutan impregnasi logam berpengaruh terhadap sifat tekstural, ukuran kristalit, distribusi logam, dan keasaman katalis. Material Ni–Mo/MS (Ni diimpregnasi terlebih dahulu) menunjukkan performa terbaik dengan luas area spesifik sebesar 227,97 m²/g, volume pori total 0,96 cm³/g, dan keasaman total sebesar 1,09 mmol/g NH₃. Pada kondisi reaksi daya *microwave* 600 Watt, rasio katalis terhadap umpan 1:100 (b/b), dan waktu reaksi 30 menit, katalis Ni–Mo/MS menghasilkan *yield* bioavtur sebesar 58,02% dan selektivitas sebesar 71,53%, lebih tinggi dibandingkan dengan Mo–Ni/MS dan NiMo/MS. Uji *reusability* selama empat siklus berurutan menunjukkan bahwa katalis Ni–Mo/MS masih memiliki stabilitas katalitik yang cukup baik dengan *yield* bioavtur dan selektivitas pada siklus keempat masing-masing sebesar 31,07% dan 59,67%.

Kata kunci: bioavtur, silika mesopori, minyak nyamplung, reaktor *microwave*, *green chemistry*

***EFFECT OF NICKEL AND MOLYBDENUM IMPREGNATION SEQUENCE
ON MESOPOROUS SILICA DERIVED FROM SALAK LEAVES WASTE
TEMPLATED BY LERAK SEED EXTRACT TOWARD ACTIVITY AND
SELECTIVITY OF HYDROTREATING OF TAMANU OIL INTO BIOJET-
FUEL***

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ABSTRACT

The development of biojet-fuel derived from non-edible feedstocks and environmentally friendly catalysts has become an important strategy to support sustainable energy transition in the aviation sector. In this study, Ni–Mo catalysts supported on mesoporous silica derived from salak leaf biomass and templated using *Sapindus rarak* seed extract were successfully synthesized for the hydrotreating of tamanu oil into biojet-fuel. A *green chemistry* approach was implemented through the utilization of biomass waste as a silica source, the use of *Sapindus rarak* extract as a natural template substituting synthetic surfactants, the application of non-edible tamanu oil as feedstock, and the employment of ultrasound-assisted impregnation and microwave-assisted hydrotreating methods with improved energy efficiency. This study aimed to evaluate the effect of metal impregnation sequence on the physicochemical properties and catalytic performance of Ni–Mo/MS, Mo–Ni/MS, and NiMo/MS catalysts.

The catalysts were characterized using FTIR, XRD, FESEM-EDX mapping, SAA, NH₃-TPD, and TEM-SAED analyses. Catalytic activity was evaluated through microwave-assisted hydrotreating of tamanu oil in a microwave reactor, while the liquid products were analyzed using GC-MS. The results demonstrated that the impregnation sequence significantly affected the textural properties, crystallite size, metal distribution, and acidity of the catalysts. The Ni–Mo/MS catalyst (Ni impregnated prior to Mo) exhibited the best performance, with a specific surface area of 227.97 m²/g, a total pore volume of 0.96 cm³/g, and a total acidity of 1.09 mmol/g NH₃. Under optimum reaction conditions of 600 W microwave power, a catalyst-to-feed ratio of 1:100, and a reaction time of 30 min, the Ni–Mo/MS catalyst achieved a biojet-fuel yield of 58.02% and a selectivity of 71.53%, outperforming both Mo–Ni/MS and NiMo/MS catalysts. Reusability evaluation over three consecutive cycles indicated that Ni–Mo/MS retained relatively good catalytic stability, with biojet-fuel yield and selectivity decreasing to 31.07% and 59.67%, respectively, after the third cycle.

Keywords: bio-jet fuel, mesoporous silica, tamanu oil, microwave reactor, green chemistry