

**PREPARASI KATALIS KALSIUM OKSIDA TERIMPREGNASI
BESI(III) OKSIDA DAN TERFUNGSIONALISASI AMINOSILAN
UNTUK KONVERSI MINYAK NYAMPLUNG (*Calophyllum inophyllum* L.)
MENJADI *FATTY ACID METHYL ESTERS***

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INTISARI

Penelitian ini berhasil mensintesis dan mengkarakterisasi katalis $\text{CaO-Fe}_2\text{O}_3\text{-APTMS}$, mengevaluasi performanya dalam produksi *fatty acid methyl esters* (FAME) dari minyak nyamplung, mengoptimasi kondisi reaksi menggunakan metode *Response Surface Methodology* (RSM), serta menguji *reusability* katalis. Katalis disintesis melalui metode *ultrasound-assisted spray impregnation* untuk impregnasi Fe_2O_3 dan *ultrasound-assisted grafting* untuk fungsionalisasi 3-APTMS. Karakterisasi katalis dilakukan menggunakan XRD, FTIR, SEM-EDX, SAA, $\text{NH}_3\text{-TPD}$, dan $\text{CO}_2\text{-TPD}$. Optimasi kondisi reaksi dilakukan menggunakan metode RSM berbasis *Hybrid Central Composite Design* (Hybrid CCD) dengan waktu reaksi, konsentrasi katalis, dan rasio molar metanol terhadap minyak sebagai variabel bebas, sementara *yield* FAME sebagai respons utama.

Hasil penelitian menunjukkan bahwa katalis $\text{CaO-Fe}_2\text{O}_3\text{-APTMS}$ memiliki sifat asam-basa yang lebih baik dibandingkan CaO dan $\text{CaO-Fe}_2\text{O}_3$, dengan total kebasaan sebesar $3,73 \text{ mmol CO}_2 \text{ g}^{-1}$ dan total keasaman sebesar $1,73 \text{ mmol NH}_3 \text{ g}^{-1}$. Karakterisasi SAA menunjukkan bahwa katalis memiliki luas permukaan spesifik sebesar $2,83 \text{ m}^2 \text{ g}^{-1}$, volume pori total sebesar $2,84 \times 10^{-2} \text{ cm}^3 \text{ g}^{-1}$, dan rerata diameter pori sebesar $401,44 \text{ \AA}$. Pada kondisi operasi yang sama, katalis $\text{CaO-Fe}_2\text{O}_3\text{-APTMS}$ menghasilkan *yield* FAME sebesar 80,61%, lebih tinggi dibandingkan CaO dan $\text{CaO-Fe}_2\text{O}_3$. Hasil optimasi menunjukkan bahwa kondisi optimum diperoleh pada waktu reaksi 4,83 jam, konsentrasi katalis 3,71%, dan rasio molar metanol terhadap minyak 12:1 dengan *yield* FAME sebesar 88,62%. Uji *reusability* menunjukkan bahwa katalis masih dapat digunakan hingga tiga siklus reaksi meskipun terjadi penurunan aktivitas katalitik. Secara keseluruhan, katalis $\text{CaO-Fe}_2\text{O}_3\text{-APTMS}$ berpotensi digunakan sebagai katalis heterogen bifungsional yang efektif untuk produksi FAME dari minyak nyamplung dengan asam lemak bebas (FFA) yang tinggi.

Kata kunci: *fatty acid methyl esters*, kalsium oksida termodifikasi besi(III) oksida dan 3-APTMS, katalis bifungsional, minyak nyamplung.

**PREPARATION OF IRON(III) OXIDE-IMPREGNATED AND
AMINOSILANE-FUNCTIONALIZED CALCIUM OXIDE CATALYST
FOR CONVERSION OF NYAMPLUNG (*Calophyllum inophyllum* L.)
OIL INTO FATTY ACID METHYL ESTERS**

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ABSTRACT

This study successfully synthesized and characterized the CaO–Fe₂O₃–APTMS catalyst, evaluated its performance in the production of fatty acid methyl esters (FAME) from nyamplung oil, optimized the reaction conditions using the Response Surface Methodology (RSM), and investigated the catalyst reusability. The catalyst was synthesized through ultrasound-assisted spray impregnation for Fe₂O₃ impregnation and ultrasound-assisted grafting for 3-APTMS functionalization. Catalyst characterization was carried out using XRD, FTIR, SEM-EDX, SAA, NH₃-TPD, and CO₂-TPD. Reaction optimization was performed using RSM based on Hybrid Central Composite Design (Hybrid CCD) with reaction time, catalyst concentration, and methanol-to-oil molar ratio as independent variables, while FAME yield was used as the main response.

The results showed that CaO–Fe₂O₃–APTMS exhibited better acid–base properties than CaO and CaO–Fe₂O₃, with total basicity and total acidity of 3.73 mmol CO₂ g⁻¹ and 1.73 mmol NH₃ g⁻¹, respectively. SAA characterization revealed that the catalyst possessed a specific surface area of 2.83 m² g⁻¹, total pore volume of 2.84 × 10⁻² cm³ g⁻¹, and average pore diameter of 401.44 Å. Under the same operating conditions, CaO–Fe₂O₃–APTMS produced a FAME yield of 80.61%, which was higher than those of CaO and CaO–Fe₂O₃. Optimization results indicated that the optimum conditions were achieved at a reaction time of 4.83 h, catalyst concentration of 3.71%, and methanol-to-oil molar ratio of 12:1, resulting in a FAME yield of 88.62%. Reusability testing demonstrated that the catalyst could still be reused for up to three reaction cycles despite a decrease in catalytic activity. Overall, CaO–Fe₂O₃–APTMS shows potential as an effective bifunctional heterogeneous catalyst for FAME production from nyamplung oil with a high free fatty acid (FFA) content.

Keywords: bifunctional catalyst, *Calophyllum inophyllum* oil, fatty acid methyl esters, iron(III) oxide and 3-APTMS modified calcium oxide.