Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk
Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

DAFTAR PUSTAKA

Aierken, Y., Sahin, H., Iyikanat, F., Horzum, S., Suslu, A., Chen, B., Senger, R.T., Tongay, S., and Peeters, F.M., 2015, Portlandite Crystal: Bulk, Bilayer, and Monolayer Structures, *Phys. Rev. B Condens. Matter Mater. Phys.*, 91, 245413.

Almeida, E.L., Andrade, C.M.G., and Santos, O.A.A., 2018, Production of Biodiesel via Catalytic Processes: A Brief Review, *Int. J. Chem. React. Eng.*, 16, 20170130.

Alothman, Z.A., and Apblett, A.W., 2011, 3-Aminopropyltrimethoxysilane Functionalized Mesoporous Materials and Uptake of Metal Ions, *Asian J. Chem.*, 23, 541–546.

Amakawa, K., Wang, Y., Kröhnert, J., Schlögl, R., and Trunschke, A., 2019, Acid Sites on Silica-Supported Molybdenum Oxides Probed by Ammonia Adsorption: Experiment and Theory, *Mol. Catal.*, 478, 110580.

American Society for Testing and Materials, 2024, *ASTM D6751-24: Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels*, ASTM International, West Conshohocken.

Anggoro, D.D., Hidayati, N., Buchori, L., and Mundriyastutik, Y., 2016, Effect of Co and Mo Loading by Impregnation and Ion Exchange Methods on Morphological Properties of Zeolite Y Catalyst, *Bull. Chem. React. Eng. Catal.*, 11, 75–83.

Anonim, 2018, Biodiesel – Spesifikasi (SNI 7182:2018), Badan Standardisasi Nasional, Jakarta.

Aparamarta, H.W., Gunawan, S., Ihsanpuro, S.I., Safawi, I., Bhuana, D.S., Mochtar, A.F., and Noer, M.Y.I., 2022, Optimization and Kinetic Study of Biodiesel Production from Nyamplung Oil with Microwave-Assisted Extraction (MAE) Technique, *Heliyon*, 8, e10254.

Arita, S., Adipati, A.S., and Sari, D.P., 2014, Pembuatan Katalis Heterogen dari Cangkang Kerang Darah (*Anadara granosa*) dan Diaplikasikan pada Reaksi Transesterifikasi dari Crude Palm Oil, *J. Tek. Kim.*, 20, 31–37.

Aslan, V., and Eryilmaz, T., 2020, Polynomial Regression Method for Optimization of Biodiesel Production from Black Mustard (*Brassica nigra* L.) Seed Oil Using Methanol, Ethanol, NaOH, and KOH, *Energy*, 209, 118386.

Atabani, A.E., and César, A.D.S., 2014, Calophyllum Inophyllum L. - A Prospective Non-Edible Biodiesel Feedstock. Study of Biodiesel Production, Properties, Fatty Acid Composition, Blending and Engine Performance,

UNIVERSITAS GADJAH MADA
Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Renew. Sustain. Energy Rev., 37, 644–655.

Azeem, M.W., Hanif, M.A., Bhatti, I.A., and Qadri, R.W.K., 2025, A New Model of Response Surface Methodology (RSM) for Optimized Biofuel Production, *Pol. J. Environ. Stud.*, 34, 6069–6077.

Aziz, M.A.A., Jalil, A.A., Wongsakulphasatch, S., and Vo, D.V.N., 2020, Understanding the Role of Surface Basic Sites of Catalysts in CO_2 Activation in Dry Reforming of Methane: A Short Review, *Catal. Sci. Technol.*, 10, 35–45.

Azzahro, U.L., and Broto, W., 2021, Pemanfaatan Limbah Cangkang Kerang Dara sebagai Katalis CaO pada Pembuatan Biodiesel Minyak Goreng Bekas, *J. Sos. Teknol.*, 1, 499–507.

Bae, J.Y., Jang, S.G., Cho, J., and Kang, M., 2025, Amine-Functionalized Mesoporous Silica for Efficient CO_2 Capture: Stability, Performance, and Industrial Feasibility, *Int. J. Mol. Sci.*, 26, 4313, 1–27.

BaQais, A., Alam, M.W., Farhan, M., Muteeb, G., Allag, N., and Mushtaq, S., 2023, Probe-Sonicated Synthesis of CuO–ZnO Hybrid Nanocomposite for Photocatalytic and Supercapacitor Applications, *Inorganics*, 11, 370.

Basumatary, S.F., Brahma, S., Hoque, M., Das, B.K., Selvaraj, M., Brahma, S., and Basumatary, S., 2023, Advances in CaO-Based Catalysts for Sustainable Biodiesel Synthesis, *Green Energy Resour.*, 1, 100032.

Box, G.E.P., Hunter, J.S., and Hunter, W.G., 2005, *Statistics for Experimenters: Design, Innovation, and Discovery*, 2nd ed., John Wiley & Sons, New York.

Breig, S.J.M., and Luti, K.J.K., 2021, Response Surface Methodology: A Review on Its Applications and Challenges in Microbial Cultures, *Mater. Today Proc.*, 42, 2277–2284.

Budiman, A.A., and Samik, S., 2023, Biodiesel Production from Wasted Frying Oil with Transesterification Method Using Catalyst, *Unesa J. Chem.*, 12, 36–48.

Bueno, A.C., Mayer, M., Weber, M., Bechelany, M., Klotz, M., and Farrusseng, D., 2019, Impregnation Protocols on Alumina Beads for Controlling the Preparation of Supported Metal Catalysts, *Catalysts*, 9, 577.

Cai, Z.Z., Wang, Y., Teng, Y.L., Chong, K.M., Wang, J.W., Zhang, J.W., and Yang, D.P., 2015, A Two-Step Biodiesel Production Process from Waste Cooking Oil via Recycling Crude Glycerol Esterification Catalyzed by Alkali Catalyst, *Fuel Process. Technol.*, 137, 186–193.

Capelo-Martínez, J.L., 2009, *Ultrasound in Chemistry: Analytical Applications*, Wiley-VCH, Weinheim, 1–157.

Chen, H.Y., and Chen, C., 2025, Importance of Using Modern Regression Analysis for Response Surface Models in Science and Technology, *Appl. Sci.*, 15, 7206.

UNIVERSITAS
GADJAH MADA
**Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk
Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi**
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Chen, L., Janssens, T.V.W., Skoglundh, M., and Grönbeck, H., 2019, Interpretation of NH_3-TPD Profiles from Cu-CHA Using First-Principles Calculations, *Top. Catal.*, 62, 93–99.

Cho, E.H., Kim, K.D., Yoon, B.S., Cho, E., Yu, Y.J., Phan, T.N., Jeon, S.G., and Ko, C.H., 2023, Efficient Synthesis of Nickel-Molybdenum/USY-Zeolite Catalyst for Eliminating Impurities (N, S, and Cl) in the Waste Plastic Pyrolysis Oil: Dispersion Effect of Active Sites by Surfactant-Assisted Melt-Infiltration, *Catalysts*, 13, 1476.

Demetriou, C., and Tzeli, D., 2025, Electronic Structure of the Ground and Low-Lying States of MoLi, *Molecules*, 30, 2874.

Devos, C., Bampouli, A., Brozzi, E., Stefanidis, G.D., Dusselier, M., Van Gerven, T., and Kuhn, S., 2025, Ultrasound Mechanisms and their Effect on Solid Synthesis and Processing, *Chem. Soc. Rev.*, 54, 85–115.

El-Araby, R.E., 2024, Biofuel Production: Exploring Renewable Energy Solutions for a Greener Future, *Biotechnol. Biofuels Bioprod.*, 17, 129.

Erchamo, Y.S., Mamo, T.T., Workneh, G.A., and Mekonnen, Y.S., 2021, Improved Biodiesel Production from Waste Cooking Oil with Mixed Methanol–Ethanol Using Enhanced Eggshell-Derived CaO Nano-Catalyst, *Sci. Rep.*, 11, 6708.

Eryildirim, B., Oktar, N., and Dogu, D., 2025, Outperformance of CaO-Incorporated Alumina-Supported Pd Catalysts in Methanol Decomposition, *Res. Chem. Intermed.*, 51, 4149–4176.

European Committee for Standardization, 2024, *Automotive Fuels – Fatty Acid Methyl Esters (FAME) for Diesel Engines – Requirements and Test Methods (EN 14214:2024)*, European Committee for Standardization, Brussels.

Fadhlullah, M., Widiyanto, S.N.B., and Restiawaty, E., 2015, The Potential of Nyamplung (*Calophyllum inophyllum* L.) Seed Oil as Biodiesel Feedstock: Effect of Seed Moisture Content and Particle Size on Oil Yield, *Energy Procedia*, 68, 177–185.

Farouk, S.M., Tayeb, A.M., Abdel-Hamid, S.M.S., and Osman, R.M., 2024, Recent Advances in Transesterification for Sustainable Biodiesel Production, Challenges, and Prospects: A Comprehensive Review, *Environ. Sci. Pollut. Res.*, 31, 12722–12747.

Febriana, S., Wahyudi, W., and Putra, R.R., 2022, Karakterisasi dan Aplikasi Kalsium Oksida (CaO) dari Batu Kapur sebagai Katalis Transesterifikasi Biodiesel, *Indones. J. Chem. Anal.*, 5, 9–17.

Fernandes, D., Stigger, A.R.N., Moreira, M.L., Ferrer, M.M., Raubach, C.W., Jardim, P.L.G., Graeff, C.F.O., Mastelaro, V.R., and Cava, S.S., 2024, $CaMoO_4$ Mesocrystals with Sonocatalytic Activity for Rhodamine B Removal, *Inorg. Chem. Commun.*, 170, 113221.

UNIVERSITAS
GADJAH MADA
**Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk
Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi**
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Fitri, A.S., Arinda, Y., and Fitriana, N., 2020, Analisis Angka Asam pada Minyak Goreng dan Minyak Zaitun, *Sainteks*, 16, 115–119.

Fitria, A., Trisunaryanti, W., Triyono, and Santoso, I., 2024, Synthesis, Characterization and Performance of Ni/Mesoporous Silica–NH_2/Mesoporous Silica and Ni–NH_2/Mesoporous Silica as Bifunctional Catalyst in One Step Conversion of Waste Palm Oil to Biodiesel, *Commun. Sci. Technol.*, 9, 430–441.

Hamza, Z.A., Dawood, J.J., and Jabbar, M.A., 2024, Ag/Mo Doping for Enhanced Photocatalytic Activity of Titanium (IV) Dioxide during Fuel Desulphurization, *Molecules*, 29, 4603.

Hayati, N., Kurniawan, W.B., and Puspita, I., 2024, Sintesis dan Karakteristik Nanopartikel CaO dari Cangkang Kerang Darah (*Anadara granosa*) Menggunakan Metode Kopresipitasi, *J. Ris. Fis. Indones.*, 4, 83–91.

Iber, B.T., Torsabo, D., Che Engku Chik, C.E.N., Wahab, F., Sheikh Abdullah, S.R., Abu Hassan, H., and Kasan, N.A., 2023, Response Surface Methodology (RSM) Approach to Optimization of Coagulation-Flocculation of Aquaculture Wastewater Treatment Using Chitosan from Carapace of Giant Freshwater Prawn *Macrobrachium rosenbergii*, *Polymers*, 15, 1058.

Istadi, I., Riyanto, T., Khofiyanida, E., Buchori, L., Anggoro, D.D., Sumantri, I., Putro, B.H.S., and Firnanda, A.S., 2021, Low-Oxygenated Biofuels Production from Palm Oil through Hydrocracking Process Using the Enhanced Spent RFCC Catalysts, *Bioresour. Technol. Rep.*, 14, 100677.

Ivanez, O., Miro i Rovira, A., and Blekkan, E.A., 2024, Impact of the Support Material on the Phosphorus Poisoning on Co-Based Catalysts for Fischer-Tropsch Synthesis, *Catal. Today*, 441, 114866.

Karacan, S., 2018, Biodiesel Production Using Reactive Distillation Column: Real Time Model Predictive Control in Matlab Simulink, *Int. J. Energy Appl. Technol.*, 5, 107–114.

Karchkhadze, K., and Khetsuriani, N., 2024, Long-Term Storage and Quality Stability of Biodiesel Fuels, *Int. J. Low-Carbon Technol.*, 19, 1198–1203.

Kaur, N., and Ali, A., 2015, Biodiesel Production via Ethanolysis of Jatropha Oil Using Molybdenum Impregnated Calcium Oxide as Solid Catalyst, *RSC Adv.*, 5, 13285–13295.

Khan, R.I.A., Ghosh, N., Siddiqui, Z., Khan, A.R., Ahmad, S., Danish, M., Jilani, S., and Halder, G., 2026, Transesterifying *Ricinus communis*, *Brassica napus*, and Waste Soybean Oil over Calcareous Heterogeneous Catalyst for Biodiesel Production: A Comparative Assessment, *Next Energy*, 11, 100553.

UNIVERSITAS
GADJAH MADA
**Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk
Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi**
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Khawaja, A.S., Zaheer, M.A., Ahmad, A., Mirani, A.A., and Ali, Z., 2023, Advances in Limitations and Opportunities of Clean Biofuel Production to Promote Decarbonization, *Fuel*, 342, 127662.

Kwak, S., 2023, Are Only p-Values Less Than 0.05 Significant? A p-Value Greater Than 0.05 Is Also Significant!, *J. Lipid Atheroscler.*, 12, 89–95.

Lefebvre, J., Galli, F., Bianchi, C.L., Patience, G.S., and Boffito, D.C., 2019, Experimental Methods in Chemical Engineering: X-Ray Photoelectron Spectroscopy-XPS, *Can. J. Chem. Eng.*, 97, 2588–2593.

Lestari, L.P., 2024, Penggunaan Tanaman Nyamplung *Calophyllum inophyllum* Sebagai Sumber Bahan Baku Energi Terbaharukan dengan Katalis KOH, *J. Mandalika Soc. Sci.*, 2, 115–122.

Leybo, D., Etim, U.J., Monai, M., Bare, S.R., Zhong, Z., and Vogt, C., 2024, Metal–Support Interactions in Metal Oxide-Supported Atomic, Cluster, and Nanoparticle Catalysis, *Chem. Soc. Rev.*, 53, 10450–10490.

Li, J., Tsunoji, N., Kumar, R., Sukmana, N.C., and Sadakane, M., 2024, Minimizing Usage of Silane Coupling Agent for Amine-Grafted Mesoporous Silica CO_2 Adsorbent, *J. Porous Mater.*, 31, 1289–1304.

Liu, F., Ma, X., Li, H., Wang, Y., Cui, P., Guo, M., Yaxin, H., Lu, W., Zhou, S., and Yu, M., 2020, Dilute Sulfonic Acid Post-Functionalized Metal Organic Framework as a Heterogeneous Acid Catalyst for Esterification to Produce Biodiesel, *Fuel*, 266, 117149.

Luo, X., Wang, Y., Xie, X., Su, T., Chen, J., Qin, Z., and Ji, H., 2021, Catalytic Ozonation of Cinnamaldehyde to Benzaldehyde over $Ca(OH)_2$, *ChemistrySelect*, 6, 5052–5060.

Makarevičienė, V., Gaidė, I., and Sendžikienė, E., 2025, Heterogeneous Catalysts from Food Waste for Biodiesel Synthesis—A Comprehensive Review, *Catalysts*, 15, 957.

Mamat, M., Kusrini, E., Yahaya, A.H., Hussein, M.Z., and Zainal, Z., 2013, Intercalation of Anthranilate Ion into Zinc-Aluminium-Layered Double Hydroxide, *Int. J. Technol.*, 4, 73–80.

Mayasari, F., Dalimi, R., and Purwanto, W.W., 2019, Projection of Biodiesel Production in Indonesia to Achieve National Mandatory Blending in 2025 Using System Dynamics Modeling, *Int. J. Energy Econ. Policy*, 9, 421–429.

McCormick, R.L., Fioroni, G.M., Mohamed, S.Y., Naser, N., Alleman, T.L., Kim, S., Wang, Z., Lin, Y., Ju, Y., and Kar, K., 2024, Fuel Property Evaluation of Unique Fatty Acid Methyl Esters Containing β-Hydroxy Esters from Engineered Microorganisms, *Fuel Commun.*, 19, 100120.

UNIVERSITAS GADJAH MADA
Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Mironenko, R.M., Saybulina, E.R., Stepanova, L.N., Gulyaeva, T.I., Trenikhin, M.V., Rodygin, K.S., and Ananikov, V.P., 2021, Sustainable Hydrogenation of Vinyl Derivatives Using Pd/C Catalysts, *Catalysts*, 11, 179.

Mukaka, M.M., 2012, A Guide to Appropriate Use of Correlation Coefficient in Medical Research, *Malawi Med. J.*, 24, 69–71.

Naik, L.R., Radhika, N., Sravani, K., Hareesha, A., Mohanakumari, B., and Bhavanasindhu, K., 2015, Optimized Parameters for Production of Biodiesel from Fried Oil, *Int. Adv. Res. J. Sci. Eng. Technol.*, 2, 62–65.

Naseef, H.H., and Tulaimat, R.H., 2025, Transesterification and Esterification for Biodiesel Production: A Comprehensive Review of Catalysts and Palm Oil Feedstocks, *Energy Convers. Manage. X*, 26, 100931.

Nasiri, S., Rabiei, M., Palevicius, A., Janusas, G., Vilkauskas, A., Nuthalapati, V., and Monshi, A., 2023, Modified Scherrer Equation to Calculate Crystal Size by XRD with High Accuracy, Examples Fe_2O_3, TiO_2 and V_2O_5, *Nano Trends*, 3, 100015.

Nidzam, M.S., Hossain, M.S., Ismail, N., Latip, R.A., Ilias, M.K.M., Siddique, M.B.M., and Zulkifli, M., 2022, Influence of the Degumming Process Parameters on the Formation of Glyceryl Esters and 3-MCPDE in Refined Palm Oil: Optimization and Palm Oil Quality Analyses, *Foods*, 11, 124, 1–16.

Novita, L., Safni, Emriadi, Freitas, F.A. de, and Zein, R., 2025, Response Surface Methodology and Artificial Neural Network Modeling for Biodiesel Production over *Elaeis guineensis* Shell Ash-Derived $MgSiO_3$ Catalyst, *Results Surf. Interfaces*, 19, 100552.

Nurhayati, Anita, S., Amri, T.A., and Linggawati, A., 2017, Esterification of Crude Palm Oil Using H2SO4 and Transesterification Using CaO Catalyst Derived from Anadara granosa, Indones, *J. Chem*., 17, 309–315.

Oliveira, F.K.F., Oliveira, M.C., Gracia, L., Tranquilin, R.L., Paskocimas, C.A., Motta, F.V., Longo, E., Andrés, J., and Bomio, M.R.D., 2018, Experimental and Theoretical Study to Explain the Morphology of $CaMoO_4$ Crystals, *J. Phys. Chem. Solids*, 114, 141–152.

Ooi, H.K., Koh, X.N., Ong, H.C., Lee, H.V., Mastuli, M.S., Taufiq-Yap, Y.H., Alharthi, F.A., Alghamdi, A.A., and Mijan, N.A., 2021, Progress on Modified Calcium Oxide Derived Waste-Shell Catalysts for Biodiesel Production, *Catalysts*, 11, 194.

Paray, A.A., 2025, Spectroscopic and Thermal Analysis of Neolithic Pottery of Kashmir Valley, India, Using XRD, FT-IR, and SEM-EDX Analysis, *L'Anthropologie*, 129, 103391.

UNIVERSITAS GADJAH MADA
Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Passos, R.M. dos, Ferreira, R.S.B., Batista, E.A.C., Meirelles, A.J.A., Maximo, G.J., Ferreira, M.C., and Sampaio, K.A., 2019, Degumming Alternatives for Edible Oils and Biodiesel Production, *Food Public Health*, 9, 139–147.

Permata, M.L., Trisunaryanti, W., Falah, I.I., Hapsari, M.T., and Fatmawati, D.A., 2020, The Effect of Nickel Content Impregnated on Zeolite Toward Catalytic Activity and Selectivity for Hydrotreating of Cashew Nut Shell Liquid Oil, *Rasayan J. Chem.*, 13, 772–779.

Purba, P.D., Amri, A., Zultiniar, and Yelmida, 2015, Sintesa Precipitated Calcium Carbonate (PCC) dari Cangkang Kerang Darah (*Anadara granosa*) dengan Variasi Suhu Kalsinasi dan Variasi Rasio CaO/HNO_3, *JOM FTEKNIK*, 2, 1–7.

Purnamasari, D.A., Nafisyah, A.L., and Sari, L.A., 2024, Innovative Utilization of Blood Cockle Shell Waste (*Anadara granosa*) as a Growth Medium for *Nitzschia* sp., *J. Mar. Coast. Sci.*, 13, 136–143.

Raigar, A.K., Manju, Saini, K., and Guleria, A., 2025, $CuFe_2O_4$-Catalyzed One-Pot Synthesis of α-Substituted 2-Benzofuranmethanamines via Tandem A^3 Coupling, 5-exo-dig Cyclization, and 1,3-Allylic Rearrangement, *RSC Adv.*, 15, 32108–32116.

Rajali, N.A., Radzi, S.M., Rehan, M.M., and Amin, N.A.M., 2022, Optimization of the Biodiesel Production via Transesterification Reaction of Palm Oil Using Response Surface Methodology (RSM): A Review, *Malays. J. Sci. Health Technol.*, 8, 58–67.

Retnaningtyas, H., Nugroho, K.S., and Hardjono, 2019, Pengaruh Rasio Massa Katalis CaO dan Rasio Mol Minyak dengan Metanol pada Proses Transesterifikasi Minyak Randu Menjadi Biodiesel, *Distilat*, 5, 189–194.

Rubel, M., Shuo, C., Boonyubol, S., Harussani, M.M., Kachhwaha, S.S., and Cross, J.S., 2026, Optimization of a Two-Step Biodiesel Production from Waste Cooking Oil: Comparative Evaluation of n-Hexane and CPME as Transesterification Cosolvents, *Chem. Eng. Res. Des.*, 226, 282–295.

Sa'diyah, A., Aulatama, A.A., Ramadhan, H.D., Fairuza, M.N., and Alfianto, E., 2024, Performance and Gas Emissions Analysis on Four Stroke Diesel Engine with Multi-Feedstock Biodiesel, *Eksergi*, 20, 60–67.

Sa'diyah, A., Aulatama, A.A., Shah, M., Mustaghfirin, M.A., Fairuza, M.N., and Haryono, E., 2024, Pengaruh Rasio Bahan Bakar Multi-Feedstock Biodiesel Terhadap Nilai Emisi Gas Buang pada Mesin Diesel 4 Langkah, *J. Teknol. Marit.*, 8, 30–41.

Salaheldeen, M., Mariod, A.A., Aroua, M.K., Rahman, S.M.A., Soudagar, M.E.M., and Fattah, I.M.R., 2021, Current State and Perspectives on Transesterification

UNIVERSITAS GADJAH MADA
Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

of Triglycerides for Biodiesel Production, *Catalysts*, 11, 1121.

Sambara, E.C., Saviola, A.J., Syoufian, A., Fitria, R.A., Mumtaziyah, A., Rozana, K., Oh, W.C., Ravindran, B., Saputri, W.D., Amin, A.K., Saputra, D.A., Rahayu, S., and Wijaya, K., 2025, Modification of Mesoporous Zirconia Using Phosphoric Acid and Calcium Oxide as a Bifunctional Nano-Catalyst for One-Pot Conversion of Used Palm Cooking Oil into Biodiesel, *Next Mater.*, 9, 101147.

Samriani, Zakir, M., Taba, P., La Nafie, N., and Indriani, I., 2022, Synthesis of MCM-41 Silica Mesoporous Modified with Zn Metal, *J. Kim. Sains Apl.*, 25, 286–291.

Sentanuhady, J., Hasan, W.H., and Muflikhun, M.A., 2022, Recent Progress on the Implementation of Renewable Biodiesel Fuel for Automotive and Power Plants: Raw Materials Perspective, *Int. J. Energy Res.*, 2022, 5452942.

Shan, R., Zhao, C., Lv, P., Yuan, H., and Yao, J., 2016, Catalytic Applications of Calcium-Rich Waste Materials for Biodiesel: Current State and Perspectives, *Energy Convers. Manage.*, 127, 273–283.

Si, Z., Geng, Z., Wang, B., Ma, J., and Zhu, M., 2025, Study on the Esterification Mechanism Catalyzed by MIL-125 for the Synthesis of 1,2-Cyclohexanedicarboxylates, *Comput. Theor. Chem.*, 1254, 115532.

Simbi, I., Aigbe, U.O., Oyekola, O.O., and Osibote, O.A., 2021, Catalyst and Elemental Analysis Involving Biodiesel from Various Feedstocks, *Catalysts*, 11, 971.

Simpen, I.N., Winaya, I.N.S., Subagia, I.D.G.A., and Suyasa, I.W.B., 2022, Green Nano-Composite of CaO/K-Sulfated TiO_2 and Its Potential as a Single-Step Reaction Solid Catalyst for Biofuel Production, *KnE Life Sci.*, 7, 382–392.

Singh, Y.K., 2023, Optimization of Biodiesel Parameters Using Response Surface Methodology and Production of Biodiesel, *Nat. Environ. Pollut. Technol.*, 22, 159–168.

Souza Júnior, R.L., Eira, L.C., Detoni, C., and Souza, M.M.V.M., 2024, Glycerol Carbonate Production via Transesterification: The Effect of Support Porosity and Catalyst Basicity, *Processes*, 12, 2256.

Suryandari, A.S., Ardiansyah, Z.R., Putri, V.N.A., Arfiansyah, I., Mustain, A., Dewajani, H., and Mufid, 2021, Sintesis Biodiesel melalui Transesterifikasi Minyak Goreng Bekas Berbasis Katalis Heterogen CaO dari Limbah Cangkang Telur Ayam, *J. Rekayasa Bahan Alam Energi Berkelanjutan*, 5, 22–27.

UNIVERSITAS
GADJAH MADA
**Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk
Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi**
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Sutianingsih, Y., and Kurniawan, T., 2022, A Review: Antibacterial Activity of Metal Impregnated Zeolite in Water Treatment Process, *J. Kartika Kim.*, 5, 24–34.

Syazwani, O.N., Rashid, U., Mastuli, M.S., and Taufiq-Yap, Y.H., 2019, Esterification of Palm Fatty Acid Distillate (PFAD) to Biodiesel Using Bi-Functional Catalyst Synthesized from Waste Angel Wing Shell (*Cyrtopleura costata*), *Renew. Energy*, 131, 187–196.

Tang, B., Tang, J., Lu, Y., Shen, H., Lu, Z., Chen, X., Tian, R., and Zhu, Z., 2021, Chemical Structure Changes of Marine Shale Caused by Supercritical Carbon Dioxide, *Energy Explor. Exploit.*, 39, 243–255.

Tang, Z.E., Lim, S., Pang, Y.L., Ong, H.C., and Lee, K.T., 2018, Synthesis of Biomass as Heterogeneous Catalyst for Application in Biodiesel Production: State of the Art and Fundamental Review, *Renew. Sustain. Energy Rev.*, 92, 235–253.

Thoai, D.N., Hang, P.T.L., and Lan, D.T., 2019, Pre-Treatment of Waste Cooking Oil with High Free Fatty Acids Content for Biodiesel Production: An Optimization Study via Response Surface Methodology, *Vietnam J. Chem.*, 57, 568–573.

Tiwari, P.K., Raj, S., Kumar, S., Singh, P., Swaraj, R., Sarkar, S., Nayak, S.K., and Mishra, P.C., 2021, Influence of *Calophyllum inophyllum* and Jojoba Oil Methyl Ester Blended with n-Pentanol Additive upon Overall Performance, Combustion and Emission Characteristics of a TDI Engine Operated in Natural Aspirated Mode, *Fuel*, 288, 119576.

Trisunaryanti, W., Azizah, S.N., Fatmawati, D.A., Triyono, and Ningrum, N.C., 2022, Performance of a Hybrid Catalyst from Amine Groups and Nickel Nanoparticles Immobilized on Lapindo Mud in Selective Production of Bio-Hydrocarbons, *Indones. J. Chem.*, 22, 896–912.

Trisunaryanti, W., Oh, W.C., Purbonegoro, J., and Kusumawati, B., 2026, One-Step Conversion of Used Palm Oil into Methyl Ester Using a Double-Base Cu- and Amino-Silane-Modified γ-Al_2O_3 Catalyst, *Mater. Sci. Eng. B*, 323, 118713.

Trisunaryanti, W., Triyono, Hadjarningrum, S.A.N., and Fatmawati, D.A., 2021, Activity of Ni-NH_2/Mesoporous Silica Material as Bifunctional Catalyst for Hydrocracking of Used Cooking Oil, *Key Eng. Mater.*, 884, 83–89.

Trisunaryanti, W., Triyono, Pradipta, M.F., Purbonegoro, J., and Pratiwi, A.E., 2025, Preparation and Performance of 3-APTMS-Modified NiO/γ-Al_2O_3 for High-Efficiency Biodiesel Production from Used Palm Oil, *J. Environ. Chem. Eng.*, 13, 116149.

Trujillo, C.A., Ramírez-Marquez, N.T., and Valencia-Rios, J.S., 2020, An Affordable Ammonia Temperature-Programmed Desorption Equipment and

UNIVERSITAS
GADJAH MADA
**Sintesis Katalis Kalsium Oksida Terimpregnasi Molibdenum dan Terfungsionalisasi Aminosilan untuk
Konversi Minyak Nyamplung menjadi Biodiesel melalui Esterifikasi-Tranesterifikasi**
Firanti Zulkarnain, Mokhammad Fajar Pradipta, S.Si., M.Eng.; Wega Trisunaryanti, Dra., M.S., Ph.D., Eng., Prof.
Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Its Calibration Using the Thermal Decomposition of Ammonium Dihydrogen Phosphate, *Thermochim. Acta*, 689, 178651.

Tsilomelekis, G., and Boghosian, S., 2010, Structural and Vibrational Properties of Molybdena Catalysts Supported on Alumina and Zirconia Studied by in Situ Raman and FTIR Spectroscopies Combined with $^{18}O/^{16}O$ Isotopic Substitution, *Catal. Today*, 158, 146–155.

Vernickaitė, E., Lelis, M., Tsyntsaru, N., Pakštas, V., and Cesiulis, H., 2020, XPS Studies on the Mo Oxide-Based Coatings Electrodeposited from Highly Saturated Acetate Bath, *Chemija*, 31, 203–209.

Vijayakumar, N., Venkataraman, S.K., Imthiaz, S., Drweesh, E.A., Elnagar, M.M., Koppala, S., and Swamiappan, S., 2023, Synthesis and Characterization of Calcium and Magnesium Based Oxides and Titanates for Photocatalytic Degradation of Rhodamine B: A Comparative Study, *Sci. Rep.*, 13, 30013.

Wang, J., and Wan, W., 2009, Experimental Design Methods for Fermentative Hydrogen Production: A Review, *Int. J. Hydrogen Energy*, 34, 235–244

Xie, W., and Zhao, L., 2014, Heterogeneous CaO–MoO_3–SBA-15 Catalysts for Biodiesel Production from Soybean Oil, *Energy Convers. Manage.*, 79, 34–42.

Xu, Z., Yang, X., Liu, S., Wang, B., Peng, Y., Zhang, Z., and Li, Z., 2025, Development of Enhanced CO_2 Adsorbents on Functionalized MCM-41 with Hybrid Amines, *New J. Chem.*, 49, 7384–7392.

Yusuf, B.O., Oladepo, S.A., and Ganiyu, S.A., 2024, Efficient and Sustainable Biodiesel Production via Transesterification: Catalysts and Operating Conditions, *Catalysts*, 14, 581.

Zhang, X., Li, Y., Kumar, A., and Chen, D., 2025. Impacts of r-GO and N-doping on the structural, magnetic, optical and photocatalytic properties of $CuAl_2O_4$: enhanced crystal violet removal under solar light irradiation. RSC Adv., 15, 24223.