

DAFTAR PUSTAKA

- Abbas, G.H., dan Ilyas, N.M., 2021, Penggunaan Katalis Heterogen pada Produksi Biodiesel, *J. Chemica*, 22(2), 99—107.
- Abed, K.A., Gad, M.S., El Morsi, A.K., Sayed, M.M., and Elyazeed, S.A., 2019, Effect of Biodiesel Fuels on Diesel Engine Emissions, *Egypt. J. Pet.*, 2(28), 183—188.
- Anantharaman, A., and George, M., 2016, Green Synthesis of Calcium Oxide Nanoparticles and its Application, *Int. J. Eng. Res. Appl.*, 6(10), 27—31.
- Angelia, D., Permatasari, G.P.W., dan Redjeki, S., 2022, Kinetika Reaksi Transesterifikasi Biodiesel Dari Minyak Jelantah Menggunakan Katalis CaO Modifikasi, *J. Tek. Kim.*, 16(2), 93—100.
- Ayodeji, A.A., Modupe, O.E., Rasheed, B., and Ayodele, J.M., 2018, Data on CaO and Eggshell Catalyst Used for Biodiesel Production, *Data in Brief*, 19, 1466—1473.
- Bakri, S., Nawir, A., Farid, M., Nurhawaisyah, S.R., Juradi, M.I., Firdaus, F., Wakila, M.H., Umar, E.P., Nurwaskito, A., Munir, A.S., Bakri, H., dan Thamsi, A.B., 2021, Karakterisasi Kandungan Mineral dan Sifat Kerentanan Magnetik Pasir Besi Pantai Galesong Takalar Sulawesi Selatan, *J. Geomine*, 9(3), 275—284.
- Balfas, R.N., Syam, A.M., Muhammad, M., Setiawan, A., and Fithra, H., 2024, Characteristic of Biodiesel Produced from Crude Palm Oil through Non-Alcohol Synthesis Route using Dimethyl Carbonate and Immobilized Eco-Enzyme Catalyst, *Energies*, 17, 1551, 1—16.
- 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, *GER.*, 1, 100032.
- Boury, A., Zussa, A., and Campos, C., 2019, Study of Biodiesel Production by Heterogeneous Catalysis using Magnetic Nanoparticles Supported in Silica in a Packed Bed Reactor, *J. Eng. Exact. Sci.*, 5(1), 137—142.
- Brinker, C.J., 1990, *Sol-Gel Science, The Physics, and Chemistry of Sol-Gel Processing*, Academic Press, Inc.
- Cargnello, M., Gordon, T.R., and Murray, C.B., 2014, Solution-Phase Synthesis of Titanium Dioxide Nanoparticles and Nanocrystals, *Chem. Rev.*, 114, 9319—9345.
- Castanheira, G.E., and Fiere, F., 2017, Environmental Life Cycle Assessment of Biodiesel Produced with Palm Oil from Colombia, *J. Life Cycle Assess.*, 22(2), 587—600.

- Cheng, J., Guo, H., Yang, X., Mao, Y., Qian, L., Zhu, Y., and Yang, W., 2021, Phosphotungstic Acid-Modified Zeolite Imidazolate Framework (ZIF-67) As An Acid-Base Bifunctional Heterogeneous Catalyst for Biodiesel Production from Microalgae Lipids, *Energy Convers. Manag.*, 232, 113872.
- Chung, Z.L., Tan, Y.H., Chan, Y.S., Kansedo, J., Mubarak, N.M., Ghasemi, M., and Abdullah, M.O., 2019, Life Cycle Assessment of Waste Cooking Oil for Biodiesel Production using Waste Chicken Eggshell Derived CaO as Catalyst via Transesterification, *Biocatal. Agric. Biotechnol.*, 21, 101317.
- Chong, N.S., Nwobodo, I., Strait, M., Cook, D., Abdulramoni, S., and Ooi, B.G., 2023, Preparation and Characterization of Shell-Based CaO Catalyst for Ultrasonication-Assisted Production of Biodiesel Toxicants in Diesel Generator Emissions, *Energies*, 2(1), 1—16.
- Colombo, K., Ender, L., and Barros, A.A.C., 2017, The Study of Biodiesel Production Using CaO as a Heterogeneous Catalytic Reaction, *Egypt. J. Pet.*, 26(2), 341—349.
- De, A., and Boxi, S.S., 2020, Application of Cu Impregnated TiO₂ as a Heterogeneous Nanocatalyst for the Production of Biodiesel from Palm Oil, *Fuel*, 265, 1—6.
- Dewi, D.K., Putri, V.M., Febriyanti, V., and Yudha, C.S., 2023, Calcination of Various Eggshell Wastes into CaO Heterogeneous Catalyst, *Equilib. J. Chem Eng.*, 7(1), 87—92.
- Dikjen Perkebunan., 2022, Statistik Perkebunan Unggulan Nasional 2020—2022.
- Eddy, D.R., Noviyanti, A.R., dan Janati, D., 2016, Sintesis Silika Metode Sol-Gel Sebagai Penyangga Fotokatalis TiO₂ Terhadap Penurunan Kadar Kromium dan Besi, *J. Sains Mater. Indones.*, 17(2), 82—89.
- Elfina, S., Pandiangan, K.D., Jamarun, N., Subriadi, F., Hafnimardiyanti., and Roswita., 2023, Transesterification of Palm Oil Catalyzed by CaO/SiO₂ Prepared from Limestone and Rice Husk Silica, *J. Multidiscip.*, 4(1), 49—57.
- Elsafitri, O., Nasri, M.Z., dan Deswardani, F., 2020, Sintesis dan Karakterisasi Nanopartikel Fe₃O₄ (*Magnetite*) dari Pasir Besi Sungai Batanghari Jambi yang Dienkapsulasi dengan *Polyethylene Glycol* (Peg-4000), *J. Pendidik. Fis. Tadulako*, 8(3), 97—103.
- Emrie, D.B., 2024, Sol-Gel Synthesis of Nanostructured Mesoporous Silica Powder and Thin Films, *J. Nanomater.*, 2(4), 1—16.
- Fahmiati., Nuryono., and Suyanta., 2017, Characteristics of Iron Sand Magnetic Material from Bugel Beach, Kulon Progo, Yogyakarta., *Mater. Sci. and Eng.*, 172, 1—9.

- Farobie, O., Jannah, Q.R., and Hartulistiyoso, E., 2021, Biodiesel Production from Crude Palm Oil under Different Free Fatty Acid Content using Eversa Transform 2.0 Enzyme, *Int. J. Renew. Energy Res.*, 11(4), 1590—1596.
- Farouk, S.M., Tayeb, A.M., Hamid, S.M.S.A., 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.
- Faruque, M.O., Razzak, S.A., and Hossain, M.M., 2020, Application of Heterogeneous Catalyst for Biodiesel Production from Microalgal Oil: A Review, *Catalyst*, 10, 1—25.
- Faustova, Z.V., and Slizhov, Y.G., 2017, Effect of Solution pH on the Surface Morphology of Sol-Gel Derived Silica Gel, *Inorg. Mater.*, 53(3), 287—291.
- Fernandéz, I.E., and Páez, J.E.R., 2019, Wet-Chemical Preparation of TiO₂-Nanostructures Using Different Solvents: Effect of CTAB Concentration and Tentative Mechanism of Particle Formation, *J. Alloys Compd.*, 780, 756—771.
- Feyzi, M., and Norouzi, L., 2016, Preparation and Kinetic Study of Magnetic Ca/Fe₃O₄@SiO₂ Nanocatalysts for Biodiesel Production, *Renew. Energy*, 94, 579—586.
- Ghosh, N.D.R., Rokhum, S.L., and Halder, G., 2024, Evaluating the Scale-up Potential of Biogenic Heterogeneous Catalyst for Biodiesel Production, *ACS. Sustain. Resour. Manag.*, 1, 480—492.
- Gómez-Daza, L.C., Escobarr, B.E.V., Díaz, D., Pena, N.G.G., and Redón, R., 2025, Amorphous and Crystalline SiO₂ Support, Interaction with ZnO Obtained by Various Methods: Implications for Rhodamine 6G Elimination, *J. Coord. Chem.*, 78(20), 2251—2270.
- Gunawan, M., Triatmo, M., dan Rahayu, A., 2013, Analisis Pangan: Penentuan Angka Peroksida dan Asam Lemak Bebas pada Minyak Kedelai dengan Variasi Menggoreng, *J. KSA.*, 6(3). 156—162.
- Gupta, J., and Agarwal, M., 2016, Preparation and Characterization of CaO Nanoparticle for Biodiesel Production, *AIP Conf. Proc.*, 1724, 020066.
- Hadiyanto, H., Afianti, A.H., Navi'a, U.I., Adetya, N.P., Widayat, W., and Sutanto, H., 2017, The Development of Heterogeneous Catalyst C/CaO/NaOH from Waste of Green Mussel Shell (*Perna varidis*) for Biodiesel Synthesis, *J. Environ. Chem. Eng.*, 5, 4559—4563.
- Handayani, L., Zuhrayani, R., Putri, N., dan Nanda, R., 2020, Pengaruh Suhu Kalsinasi Terhadap Nilai Rendemen CaO Cangkang Tiram (*Crassostrea Gigas*), *J. TILAPIA*, 1(1), 1—6.

- Haq, A., Rehman, M.L.U., Rana, Q.U.A., Khan, A., Sajjad, W., Khan, H., Khan, S., Shah, A.A., Hasan, F., Ahmed, S., Islam, A., Badshah, M., Shah, T.A., Dawoud, T.M., and Bourhia, M., 2023, Production, Optimization, and Physicochemical Characterization of Biodiesel from Seed Oil of Indigenously Grown *Jatropha curcas*, *Front. Energy Res.*, 102, 1—14.
- Harahap, R.A., Azhari., Meriatna., Sulhatun., dan Suryati., 2021, Penentuan Kadar *Free Fatty Acid* (FFA) Pada *Crude Palm Oil* (CPO) dengan Proses Esterifikasi Menggunakan Katalis Asam Sulfat (H₂SO₄), *Chem. Eng. J. Stor.*, 1(2), 56—63.
- Haryono., Natanael, C.L., Rukiah., dan Yulianti, Y.B., 2018, Kalsium Oksida Mikropartikel dari Cangkang Telur sebagai Katalis Pada Sintesis Biodiesel dari Minyak Goreng Bekas, *J. Mater. dan Energi Indonesia*, 1(8), 8—15.
- Hazrat, M.A., Rasul, M.G., Khan, M.M.K., Ashwath, N., Silitonga, A.S., Fattah, I.M.R., and Mahlia, T.M.I., 2022, Kinetic Modelling of Esterification and Transesterification Processes for Biodiesel Production Utilising Waste-Based Resource, *Catalyst*, 12, 1472, 1—37.
- Hidayati, N., Ariyanto, T.S., dan Septiawan, H., 2017, Transesterifikasi Minyak Goreng Bekas Menjadi Biodiesel dengan Katalis Kalsium Oksida, *J. Teknol. Bahan Alam* 1(1), 1—5.
- Husain, F., dan Marzuki, I., 2021, Pengaruh Temperatur Penyimpanan Terhadap Mutu dan Kualitas Minyak Goreng Kelapa Sawit, *Serambi Eng.*, 6(4), 2270—2278.
- Husain, S., Irfansyah, M., Haryanti, N.H., Suryajaya, S., Arjo, S., and Maddu, A., 2019, Synthesis and Characterization of Fe₃O₄ Magnetic Nanoparticles From Iron Ore., *J. Phys.*, 1242(1), 1—10.
- Indrayanah, S., Erwin., Marsih, I.N., Suprpto., and Murwani, I.K., 2017, Methyl Ester Production via Heterogeneous Acid-Catalyzed Simultaneous Transesterification and Esterification Reactions, *The 4th International Conference on Advanced Materials Science and Technology*, 202, 012069.
- Khairunnisa, U., Lubis, R.Y., dan Jumiati, E., 2024, Karakterisasi Pasir Besi dan Sifat Magnetik Pantai Romantis Kabupaten Serdang Bedagai, *J. Mat. Sains, Pembelaj.*, 10(2), 276—282.
- Khan, Z., Javed, F., Shamair, Z., Hafeez, A., Fazal, T., and Aslam, A., 2021, Current Development in Esterification Reaction: A Review on Process and Parameters. *J. Ind. Eng. Chem.*, 103, 80—101.
- Khatiwada, D., Palmen, C., and Silveira, S., 2021, Evaluating the Palm Oil Demand into Indonesia: Production Trends, Yields, and Emerging Issues, *Biofuels*, 12, 135—147.
- Kotarumalos, S.H., Limehuwey, R., dan Multi, W., 2023, Genesa dan Karakteristik Endapan Pasir Besi, *Tanah Goyang: J. Geosains*, 1(1), 26—37.

- Kumar, S., Malik, M.M., and Purohit, R., 2017, Synthesis Methods of Mesoporous Silica Materials, *Mater. Today Proc.*, 4(2), 350—357.
- Lakshmi, S.B.A.V.S., Niju, S., Mohamed, M.S.B.K., and Narayanan, A., 2024, Catalyst Reusability and Kinetic Modeling of Biodiesel Produced from Rubber Seed Oil, *Energy Sources Part A-Recover. Util. Environ. Eff.*, 1(46), 1—16.
- Lani, N.S., Ngadi, N., and Inuwa, I.M., 2020, New Route for the Synthesis of Silica-Supported Calcium Oxide Catalyst in Biodiesel Production, *Renew. Energy*, 156, 1266—1277.
- Lani, N.S., Ngadi, N., and Taib, M.R., 2017, Parametric Study on the Transesterification Reaction by using CaO/Silica Catalyst, *Chem. Eng. Trans.*, 56, 601-606.
- Li, H., Jin, H., Li, R., Hua, J., Zhang, Z., and Li, R., 2024, Magnetic Fe₃O₄@SiO₂ Study on Adsorption of Methyl Orange on Nanoparticles, *Sci. Rep.*, 14:1217, 1—16.
- Li, Z., Sun, Y., Ge, S., Zhu, F., Yin, F., Gu, L., Yang, F., Hu, P., Chen, G., Wang, K., and Volinsky, A.A., 2023, An Overview of Synthesis and Structural Regulation of Magnetic Nanomaterials Prepared by Chemical Co-Precipitation, *Metals*, 152, 1—19.
- Lu, M., Liu, X., Li, Y., Nie, Y., Lu, X., Deng, D., Xie, Q., and Ji, J., 2016, Hydrocracking of Bio-alkanes Over Pt/Al-MCM-41 Mesoporous Molecular Sieves for Bio-jet Fuel Production, *J. Renew. Sustain. Energy*, 8(5), 053103, 1—10.
- Ma, X., Liu, F., Helian, Y., Li, C., Wu, Z., and Li, H., 2021, Current Application of MOFs Based Heterogeneous Catalysts in Catalyzing Transesterification/Esterification for Biodiesel Production: A Review, *Energy Convers Manag*, 229, 1—10.
- Madhu, D., Arora, R., Sahani, S., Singh, V., and Sharma, Y.C., 2017, Synthesis of High-Quality Biodiesel Using Feedstock and Catalyst Derived from Fish Waste, *J. Agric. Food Chem.*, 65(10), 2100—2109.
- Maisyarah, A.O., Shofiyani, A., dan Rudiyanasyah., 2019, Sintesis CaO dari Cangkang Kerang Ale-Ale (*Meretrix meretrix*) Pada Suhu Kalsinasi 900 °C, *J. Kim. Khatulistiwa*, 8(1), 37—40.
- Malau, N.D., Bintang, H.C.D., and Vita, N., 2022, Calcination of CaO Compunds from Cow Bone Waste and Tuna Fish Bones, *IJPSAT*, 32(1), 67—72.
- Manurung, R., Parinduri, S.Z.D.M., Hasibuan, R., Tarigan, B.H., and Siregar, A.G.A., 2023, Synthesis of Nano-CaO Catalyst with SiO₂ Matrix based on Palm Shell Ash as Catalyst Support for One Cycle Developed in the Palm Biodiesel Process, *Case Stud. in Chem. Environ. Eng.*, 100345.

- Marinković, D.M. and Pavlović, S.M., 2023, Recent Advances in Waste-Based and Natural Zeolitic Catalytic Materials for Biodiesel Production, *Hem. Ind.*, 77, 5–38.
- Marinković, D.M., Stanković, M.V., Veličković, A.V., Avramović, J.M., Miladinović, M.R., Stamenković, O.O., Veljković, V.B., and Jovanković, D.M., 2016, Calcium Oxide as a Promising Heterogeneous Catalyst for Biodiesel Production: Current State and Perspective, *Energy Rev.*, 56, 1387—1408.
- Maulana, R., Helwani, Z., dan Saputra, E., 2017, Preparasi Katalis CaO/Fly Ash dan Penggunaannya Pada Reaksi Transesterifikasi Minyak Sawit Off-Grade menjadi Biodiesel, *JomFTEKNIK*, 4, 1—5.
- Maulidiyah, M., Watoni, A.H., Maliana, N., Irwan, I., Salim, L.O., Arham, Z., and Nurdin, M., 2022, Biodiesel Production from Crude Palm Oil Using Sulfuric Acid and K₂O Catalyst through a Two-Stage Reaction, *Biointerface Res. Appl. Chem.*, 12, 3150—3160.
- Mazaheri, H., Ong, H.C., Amini, Z., Masjuki, H.H., Mofijur, M., Su, C.H., Badruddin, I.A., and Khan, T.M.Y., 2021, An Overview of Biodiesel Production via Calcium Oxide Based Catalysts: Current State and Perspective, *Energies*, 14, 1—23.
- McLean, B., and Yarovsky, L., 2024, Structure, Properties, and Application of Silica Nanoparticles: Recent Theoretical Modeling Advances, Challenges, and Future Dimension, *Small*, 2405299, 1—34.
- Mehmood, A., Ghafar, H., Yaqoob, S., Gohar, U.F., and Ahmad, B., 2017, Mesoporous Silica Nanoparticles: A Review, *J. Dev. Drugs*, 6, 174—188.
- Miyuranga, K.A.V., Arachchige, U.S.P.R., Marso, T.M.M., and Samarakoon, G., 2023, Biodiesel Production Through the Transesterification of Waste Cooking Oil Over Typical Heterogeneous Base or Acid Catalysts, *Catalyst*, 13, 1—20.
- Mota, T.L.R., Oliveira, A.P.M., Nunes, E.H.M., and Houmard, M., 2017, Simple Process for Preparing Mesoporous Sol-Gel Silica Adsorbents with High Water Adsorption Capacities, *Microporous and Mesoporous Mater.*, 253, 177—182.
- Mufandia, I., Kholisa, M.N., Suntivarakorn, R., Nugraha, D.N., and Prathista, R.W.A 2024, Evaluation of Chicken Bone-Derived CaO Catalyst for Biodiesel Production, *J. Ilm. Tek. Kim.*, 21(2), 133—139.
- Mulyani, Y., Nurhayati., and Awaluddin, A., 2024, Effect of Acidity, Basicity, Heterogeneous CaO/Silica Gel Catalyst from Biomass Waste on Biodiesel Yield from Crude Palm Oil, *J. Ilmu Kim. Terap.*, 2(11), 122—131.
- Munasir., Dewanto, A.S., Kusumawati, D.H., Putri, N.P., Yulianingsih, A., Sa’adah, I.K.F., Taufiq, A., Hidayat, N., Sunaryono, S., dan Supardi, Z.A.I., Structure

Analysis of Fe₃O₄@SiO₂ Core Shells Prepared from Amorphous and Crystalline SiO₂ Particles, *IOP Conf. Ser: Mater. Sci. Eng.*, 367, 1—8.

Munasir., Luvita, N.R.D., Kusumawati, D.H., Putri, N.P., Triwikantoro., and Supardi, Z.A.I., 2018, Synthesis of PANi-SiO₂ Nanocomposite with In-Situ Polymerization Method: Nanoparticle Silica (NPS) Amorphous and Crystalline Phase, *J. Phys.*, 997, 1—8.

Munawaroh, F., Masdya, Y., Baqiya, M.A., and Triwikantoro., 2024, Synthesis and Characterization of CaO Prepared from Limestone using Sol-Gel Method, *Indones. Phys. Rev.*, 7(2), 249—258.

Mustofa., Ali., Aulia, T., and Syafitra, W.N., 2022, Kajian Literatur: Tantangan Transisi Energi (BBM Fosil ke Bahan Bakar Nabati) Menggunakan Minyak Sawit Mentah, *Prosiding Seminar Nasional BSKJI, Post Pandemic Economy Recovery*.

Naseef, H.H., and Tulaimat, R.H., 2025, Transesterification and Esterification for Biodiesel Production: A Comprehensive Review of Catalyst and Palm Oil Feedstock, *Energy Convers. Manag.*, 26, 1—42.

Ndak, Y.A., Sarifudin, K., dan Sudirman., 2021, Pengaruh Komposisi SiO₂ Pada Katalis CaO/SiO₂ Terhadap Karakter Morfologi Permukaan, Ukuran Partikel, dan Rendemen Metil Ester Reaksi Transesterifikasi Minyak Jarak, *J. Beta Kim.*, 1(2), 64—77.

Nengsih, S., 2019, Karakteristik Nanopartikel Magnetite Besi Oksida Lampanah Aceh Besar Melalui Metode Kopresipitasi, *Elkawnie*, 5, 76.

Nengsih, S., Madjid, S.N., Mursal., and Jalil, Z., 2023, Synthesis and Characterization of Magnetite Particles from Syiah Kuala Iron Sand Prepared by Co-Precipitation Method, *J. Phys.*, 2582, 1—8.

Ngo, T.T.T., Besson, E., Bloch, E., Bourelly, S., Llewellyn, R., Gastaldi, S., Llewellyn, P.L., Gimes, D., and Phana T.N.T., 2021, One-Pot Synthesis of Organic Polymer Functionalized Mesoporous Silicas, *Microporous Mesoporous Mater.*, 19: 111036, 1—12.

Nguyen, M.D., Tran, H., Xu, S., and Lee, R., 2021, Fe₃O₄ Nanoparticles: Structures, Synthesis, Magnetic Properties, Surface Functionalization, and Emerging Applications, *Appl. Sci.*, 11, 1—34.

Nika, J., Anisah, A., dan Saleh, R., 2019, Pemanfaatan Limbah Cangkang Kerang Hijau dengan Variasi Suhu Pembakaran sebagai Bahan Pengganti Sebagian Semen Pada Pembuatan Beton, *J. Pendidik. Tek. Bangunan*, 1(14), 10—17.

Ningsih, S.K.W., 2016, *Sintesis Anorganik*, Padang, UNP Press.

- Ningtyas, D.P., Budhiyanti, S.A., dan Sahubawa, L., 2013, Pengaruh Katalis Basa (NaOH) Pada Tahap Reaksi Transesterifikasi Terhadap Kualitas Biofuel dari Minyak Tepung Ika Sardin, *J. Teknosains*, 2(2), 71—158.
- Noguera, V.C., Amoros, P., Aznar, E., Marcos, M.D., and Manez, R.M., 2024, Systematic Study of the Implications of Calcination and Solvent Extraction the Surfactant in MCM-41-Type Mesoporous Silica Nanoparticles, *Microporous and Mesoporous Mater.*, 373, 1—61.
- Nongbe, M.C., Ekou, T., Ekou, L., Yao, K.B., Grogne, E.L., and Felpin, F.X., 2017, Biodiesel Production from Palm Oil Using Sulfonated Graphene Catalyst, *Renew. Energy*, 106, 135—141.
- Nurdina, R.A., and Nuryono., 2025, Synthesis and Characterization of Magnetic Material/SiO₂/CaO Catalyst for Tripalmitin Transesterification, *Thesis*, Universitas Gadjah Mada.
- Nurhana, E.A., Perdani, M.S., Umam, H.I., Fadila, A.D., Sitanggang, C.O., 2025, Physicochemical Characterization and Reusability of CaO/SiO₂ Catalyst Derived from Eggshell and Rice Husk for Biodiesel Application, *Indones. J. Chem. Res.*, 13(2), 176—185.
- 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.
- Nurhayati, N., Muhdarina, M., Linggawati, A., and Siregar, S.S., 2025, Synthesis and Characterization of CaO-SiO₂ Heterogeneous Catalyst of Blood Cockle Shells and Coconut Fiber Ash for Biodiesel Production from Crude Palm Oil, *Indones. J. Chem.*, 25(4), 998—1011.
- Nurhayati, N., Saputra, L., Awaluddin, A., and Kurniawan, E., 2021, Converting Waste Cooking Oil to Biodiesel Catalyzed by NaOH-Impregnated CaO Derived from Cockle Shell (*Anadara granosa*), *Kinet. Catal.*, 62(6), 860—865.
- Nurmalasari, N., Trisunaryanti, W., Sutarno, S., and Falah, I., 2016, Mesoporous Silica Impregnated by Ni and NiMo as Catalyst for Hydrocracking of Waste Lubricant, *Int. J. ChemTech Res.*, 9(9), 607-614.
- Nursari, E.E., Ningrum, W., Yunata, E.E., Suaebah, E., Firdaus, R.A., 2025, Review: Sintesis Nanopartikel Silika dari Beberapa Material dengan Metode Sol-Gel, *J. Inov. Fis. Indones.*, 14(1), 115—123.
- Oko, S., Kurniawan, A., dan Rahmatina, J., 2021, Pengaruh Perbandingan Massa Ca dan C pada Katalis NaOH/CaO/C dalam Sintesis Biodiesel Menggunakan Minyak Jelantah, *Prosiding the 12th Industrial Research Workshop and National Seminar*, Bandung.

- Othman, Z.A., 2012, A Review: Fundamental Aspects of Silicate Mesoporous Materials, *Materials*, 5, 2874—2902.
- Oueda, N., Coulibaly, Y.L.B., and Ouedraogo, I.W.K., 2017, Deactivation Processes, Regeneration Conditions, and Reusability Performance of CaO or MgO Based Catalyst Used for Biodiesel Production: A Review, *Mater. Sci. Appl.*, 8(1), 2—10.
- Palitsakun, S., Koonuker, K., Topool, B., Seubsai, A., and Sudsakorn, K., 2021, Transesterification of Jatropha Oil to Biodiesel using SrO Catalysts Modified with CaO from Waste Eggshell, *Catal. Commu.*, 149, 106233.
- Paminto, A.K., Karuniasa, M., and Frimawaty, E., 2022, Potential Environmental Impact of Biodiesel Production from Palm Oil using Life Cycle Assessment in Indonesia, *J. Nat. Resour. Environ. Manag.*, 12(1), 64—71.
- Pasandideh, E.K., Kakavandi, B., Nasser, S., Mahvi, A.H., Nabizadeh, R., Esrafil, A., and Rezaei, R., 2016, Silica-Coated Magnetite Nanoparticles Core-Shell Spheres (Fe₃O₄) for Natural Organic Matter Removal, *Sci. Eng.*, 14(21), 1—13.
- Prabhakar, R.S.S., Benitha, V.S., and Nagarajan, J., 2021, Improved Yield of Palm Oil Biodiesel Through Nano Catalytic Transesterification, *Mater. Today Proc.*, 46, 8433—8437.
- Prasdiyanti, R., 2020, Pencucian Material Magnetik Pasir Besi Lansilowo Menggunakan Larutan Asam Klorida, *J. Teknosains*, 10(1), 75—85.
- Precelia, S.C., Subagyo, D.J.N., dan Saleh, C., 2018, Sintesis Silika Mesopori Tersulfonasi dari Abu Daun Bambu Petung, *J. Atomik*, 3(1), 61—67.
- Pujiastuti, C., Muljani, S., and Sumada, K., 2023, Precipitated Calcium Oxide Nanosize from Limestone and Blood Clam Shells, *J. Nat. Sci. Math. Res.*, 9(1), 12—18.
- Puspitasari, P., Pramono, D.D., Fiansyah, D.N., Permasari, A.A., Mufti, N., and Razak, J.A., 2024, Biodiesel Production from Waste Cooking Oil Using Calcium Oxide Derived from Scallop Shell Waste, *Clean Energy*, 8(2), 113—126.
- Putra, M.D., Irawan, C., Udiantoro., Ristianingsih, Y., and Nata, I.F., 2018, A Cleaner Process for Biodiesel Production from Waste Cooking Oil using Waste Materials as a Heterogeneous Catalyst and its Kinetic Study, *J. Clean. Prod.*, 1016.
- Putri, D.R., Irwan, M., dan Nadir, M., 2024, Pengaruh Jenis Katalis pada Pembuatan Biodiesel Minyak Jelantah, *J. Pend. Kim. Ilmu. Kim.*, 7(2), 108-114.
- Rachmadona, N., Nurruyda, F.S., Sumeru, H.A., dan Kusuma, H.D., 2023, Produksi Biodiesel dari Crude Palm Oil (CPO) dengan Menggunakan Lipase dan Etanol Konsentrasi Rendah, *Kimia Padjajaran*, 2(1), 1—7.

- Rahman, I.A., and Padavettan, V., 2012, Synthesis of Silica Nanoparticles by Sol-Gel: Size-Dependent Properties, Surface Modification, and Application in Silica-Polymer Nanocomposite: A Review, *J. Nanomater.*, 132424, 1—15.
- Rahman, W.U., Khan, A.M., Anwer, A.H., Hasan, U., Karmakar, B., and Halder, G., 2022, Parametric Optimization of Calcined and Zn-Doped Waste Eggshell Catalyzed Biodiesel Synthesis from Hevea Barsiliensis Oil, *Energy Nexus*, 6, 1—10.
- Rahmawati, E., dan Utami, M., 2022, Analisis Kadar Asam Lemak Bebas dan Kadar Air Pada *Crude Palm Oil* di Laboratorium PT. Bina Pitri Jaya Mill, *IJCR*, 7(2), 26—35.
- 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(2), 58—67.
- Ramdhani, M., Yani, M., dan Ismayana, A., 2019, Analisis Emisi GRK dan Konversi Energi pada Produksi Minyak Jarak (*Ricinus communis* L.) dengan Metode *Life Cycle Assessment* (LCA), *J. Nat. Resour. Environ. Manag.*, 9(3), 680—691.
- Ramirez, J.L.A., Vallejo, O.R., Okoye, P.U., Albores, R.S., Alvarez, A.M., and Sebastian, P.J., 2022, Development of a Reusable CaO/Fe₃O₄ Heterogeneous Catalyst for Biodiesel Production, *Res. Sq.*, 112, 1—25.
- Ramos., Marta., Dias, A.P.S., Puna, J.F., Gomes, J., and Bordado, C., 2019, Biodiesel Production Processes and Sustainable Raw Materials, *Energies*, 12(23).
- Rianna, M., Susilawati., and Fitri, H., 2023, Study and Characterization of Fe₃O₄-PEG Nanoparticles Using The Co-Precipitation Method For The Production of Permanent Magnets, *J. Technomater. Phys.*, 5(1), 8—14.
- Rozina., Ahmad, M., Zafar, M., and Ali, N., 2019, Biodiesel Synthesis and Physiochemical Analysis of *Taraxacum Officinale* F.H. Wigg Seed Oil, *Int. J. Environ. Sci. Tech.*, 16, 4103—4112.
- Rukyana, N.R., Rahayu, S., dan Kurniawati, D.W., 2024, Pengaruh Suhu Kalsinasi Terhadap Karakteristik Kalsium Oksida (CaO) dari Cangkang Kerang Mutiara (*Pinctada maxima*), *Indones. Phys. Rev.*, 5(3), 1—10.
- Rumbino, Y., Tita, L.C.M.D., dan Nuryoto., 2025, Strategi Pengkonversian Batu Gamping Nusa Tenggara Timur, *J. Ilmu Lingkung.*, 23(4), 1123—1130.
- Salsabila, N., Ernah., Trimo., L., dan Suminartika, E., 2024, Pengembangan Biodiesel Kelapa Sawit Indonesia dalam Mencapai Target Bauran Energi Baru Tahun 2025, *J. Pemikir. Masy. Ilm. Berwawasan Agribis.*, 10(2), 1709—1719.

- Santos, H.C.L.D., Gonçalves, M.A., Lima, V.D.S., Viegas, A.D.C., Filho, G.N.D.R., Conceição, L.R.V., 2024, NaAlO₂/CuFe₂O₄ as a Novel Basic Magnetic Heterogeneous Catalyst for Effective Biodiesel Production: Synthesis, Characterization, and Optimization via RSM-FCCD Modeling Approach, *Process Saf. Environ. Prot.*, 189, 228—245.
- Santoso, A., Rizky, M., Sumari, S., Retnosari, A., dan Asrori, M.R., 2021, Pengaruh Jenis Alkohol Dalam Trans-Esterifikasi Minyak Sawit (CPO) dengan Katalis Heterogen CaO-MgO, *J. Rekayasa Bahan Alam dan Energi Berkelanj.*, 5(1), 1—9.
- Sari, N., Andi Fadlly, T., Hotmaida, R., Purba, H., Ratna, N.I., dan Ari Fahril, M., 2024, Identifikasi Mineral dan Karakterisasi Sifat Magnetik Pasir Besi di Pesisir Pantai Leuge Aceh Timur, *Gravitasi*, 7.
- Schubert, U., 2015, *Chemistry and Fundamentals of the Sol-Gel Process*, The Sol Gel Handbook, Wiley, New York.
- Setianto, B., Santosa, D., Hidayat., and Panatarani., 2017, Quantitative Analysis of Mixture of Oxide Compounds as a Basis for Identifying Content of Natural Resources, *Exacta*, 18(2), 173—177.
- Shihab, B.F and Twej, W.A.A., 2018, Influence of Chemical and Thermal Treatment on The Purity of Silica Extracted from Rice Husk, *Iraqi J. Phys.*, 16, 117—123.
- Silahooy, S., 2020, Analisis Serbuk Silika Amorf (SiO₂) Berbahan Dasar Pasir, *Scie. Map. J.*, 2(2), 75—78.
- Singh, N., Saluja, R.K., Rao, H.J., Kaushal, R., Gahlot, N.K., Suyambulingam, I., Sanjay, M.R., Divakaran, D., and Siengchin, S., 2024 Progress and Facts on Biodiesel Generations, Production Methods, Influencing Factors, and Reactors: A Comprehensive Review From 2000 to 2023, *Energy Convers. Manag.*, 302, 118157, 5—11.
- Soltani, S., Rashid, U., Al-Resayes, S.I., Nehdi, I.A., 2017, Recent Progress in Synthesis and Surface Functionalization of Mesoporous Acidic Heterogeneous Catalyst for Esterification of Free Fatty Acid Feedstock: A Review, *Energy Convers Manag.*, 141, 183—205.
- Stober, W.E.R.N.E.R., 1968, Controlled Growth of Monodisperse Silica Spheres in the Micron Size Range 1, *J. Colloid Interface Sci.*, 69, 62—69.
- Sulaiman, S., Jamaludin, N.F.A., Kabbashi, N.A., 2019, Development of CaO/PVA Catalyst from Fish Bone for Biodiesel Production, *Bull. Chem. React. Eng. Catal.*, 14(1), 153—157.
- Šuljagić, M., Vulić, P., Jeremić, D., Pavlović, V., Filipović, S., Kilanski, L., Lewinska, S., Slawska-Waniewska, A., Milenković, M.R., and Nikolić, A.S., 2021, The Influence of the Starch Coating on the Magnetic Properties of Nanosized Cobalt

Ferrites Obtained by Different Synthetic Methods, *Mater. Res. Bull.*, 134, 1—9.

- Sulaiman, N.F., Yacob, A.R., and Lee, S.L., 2020, Transesterification Reaction from Rice Bran Oil to Biodiesel Over Heterogeneous Base Calcium Oxide Nanoparticles Catalyst, *Sci. Technol. Indones.*, 5(3), 62—69.
- Sumaro, S., Santoso, A., and Asrori, M.B., 2021, A Review: Synthesis of Biodiesel from Low/Off Grade Crude Palm Oil on Pretreatment, Transesterification, and Characteristics, *Orbital: Electron. J. Chem.*, 13(4), 385—391.
- Suresh, S., Sinha, D., and Murugavelh, S., 2016, Biodiesel Production from Waste Cotton Seed Oil: Engine Performance and Emission Characteristics, *Biofuels*, 7, 689—698.
- Syihabuddin, D.M., dan Munasir., 2024, Green Synthesis Nanopartikel Fe₃O₄ dengan Bioreduktor Ekstrak Daun Mimba (*Azadirachta indica*): Aplikasi Sebagai Material Fotokatalis Degradasi *Methylene Blue*, *J. IFI*, 13(3), 118—123.
- Tahya, K., Tahya, C., dan Kainama, H., 2019, Transesterifikasi Minyak Ikan Perak (*Mene Maculata*) dengan Katalis CaO dari Cangkang Telur Ayam, *Indo. J. Chem. Res.*, 7(1), 69—76.
- Tahvil, K., Anaraki, Y.N., Fazaeli, R., Mirpanji, S., and Delrish, E., 2015, The Study of CaO and MgO Heterogenic Nano-Catalyst Coupling on Transesterification Reaction Efficacy in the Production of Biodiesel from Recycled Cooking Oil, *J. Environ. Health Sci. Eng.*, 13(73), 1—10.
- Tanez, P.T., and Pinnavaia, T.J., 1995, A Neutral Templating Route to Mesoporous Molecular Sieves, *Sci.*, 267, 865—872.
- Tavizón-Pozo, J.A., Chavez-Esquivel, G., Suárez-Toriello, V.A., Santolalla-Vargas, C.E., Luévano-Rivas, O., Valdés-Martinez, O.U., Talavera-López, A., and Rodriguez, J.A., 2021, State of Art of Alkaline Earth Metal Oxides Catalyst Used in the Transesterification of Oils for Biodiesel Production, *Energies*, 14, 1—24.
- Teo, S.H., Islam, A., Chan, E.S., Choong, T.S.Y., Alharthi, N.H., Taufiq-Yap, Y.H., and Awual, M.R., 2019, Efficient Biodiesel Production from *Jatropha Curcus* Using CaSO₄/Fe₂O₃-SiO₂ Core-Shell Magnetic Nanoparticles, *J. Clean. Prod.*, 208, 816—826.
- Thahir, R., Widiyanti, S.E., Katu, I., dan Idar, N.N., 2021, *Ekstraksi dan Analisis Karakterisasi Silika dari Sekam Padi*, Seminar Nasional Penelitian & Pengabdian Kepada Masyarakat.
- Thangaraj, B., Solomon, P.R., Muniyadi, B., Ranganathan, S., and Lim, L., 2019, Catalysis in Biodiesel Production: A Review, *Clean Energy*, 3(1), 2—23.

- Tigro, A.A., Hailegiorgis, S.M., and Reshad, A.S., 2025, Heterogeneous Alkaline Calcium Oxide Nano-Catalyst Supported on Porous Materials Transesterification Reaction: A Review, *Results Eng.*, 27, 105912.
- Trinita, G., Sari, D.A., and Hakim, M.F., 2025, Effect of Time Variation and Mole Ratio on Biodiesel Production from Coconut Oil Using CaO Catalyst via Transesterification Method, *J. Ris. Sains Teknol.*, 9(2), 289—295.
- Wahyuningsih, K., dan Perdani, L., 2018, Aktivitas Partikel Nano CaO dari Kulit *Pinctada Maxima* sebagai Antimikroba, *J. Kim. dan Kemasan.*, 42(1), 14—25.
- Wei, Y., Yang, W., and Yang, Z., 2022, An Excellent Universal Catalyst Support-Mesoporous Silica: Preparation, Modification, and Applications in Energy-Related Reactions, *Int. J. Hydrogen Energy*, 47, 9537—9565.
- Wirawan, S.S., Solikhah, M.D., Setiaprja, H., and Sugiyono, A., 2024, Biodiesel Implementation in Indonesia: Experiences and Future Perspectives, *Renew. Sustain. Energy Rev.*, 113911.
- Witoon, T., Bumrungsalee, S., Vathavanichkul, P., Palitsakun, S., Saisriyoot, M., and Faungnawakij, K., 2014, Biodiesel Production from Transesterification of Palm Oil with Methanol Over CaO Supported on Bimodal Meso-Macroporous Silica Catalyst, *Bioresour. Technol.*, 156, 329—334.
- Xie, C., Yan, D., Li, H., Du, S., Chen, W., Wang, Y., Zou, Y., Chen, R., and Wang, S., 2020, Defect Chemistry in Heterogeneous Catalysis: Recognition, Understanding, and Utilization, *ACS Catal.*, 10(19), 11082—11089.
- Xie, W., and Wang, H., 2020, Immobilized Polymeric Sulfonated Ionic Liquid on Core-Shell Structured Fe₃O₄/SiO₂ Composites: A Magnetically Recyclable Catalyst for Simultaneous Transesterification and Esterification of Low-Cost Oils to Biodiesel, *Renew. Energy*, 145, 1709—1719.
- Xie, W., and Zang, X., 2016, Immobilized Lipase on Core-Shell Structured Fe₃O₄-MCM-41 Nanocomposites as a Magnetically Recyclable Biocatalyst for Interesterification of Soybean Oil and Lard, *Food Chem.*, 194, 1283—1292.
- Xu, L., Zhang, J., Ding, J., Liu, T., Shi, G., Li, X., Dang, W., Cheng, Y., and Guo, R., 2020, Pore Structure and Fractal Characteristics of Different Shale Lithofacies in the Dalong Formation in the Western Area of the Lower Yangtze Platform, *Minerals*, 10, 72.
- Yang, J., Cong, W.J., Zhu, Z., Miao, Z.D., Wang, Y.T., Nelles, M., and Fang, Z., 2023, Microwave-Assisted One-Step Production of Biodiesel from Waste Cooking Oil by Magnetic Bifunctional SrO-ZnO/MOF Catalyst, *J. Clean. Prod.*, 395, 136182.

- Yanti, D.N.F., Zamhari, M., and Yerizam, M., 2025, Peran Katalis Heterogen CaO/TiO₂ untuk Produksi Biodiesel dari *Crude Palm Oil* (CPO), *Chem. Eng. J.*, 5(6), 1126—1140.
- Yasar, F., 2019, Biodiesel Production via Waste Eggshell as a Low-Cost Heterogeneous Catalyst: Its Effects on some Critical Fuel Properties and Comparison with CaO, *Fuel*, 255, 115828.
- Yee, K.F., Kansedo, J., and Lee, K.T., 2010, Biodiesel Production from Palm Oil via Heterogeneous Transesterification: Optimization Study, *Chem. Eng. Comm.*, 197, 1597—1611.
- Yin, X., Duan, X., You, Q., Dai, C., Tan, Z., and Zhu, X., 2016, Biodiesel Production from Soybean Oil Deodorizer Distillate Using Calcined Duck Eggshell as Catalyst, *Energy Convers. Manag.*, 112, 199—207.
- Yusuf, A.S., Gbasamosi, A.O., and Popola, L.T., 2021, Biodiesel Production from Transesterified Waste Cooking Oil by Zinc-Modified Anthill Catalyst: Parametric Optimization and Biodiesel Properties Improvement, *J. Environ. Chem. Eng.*, 9(2), 104955.
- Yuwanda, A.N., Rahmayuni, R., Visgun, D.A., Rahmi, A., Rifai, H., and Dwiridal, L., 2022, Characterization of Magnetic Minerals of Iron Sand Pasia Nan Tigo Padang Beach Using X-Ray Diffraction (XRD), *IJAP*, 12(1), 35—47.
- Zahra, M.A., Hiyahara, I., dan Syaima, H., 2025, Pemanfaatan Cangkang Telur Sebagai Sumber CaO: Studi Karakterisasi Menggunakan Fourier Transform Infrared Spectroscopy (FTIR), *J. Atomik*, 10(2), 133—137.
- Zeng, Q., Song, Z., Qin, H., Cheng, H., Chen, L., and Pan, M., 2020, Ionic Liquid (BMIm) (H₂SO₄) as Dual Catalyst-Solvent for the Esterification of Hexanoic Acid with n-Butanol, *Catal. Today*, 339, 113—120.
- Zhao, X.S., Lu, G.Q., Whittaker, A.J., Millar, G.J., and Zhu, H.Y., 1997, Comprehensive Study of Surface Chemistry of MCM-41 Using ²⁹Si CP/MAS NMR, FTIR, Pyridine-TPD, and TGA, *J. Phys. Chem.*, 101: 6525.
- Zhou, L., Yao, J., Ren, Z., Yu, Z., and Cai, H., 2020, Development of Magnetic Multi-Shelled Hollow Catalyst for Biodiesel Production, *Energies*, 13, 2—14.
- Zhuang, D., Chen, Z., and Sun, B., 2025, Thermal Decomposition of Calcium Carbonate at Multiple Heating Rates in Different Atmosphere Using the Technique of TG, DTG, and DSC, *Crystals*, 15, 1—15.
- Zul, S.G., Hamidon, T.S., Oh, W.D., and Hussin, M.H., 2021, A Review on the Utilization of Calcium Oxide as a Base Catalyst in Biodiesel Production, *J. Environ. Chem. Eng.*, 9(4), 105741, 1—10.