

UCAPAN TERIMA KASIH

Puji syukur penulis panjatkan ke hadirat Allah SWT atas limpahan rahmat, hidayah, dan karunia-Nya, sehingga penulis dapat menyelesaikan skripsi ini dengan baik dan tepat waktu. Dalam kesempatan ini, penulis menyampaikan rasa terima kasih yang sebesar-besarnya kepada:

1. Bapak Prof. Dr. Suharnomo, S.E., M.Si., selaku rektor dari Universitas Diponegoro.
2. Bapak Prof. Dr. Kusworo Adi, S.Si., M.T., selaku dekan Fakultas Sains dan Matematika, Universitas Diponegoro.
3. Bapak Prof. Drs. Sapto Purnomo Putro, M.Si., Ph.D., selaku ketua Departemen Biologi, Fakultas Sains dan Matematika, Universitas Diponegoro
4. Bapak Dr. Sri Pujiyanto, S.Si., M.Si., selaku Ketua Program Studi Bioteknologi, Departemen Biologi Fakultas Sains dan Matematika Universitas Diponegoro.
5. Ibu Dr. Dra. Arina Tri Lunggani, M.Si., selaku dosen pembimbing I, yang telah memberikan bimbingan, arahan, serta masukan yang sangat berarti untuk kelancaran penulisan skripsi ini.
6. Ibu Nurina Tahta Afwi Maulina, S.Si., M.Biotech., selaku dosen pembimbing II, yang telah memberikan bimbingan, arahan, serta masukan yang sangat berarti untuk kelancaran penulisan skripsi ini.

7. Ibu Nisrina Fitri Nurjannah, S.Si., M.Si., selaku dosen penguji, yang telah memberikan kritik, saran, serta koreksi yang membangun sejak tahap proposal hingga penyusunan akhir skripsi ini.
8. Seluruh dosen pengajar Program Studi Bioteknologi Universitas Diponegoro, yang telah memberikan ilmu, bimbingan, serta inspirasi baik secara teori maupun praktik selama masa perkuliahan.
9. Keluarga tercinta yang senantiasa mendoakan, mendukung, dan memberikan semangat yang tiada henti kepada penulis selama proses penyusunan skripsi ini.
10. Teman-teman seperjuangan yang telah memberikan dukungan moral, semangat, serta masukan yang bermanfaat dalam penyusunan laporan ini.

Penulis menyadari bahwa skripsi ini masih jauh dari sempurna. Oleh karena itu, segala bentuk saran dan kritik yang membangun akan sangat penulis hargai demi perbaikan di masa yang akan datang.

DAFTAR PUSTAKA

- Agu, P. C., Afiukwa, C. A., Orji, O. U., Ezech, E. M., Ofoke, I. H., Ogbu, C. O., & Aja, P. M. (2023). Molecular docking as a tool for the discovery of molecular targets of nutraceuticals in diseases management. *Scientific reports*, 13(1), 13398.
- Agustin, R., Silsadilla, A., & Ismed, F. (2025). Nanoemulsion Formulation Of Cardamom Essential Oil (Amomum Compactum S.) And It's In Vitro Anti-Aging Activity.
- Almoughrabie, S., Cau, L., Cavagnero, K., O'Neill, A. M., Li, F., Roso-Mares, A., & Gallo, R. L. (2023). Commensal Cutibacterium acnes induce epidermal lipid synthesis important for skin barrier function. *Science advances*, 9(33), eadg6262.
- Aloliqi, A. A. (2024). Towards identification of therapeutics against multi-infections and cancers causing Propionibacterium acnes: Molecular modeling and dynamics simulation investigation. *Journal of Molecular Liquids*, 415, 126373.
- Aman O, Ischak NI, Tuloli TS, Arfan A, Asnawi A. Multiple ligands simultaneous molecular docking and dynamics approach to study the synergetic inhibitory of curcumin analogs on ErbB4 tyrosine phosphorylation. *Res Pharm Sci*. 2024 Dec 15;19(6):754-765. doi: 10.4103/RPS.RPS_191_23. PMID: 39911900; PMCID: PMC11792710.
- Amrulloh, L. S. W. F., Harmastuti, N., Prasetyo, A., & Herowati, R. (2023). Analysis of molecular docking and dynamics simulation of mahogany (Swietenia macrophylla King) compounds against the PLpro enzyme SARS-COV-2. *Jurnal Farmasi dan Ilmu Kefarmasian Indonesia*, 10(3), 347-359.
- Ankith, G. N., Rajesh, M. R., Karthik, K. N., Avinash, H. C., Kekuda, P. T., & Vinayaka, K. S. (2017). Antibacterial and antifungal activity of three Ramalina species. *J. drug deliv. ther*, 7(5), 27-32.
- Arief, I., & Hairunnisa, H. (2022). Profil ADME dari entitas molekul baru yang disetujui oleh FDA tahun 2021: Suatu kajian in silico. *Jambura Journal of Chemistry*, 4(2), 1-11.
- Arya, M., Kaur, J., Singh, S., & Patil, A. (2021). Bioprospecting Importance Of Certain Ramalina Species And Promising Role Of Its Biological Active Compounds. *Journal of Phytological Research*, 34(1).
- Ausubel, F. M., Brent, R., Kingston, R. E., Moore, D. D., Seidman, J. G., Smith, J. A., & Struhl, K. (1992). Short protocols in molecular biology.

- Ayodele, P. F., Bamigbade, A., Bamigbade, O. O., Adeniyi, I. A., Tachin, E. S., Seweje, A. J., & Farohunbi, S. T. (2023). Illustrated procedure to perform molecular docking using PyRx and Biovia discovery studio visualizer: a case study of 10kt with atropine. *Progress in Drug Discovery & Biomedical Science*, 6(1).
- Báčkor, M., Kecsey, D., Drábová, B., Urminská, D., Šemeláková, M., & Goga, M. (2024). Secondary Metabolites from Australian Lichens *Ramalina celastri* and *Stereocaulon ramulosum* Affect Growth and Metabolism of Photobiont *Asterochloris erici* through Allelopathy. *Molecules*, 29(19). 4620.
- Banerjee, P., Eckert, A. O., Schrey, A. K., & Preissner, R. (2018). ProTox-II: a webserver for the prediction of toxicity of chemicals. *Nucleic Acids Research*, 46(W1), W257–W263.
- Banerjee, P., Kemmler, E., Dunkel, M., & Preissner, R. (2024). ProTox 3.0: a webserver for the prediction of toxicity of chemicals. *Nucleic Acids Research*, 52(W1), W513–W520.
- Banerjee, S., Pal, S. K., & Das, A. (2016). Docking and its applications in drug design: A review. *Journal of Medicinal Chemistry*, 59(10), 4189–4200.
- Bano, A., Razaq, A., Ishaq, A., Ilyas, S., & Liaqat, H. (2024). Molecular identification and phylogenetic analysis of a lichen, *Protoparmeliopsis* (lecanoraceae, ascomycota), a new lichen genus for Khaplu valley, Gilgit-Baltistan, Pakistan. *Studies in Fungi*, 9(1).
- Bitencourt-Ferreira, G., Veit-Acosta, M., & de Azevedo Jr, W. F. (2019). Electrostatic energy in protein–ligand complexes. In *Docking Screens for Drug Discovery* (pp. 67-77). New York, NY: Springer New York.
- Brodo, I. M., Sharnoff, S. D., & Sharnoff, S. (2001). *Lichens of North America*. Yale University Press.
- Burkhart, C. G. (2024). Assessment of *Cutibacterium acnes*: Acne Biofilm, Comedones, and Future Treatments for Acne. *The Open Dermatology Journal*, 18(1).
- Carrasco, F., Hernández, W., Castro, N., Guerrero, M., Tamariz-Angeles, C., Olivera-Gonzales, P., & Rodilla, J. M. (2024). Identification and determination of usnic acid and fatty acid from various lichen species in arequipa, Peru, as well as antibacterial and antioxidant capacity. *Heliyon*, 10(21).
- Cavallo, I., Sivori, F., Truglio, M., De Maio, F., Lucantoni, F., Cardinali, G., & Di Domenico, E. G. (2022). Skin dysbiosis and *Cutibacterium acnes* biofilm in inflammatory acne lesions of adolescents. *Scientific reports*, 12(1), 21104.

- Chen, D., Oezguen, N., Urvil, P., Ferguson, C., Dann, S. M., & Savidge, T. C. (2016). Regulation of protein-ligand binding affinity by hydrogen bond pairing. *Science advances*, 2(3), e1501240.
- Cheon, D., Kim, J., Jeon, D., Shin, H. C., & Kim, Y. (2019). Target proteins of phloretin for its anti-inflammatory and antibacterial activities against *Propionibacterium acnes*-induced skin infection. *Molecules*, 24(7), 1319.
- Cicih, A. (2022). Interaksi farmakokinetik dan farmakodinamik metformin-herbal. *Jurnal Ilmiah Farmasi*, 18(1), 13-25.
- Daina A., Michielin O., Zoete V. (2017). SwissADME: a free web tool to evaluate pharmacokinetics, drug-likeness and medicinal chemistry friendliness of small molecules. *Sci Rep*. 7:42717.
- Dankwah, K. O., Mohl, J. E., Begum, K., & Leung, M. Y. (2022). What makes GPCRs from different families bind to the same ligand?. *Biomolecules*, 12(7), 863.
- Dar, T. U. H., Dar, S. A., Islam, S. U., Mangral, Z. A., Dar, R., Singh, B. P., & Haque, S. (2022, November). Lichens as a repository of bioactive compounds: an open window for green therapy against diverse cancers. In *Seminars in cancer biology* (Vol. 86, pp. 1120-1137). *Academic Press*.
- Deng, M., Farahani, K., & Agak, G. W. (2025). Insights into early acne pathogenesis: Exploring intercellular dynamics and key dysregulated genes. *Cell signaling*, 3(1), 32.
- Dessinioti, C., & Katsambas, A. (2024). The microbiome and acne: perspectives for treatment. *Dermatology and Therapy*, 14(1), 31-44.
- DEV, Blundell TL, Ascher DB. 2015. "Predicting Small-Molecule Pharmacokinetic and Toxicity Properties Using Graph-Based Signatures." *Med Chem* 68 (9): 4066–72. <https://doi.org/10.1021/acs.jmedchem.5b00104>.
- Elsaie, M. L. (2016). Hormonal treatment of acne vulgaris: an update. *Clinical, cosmetic and investigational dermatology*, 241-248.
- Fatoki, T. H., Balogun, T. C., Ojewuyi, A. E., Omole, A. C., Olukayode, O. V., Adewumi, A. P., & Isah, M. J. (2024). In silico molecular targets, docking, dynamics simulation and physiologically based pharmacokinetics modeling of oritavancin. *BMC Pharmacology and Toxicology*, 25(1), 79.
- Feng, Y., Li, J., Mo, X., & Ju, Q. (2024). Macrophages in acne vulgaris: mediating phagocytosis, inflammation, scar formation, and therapeutic implications. *Frontiers in Immunology*, 15, 1355455.

- Ferreira, L. G., dos Santos, R. N., Oliva, G., & Andricopulo, A. D. (2015). Molecular docking and structure-based drug design strategies. *Molecules*, 20(7), 13384–13421.
- Firlej, E., Kowalska, W., Szymaszek, K., Roliński, J., & Bartosińska, J. (2022). The role of skin immune system in acne. *Journal of Clinical Medicine*, 11(6), 1579.
- Forli, S., Huey, R., Pique, M. E., Sanner, M. F., & Goodsell, D. S. (2016). Computational docking of small molecules to proteins: A review of the molecular docking process and its application in drug discovery. *Current Topics in Medicinal Chemistry*, 16(2), 138–151.
- Gamblin, S. J., & Skehel, J. J. (2010). Influenza hemagglutinin and neuraminidase membrane glycoproteins. *Journal of biological chemistry*, 285(37), 28403–28409.
- Gazo, S. M. T., Santiago, K. A. A., Tjitrosoedirjo, S. S., & Cruz, T. E. E. D. (2019). Antimicrobial and herbicidal properties of the fruticose lichen *Ramalina* from Guimaras Island, Philippines. *Biotropia*, 26(1), 23–32.
- Gunasekaran, S., Rajan, V. P., Ramanathan, S., Murugaiyah, V., Samsudin, M. W., & Din, L. B. (2016). Antibacterial and antioxidant activity of lichens *Usnea rubrotincta*, *Ramalina dumeticola*, *Cladonia verticillata* and their chemical constituents. *Malaysian Journal of Analytical Sciences*, 20(1), 1–13.
- Gupta, A., Singh, A. P., Singh, P. R., Upreti, D. K., & Sinha, R. P. (2025). The Role of Ultraviolet Radiation in Regulating Certain Physiological and Biochemical Processes in the Lichens *Xanthoria candelaria* (L.) Th. Fr. and *Xanthoria elegans* (L.) Th. Fr. *Journal of Plant Growth Regulation*, 1–13.
- Hall, B. G. (2013). *Phylogenetic Trees Made Easy: A How-To Manual* (4th ed.). Sinauer Associates.
- Havird, J. C., & Santos, S. R. (2014). Performance of single and concatenated sets of mitochondrial genes at inferring metazoan relationships relative to full mitogenome data. *PLoS One*, 9(1), e84080.
- Hollingsworth, S. A., & Dror, R. O. (2018). Molecular dynamics simulation for all. *Neuron*, 99(6), 1129–1143.
- Huang, L., Yang, S., Yu, X., Fang, F., Zhu, L., Wang, L., & Zhu, T. (2024). Association of different cell types and inflammation in early acne vulgaris. *Frontiers in Immunology*, 15, 1275269.
- Huneck, S., Yoshimura, I. (1996). Identification of Lichen Substances. In: *Identification of Lichen Substances*. Springer, Berlin, Heidelberg.

- Ismed, F., Arifa, N., Nissa, M. Q., Putra, D. P., Orue, A. I., Clegg, J. K., & Dévéhat, F. L. (2025). Lichen substances from *Teloschistes flavicans* (Sw.) Norman: Isolation, crystal structure, and evaluation of their antibacterial activities.
- Jayalal, U., Oh, S. O., Lücking, R., Joshi, S., Kim, J. A., Park, J. S., & Hur, J. S. (2013). Contributions to the foliicolous lichens flora of South Korea. *Mycobiology*, 41(4), 202-209.
- Jin, L., Li, R., Zhou, X., Chen, W., Chen, X., & Zhu, W. (2025). Dihydromyricetin exerts dual anti-acne actions by suppressing *Propionibacterium acnes* proliferation and host inflammatory responses via TLR2/NF- κ B/MAPK pathway inhibition. *European Journal of Pharmacology*, 178161.
- Junren, C., Xiaofang, X., Mengting, L., Qiuyun, X., Gangmin, L., Huiqiong, Z., & Cheng, P. (2021). Pharmacological activities and mechanisms of action of *Pogostemon cablin* Benth: a review. *Chinese medicine*, 16(1), 5.
- Karami, T. K., Hailu, S., Feng, S., Graham, R., & Gukasyan, H. J. (2022). Eyes on Lipinski's rule of five: A New “rule of thumb” for physicochemical design space of ophthalmic drugs. *Journal of ocular pharmacology and therapeutics*, 38(1), 43-55.
- Khehra N, Padda IS, Zubair M. Polymerase Chain Reaction (PCR) [Updated 2025 Jul 7]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan-.
- Kim, H. J., & Kim, Y. H. (2024). Exploring acne treatments: From pathophysiological mechanisms to emerging therapies. *International journal of molecular sciences*, 25(10), 5302.
- Kim, Y. G., Lee, J. H., & Lee, J. (2021). Antibiofilm activities of fatty acids including myristoleic acid against *Cutibacterium acnes* via reduced cell hydrophobicity. *Phytomedicine*, 91, 153710.
- Kistenich, S., Timdal, E., Bendiksby, M., & Ekman, S. (2018). Molecular systematics and character evolution in the lichen family Ramalinaceae (Ascomycota: Lecanorales). *Taxon*, 67(5), 871-904.
- Kocovic, A., Jeremic, J., Bradic, J., Sovrljic, M., Tomovic, J., Vasiljevic, P., ... & Manojlovic, N. (2022). Phytochemical analysis, antioxidant, antimicrobial, and cytotoxic activity of different extracts of *Xanthoparmelia stenophylla* lichen from Stara Planina, Serbia. *Plants*, 11(13), 1624.
- Lemkul, J. A. (2024). Introductory tutorials for simulating protein dynamics with GROMACS. *The Journal of Physical Chemistry B*, 128(39), 9418-9435.

- Lindor, N. M., Yang, P., Evans, I., Schowalter, K., De Andrade, M., Li, J., ... & Thibodeau, S. N. (2010). Alpha-1-antitrypsin deficiency and smoking as risk factors for mismatch repair deficient colorectal cancer: a study from the colon cancer family registry. *Molecular genetics and metabolism*, 99(2), 157-159.
- Loureiro, L., Morais, J., Silva, R., Martins, J. T., Geda, P., Vasconcelos, V., & Vicente, A. A. (2024). Isolation and identification of lichen photobionts collected from different environments in north of Portugal and evaluation of bioactivities of their extracts. *Foods*, 13(11), 1759.
- Lücking, R., Leavitt, S. D., & Hawksworth, D. L. (2021). Species in lichen-forming fungi: balancing between conceptual and practical considerations, and between phenotype and phylogenomics. *Fungal Diversity*, 109(1), 99-154.
- Martiny, J. B. H. (2001). Population diversity, overview. In S. A. Levin (Ed.), *Encyclopedia of biodiversity* (2nd ed., pp. 168–174). Academic Press. <https://doi.org/10.1016/B978-0-12-384719-5.00114-3>
- Mawardi, P., Ardiani, I., Primisawitri, P.P., Nareswari, A. 2021. Dual role of *Cutibacterium acnes* in acne vulgaris pathophysiology. *Bali Medical Journal*. 10(2): 486-490. DOI: 10.15562/bmj.v10i2.2358
- Mayslich, C., Grange, P. A., & Dupin, N. (2021). *Cutibacterium acnes* as an opportunistic pathogen: an update of its virulence-associated factors. *Microorganisms*, 9(2), 303.
- Mendili, M., Khadhri, A., Mediouni-Ben Jemâa, J., Andolfi, A., Tufano, I., Aschi-Smiti, S., & DellaGreca, M. (2022). Anti-inflammatory potential of compounds isolated from Tunisian lichens species. *Chemistry & Biodiversity*, 19(8), e202200134.
- Micheletti, A. C., Honda, N. K., Ravaglia, L. M., Matayoshi, T., & Spielmann, A. A. (2021). Antibacterial potencial of 12 Lichen species. *Anais da Academia Brasileira de Ciências*, 93(4).
- Mishra, G. K. (2019). Species and chemical diversity in lichen family Teloschistaceae, and their bioprospecting potential: A review in Indian context.
- Mishra, S., Raval, M., Singh, V., & Tiwari, A. K. (2023). Synthetic receptors in medicine. *Progress in Molecular Biology and Translational Science*, 196, 303-335.
- Moreira, A. S. N., Braz-Filho, R., Mussi-Dias, V., & Vieira, I. J. C. (2015). Chemistry and biological activity of Ramalina lichenized fungi. *Molecules*, 20(5), 8952-8987.

- Morillas, L., Roales, J., Cruz, C., & Munzi, S. (2022). Lichen as multipartner symbiotic relationships. *Encyclopedia*, 2(3), 1421-1431.
- Muggia, L., Ametrano, C. G., Sterflinger, K., & Tesei, D. (2020). An overview of genomics, phylogenomics and proteomics approaches in Ascomycota. *Life*, 10(12), 356.
- Newman L., Duffus A. L., Lee C. (2016). Using the free program MEGA to build phylogenetic trees from molecular data. *Am. Biol. Teach.* 78, 608–612.
- Nursanti, O. (2021, June). Validasi penambatan molekul untuk mendapatkan ligan aktif pada reseptor cyclooxygenase 2. In *Prosiding Seminar Informasi Kesehatan Nasional* (pp. 411-430).
- Nussinov, R., Tsai, C. J., & Jang, H. (2019). Allosteric modulation of protein activity in drug discovery. *Journal of Biological Chemistry*.
- Paichitrojjana, A., & Paichitrojjana, A. (2023). Oral isotretinoin and its uses in dermatology: a review. *Drug Design, Development and Therapy*, 2573-2591.
- Palmieri, B., Manenti, A., Vadalà, M., & Palmieri, L. (2021). Alive and Inactivated Cutibacterium Acnes: Properties, Functions and Pathogenicity. *J Clin Immunol Immunother*, 7(069), 2.
- Park, S. Y., Jang, S. H., Oh, S. O., Kim, J. A., & Hur, J. S. (2014). An easy, rapid, and cost-effective method for DNA extraction from various lichen taxa and specimens suitable for analysis of fungal and algal strains. *Mycobiology*, 42(4). 311-316.
- Patil, R., Das, S., Stanley, A., Yadav, L., Sudhakar, A., & Varma, A. K. (2010). Optimized hydrophobic interactions and hydrogen bonding at the target-ligand interface leads the pathways of drug-designing. *PloS one*, 5(8), e12029.
- Poulsen-Silva, E., Gordillo-Fuenzalida, F., Atala, C., Moreno, A. A., & Otero, M. C. (2023). Bioactive lichen secondary metabolites and their presence in species from Chile. *Metabolites*, 13(7), 805.
- Purushothaman, R., Vishnuram, G., & Ramanathan, T. (2025). Antiinflammatory efficacy of n-Hexadecanoic acid from a mangrove plant Excoecaria agallocha L. through in silico, in vitro and in vivo. *Pharmacological Research-Natural Products*, 7, 100203.
- Pyrczak-Felczykowska, A., Narlawar, R., Pawlik, A., Guzow-Krzemińska, B., Artymiuk, D., Hać, A., ... & Kassiou, M. (2019). Synthesis of usnic acid derivatives and evaluation of their antiproliferative activity against cancer cells. *Journal of Natural Products*, 82(7), 1768-1778.