References

Abdi, G., Karande, V. C., Mohammed, A., Abbasi Tarighat, M., Wen Goh, K., Abdul Kari, Z., Seong Wei, L., Ahmad Mohd Zain, M. R., Mohammadi, M., Ee Lee, G., & Barwant, M. M. (2022). Pharmacological potential of Sargassum sp. of west coast of Maharashtra Kunkeshwar, India. *Frontiers in Marine Science*, *9*. https://doi.org/10.3389/fmars.2022.1011218

Aduba, D., & Yang, H. (2017). Polysaccharide Fabrication Platforms and Biocompatibility Assessment as Candidate Wound Dressing Materials. *Bioengineering*, *4*(4), 1. https://doi.org/10.3390/bioengineering4010001

Ahmad, N. (2022). In Vitro and In Vivo Characterization Methods for Evaluation of Modern Wound Dressings. *Pharmaceutics*, *15*(1), 42. https://doi.org/10.3390/pharmaceutics15010042

Al-Roub, A., Akhter, N., Al-Rashed, F., Wilson, A., Alzaïd, F., Al-Mulla, F., Sindhu, S., & Ahmad, R. (2023). TNFα induces matrix metalloproteinase-9 expression in monocytic cells through ACSL1/JNK/ERK/NF-kB signaling pathways. *Scientific Reports*, *13*(1). https://doi.org/10.1038/s41598-023-41514-6

Alexander-Sinclair, E. I., Lapina, E. S., Edomenko, N. V., Kostyakov, D. V., Zinoviev, E. V., Blinova, M. I., & Mikhailova, N. A. (2025). Biocompatibility Issues of Wound Dressings. *Bioengineering*, *12*(11), 1196–1196. https://doi.org/10.3390/bioengineering12111196

Almadani, Y. H., Vorstenbosch, J., Davison, P., & Murphy, A. (2021). Wound Healing: A Comprehensive Review. *Seminars in Plastic Surgery*, *35*(3). https://doi.org/10.1055/s-0041-1731791

Andriani, F., Hendrayanti, D., & Yasman, Y. (2024). Exploring Microalgae Diversity in Indonesia: Harnessing Potential for Lead Bioremediation. *BIOEDUSCIENCE*, *8*(1), 26–42. https://doi.org/10.22236/jbes/13225

Aqilah, S., Rossa, A., Lubbiyah, F. F., & Irpan, A. M. (2024). Macroalgae Ecology Index in Leuweung Sancang Nature Reserve Area. *Biosfer: Jurnal Tadris Biologi*, *15*(2), 269-278.

Baghel, R. S., Reddy, C. R. K., & Singh, R. P. (2021). Seaweed-based cellulose: Applications, and future perspectives. *Carbohydrate Polymers*, *267*, 118241. https://doi.org/10.1016/j.carbpol.2021.118241

Bar-Shai, N., Sharabani-Yosef, O., Zollmann, M., Lesman, A., & Golberg, A. (2021). Seaweed cellulose scaffolds derived from green macroalgae for tissue engineering. *Scientific Reports*, *11*(1), 11843. https://doi.org/10.1038/s41598-021-90903-2

Basu, A., Lindh, J., Ålander, E., Strømme, M., & Ferraz, N. (2017). On the use of ion-crosslinked nanocellulose hydrogels for wound healing solutions: Physicochemical properties and application-oriented biocompatibility studies. *Carbohydrate Polymers*, *174*, 299–308. https://doi.org/10.1016/j.carbpol.2017.06.073

Bawadi, H. A., Antunes, T. M., Shih, F., & Losso, J. N. (2004). In Vitro Inhibition of the Activation of Pro-matrix Metalloproteinase 1 (Pro-MMP-1) and Pro-matrix Metalloproteinase 9 (Pro-MMP-9) by Rice and Soybean Bowman−Birk Inhibitors. *Journal of Agricultural and Food Chemistry*, *52*(15), 4730–4736. https://doi.org/10.1021/jf034576u

Bell, G. (2016). Replicates and repeats. *BMC Biology*, *14*(1). https://doi.org/10.1186/s12915-016-0254-5

Britto, E. J., Nezwek, T. A., & Robins, M. (2024). *Wound Dressings*. PubMed; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK470199/

Bukatuka, C. F., Mbituyimana, B., Xiao, L., Qaed Ahmed, A. A., Qi, F., Adhikari, M., Shi, Z., & Yang, G. (2025). Recent Trends in the Application of Cellulose-Based Hemostatic and Wound Healing Dressings. *Journal of Functional Biomaterials*, *16*(5), 151. https://doi.org/10.3390/jfb16050151

Caley, M. P., Martins, V. L. C., & O’Toole, E. A. (2015). Metalloproteinases and Wound Healing. *Advances in Wound Care*, *4*(4), 225–234. https://doi.org/10.1089/wound.2014.0581

Catulin, A. L., & Sambrana, J. R. (2023). Seaweed wonders: Phytochemical, antibacterial property and burn wound healing effect of Nagkayasan (Chaetomorpha crassa) extract vaseline based ointment. *Journal of Biodiversity and Environmental Sciences*, *22*(6), 12–20. https://innspub.net/seaweed-wonders-phytochemical-antibacterial-property-and-burn-wound-healing-effect-of-nagkayasan-chaetomorpha-crassa-extract-vaseline-based-ointment/

Chen, K., Xu, M., Lu, F., & He, Y. (2023). Development of Matrix Metalloproteinases-Mediated Extracellular Matrix Remodeling in Regenerative Medicine: A Mini Review. *Tissue Engineering and Regenerative Medicine*, *20*(5), 661–670. https://doi.org/10.1007/s13770-023-00536-x

Cheng, W., Zhu, Y., Jiang, G., Cao, K., Zeng, S., Chen, W., Zhao, D., & Yu, H. (2023). Sustainable cellulose and its derivatives for promising biomedical applications. *Progress in Materials Science*, *138*, 101152–101152. https://doi.org/10.1016/j.pmatsci.2023.101152

Diban, F., Di Lodovico, S. ., Di Fermo, P., a D'Ercole, S., D'Arcangelo, S., Nostro, A., & Cellini, L. (2023). Biofilms in Chronic Wound Infections: Innovative Antimicrobial Approaches Using the In Vitro Lubbock Chronic Wound Biofilm Model. *International Journal of Molecular Sciences*, *24*(2), 1004–1004. https://doi.org/10.3390/ijms24021004

Diller, R. B., & Tabor, A. J. (2022). The Role of the Extracellular Matrix (ECM) in Wound Healing: A Review. *Biomimetics*, *7*(3), 87. https://doi.org/10.3390/biomimetics7030087

Downer, M., Berry, C. E., Parker, J. B., Kameni, L., & Griffin, M. (2023). Current Biomaterials for Wound Healing. *Bioengineering*, *10*(12), 1378. https://doi.org/10.3390/bioengineering10121378

El-Ghoul, Y., Altuwayjiri, A. S., & Alharbi, G. A. (2024). Synthesis and characterization of new electrospun medical scaffold-based modified cellulose nanofiber and bioactive natural propolis for potential wound dressing applications. *RSC Advances*, *14*(36), 26183–26197. https://doi.org/10.1039/d4ra04231j

El-Sheekh, M. M., Yousuf, W. E., Kenawy, E.-R., & Mohamed, T. M. (2023). Biosynthesis of cellulose from Ulva lactuca, manufacture of nanocellulose and its application as antimicrobial polymer. *Scientific Reports*, *13*, 10188. https://doi.org/10.1038/s41598-023-37287-7

Ellis, S., Lin, E. J., & Tartar, D. (2018). Immunology of Wound Healing. *Current Dermatology Reports*, *7*(4), 350–358. https://doi.org/10.1007/s13671-018-0234-9

Eming, S. A., Murray, P. J., & Pearce, E. J. (2021). Metabolic orchestration of the wound healing response. *Cell Metabolism*, *33*(9), 1726–1743. https://doi.org/10.1016/j.cmet.2021.07.017

Farobie, O., Syaftika, N., Hartulistiyoso, E., Amrullah, A., Bayu, A., Moheimani, N. R., Matsumura, Y., & Karnjanakom, S. (2022). The Potential of Sustainable Biogas Production from Macroalgae in Indonesia. *IOP Conference Series*, *1038*(1), 012020–012020. https://doi.org/10.1088/1755-1315/1038/1/012020

Fauzi, M. B., Rashidbenam, Z., Bin Saim, A., & Binti Hj Idrus, R. (2020). Preliminary Study of In Vitro Three-Dimensional Skin Model Using an Ovine Collagen Type I Sponge Seeded with Co-Culture Skin Cells: Submerged versus Air-Liquid Interface Conditions. *Polymers*, *12*(12), 2784. https://doi.org/10.3390/polym12122784

Fernandez-Guarino, M., Naharro-Rodriguez, J., & Bacci, S. (2024). Aberrances of the Wound Healing Process: A Review. *Cosmetics*, *11*(6), 209. https://doi.org/10.3390/cosmetics11060209

Firmansyah, Y., Sidharta, V. M., Wijaya, L., & Tan, S. T. (2024). Unraveling the Significance of Growth Factors (TGF-β, PDGF, KGF, FGF, Pro Collagen, VEGF) in the Dynamic of Wound Healing. *Asian Journal of Medicine and Health*, *22*(3), 49–61. https://doi.org/10.9734/ajmah/2024/v22i3992

Ghomi, E. R., Khalili, S., Khorasani, S. N., Neisiany, R. E., & Ramakrishna, S. (2019). Wound dressings: Current advances and future directions. *Journal of Applied Polymer Science*, *136*(27), 47738. https://doi.org/10.1002/app.47738

Hasanin, M. S. (2022). Cellulose-Based Biomaterials: Chemistry and Biomedical Applications. *Starch - Stärke*, *74*(7-8), 2200060. https://doi.org/10.1002/star.202200060

Henggu, K. U., Jodi, J. U., Ratu, O. H., Sihono, S., & Nurdiansyah, Y. (2024). Karakteristik fisik selulosa dari rumput laut Chaetomorpha crassa yang diekstraksi dengan suhu yang berbeda. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *27*(11), 1074-1090.

International Organization for Standardization. (2020). ISO 10993-5:2009(en) Biological evaluation of medical devices — Part 5: Tests for in vitro cytotoxicity. In *Iso.org*. https://www.iso.org/obp/ui/#iso:std:iso:10993:-5:ed-3:v1:en

Jang, K.-S., Park, S.-J., Choi, J.-J., Kim, H.-N., Shim, K.-M., Kim, M.-J., Jang, I.-H., Jin, S.-W., Kang, S.-S., Kim, S.-E., & Moon, S.-H. (2021). Therapeutic Efficacy of Artificial Skin Produced by 3D Bioprinting. *Materials*, *14*(18), 5177. https://doi.org/10.3390/ma14185177

Jiang, X., Zhang, D., Teng, M., Zhang, Q., Zhang, J., & Huang, Y. (2013). Downregulation of CD9 in Keratinocyte Contributes to Cell Migration via Upregulation of Matrix Metalloproteinase-9. *PLoS ONE*, *8*(10), e77806. https://doi.org/10.1371/journal.pone.0077806

Kaur, P., Agrawal, R., Pfeffer, F. M., Williams, R. J., & Bohidar, H. B. (2023). Hydrogels in Agriculture: Prospects and Challenges. *Journal of Polymers and the Environment*, *31*(9), 3701–3718. https://doi.org/10.1007/s10924-023-02859-1

Kawaroe, M., Sunuddin, A., Hwangbo, B., & Shaumi, A. (2015). Characteristics and selulotic activities of endophytic fungi in macroalgae (Sargassum sp., Gracilaria sp., Gelidium sp., and Caulerpa sp.) from seagrass habitat in Pari Island, Thousand Islands, Jakarta. *International Journal of Sciences: basic and applied research*, 149-160.

Klein, T., & Bischoff, R. (2010). Physiology and pathophysiology of matrix metalloproteases. *Amino Acids*, *41*(2), 271–290. https://doi.org/10.1007/s00726-010-0689-x

Kobayashi, T., Hattori, S., Nagai, Y., Tajima, S., & Nishikawa, T. (1998). Differential Regulation of MMP-2 and MMP-9 Gelatinases in Cultured Human Keratinocytes. *Dermatology*, *197*(1), 1–5. https://doi.org/10.1159/000017967

Krishnan, L., Ravi, N., Anjon Kumar Mondal, Aktar, F., Kumar, M., Ralph, P. J., & Unnikrishnan Kuzhiumparambil. (2024). Seaweed-based polysaccharides-Review of extraction, characterization, and bioplastic application. *Green Chemistry*, *26*, 5790–5823. https://doi.org/10.1039/d3gc04009g

Lagoa, T., Queiroga, M. C., & Martins, L. (2024). An Overview of Wound Dressing Materials. *Pharmaceuticals*, *17*(9), 1110–1110. https://doi.org/10.3390/ph17091110

Lei, J., Priddy, L. B., Lim, J. J., Massee, M., & Koob, T. J. (2017). Identification of Extracellular Matrix Components and Biological Factors in Micronized Dehydrated Human Amnion/Chorion

Membrane. *Advances in Wound Care*, *6*(2), 43–53. https://doi.org/10.1089/wound.2016.0699

Li, R., Xing, R., Li, H., Ren, J., Chen, L., Yu, Z., Zhang, H., Wu, W., Li, C., Zhu, L., & Cao, X. (2025). From Terrestrial Plants to Marine Macroalgae: A Comprehensive Review of Cell Wall Component-Properties, Extraction, Modification, and Application of Algal Cellulose. *Journal of Agricultural and Food Chemistry*, *73*(38). https://doi.org/10.1021/acs.jafc.5c07001

Machado, B., Costa, S. M., Costa, I., Fangueiro, R., & Ferreira, D. P. (2024). The potential of algae as a source of cellulose and its derivatives for biomedical applications. *Cellulose*, *31*(6), 3353–3376. https://doi.org/10.1007/s10570-024-05816-w

Masoud, A. R., Velisdeh, Z. J., Jabed, M., Pandey, G., Saberian, E., & Mills, D. K. (2025). Cellulose-Based Nanofibers in Wound Dressing. *Biomimetics*, *10*(6), 344–344. https://doi.org/10.3390/biomimetics10060344

Mazurkiewicz, J., Simiczyjew, A., Dratkiewicz, E., Kot, M., Pietraszek-Gremplewicz, K., Wilk, D., Ziętek, M., Matkowski, R., & Nowak, D. (2022). Melanoma stimulates the proteolytic activity of HaCaT keratinocytes. *Cell Communication and Signaling*, *20*(1). https://doi.org/10.1186/s12964-022-00961-w

Modulevsky, D. J., Cuerrier, C. M., & Pelling, A. E. (2016). Biocompatibility of Subcutaneously Implanted Plant-Derived Cellulose Biomaterials. *PLOS ONE*, *11*(6), e0157894. https://doi.org/10.1371/journal.pone.0157894

Naomi, R., Bt Hj Idrus, R., & Fauzi, M. B. (2020). Plant- vs. Bacterial-Derived Cellulose for Wound Healing: A Review. *International Journal of Environmental Research and Public Health*, *17*(18), 6803. https://doi.org/10.3390/ijerph17186803

Naseem, S., & Rizwan, M. (2024). Seaweed-derived etherified carboxymethyl cellulose for sustainable tissue engineering. *Carbohydrate Research*, *545*, 109291. https://doi.org/10.1016/j.carres.2024.109291

Nguyen, H. M., Le, T. T. N., Nguyen, A. T., Le, H. N. T., & Pham, T. T. (2023). Biomedical materials for wound dressing: recent advances and applications. *RSC Advances*, *13*(8), 5509–5528. https://doi.org/10.1039/D2RA07673J

Nurhayati, Irianto, H. E., Supriyanto, A., Kusumawati, R., Basmal, J., Munifah, I., Setiawati, N. P., ... & Chalid, M. (2025). Isolation and Characterization of Cellulose Microfibril (MFC) from Gracilaria sp. with Different Quality Grades. *Science and Technology Indonesia*, *10*(3), 712-724.

Nuutila, K., & Eriksson, E. (2020). Moist wound healing with commonly available dressings. *Advances in Wound Care*, *10*(12). https://doi.org/10.1089/wound.2020.1232

Ozgok Kangal, M. K., & Regan, J.-P. (2018, December 4). *Wound Healing*. Nih.gov; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK535406/

Park, H. B., Yang, J. H., & Chung, K. H. (2011). Characterization of the cytokine profile of platelet rich plasma (PRP) and PRP-induced cell proliferation and migration: Upregulation of matrix metalloproteinase-1 and -9 in HaCaT cells. *The Korean Journal of Hematology*, *46*(4), 265–265. https://doi.org/10.5045/kjh.2011.46.4.265

Pastar, I., Liang, L., Sawaya, A. P., Wikramanayake, T. C., Glinos, G. D., Drakulich, S., Chen, V., Stojadinovic, O., Davis, S. C., & Tomic-Canic, M. (2018). Preclinical models for wound-healing studies. *Skin Tissue Models for Regenerative Medicine*, 223–253. https://doi.org/10.1016/b978-0-12-810545-0.00010-3

Qian, L., & Zhang, S. (2025). Gelatin Zymography: Principle, Method and Application in Cancer Research. *Methods in Molecular Biology (Clifton, N.J.)*, *2917*, 3–10. https://doi.org/10.1007/978-1-0716-4478-2_1

Ries, C., Popp, T., Egea, V., Kehe, K., & Jochum, M. (2009). Matrix metalloproteinase-9 expression and release from skin fibroblasts interacting with keratinocytes: Upregulation in response to sulphur mustard. *Toxicology*, *263*(1), 26–31. https://doi.org/10.1016/j.tox.2008.08.011

Saraswati, Giriwono, P. E., Iskandriati, D., & Andarwulan, N. (2021). Screening of In-Vitro Anti-Inflammatory and Antioxidant Activity of Sargassum ilicifolium Crude Lipid Extracts from

Different Coastal Areas in Indonesia. *Marine Drugs*, *19*(5), 252. https://doi.org/10.3390/md19050252

Schauer, N., Dinc, M., Raabe, B., Hummel, T., Müller, M., Sobek, H., & Mizaikoff, B. (2018). Selective binding of matrix metalloproteases MMP-9 and MMP-12 to inhibitor-assisted thermolysin-imprinted beads. *RSC Advances*, *8*(57), 32387–32394. https://doi.org/10.1039/c8ra04444a

Sheikholeslam, M., Wright, M. E. E., Jeschke, M. G., & Amini-Nik, S. (2018). Biomaterials for Skin Substitutes. *Advanced Healthcare Materials*, *7*(5). https://doi.org/10.1002/adhm.201700897

Silva, A., Silva, S. A., Carpena, M., Garcia-Oliveira, P., Gullón, P., Barroso, M. F., Prieto, M. A., & Simal-Gandara, J. (2020). Macroalgae as a Source of Valuable Antimicrobial Compounds: Extraction and Applications. *Antibiotics*, *9*(10), 642. https://doi.org/10.3390/antibiotics9100642

Simões, D., Miguel, S. P., Ribeiro, M. P., Coutinho, P., Mendonça, A. G., & Correia, I. J. (2018). Recent advances on antimicrobial wound dressing: A review. *European Journal of Pharmaceutics and Biopharmaceutics*, *127*, 130–141. https://doi.org/10.1016/j.ejpb.2018.02.022

Srivastava, G. K., Martinez-Rodriguez, S., Md Fadilah, N. I., Looi Qi Hao, D., Markey, G., Shukla, P., ... & Panetsos, F. (2024). Progress in wound-healing products based on natural compounds, stem cells, and microRNA-based biopolymers in the European, USA, and Asian markets: Opportunities, barriers, and regulatory issues. *Polymers, 16*(9), 1280. https://doi.org/10.3390/polym16091280

Suhartini, S., Pangestuti, M. B., Elviliana, Rohma, N. A., Junaidi, M. A., Paul, R., Nurika, I., Rahmah, N. L., & Melville, L. (2024). Valorisation of macroalgae for biofuels in Indonesia: an integrated biorefinery approach. *Environmental Technology Reviews*, *13*(1), 269–304. https://doi.org/10.1080/21622515.2024.2336894

Susanti, F., Adharini, R. I., Rahmi, K. A., Kartika Sari, D. W., & Kandasamy, G. (2022). Identification of Gracilaria spp. in Gunungkidul Regency, Yogyakarta Indonesia Based on DNA Barcoding Target

Cytochrome Oxidase Subunit 1. *ILMU KELAUTAN: Indonesian Journal of Marine Sciences*, *27*(3).

Tajhya, R. B., Patel, R. S., & Beeton, C. (2017). Detection of Matrix Metalloproteinases by Zymography. *Methods in Molecular Biology*, 231–244. https://doi.org/10.1007/978-1-4939-6863-3_12

Tottoli, E. M., Dorati, R., Genta, I., Chiesa, E., Pisani, S., & Conti, B. (2020). Skin Wound Healing Process and New Emerging Technologies for Skin Wound Care and Regeneration. *Pharmaceutics*, *12*(8), 735. https://doi.org/10.3390/pharmaceutics12080735

Vasilakis, G., Marka, S., Ntzouvaras, A., Zografaki, M.-E., Kyriakopoulou, E., Kalliampakou, K. I., Bekiaris, G., Korakidis, E., Papageorgiou, N., Christofi, S., Vassilaki, N., Moschopoulou, G., Tzovenis, I., Economou-Amilli, A., Papanikolaou, S., & Flemetakis, E. (2025). Wound Healing, Antioxidant, and Antiviral Properties of Bioactive Polysaccharides of Microalgae Strains Isolated from Greek Coastal Lagoons. *Marine Drugs*, *23*(2), 77–77. https://doi.org/10.3390/md23020077

Wallace, H. A., Zito, P. M., & Basehore, B. M. (2023). *Wound Healing Phases*. Nih.gov; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK470443/

Wang, X., Qi, J., Zhang, W., Pu, Y., Yang, R., Wang, P., Liu, S., Tan, X., & Chi, B. (2021). 3D-printed antioxidant antibacterial carboxymethyl cellulose/ε-polylysine hydrogel promoted skin wound repair. *International Journal of Biological Macromolecules*, *187*, 91–104. https://doi.org/10.1016/j.ijbiomac.2021.07.115

Wechselberger, C., Doppler, C., & Bernhard, D. (2019). An Inexpensive Staining Alternative for Gelatin Zymography Gels. *Methods and Protocols*, *2*(3), 61. https://doi.org/10.3390/mps2030061

Widyaswari, S. G., Metusalach, M., Kasmiati, K., & Amir, N. (2024). Bioactive compounds and DPPH antioxidant activity of underutilized macroalgae (Sargassum spp.) from coastal water of Makassar, Indonesia. *Biodiversitas Journal of Biological Diversity*, *25*(1).

Wilkinson, H. N., & Hardman, M. J. (2020). Wound healing: Cellular Mechanisms and Pathological Outcomes. *Open Biology*, *10*(9). https://doi.org/10.1098/rsob.200223

Wodziński, D., Wosiak, A., Pietrzak, J., Świechowski, R., Kordek, R., & Balcerczak, E. (2022). Assessment of the TGFB1 gene expression and methylation status of the promoter region in patients with colorectal cancer. *Scientific Reports*, *12*(1), 11488. https://doi.org/10.1038/s41598-022-15599-4

Yang, G., Zhang, Z., Liu, K., Ji, X., Fatehi, P., & Chen, J. (2022). A cellulose nanofibril-reinforced hydrogel with robust mechanical, self-healing, pH-responsive and antibacterial characteristics for wound dressing applications. *Journal of Nanobiotechnology*, *20*(1). https://doi.org/10.1186/s12951-022-01523-5

Yousefian, F., Hesari, R., Jensen, T., Obagi, S., Rgeai, A., Damiani, G., Bunick, C. G., & Grada, A. (2023). Antimicrobial Wound Dressings: A Concise Review for Clinicians. *Antibiotics (Basel, Switzerland)*, *12*(9), 1434. https://doi.org/10.3390/antibiotics12091434

Zanchetta, E., Mercier, B., Frabboni, M., Damergi, E., Ludwig, C., & Pick, H. (2025). Purification of Cellulose and Chitin Polymers and Other Value-Added Products from the Microalga Chlorella vulgaris Using a Green Biorefinery Process. *Fermentation*, *11*(3), 120–120. https://doi.org/10.3390/fermentation11030120