

BAB 5

KESIMPULAN DAN SARAN

5.1 Kesimpulan

1. Penambahan keratin meningkatkan kekuatan tarik dan daya lekat hidrogel, namun menurunkan daya sebar akibat viskositas yang semakin tinggi. Formula dengan keratin 0,6% menghasilkan sifat mekanik paling optimal, ditandai dengan film yang tebal dan kuat.
2. Peningkatan konsentrasi keratin menyebabkan penurunan kapasitas *swelling* dan daya serap air karena struktur gel menjadi lebih rapat. Formula dengan keratin 0,6% menunjukkan *swelling* paling rendah, menandakan kerapatan jaringan polimernya paling tinggi.

5.2 Saran

1. Perlu dilakukan penelitian mengenai efektivitas hidrogel *peel-off* dengan bahan aktif keratin dalam mempercepat penyembuhan luka dan menjaga kelembapan kulit dan dibandingkan dengan kelompok kontrol.

DAFTAR PUSTAKA

- Abbaszadeh, A., MacNaughtan, W., Sworn, G., & Foster, T. J. 2016, New insights into xanthan synergistic interactions with konjac glucomannan: A novel interaction mechanism proposal. *Carbohydrate polymers*, 144, 168–177. <https://doi.org/10.1016/j.carbpol.2016.02.026>
- Aluigi, A., Tonetti, C., Vineis, C., Tonin, C. and Mazzuchetti, G. 2015, Keratin-based biomaterials for biomedical applications, *Journal of Biobased Materials and Bioenergy*, 5(1): 1–11.
- Alves, N. M., & Mano, J. F. 2020, Polysaccharide-based materials for biomedical applications, *Carbohydrate Polymers*, 229, 115551. <https://doi.org/10.1016/j.carbpol.2019.115551>
- Bahram, M., Mohseni, N. and Moghtader, M. 2016, An introduction to hydrogels and some recent applications, *Emergent Materials Research*, 5(1): 1–15.
- Baghaie, S., Khorasani, M.T. and Zarrabi, A. 2017, Wound healing properties of PVA/starch/chitosan hydrogel membranes containing silver sulfadiazine, *International Journal of Biological Macromolecules*, 104:345–354.
- Bashir, S., Hina, M., Iqbal, J., Rajpar, A. H., Mujtaba, M. A., Alghamdi, N. A., Wageh, S., Ramesh, K., & Ramesh, S. 2020, Fundamental Concepts of Hydrogels: Synthesis, Properties, and Their Applications. *Polymers*, 12(11), 2702. <https://doi.org/10.3390/polym12112702>
- Bayan, M.F., Chandrasekaran, B. and Alyami, M.H. 2023, Development and characterization of econazole topical gel, *Gels*, 9(12):.929.
- Behera, S. S., & Ray, R. C. 2017, Nutritional and potential health benefits of Konjac Glucomannan A Promising Polysaccharide of Elephant Foot Yam, *Amorphophallus konjac* K. Koch: A review, *Taylor and Francis Inc*, 33(1) :22–43.
- Burnett, C.L., Bergfeld, W.F., Belsito, D.V., Hill, R.A., Klaassen, C.D., Liebler, D.C., Marks Jr, J.G., Shank, R.C., Slaga, T.J., Snyder, P.W. and Gill, L.J. 2021, Safety assessment of keratin and keratin-derived ingredients as used in cosmetics. *International journal of toxicology*, 40(2), pp.36S-51S.

- Cao, L., Lu, W., Mata, A., Nishinari, K., & Fang, Y. 2020, Egg-box model-based gelation of alginate and pectin: A review, *Carbohydrate polymers*, 242, 116389. <https://doi.org/10.1016/j.carbpol.2020.116389>
- Caló, E., & Khutoryanskiy, V. V. 2015, Biomedical applications of hidrogels: A review of patents and commercial products, *European Polymer Journal*, 65, 252–267. <https://doi.org/10.1016/j.eurpolymj.2014.11.024>
- Candi, E., Schmidt, R. & Melino, G. 2005, The cornified envelope: a model of cell death in the skin, *Nature Reviews Molecular Cell Biology*, 6(4), pp.328–340.
- Delfi, M., Ghomi, M., Zarrabi, A., Mohammadinejad, R., Taraghdari, Z. B., Ashrafizadeh, M., Zare, E. N., Agarwal, T., Padil, V. V. T., Mokhtari, B., Rossi, F., Perale, G., Sillanpaa, M., Borzacchiello, A., Kumar Maiti, T., & Makvandi, P. 2020, Functionalization of Polymers and Nanomaterials for Biomedical Applications: Antimicrobial Platforms and Drug Carriers. *Prosthesis*, 2(2), 117-139. <https://doi.org/10.3390/prosthesis2020012>
- Dodda, J.M., Deshmukh, K., Bezuidenhout, D. and Yeh, Y.C. 2023, Hidrogels: definition, history, classifications, formation, constitutive characteristics, and applications.
- Feroz, S., Muhammad, N., Ranayake, J., & Dias, G. 2020, Keratin - Based materials for biomedical applications, *Bioactive materials*, 5(3), 496–509. <https://doi.org/10.1016/j.bioactmat.2020.04.007>
- Huang, Y.C., Chu, H.W., Huang, C.C., Wu, W.C., & Tsai, J.-S. 2015, Alkali-treated konjac glucomannan film as a novel wound dressing. *Carbohydrate Polymers*, 117: 778–787. <https://doi.org/10.1016/j.carbpol.2014.10.033>
- I. Setiawan, N. Y. Lindawati, and B. Amalia. 2016, Formulasi dan Uji Antiinflamasi Sediaan Hidrogel Ekstrak Jahe Merah, *Media Farm. Indonesia*, 13(1) :1330–1334
- Jayakumar, R., Prabakaran, M., Sudheesh Kumar, P. T., Nair, S. v., & Tamura, H. 2011, Biomaterials based on chitin and chitosan in wound dressing applications, *Biotechnology Advances*, 29(3): 322–337.
- Kalia, S., & Roy Choudhury, A. 2019, Synthesis and rheological studies of a novel composite hidrogel of xanthan, gellan and

- pullulan, *International journal of biological macromolecules*, 137: 475–482. <https://doi.org/10.1016/j.ijbiomac.2019.06.212>
- Kim, S.Y., Park, B.J., Lee, Y., Park, N.J., Park, K.M., Hwang, Y.S. and Park, K.D. 2019, Human hair keratin-based hidrogels as dynamic matrices for facilitating wound healing, *Journal of Industrial and Engineering Chemistry*, 73:142-151.
- Kjeldahl, J. 1883, New method for the determination of nitrogen in organic substances, *Zeitschrift für analytische Chemie*, 22 (1): 366-383.
- Konop, M., Rybka, M., & Drapała, A. 2021, Keratin Biomaterials in Skin Wound Healing, an Old Player in Modern Medicine: A Mini Review. *Pharmaceutics*, 13(12), 2029, <https://doi.org/10.3390/pharmaceutics13122029>
- Kuo, C. K., & Ma, P. X. 2001, Ionically crosslinked alginate hidrogels as scaffolds for tissue engineering: part 1. Structure, gelation rate and mechanical properties. *Biomaterials*, 22(6), 511–521, [https://doi.org/10.1016/s0142-9612\(00\)00201-5](https://doi.org/10.1016/s0142-9612(00)00201-5)
- Langbein, L., Rogers, M.A., Winter, H., Praetzel, S., Beckhaus, U., Rackwitz, H.R. & Schweizer, J. 1999, The catalog of human hair keratins: I. Expression of the nine type I members in the hair follicle, *Journal of Biological Chemistry*, 274(28): 19874–19884.
- Langbein, L. & Schweizer, J. 2005, Keratins of the human hair follicle, *International Review of Cytology*, 243: 1–78.
- Li, J. and Mooney, D.J. 2016, Designing hidrogels for controlled drug delivery. *Nature Reviews Materials*, 6(9): 678–693.
- Li, X., Yang, D., Zhu, J., Liu, Y., Zhao, T. and Wang, Z. 2024, Polyvinyl Alcohol (PVA)-Based Hidrogels: Recent Progress in Fabrication, Properties, and Multifunctional Applications. *Polymers*, 16(19): 2755. [doi:10.3390/polym16192755](https://doi.org/10.3390/polym16192755)
- Liu, Z., & Yao, P. 2015, Injectable thermo-responsive hidrogel composed of xanthan gum and methylcellulose double networks with shear-thinning property, *Carbohydrate polymers*, 132: 490–498. <https://doi.org/10.1016/j.carbpol.2015.06.013>
- Lee, K. Y., & Mooney, D. J. 2012, Alginate: properties and biomedical applications. *Progress in polymer science*, 37(1): 106–126. <https://doi.org/10.1016/j.progpolymsci.2011.06.003>

- Lee, K. Z., Jeon, J., Jiang, B., Subramani, S. V., Li, J., & Zhang, F. 2023, Protein-Based Hidrogels and Their Biomedical Applications. *Molecules*, 28(13):4988
- Lee, Y.J., Rice, R.H. and Lee, Y.M. 2006, Proteome analysis of human hair shaft: from protein identification to posttranslational modification, *Molecular and cellular proteomics*, 5(5): 789-800.
- Lv, Q., Wu, M. and Shen, Y. 2019, Enhanced swelling ratio and water retention capacity for novel super-absorbent hydrogel, *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 583: 123-972.
- Ma, J., Wang, P., Tang, C., Liao, H., Zhang, W., Yang, R., Shi, T., Tan, X., & Chi, B. 2022, Injectable shear-thinning sodium alginate hydrogels with sustained submucosal lift for endoscopic submucosal dissection, *International journal of biological macromolecules*, 223: 939–949. <https://doi.org/10.1016/j.ijbiomac.2022.11.103>
- Marwah, H., Garg, T., Goyal, A. K., & Rath, G. 2016, Permeation enhancer strategies in transdermal drug delivery, *In Drug Delivery Taylor and Francis Ltd*, 23(2): 564–578.
- Martin, Y.H., Lali, F.V. & Metcalfe, A.D. 2016, Modelling wound healing, in *wound healing biomaterials*, 1: 151-170.
- Mikušová, V., Ferková, J., Žigayová, D., Krchňák, D. and Mikuš, P. 2022, Comparative study of polysaccharide-based hydrogels: Rheological and texture properties and ibuprofen release, *Gels*, 8(3):168
- Mina, R., Ali, A., McConnell, M., & Cabral, J. 2020, Keratinous materials: Structures and functions in biomedical applications, *Materials Science and Engineering: C*, 110: 1106. <https://doi.org/10.1016/j.msec.2019.110612>
- Moll, R., Divo, M., & Langbein, L. 2008, The human keratins: biology and pathology. *Histochemistry and cell biology*, 129(6): 705–733. <https://doi.org/10.1007/s00418-008-0435-6>
- Naga, M. S., Helal, H. M., Kamoun, E. A., Moaty, M. A., Omar, S. S. A. R., Ghareeb, A. Z., El-Fakharany, E. M., & El Din, M. M. 2025, Laboratory performance of novel injectable keratin nanoparticle from poultry feathers loaded-alginate composite hydrogel as a pulpotomy filling biomaterial for dentin regeneration. *BMC Oral Health*, 25(1): 1377, <https://doi.org/10.1186/s12903-025-06535-9>.

- Nsengiyumva, E. M., & Alexandridis, P. 2022, Xanthan gum in aqueous solutions: Fundamentals and applications, *International journal of biological macromolecules*, 216: 583–604. <https://doi.org/10.1016/j.ijbiomac.2022.06.189>.
- Oliveira, N., Cádiz-Gurrea, M. d. l. L., Silva, A. M., Macedo, C., Rodrigues, F., & Costa, P. 2022, Development and Optimization of a Topical Formulation with *Castanea sativa* Shells Extract Based on the Concept “Quality by Design”. *Sustainability*, 14(1), 129. <https://doi.org/10.3390/su14010129>
- Olson, B. J. S. C. 2016, Assays for determination of protein concentration. *Current Protocols in Pharmacology*.
- Peña-Juárez, M. C., Guadarrama-Escobar, O. R., & Escobar-Chávez, J. J., 2022, Transdermal Delivery Systems for Biomolecules. *Journal of pharmaceutical innovation*, 17(2): 319–332. <https://doi.org/10.1007/s12247-020-09525-2>
- Percival, S.L., McCarty, S., Hunt, J.A. and Woods, E.J. 2014, The effects of pH on wound healing, biofilms, and antimicrobial efficacy, *Wound repair and regeneration*, 22(2): 174-186.
- Qiu, J., Wilkens, C., Barrett, K., & Meyer, A. S., 2020, Microbial enzymes catalyzing keratin degradation: Classification, structure, function. *Biotechnology advances*, 44, 107607. <https://doi.org/10.1016/j.biotechadv.2020.107607>.
- Rahmi, A. and Yusuf, A. L., 2024, Formulation and Evaluation of Peel-Off Gel Mask with Tomato Fruit Extract Using PVA Base, Ad-Dawaa: *Journal of Pharmacy*, 2(1): 58–64. doi:10.52221/dwj.v2i1.731
- Rajabi, M., Ali, A., McConnell, M., & Cabral, J. 2020, Keratinous materials: Structures and functions in biomedical applications, *Materials science & engineering. C, Materials for biological applications*, 110, 110612. <https://doi.org/10.1016/j.msec.2019.110612>
- Remoué, N., Bonod, C., Fromy, B. and Sigaudou-Roussel, D., 2020, Animal models in chronic wound healing research: for innovations and emerging technologies in wound care, *Innovations and emerging technologies in wound care*, pp.197-224.
- Ren, Y., Wang, Q., Xu, W., Yang, M., Guo, W., He, S., & Liu, W. 2024, Alginate-based hidrogels mediated biomedical applications: A

- review, *International journal of biological macromolecules*, 279(1), 135019. <https://doi.org/10.1016/j.ijbiomac.2024.135019>.
- Sari, R., Erawati, T., Fauziah, F. and Yuniarti, W.M. 2019, Formulation, physical characterization and wound healing activity evaluation of carboxymethyl chitosan-curcumin carbomer-based hidrogel, *International Journal of Drug Delivery Technology*, 9(4): 697-703.
- Shahbudin, N. A., *et al.* 2014, Potential of konjac glucomannan-based hidrogel in wound healing: A preliminary in vitro study, *Journal of Biomaterials and Tissue Engineering*, 4(10): 812–817.
- Shavandi, A., Silva, T.H., Bekhit, A.A. and Bekhit, A.E.D. 2017, Keratin: dissolution, extraction and biomedical application. *Biomaterials Science*, 5(9), pp.1699–1735.
- Shubha, A., Sharmita, G. & Manaswi, R. 2024, Recent advances in preparation and biomedical applications of keratin based biomaterials, *Biotechnology for Sustainable Materials*, 1, p.16. <https://doi.org/10.1186/s44316-024-00016-9>.
- Sievers, J., Sperlich, K., Stahnke, T., Kreiner, C., Eickner, T., Martin, H., Guthoff, R. F., Schünemann, M., Bohn, S., & Stachs, O. 2021, Determination of hidrogel swelling factors by two established and a novel non-contact continuous method, *Journal of Applied Polymer Science*, 138(18).
- Sorg, H., Tilkorn, D. J., Hager, S., Hauser, J., & Mirastschijski, U. 2017, Skin Wound Healing: An Update on the Current Knowledge and Concepts. *European Surgical Research* 58(1) : 81–94.
- Strnad, S., Oberhollenzer, Z., Sauperl, O., Kreze, T. and Zemljic, L.F. 2019, Modifying properties of feather keratin bioplastic films using konjac glucomannan, *Cellulose Chemistry and Technology*, 53(9): 1017-1027.
- Supe, S., & Takudage, P. 2021, Methods for evaluating penetration of drug into the skin: A review, In *Skin Research and Technology*, 27(3): 299–308.
- Tanjung, R. P., & Rokaeti, A. 2020, Formulasi dan Uji Aktivitas Masker Gel Peel-Off Ekstrak Etanol Bunga Telang (*Clitoria ternatea* L.) sebagai Antioksidan, *Jurnal Riset Farmasi*, 2(2): 79-87.

- Tomblynn, S., Pettit Kneller, E. L., Walker, S. J., Ellenburg, M. D., Kowalczewski, C. J., Van Dyke, M., Burnett, L., & Saul, J. M. 2016, Keratin hidrogel carrier system for simultaneous delivery of exogenous growth factors and muscle progenitor cells, *Journal of biomedical materials research. Part B, Applied biomaterials*, 104(5): 864–879. <https://doi.org/10.1002/jbm.b.33438>
- Vo, T.S., Vo, T.T.B.C., Tran, T.T. and Pham, N.D. 2022, Enhancement of water absorption capacity and compressibility of hidrogel sponges prepared from gelatin/chitosan matrix with different polyols, *Progress in Natural Science: Materials International*, 32(1), pp.54-62.
- Waje, S. S., Meshram, M. W., Chaudhary, V., Pandey, R. Mahanawar, P. A., Thorat, B. N. Drying and shrinkage of polymer gels. *Brazilian Journal of Chemical Engineering*, 22(2):209-216. 2005.
- Walker JM. 2009, Buku Pegangan Protokol Protein, Edisi Ketiga, Springer-Verlag New York, LLC.
- Wang, S., Taraballi, F., Tan, L.P. and Ng, K.W. 2015, Human keratin hidrogels support fibroblast attachment and proliferation in vitro, *Cell and Tissue Research*, 358(3): 763–773.
- Wei, L., Zhu, S., Yang, H., Liao, Z., Gong, Z., Zhao, W., Li, Y., Gu, J., Wei, Z., & Yang, J. 2022, Keratin-Based Composite Bioactive Films and Their Preservative Effects on Cherry Tomato. *Molecules (Basel, Switzerland)*, 27(19), 6331. <https://doi.org/10.3390/molecules27196331>
- Yalçın, D. and Top, A. 2024, Evaluation of Partially Reduced Keratins Extracted from Wool Fibers as a Hidrogel Forming Biomaterial, *Brazilian Archives of Biology and Technology*, 67, p.e24231028
- Ye, W., Qin, M., Qiu, R., & Li, J. 2022, Keratin-based wound dressings: From waste to wealth. *International journal of biological macromolecules*, 211, 183–197. <https://doi.org/10.1016/j.ijbiomac.2022.04.216>
- Yue, K., Liu, Y., Byambaa, B., Singh, V., Liu, W., Li, X., Sun, Y., Zhang, Y. S., Tamayol, A., Zhang, P., Ng, K. W., Annabi, N., & Khademhosseini, A. 2018, Visible light crosslinkable human hair keratin hidrogels, *Bioengineering & translational medicine*, 3(1), 37–48, <https://doi.org/10.1002/btm2.10077>.

- Yu, Y., Yang, W., Wang, B., & Meyers, M. A. 2017, Structure and mechanical behavior of human hair. *Materials science & engineering. C, Materials for biological applications*, 73: 152–163. <https://doi.org/10.1016/j.msec.2016.12.008>
- Zhang, C., Liu, K., He, Y., Chang, R., Guan, F. and Yao, M. 2023, A multifunctional hidrogel dressing with high tensile and adhesive strength for infected skin wound healing in joint regions, *Journal of Materials Chemistry B*, 11(46): 11135-11149.
- Zhou, N., Zheng, S., Xie, W., Cao, G., Wang, L., & Pang, J. 2022, Konjac glucomannan: A review of structure, physicochemical properties, and wound dressing applications, *Journal of Applied Polymer Science*, 139.