BAB V
KESIMPULAN DAN SARAN

Berdasarkan hasil uji yang telah dilakukan, ditarik kesimpulan yang terlampir pada Tabel V.1. secara umum penambahan ZIF-8 serta nanopartikel perak baik AgNW maupun AgND menambah sifat antibakteri pada bioplastik tanpa mengubah morfologi bioplastik. Selain itu, dapat disimpulkan juga bahwa berdasarkan hasil percobaan yang didapatkan, bioplastik 500 ND@ZIF merupakan variasi bioplastik yang paling baik daripada bioplastik yang dihasilkan dalam penelitian ini. Bioplastik 500 ND@ZIF memperoleh hasil yang lebih baik pada uji kandungan air, permeabilitas uap air, biodegradasi, aktivitas antimikroba, dan uji pengemasan makanan. Meskipun begitu, bioplastik yang telah dibuat tidak dapat menyimpan makanan dalam waktu yang lama terlebih pada makanan yang mengandung kadar air yang tinggi. Selain itu, bioplastik juga dapat dengan mudah terdegradasi dikarenakan sifatnya yang dapat larut dalam air. Oleh karena itu, sebaiknya pengemasan makanan dengan menggunakan bioplastik tidak diaplikasikan pada makanan yang mengandung kadar air yang tinggi, agar makanan tidak terkontaminasi oleh bioplastik yang hancur.

Saran untuk penelitian selanjutnya adalah agar dapat melakukan uji elastisitas dan meningkatkan kestabilan suhu bioplastik apabila bioplastik tersebut memang ditujukan sebagai bahan kemasan makanan. Hal tersebut cukup penting karena apabila makanan yang dikemas menggunakan bioplastik akan dihangatkan

menggunakan *microwave* maka bioplastik tersebut tentunya harus dapat bertahan pada suhu yang tinggi. Sebaliknya, apabila makanan tersebut akan disimpan di lemari es maka bioplastik juga harus dapat bertahan pada suhu yang sangat rendah. Selain itu, diperlukan juga penelitian lebih lanjut untuk pengecekan terhadap kemampuan *toxicity* bioplastik apabila digunakan sebagai bahan kemasan makanan serta untuk efektifitas AgNW dan AgND terhadap jenis bakteri gram positif dan negatif.

Tabel V.1. Kesimpulan Hasil Uji Bioplastik

Variasi Bioplastik	Uji *Swelling* (%)	Uji Kelarutan (% massa hilang)	Uji Kandungan Air (%)	Uji Permeabilitas Uap Air (g. mm. m^{-2}. $hari^{-1}$)	Uji Biode-gradasi (hari ke-)	Uji Aktivitas Antimikroba (Pengenceran ke-6, CFU/mL)		Uji Kemasan Makanan (% penurunan massa roti)	Uji *contact angle* (°)
						E. coli	*S. aureus*		
Polos	769,00	98,56	28,12	0,0001000	7	$2,4\times10^{8}$	$1,26\times10^{9}$	9,6192	55,39
150 NW	463,77	97,26	27,10	0,0000690	21	$2,4\times10^{8}$	5×10^{7}	14,9067	61,2
300 NW	575,36	95,58	25,49	0,0000618	21	$1,1\times10^{8}$	2×10^{7}	12,4129	76,36
500 NW	624,74	93,02	27,46	0,0000400	14	1×10^{7}	0	17,4916	75,3
150 ND	556,87	92,74	25,73	0,0000482	7	5×10^{7}	$1,42\times10^{9}$	9,5304	78,79
300 ND	598,85	94,20	23,87	0,0000383	21	5×10^{7}	$1,16\times10^{9}$	15,7742	67,8
500 ND	379,03	82,07	25,69	0,0000373	21	0	4×10^{8}	12,0226	66,6
ZIF-8	553,45	89,09	24,05	0,0000248	7	0	6×10^{7}	11,7353	109,6
150 NW@ZIF	472,83	84,82	25,68	0,0000385	30	2×10^{7}	$1,09\times10^{9}$	13,5772	81,53
300 NW@ZIF	531,45	81,32	25,43	0,0000375	30	0	$2,8\times10^{8}$	11,0494	90,3
500 NW@ZIF	556,51	79,37	24,34	0,0000321	30	1×10^{7}	$3,4\times10^{8}$	15,0281	93,51
150 ND@ZIF	703,94	74,15	31,08	0,0000193	7	0	4×10^{7}	10,0941	94,42
300 ND@ZIF	495,59	78,69	28,63	0,0000175	7	0	1×10^{7}	15,2501	95,41
500 ND@ZIF	419,69	89,52	26,86	0,0000129	21	1×10^{7}	6×10^{7}	9,5234	77,54

DAFTAR PUSTAKA

1. A. Okunola A, O. Kehinde I, A. Oluwaseun, and A. Olufiropo E, "Public and Environmental Health Effects of Plastic Wastes Disposal: A Review," *J. Toxicol. Risk Assess.*, vol. 5, no. 2, 2019.
2. P. Purwaningrum, "Upaya Mengurangi Timbulan Sampah Plastik Di Lingkungan," *Indones. J. Urban Environ. Technol.*, vol. 8, no. 2, p. 141, 2016.
3. B. A. Harsojuwono and I. W. Arnata, "Teknologi Polimer Industri Pertanian," *Teknol. Polim.*, p. 108, 2015.
4. S. K, "Negative Impacts of Plastic Pollution A Major Threat To Our Environment," *Oceanogr. Fish. Open access J.*, vol. 8, no. 2, pp. 8–10, 2018.
5. Y. Tokiwa, B. P. Calabia, C. U. Ugwu, and S. Aiba, "Biodegradability of plastics," *Int. J. Mol. Sci.*, vol. 10, no. 9, pp. 3722–3742, 2009.
6. B. G. R., J. Jeevitha R. S., and A. T. Booshan S., "Polyvinyl alcohol/starch/carboxymethyl cellulose ternary polymer blends: synthesis, characterization and thermal properties," *Int J Curr Res Chem Pharm Sci*, vol. 3, pp. 43–50, 2016.
7. M. A. Budiman, Uju, and K. Tarman, "A Review on the difference of physical and mechanical properties of bioplastic from seaweed hydrocolloids with various plasticizers," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 967, no. 1, 2022.
8. K. Nisah, "Pembuatan Plastik Biodegradable Dari Polimer Alam," *Elkawnie*, vol. 4, no. 2, 2018.

9. M. S. Yasinta *et al.*, “Dual function of silver nanoparticles as matrix extracell removal and antimicrobial agent in polymycrobial biofilms,” *Indones. J. Chem.*, vol. 21, no. 2, pp. 286–295, 2021.
10. A. Bratovcic, A. Odobasic, S. Catic, and I. Sestan, “Application of polymer nanocomposite materials in food packaging,” *Croat. J. Food Sci. Technol.*, vol. 7, no. 2, pp. 86–94, 2015.
11. A. U. Ortiz, A. P. Freitas, A. Boutin, A. H. Fuchs, and F. X. Coudert, “What makes zeolitic imidazolate frameworks hydrophobic or hydrophilic? the impact of geometry and functionalization on water adsorption,” *Phys. Chem. Chem. Phys.*, vol. 16, no. 21, pp. 9940–9949, 2014.
12. A. Yuniari, “Morfologi Sifat Fisika Polipaduan Low Density Polyethylene-pati Tergrafting Maleat Ahidrat,” *Indones. J. Ind. Res.*, vol. 5, no. 3, pp. 239–247, 2011.
13. R. Geyer, J. R. Jambeck, and K. L. Law, “Production, use, and fate of all plastics ever made [Producción, uso y destino de todos los plásticos jamás fabricados],” *Sci. Adv.*, vol. 3, no. 7, p. e1700782, 2017.
14. T. S. Hebner and M. A. Maurer-Jones, “Characterizing microplastic size and morphology of photodegraded polymers placed in simulated moving water conditions,” *Environ. Sci. Process. Impacts*, vol. 22, no. 2, pp. 398–407, 2020.
15. A. Sa and Y. Trihadiningrum, “Kajian Fragmentasi Low Density Polyethylene Akibat Radiasi Sinar Ultraviolet dan Kecepatan,” vol. 9, no. 2, 2020.

16. Sivakumar, “Negative Impacts of Plastic Pollution A Major Threat To Our Environment,” *Oceanogr. Fish. Open access J.*, vol. 8, no. 2, pp. 8–10, 2018.
17. Y. Bow, Zulkarnain, S. P. Lestari, S. R. M. Sihombing, S. A. Kharissa, and Y. A. Salam, “Pengolahan Sampah Low denstity polypropylene (PP) Menjadi Bahan Bakar Cair Alternatif menggunakan Prototipe Pirolisis Thermal Cracking,” *J. Politek. Negeri Sriwij. Kinet.*, vol. 9, no. 03, pp. 1–6, 2018.
18. United Nations Environment Programme, *Pollution to Solution: A global assessment of marine litter and plastic pollution.*, 10, 2021.
19. I. S. Sidek, S. F. S. Draman, S. R. S. Abdullah, and N. Anuar, “Current Development on Bioplastics and Its Future Prospects: an Introductory Review,” *INWASCON Technol. Mag.*, vol. 1, pp. 03–08, 2019.
20. Waryat, M. Romli, A. Suryani, I. Yuliasih, and S. J. A. Nasiri, “Karakteristik Mekanik, Permeabilitas Dan Biodegrabilitas Plastik Biodegradable Berbahan Baku Komposit Pati Termoplastik-Lldpe,” *J. Agroindustrial Technol.*, vol. 23, no. 2, pp. 153–163, 2013.
21. S. Sumimi, F. Diba, N. Nurhaida, and D. Setyawati, “Kualitas papan komposit kulit batang sagu (Metroxylon sp) dan limbah plastik polipropilena berdasarkan penambahan compatibilizer,” *J. Hutan Lestari*, vol. 4, no. 4, pp. 570–579, 2016.
22. S. Hidayati, Zulferiyenni, U. Maulidia, W. Satyajaya, and S. Hadi, “Effect of glycerol concentration and carboxy methyl

cellulose on biodegradable film characteristics of seaweed waste," *Heliyon*, vol. 7, no. 8, p. e07799, 2021.

23. M. Rinaudo, "Biomaterials based on a natural polysaccharide: alginate," *Tip*, vol. 17, no. 1, pp. 92–96, 2014.
24. J. Zheng, R. Zeng, F. Zhang, and J. Kan, "Effects of sodium carboxymethyl cellulose on rheological properties and gelation behaviors of sodium alginate induced by calcium ions," *Lwt*, vol. 103, no. January, pp. 131–138, 2019.
25. Y. Han, M. Yu, and L. Wang, "Physical and antimicrobial properties of sodium alginate/carboxymethyl cellulose films incorporated with cinnamon essential oil," *Food Packag. Shelf Life*, vol. 15, no. October 2016, pp. 35–42, 2017.
26. R. Ramakrishnan and S. V. Kulandhaivelu, "Preparation and properties of sodium alginate/carboxymethyl cellulose films for packaging application," *Chiang Mai J. Sci.*, vol. 48, no. 6, pp. 1634–1644, 2021.
27. S. Roy and J. W. Rhim, "Carboxymethyl cellulose-based antioxidant and antimicrobial active packaging film incorporated with curcumin and zinc oxide," *Int. J. Biol. Macromol.*, vol. 148, pp. 666–676, 2020.
28. S. Ni, H. Zhang, H. Dai, and H. Xiao, "Starch-based flexible coating for food packaging paper with exceptional hydrophobicity and antimicrobial activity," *Polymers (Basel).*, vol. 10, no. 11, 2018.
29. Y. He, H. Li, X. Fei, and L. Peng, "Carboxymethyl cellulose/cellulose nanocrystals immobilized silver nanoparticles

as an effective coating to improve barrier and antibacterial properties of paper for food packaging applications," *Carbohydr. Polym.*, vol. 252, no. September, p. 117156, 2021.

30. B. He, W. Wang, Y. Song, Y. Ou, and J. Zhu, "Structural and physical properties of carboxymethyl cellulose/gelatin films functionalized with antioxidant of bamboo leaves," *Int. J. Biol. Macromol.*, vol. 164, pp. 1649–1656, 2020.
31. D. Ariyani, E. Puryati Ningsih, and S. Sunardi, "Pengaruh Penambahan Carboxymethyl Cellulose Terhadap Karakteristik Bioplastik Dari Pati Ubi Nagara (Ipomoea batatas L.)," *Indo. J. Chem. Res.*, vol. 7, no. 1, pp. 77–85, 2019.
32. Y. Han and L. Wang, "Sodium alginate/carboxymethyl cellulose films containing pyrogallic acid: physical and antibacterial properties," *J. Sci. Food Agric.*, vol. 97, no. 4, pp. 1295–1301, 2017.
33. S. Tang and J. Zheng, "Antibacterial Activity of Silver Nanoparticles: Structural Effects," *Adv. Healthc. Mater.*, vol. 7, no. 13, pp. 1–10, 2018.
34. S. Kumar, A. Shukla, P. P. Baul, A. Mitra, and D. Halder, "Biodegradable hybrid nanocomposites of chitosan/gelatin and silver nanoparticles for active food packaging applications," *Food Packag. Shelf Life*, vol. 16, no. March, pp. 178–184, 2018.
35. Y. F. Guo *et al.*, "Facile synthesis of Ag@ZIF-8 core-shell heterostructure nanowires for improved antibacterial activities," *Appl. Surf. Sci.*, vol. 435, pp. 149–155, 2018.
36. J. Helmlinger *et al.*, "Silver nanoparticles with different size and

shape: Equal cytotoxicity, but different antibacterial effects," *RSC Adv.*, vol. 6, no. 22, pp. 18490–18501, 2016.

37. R. S. Jones, R. R. Draheim, and M. Roldo, "Silver nanowires: Synthesis, antibacterial activity and biomedical applications," *Appl. Sci.*, vol. 8, no. 5, 2018.
38. S. Azlin-Hasim, M. C. Cruz-Romero, T. Ghoshal, M. A. Morris, E. Cummins, and J. P. Kerry, "Application of silver nanodots for potential use in antimicrobial packaging applications," *Innov. Food Sci. Emerg. Technol.*, vol. 27, pp. 136–143, 2015.
39. E. E. Sann, Y. Pan, Z. Gao, S. Zhan, and F. Xia, "Highly Hydrophobic ZIF-8 Particles and Application for Oil-Water Separation," *Sep. Purif. Technol.*, vol. 206, no. April, pp. 186–191, 2018.
40. X. Zheng *et al.*, "Robust ZIF-8/alginate fibers for the durable and highly effective antibacterial textiles," *Colloids Surfaces B Biointerfaces*, vol. 193, no. February, pp. 1–7, 2020.
41. S. Lee *et al.*, "The study of zeolitic imidazolate framework (ZIF-8) doped polyvinyl alcohol/starch/methyl cellulose blend film," *Polymers (Basel).*, vol. 11, no. 12, 2019.
42. M. Taheri *et al.*, "Stability of ZIF-8 nanopowders in bacterial culture media and its implication for antibacterial properties," *Chem. Eng. J.*, vol. 413, p. 127511, 2021.
43. C. W. Tsai and E. H. G. Langner, "The effect of synthesis temperature on the particle size of nano-ZIF-8," *Microporous Mesoporous Mater.*, vol. 221, pp. 8–13, 2016.
44. P. Zhang *et al.*, "Silver nanowires: Synthesis technologies,

growth mechanism and multifunctional applications," *Mater. Sci. Eng. B Solid-State Mater. Adv. Technol.*, vol. 223, pp. 1–23, 2017.

45. X. Dong, X. Ji, H. Wu, L. Zhao, J. Li, and W. Yang, "Shape control of silver nanoparticles by stepwise citrate reduction," *J. Phys. Chem. C*, vol. 113, no. 16, pp. 6573–6576, 2009.
46. J. S. Yaradoddi *et al.*, "Biodegradable Carboxymethyl Cellulose Based Material for Sustainable Packaging Application," *Sci. Rep.*, vol. 10, no. 1, pp. 1–13, 2020.
47. M. Shanmathy, M. Mohanta, and A. Thirugnanam, "Development of Biodegradable Bioplastic films from Taro Starch Reinforced with Bentonite," *Carbohydr. Polym. Technol. Appl.*, vol. 2, no. August, p. 100173, 2021.
48. M. K. Marichelvam, M. Jawaid, and M. Asim, "Corn and rice starch-based bio-plastics as alternative packaging materials," *Fibers*, vol. 7, no. 4, pp. 1–14, 2019.
49. H. Y. Wu *et al.*, "Thin-film coated plastic wrap for food packaging," *Materials (Basel).*, vol. 10, no. 7, pp. 1–7, 2017.
50. J. Hudzicki, "Kirby-Bauer Disk Diffusion Susceptibility Test Protocol Author Information," *Am. Soc. Microbiol.*, no. December 2009, pp. 1–13, 2012.
51. J. J. Biemer, "Antimicrobial susceptibility testing by the Kirby-Bauer disc diffusion method.," *Ann. Clin. Lab. Sci.*, vol. 3, no. 2, pp. 135–140, 1973.
52. Y. R. Lee, M. S. Jang, H. Y. Cho, H. J. Kwon, S. Kim, and W. S. Ahn, "ZIF-8: A comparison of synthesis methods," *Chem. Eng.*

J., vol. 271, pp. 276–280, 2015.

53. B. Molleman and T. Hiemstra, "Surface Structure of Silver Nanoparticles as a Model for Understanding the Oxidative Dissolution of Silver Ions," *Langmuir*, vol. 31, no. 49, pp. 13361–13372, 2015.
54. H. M. S. Akhtar *et al.*, "Production and characterization of CMC-based antioxidant and antimicrobial films enriched with chickpea hull polysaccharides," *Int. J. Biol. Macromol.*, vol. 118, pp. 469–477, 2018.
55. A. Shellikeri, V. Kaulgud, J. Yaradoddi, S. Ganachari, N. Banapurmath, and A. Shettar, "Development of Neem Based Bioplastic for Food Packaging Application," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 376, no. 1, pp. 0–6, 2018.
56. M. Muhammad, R. Ridara, and M. Masrullita, "Sintesis Bioplastik Dari Pati Biji Alpukat Dengan Bahan Pengisi Kitosan," *J. Teknol. Kim. Unimal*, vol. 9, no. 2, p. 1, 2021.
57. P. S. Sari and A. Putra, "The Effect of Additional Chitosan on the Manufacturing of Biodegradable Plastic from Coconut Water," vol. 4, no. 6, pp. 60–69, 2021.
58. I. Illing and M. Satriawan, "Uji Ketahanan Air Bioplastik Dari Limbah Ampas Sagu Dengan Penambahan Variasi Konsentrasi Gelatin," *Pros. Semin. Nas. Univ. Cokroaminoto Palopo*, vol. 03, no. 1, pp. 182–189, 2017.
59. O. O. Oluwasina, B. P. Akinyele, S. J. Olusegun, O. O. Oluwasina, and N. D. S. Mohallem, "Evaluation of the effects of additives on the properties of starch-based bioplastic film," *SN*

Appl. Sci., vol. 3, no. 4, pp. 1–12, 2021.

60. O. O. Oluwasina and I. O. Awonyemi, “Citrus Peel Extract Starch-Based Bioplastic: Effect of Extract Concentration on Packed Fish and Bioplastic Properties,” *J. Polym. Environ.*, vol. 29, no. 6, pp. 1706–1716, 2021.
61. F. M. Fakhouri, S. M. Martelli, T. Caon, J. I. Velasco, and L. H. I. Mei, “Edible films and coatings based on starch/gelatin: Film properties and effect of coatings on quality of refrigerated Red Crimson grapes,” *Postharvest Biol. Technol.*, vol. 109, pp. 57–64, 2015.
62. J. Yang, Y. C. Ching, C. H. Chuah, and N. S. Liou, “Preparation and characterization of starch/empty fruit bunch-based bioplastic composites reinforced with epoxidized oils,” *Polymers (Basel).*, vol. 13, no. 1, pp. 1–15, 2021.
63. S. N. H. M. Azmin, N. A. B. M. Hayat, and M. S. M. Nor, “Development and characterization of food packaging bioplastic film from cocoa pod husk cellulose incorporated with sugarcane bagasse fibre,” *J. Bioresour. Bioprod.*, vol. 5, no. 4, pp. 248–255, 2020.
64. S. Gujar, B. Pandel, and A. S. Jethoo, “Effect of Plasticizer on Mechanical and Moisture Absorption Properties of,” *Int. Quaterly Sci. J.*, vol. 13, no. 2, pp. 425–428, 2014.
65. N. A. Othman, F. Adam, and N. H. Mat Yasin, “Reinforced bioplastic film at different microcrystalline cellulose concentration,” *Mater. Today Proc.*, vol. 41, pp. 77–82, 2020.
66. A. Rejak, A. Wójtowicz, T. Oniszczuk, D. Niemczuk, and M.

Nowacka, “Evaluation of Water Vapor Permeability of Biodegradable Starch-Based Films,” *Teka. Comm. Mot. Energ. Agric.*, vol. 14, no. 3, pp. 89–94, 2014.

67. L. Suryanegara *et al.*, “Novel antimicrobial bioplastic based on PLA-chitosan by addition of TiO2 and ZnO,” *J. Environ. Heal. Sci. Eng.*, vol. 19, no. 1, pp. 415–425, 2021.
68. C. L. Luchese, J. M. Frick, V. L. Patzer, J. C. Spada, and I. C. Tessaro, “Synthesis and characterization of biofilms using native and modified pinhão starch,” *Food Hydrocoll.*, vol. 45, pp. 203–210, 2015.
69. Y. Dou, B. Zhang, M. He, G. Yin, and Y. Cui, “The structure, tensile properties and water resistance of hydrolyzed feather keratin-based bioplastics,” *Chinese J. Chem. Eng.*, vol. 24, no. 3, pp. 415–420, 2016.
70. S. Liu, K. Huang, H. Yu, and F. Wu, “Bioplastic based on 1,8-octanediol-plasticized feather keratin: A material for food packaging and biomedical applications,” *J. Appl. Polym. Sci.*, vol. 135, no. 30, pp. 1–8, 2018.
71. S. Jiang and C. P. Teng, “Fabrication of silver nanowires-loaded polydimethylsiloxane film with antimicrobial activities and cell compatibility,” *Mater. Sci. Eng. C*, vol. 70, pp. 1011–1017, 2017.