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DAFTAR PUSTAKA

Aini, H.N., Rumhayati, B., Fardiyah, Q., Wiryawan, A., Andayani, U., and Azzah, A.N., 2022, The Performance and Characterization of Polymeric Inclusion Membranes (PIMs) Containing 2-Nitro Phenyl Octyl Ether as Plasticizer on Phosphate Transport, *Jurnal Kimia Valensi*, 8, 178–189.

Alharbi, K., Ghoneim, A., Ebid, A., El-Hamshary, H., and El-Newehy, M.H., 2018, Controlled release of phosphorous fertilizer bound to carboxymethyl starch-g-polyacrylamide and maintaining a hydration level for the plant, *Int. J. Biol. Macromol.*, 116, 224–231.

Al-Masry, W.A., Haider, S., Mahmood, A., Khan, M., Adil, S.F., and Siddiqui, M.R.H., 2021, Evaluation of the thermal and morphological properties of γ-irradiated chitosan-glycerol-based polymeric films, *Processes*, 9(10), 1 – 13.

Almutari, M.M., 2023, Synthesis and modification of slow-release fertilizers for sustainable agriculture and environment: a review, *Arabian Journal of Geosciences*, 16(9), 1 – 18.

Ariadi Lusiana, R., Widiarti Mariyono, P., Muhtar, H., Edi Cahyaningrum, S., Abdillah Natsir, T., and Efiyanti, L., 2024, Environmentally friendly slow-release urea fertilizer based on modified chitosan membrane, *Environ. Nanotechnol. Monit. Manag.*, 22, 100996 – 101006.

Aziz, N.N.C., Adam, F., Azman, N.A.M., and Yasin, N.H.M., 2025, Effect of chitosan and polyethylene glycol as plasticizer improves the physical, mechanical, moisture, and thermal properties of films for food packaging, *AIP Conf. Proc.*, 3225(1), 020013.

Baroudi, A., García-Payo, C., and Khayet, M., 2023, Chitosan-Based Composite Membranes with Different Biocompatible Metal Oxide Nanoparticles: Physicochemical Properties and Drug-Release Study, *Polymers (Basel).*, 15(13), 1 – 25.

Berezina, N., 2014, Biotechnological productions of citric acid,. In, *Citric Acid: Occurrence, Biochemistry, Applications and Processing*., 41, 53–70.

Bôlla de Menezes, L., Cristine Ladwig Muraro, P., Moro Druzian, D., Patricia Moreno Ruiz, Y., Galembeck, A., Pavoski, G., Crocce Romano Espinosa, D., and Leonardo da Silva, W., 2024, Calcium oxide nanoparticles: Biosynthesis, characterization and photocatalytic activity for application in yellow tartrazine dye removal, *J. Photochem. Photobiol. A Chem.*, 447(15), 115182.

Cahyaningrum, S.E., Muhaimin, F.I., Lusiana, R.A., Natsir, T.A., Marena, B., and Purnamasari, A.P., 2026, Modified Chitosan–Polyvinyl Alcohol Membrane as Environmentally Friendly Slow-Release Urea Fertilizer, *Asian Journal of Green Chemistry*, 10(4), 729–741.

Catanzano, O., Gomez d'Ayala, G., D'Agostino, A., Di Lorenzo, F., Schiraldi, C., Malinconico, M., Lanzetta, R., Bonina, F., and Laurienzo, P., 2021, PEG–Crosslinked–Chitosan hydrogel films for in situ delivery of Opuntia ficus-indica extract, *Carbohydr. Polym.*, 264, 117987–117996.

UNIVERSITAS
GADJAH MADA
Pengaruh Penambahan Polietilen Glikol (PEG) terhadap Laju Pelepasan Nutrien P pada Membran Multilayer Berbasis Kitosan sebagai Pupuk Lepas Lambat
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Catoira, M.C., Fusaro, L., Di Francesco, D., Ramella, M., and Boccafoschi, F., 2019, Overview of natural hydrogels for regenerative medicine applications, *J. Mater. Sci. Mater. Med.*, 30(10), 115–125.

Chamorro, A.F., Palencia, M., and Arrieta, Á.A., 2024, Development of High-Efficiency Fertilizer by Hydrogels Obtained from Cassava Starch and Citric Acid for Slow Release of Ammonium and Potassium, *Gels*, 10(7), 434–450.

Chang, F.C., Levengood, S.L., Cho, N., Chen, L., Wang, E., Yu, J.S., and Zhang, M., 2018, Crosslinked Chitosan-PEG Hydrogel for Culture of Human Glioblastoma Cell Spheroids and Drug Screening, *Adv. Ther. (Weinh).*, 1(7), 1–23.

Chen, J., Lü, S., Zhang, Z., Zhao, X., Li, X., Ning, P., and Liu, M., 2018, Environmentally friendly fertilizers: A review of materials used and their effects on the environment, *Science of the Total Environment*, 613–614, 829–839.

Clasen, C., Wilhelms, T., and Kulicke, W.M., 2006, Formation and characterization of chitosan membranes, *Biomacromolecules*, 7(11), 3210–3222.

Cohen, E. and Poverenov, E., 2022, Hydrophilic Chitosan Derivatives: Synthesis and Applications, *Chemistry - A European Journal*, 28(67), 1–13.

Cui, L., Gao, S., Song, X., Huang, L., Dong, H., Liu, J., Chen, F., and Yu, S., 2018, Preparation and characterization of chitosan membranes, *RSC Adv.*, 8(50), 28433–28439.

de Souza, A.M.N., Avila, L.B., Contessa, C.R., Valério Filho, A., de Rosa, G.S., and Moraes, C.C., 2024, Biodegradation Study of Food Packaging Materials: Assessment of the Impact of the Use of Different Biopolymers and Soil Characteristics, *Polymers (Basel).*, 16(20), 2941 – 2954.

Deygen, I.M. and Kudryashova, E. V., 2016, New versatile approach for analysis of PEG content in conjugates and complexes with biomacromolecules based on FTIR spectroscopy, *Colloids Surf. B Biointerfaces*, 141, 36–43.

Dovzhenko, A.P., Yapryntseva, O.A., Sinyashin, K.O., Doolotkeldieva, T., and Zairov, R.R., 2024, Recent progress in the development of encapsulated fertilizers for time–Controlled release, *Heliyon*, 10(15), 34895–34914.

Enescu, D. and Pastrana, L.M., 2020, The Effect of Simultaneous Radical Polymerization of Poly(N-vinyl pyrrolidone)/α,ω-Bis(methacryloyloxy-poly(ethylene glycol)) on Physical Properties of Marine Polysaccharide, *J. Polym. Environ.*, 28(1), 152–165.

Esam, E., Elham, E., Azizah, M., and Hamid, Y.A., 2024, Characterization of Chitosan Films Cast from Different Solvents: FTIR, Surface and Mechanical Investigations, *Res. J. Chem. Environ.*, 28(3), 25–31.

Fertahi, S., Bertrand, I., Amjoud, M., Oukarroum, A., Arji, M., and Barakat, A., 2019, Properties of Coated Slow-Release Triple Superphosphate (TSP) Fertilizers Based on Lignin and Carrageenan Formulations, *ACS Sustain. Chem. Eng.*, 7(12), 10371–10382.

Fertahi, S., Ilsouk, M., Zeroual, Y., Oukarroum, A., and Barakat, A., 2021, Recent trends in organic coating based on biopolymers and biomass for controlled and slow release fertilizers, *Journal of Controlled Release*, 330, 341–361.

UNIVERSITAS
GADJAH MADA
Pengaruh Penambahan Polietilen Glikol (PEG) terhadap Laju Pelepasan Nutrien P pada Membran Multilayer Berbasis Kitosan sebagai Pupuk Lepas Lambat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Foster, L.J.R., Ho, S., Hook, J., Basuki, M., and Marçal, H., 2015, Chitosan as a biomaterial: Influence of degree of deacetylation on its physiochemical, material and biological properties, *PLoS One*, 10(8), 1 – 22.

Ghorpade, V.S., Yadav, A.V., Dias, R.J., Mali, K.K., Pargaonkar, S.S., Shinde, P.V., and Dhane, N.S., 2018, Citric acid crosslinked carboxymethylcellulose-poly(ethylene glycol) hydrogel films for delivery of poorly soluble drugs, *Int. J. Biol. Macromol.*, 118, 783–791.

Grzybek, P., Jakubski, Ł., and Dudek, G., 2022, Neat Chitosan Porous Materials: A Review of Preparation, Structure Characterization and Application, *Int. J. Mol. Sci.*, 23(17), 9932 – 9957.

He, C., Huang, Y., Shao, Q., Kong, F., Zheng, D., and Qiu, X., 2025, Lignin-based ternary composite hydrogel for slow-release of fertilizer and soil water retention, *Int. J. Biol. Macromol.*, 296, 139679 – 139688.

He, L.-H., Xue, R., Yang, D.-B., Liu, Y., and Song, R., 2009, Effect of blending chitosan with PEG on surface morphology, crystallization and thermal properties, *Chinese Journal of Polymer Science*, 27(4), 501 – 510.

Huhtamäki, T., Tian, X., Korhonen, J.T., and Ras, R.H.A., 2018, Surface-wetting characterization using contact-angle measurements, *Nat. Protoc.*, 13(7), 1521–1538.

Ibrahim, M., Ramadan, E., Elsadek, N.E., Emam, S.E., Shimizu, T., Ando, H., Ishima, Y., Elgarhy, O.H., Sarhan, H.A., Hussein, A.K., and Ishida, T., 2022, Polyethylene glycol (PEG): The nature, immunogenicity, and role in the hypersensitivity of PEGylated products, *Journal of Controlled Release*, 351, 215–230.

Jahan, F. and Mathad, R.D., 2016, Mechanical Studies on Chitosan/PVA Blend With Calcium Chloride as Ionic Crosslinker, *International Journal of Advances in Science Engineering and Technology*, 4(4), 31 – 34.

Jia, Y., Hu, Z., Mu, J., Zhang, W., Xie, Z., and Wang, G., 2020, Preparation of biochar as a coating material for biochar–Coated urea, *Science of the Total Environment*, 731, 139063–139073.

Jiang, S., Duan, Q., Ma, L., Song, Y., Xie, H., Liu, H., Chen, L., and Yu, L., 2024, Preparation and characterization of slow-release fertilizer through coating acrylate epoxidized soybean oil, *Environ. Technol. Innov.*, 34, .

Jiang, S., Qiao, C., Liu, R., Liu, Q., Xu, J., and Yao, J., 2023, Structure and properties of citric acid cross-linked chitosan/poly(vinyl alcohol) composite films for food packaging applications, *Carbohydr. Polym.*, 312, 120842 – 120851.

Kaavessina, M., Distantina, S., and Shohih, E.N., 2021, A slow-release fertilizer of urea prepared via melt blending with degradable poly(Lactic acid): Formulation and release mechanisms, *Polymers (Basel).*, 13, 1856 – 1870.

Kanduč, M., Schneck, E., and Netz, R.R., 2023, Understanding the “Berg limit”: the 65° contact angle as the universal adhesion threshold of biomatter, *Physical Chemistry Chemical Physics*, 26(2), 713–723.

Kappert, E.J., Raaijmakers, M.J.T., Tempelman, K., Cuperus, F.P., Ogieglo, W., and Benes, N.E., 2019, *Swelling* of 9 polymers commonly employed for

UNIVERSITAS
GADJAH MADA
Pengaruh Penambahan Polietilen Glikol (PEG) terhadap Laju Pelepasan Nutrien P pada Membran Multilayer Berbasis Kitosan sebagai Pupuk Lepas Lambat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

solvent-resistant nanofiltration membranes: A comprehensive dataset, *J. Memb. Sci.*, 569, 177–199.

Kayani, A., Raza, M.A., Raza, A., Hussain, T., Akram, M.S., Sabir, A., Islam, A., Haider, B., Khan, R.U., and Park, S.H., 2021, Effect of varying amount of polyethylene glycol (Peg-600) and 3-aminopropyltriethoxysilane on the properties of chitosan based reverse osmosis membranes, *Int. J. Mol. Sci.*, 22(5), 1–15.

Kiswandono, A.A., Kimia, J., Lampung, U., and Lampung, B., 2016, Metode Membran Cair Untuk Pemisahan Fenol, 1(1), 74–88.

Kontárová, S., Přikryl, R., Škarpa, P., Kriška, T., Antošovský, J., Gregušková, Z., Figalla, S., Jašek, V., Sedlmajer, M., Menčík, P., and Mikolajová, M., 2022, Slow-Release Nitrogen Fertilizers with Biodegradable Poly(3-hydroxybutyrate) Coating: Their Effect on the Growth of Maize and the Dynamics of N Release in Soil, *Polymers (Basel).*, 14(20), 4323–4343.

Kottegoda, N., Sandaruwan, C., Priyadarshana, G., Siriwardhana, A., Rathnayake, U.A., Berugoda Arachchige, D.M., Kumarasinghe, A.R., Dahanayake, D., Karunaratne, V., and Amaratunga, G.A.J., 2017, Urea-Hydroxyapatite Nanohybrids for Slow Release of Nitrogen, *ACS Nano*, 11(2), 1214–1221.

Kusumaningrum, S.I., 2019, Pemanfaatan Sektor sebagai Penunjang Pertumbuhan Perekonomian Indonesia, *Jurnal Transaksi,* 11(1), 80–89.

Kusumastuti, Y., Istiani, A., Rochmadi, and Purnomo, C.W., 2019, Chitosan-Based Polyion *Multilayer* Coating on NPK Fertilizer as Controlled Released Fertilizer, *Advances in Materials Science and Engineering*, 2019, 1–8.

Lakshani, N., Wijerathne, H.S., Sandaruwan, C., Kottegoda, N., and Karunarathne, V., 2023, Release Kinetic Models and Release Mechanisms of Controlled-Release and Slow-Release Fertilizers, *ACS Agricultural Science and Technology*, 3(11), 939–956.

Lawrencia, D., Wong, S.K., Low, D.Y.S., Goh, B.H., Goh, J.K., Ruktanonchai, U.R., Soottitantawat, A., Lee, L.H., and Tang, S.Y., 2021, Controlled Release Fertilizers: A Review on Coating Materials and Mechanism of Release, *Plants 2021,* 10(2), 1–26.

Lestari, R.S.D., Jayanudin, J., Irawanto, D., Rozak, R., Wardana, R.L.A., and Muhammad, F., 2020, Preparasi dan Karakterisasi Kitosan Tertaut Silang Glutaraldehide Sebagai Matrik Pupuk Urea, *JURNAL INTEGRASI PROSES*, 9(2), 27 – 33.

Li, X., Ma, H., Wang, P., Liu, Z., Peng, J., Hu, W., Jiang, Z., Liu, B., and Guiver, M.D., 2020, Highly Conductive and Mechanically Stable Imidazole-Rich Cross-Linked Networks for High-Temperature Proton Exchange Membrane Fuel Cells, *Chemistry of Materials*, 32(3), 1182–1191.

Li, Y. and Sun, J., 2026, Reversibly Cross-Linked Polymers: A New Method for High-Performance and Sustainable Polymer Materials, *Acc. Chem. Res.*, 59(2), 298–310.

Lusiana, R.A., Cahyaningrum, S.E., Natsir, T.A., Efiyanti, L., and Muhtar, H., 2025, A slow-release urea prepared via *sandwich* with degradable chitosan: Formulation and release mechanisms, *Biocatal. Agric. Biotechnol.*, 67, 103626 – 103638.

UNIVERSITAS
GADJAH MADA
Pengaruh Penambahan Polietilen Glikol (PEG) terhadap Laju Pelepasan Nutrien P pada Membran Multilayer Berbasis Kitosan sebagai Pupuk Lepas Lambat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Lusiana, R.A., Isdadiyanto, S., and Khabibi, 2016, Urea Permeability of Citric Acid Crosslinked Chitosan-Poly (Vinyl Alcohol) Blend Membranes, *International Journal of Chemical Engineering and Applications*, 7(3), 186–189.

Lusiana, R.A., Khabibi, K., Nuryanto, R., and Al Aziz, M.R.S., 2024, Development and Characterization of a Chitosan and Polyvinyl Alcohol (CS/PVP)-Based Slow-Release Urea Fertilizer Membrane, *Jurnal Kimia Sains dan Aplikasi*, 27(10), 470–476.

Maddaloni, M., Vassalini, I., and Alessandri, I., 2020, Green Routes for the Development of Chitin/Chitosan Sustainable Hydrogels, *Sustainable Chemistry*, 1(3), 325–344.

Madera-Santana, T.J., Herrera-Méndez, C.H., and Rodríguez-Núñez, J.R., 2018, An overview of the chemical modifications of chitosan and their advantages, *Green Mater.*, 6(4), 131–142.

Mantia, F.P.L., Ascione, L., Mistretta, M.C., Rapisarda, M., and Rizzarelli, P., 2020, Comparative investigation on the soil burial degradation behaviour of polymer films for agriculture before and after photo–Oxidation, *Polymers (Basel).*, 12(4), 753 – 766.

Martínez, C.S., Galicia-Aguilar, J.A., Águila Almanza, E., López-Badillo, M., and Rodríguez Lugo, V., 2025, Effect of citric acid crosslinking on the physicochemical and permeation properties of chitosan membranes for diclofenac separation, *Polymer Bulletin*, 82(16), 10879–10902.

Mendonca Cidreira, A.C., Wei, L., Aldekhail, A., and Islam Rubel, R., 2025, Controlled-release nitrogen fertilizers: A review on bio-based and smart coating materials, *J. Appl. Polym. Sci.*, 142(3), 1–20.

Mistriotis, A., Papardaki, N.G., and Provata, A., 2019, Biodegradation of Cellulose in Laboratory-Scale Bioreactors: Experimental and Numerical Studies, *J. Polym. Environ.*, 27(12), 2793–2803.

Nabella, N. and Azizah, F.I., 2025, Dari Limbah Menjadi Material: Eksplorasi Hidroksiapatit Tulang Ayam sebagai Filler Membran Komposit, *RIGGS: Journal of Artificial Intelligence and Digital Business*, 4(4), 4765–4773.

Natsir, T.A., Iknawati, A.M., Wanadri, I.D., Siswanta, D., Lusiana, R.A., and Cahyaningrum, S.E., 2025, Environmentally friendly membrane based on chitosan, citric acid, and calcium for slow-release fertilizer, *Heliyon*, 11(1), 41378 – 41388.

Padmaa Paarakh, M., Ani Jose, P., Setty, C.M., and Christoper, G.V.P., 2019, Release Kinetics – Concepts and Applications, *International Journal of Pharmacy Research & Technology*, 8(1), 12–20.

Pereira, I.C., Duarte, A.S., Neto, A.S., and Ferreira, J.M.F., 2019, Chitosan and polyethylene glycol based membranes with antibacterial properties for tissue regeneration, *Materials Science and Engineering C*, 96, 606–615.

Pimsen, R., Porrawatkul, P., Nuengmatcha, P., Ramasoot, S., and Chanthai, S., 2021, Efficiency enhancement of slow release of fertilizer using nanozeolite–chitosan/sago starch-based biopolymer composite, *J. Coat. Technol. Res.*, 18(5), 1321–1332.

UNIVERSITAS
GADJAH MADA
Pengaruh Penambahan Polietilen Glikol (PEG) terhadap Laju Pelepasan Nutrien P pada Membran Multilayer Berbasis Kitosan sebagai Pupuk Lepas Lambat
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

Puspadewi, R., Anugrah, R., and Sabila, D., 2017, Kemampuan Aspergillus wentii Dalam Menghasilkan Asam Sitrat, *Kartika Jurnal Ilmiah Farmasi*, 5(1), 15–20.

Rahmani, F., Larbi Bouamrane, O., Ben Bouabdallah, A., Atanase, L.I., Hellal, A., and Apintiliesei, A.N., 2023, Biomimetic Hydroxyapatite Crystals Growth on Phosphorylated Chitosan Films by In Vitro Mineralization Used as Dental Substitute Materials, *Polymers (Basel).*, 15(11), 2470 – 2492.

Rekik, S.B., Gassara, S., and Deratani, A., 2023, Green Fabrication of Sustainable Porous Chitosan/Kaolin Composite Membranes Using Polyethylene Glycol as a Porogen: Membrane Morphology and Properties, *Membranes (Basel).*, 13(4), 378 – 397.

Rizwan, M., Rubina Gilani, S., Iqbal Durani, A., and Naseem, S., 2021, Materials diversity of hydrogel: Synthesis, polymerization process and soil conditioning properties in agricultural field, *J. Adv. Res.*, 33, 15–40.

Rusdiana, S. and Maesya, A., 2017, Pertumbuhan ekonomi dan kebutuhan Pangan di Indonesia, *Agriekonomika*, 6(1), 12–25.

Saiful, Mardiana, L., Rahmah, Z., Ajrina, M., Imanda, M.R., Rahmi, Khairi, Ramli, M., and Marlina, 2021, Preparation and characterization of chitosan-starch Janeng membranes cross-linking with citric acid, *IOP Conf. Ser. Mater. Sci. Eng.*, 1087(1), 012066.

Salihu, R., Abd Razak, S.I., Ahmad Zawawi, N., Rafiq Abdul Kadir, M., Izzah Ismail, N., Jusoh, N., Riduan Mohamad, M., and Hasraf Mat Nayan, N., 2021, Citric acid: A green cross-linker of biomaterials for biomedical applications, *Eur. Polym. J.*, 146, 110271 – 110283.

Sapuła, P., Bialik-Wąs, K., and Malarz, K., 2023, Are Natural Compounds a Promising Alternative to Synthetic Cross-Linking Agents in the Preparation of Hydrogels?, *Pharmaceutics*, 15(1), 253 – 288.

Saxena, P., Shukla, P., and Gaur, M.S., 2021, Thermal analysis of polymer blends and double layer by DSC, *Polymers and Polymer Composites*, 29(9), S11–S18.

Seredin, P., Goloshchapov, D., Kashkarov, V., Khydyakov, Y., Nesterov, D., Ippolitov, I., Ippolitov, Y., and Vongsvivut, J., 2022, Development of a Hybrid Biomimetic Enamel-Biocomposite Interface and a Study of Its Molecular Features Using Synchrotron Submicron ATR-FTIR Microspectroscopy and Multivariate Analysis Techniques, *Int. J. Mol. Sci.*, 23(19), 11699 – 11721.

Shaikh, R.P., Pillay, V., Choonara, Y.E., Du Toit, L.C., Ndesendo, V.M.K., Bawa, P., and Cooppan, S., 2010, A review of multi-responsive membranous systems for rate-modulated drug delivery, *AAPS PharmSciTech*, 11(1), 441–459.

Sharmin, N., Rosnes, J.T., Prabhu, L., Böcker, U., and Sivertsvik, M., 2022, Effect of Citric Acid Cross Linking on the Mechanical, Rheological and Barrier Properties of Chitosan, *Molecules*, 27(16), 5118 – 5134.

Song, Y., Ma, L., Duan, Q., Xie, H., Zhang, H., Dong, X., and Yu, L., 2024, Development of Slow-Release Fertilizers with Function of Water Retention Using Eco-Friendly Starch Hydrogels, *Molecules*, 29(20), 4835 – 4860.

UNIVERSITAS
GADJAH MADA
Pengaruh Penambahan Polietilen Glikol (PEG) terhadap Laju Pelepasan Nutrien P pada Membran Multilayer Berbasis Kitosan sebagai Pupuk Lepas Lambat
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Stefani, N.O. and Cahyaningrum, S.E., 2025a, Penggunaan Kitosan-Polivinil Alkohol (PVA)-Kalsium Karbonat Sebagai Matriks Urea Slow-Release Fertilizer (SRF), *Unesa Journal of Chemistry*, 14(1), 306–312.

Suwardi, Suryaningtyas, D.T., Ghofar, A., Rosjidi, M., Mustafa, A., and Saputra, H., 2024, Effect of Polyethylene Glycol and Humic Acid Coating on NPK Release From Controlled-Release Fertilizer, *Scientific World Journal*, 2024, 1 – 16.

Thippaiah, D. and Rudrappa, S.L., 2018, Synthesis and *swelling* behavior of sodium alginate / poly (vinyl alcohol) hydrogels, *The Turkish Journal of Pharmaceutical Sciences*, 16(3), 252 – 260.

Wang, Y., Chen, S., Yao, Y., Wu, N., Xu, M., Yin, Z., Zhao, Y., and Tu, Y., 2023, Effects of citric acid crosslinking on the structure and properties of ovotransferrin and chitosan composite films, *Int. J. Biol. Macromol.*, 229, 268–281.

Wang, Z., Ye, Q., Yu, S., and Akhavan, B., 2023, Poly Ethylene Glycol (PEG)-Based Hydrogels for Drug Delivery in Cancer Therapy: A Comprehensive Review, *Adv. Healthc. Mater.*, 12(18), 2300105 – 2300126.

Wibisono, Y., Ummah, S.R., Hermanto, M.B., Djoyowasito, G., and Noviyanto, A., 2024, Slow-release hydroxyapatite fertilizer from crab shells waste for sustainable crop production, *Results in Engineering*, 21, 101781 – 101746.

Wibowo, A.H., Fehragucci, H., and Purnawan, C., 2023, Effect of Plasticizer Addition on The Characteristics of Chitosan-Alginate Edible Film, *ALCHEMY Jurnal Penelitian Kimia*, 19(2), 123 – 129.

Włodarczyk, M., Siwek, H., Lubkowski, K., and Buchwał, A., 2024, Release of selected nutrients from polymer–Coated fertilisers in the soil environment, *Journal of Water and Land Development*, 26, 201–211.

Wu, L. and Liu, M., 2008, Preparation and properties of chitosan–Coated NPK compound fertilizer with controlled-release and water-retention, *Carbohydr. Polym.*, 72, 240–247.

Wu, M., Lu, J., Zhang, Y., Ling, Z., Lu, R., Zhu, J., Li, Y., Cai, Y., Xiang, H., Zhang, Z., and Yu, B., 2025, Chitosan hydrogel membrane embedded by metal-modified biochars for slow-release fertilizers, *Int. J. Biol. Macromol.*, 306, 141296 – 141310.

Yang, B., Liu, B., Gao, Y., Wei, J., Li, G., Zhang, H., Wang, L., and Hou, Z., 2024, PEG–Crosslinked O–Carboxymethyl chitosan films with degradability and antibacterial activity for food packaging, *Sci. Rep.*, 14(1), 10825 – 10838.