REFERENCES

Adarsh, R.K., Das, E.C., Gopan, G.V., Rajan, R.K., and Komath, M., 2022, Quaternised chitosan composites with in situ precipitated nano calcium phosphate for making bioactive and degradable tissue engineering scaffolds, *J. Polym. Res.*, 29(7), 267.

Agu, A.B.S., Benablo, P.J.L., Mesias, V.S.D., and Penaloza, D.P., 2019, Synthesis and characterization of a chitosan-based citric acid-crosslinked encapsulant system, *J. Chil. Chem. Soc.*, 64, 4610–4612.

Ahmad, N.N.R., Fernando, W.J.N., and Uzir, M.H., 2015, Parametric evaluation using mechanistic model for release rate of phosphate ions from chitosan-coated phosphorus fertiliser pellets, *Biosyst. Eng.*, 129, 78–86.

Ali, H.S., Abou-El-Sherbini, K.S., El-Seedy, M.E., Talha, N.I., and El-Gammal, O.A., 2024, A new direction in wheat cultivation by preparation of biochar and rice straw NPK slow-release fertilizers to improve nutrient release performance, *Egypt. J. Chem.*, 509-520.

ALnaass, N.S., Agil, H.K., and Ibrahim, H.K., 2021, Use of fertilizers or importance of fertilizers in agriculture, *Int. J. Adv. Acad. Stud.*, 3, 52–57.

Becerra, J., Rodriguez, M., Leal, D., Noris-Suarez, K., and Gonzalez, G., 2022, Chitosan-collagen-hydroxyapatite membranes for tissue engineering, *J. Mater. Sci. Mater. Med.*, 33(2), .

Bhushan, B., 2018, Strategies for micropatterned, nanopatterned, and hierarchically structured lotus-like surfaces, *Springer Ser. Mater. Sci.*, , 121–197.

Bo, W., Zhi-Peng, L., Yue, L., Qian-Ru, Y., Zhen-Rui, L., Wen-Shu, W., Xiao-Jie, C., and Fei-Xian, L., 2025, Lignin-polybutylene adipate-co-terephthalate(PBAT)-starch@urea bilayer nanohybrid biocomposite enable superior controlled slow-released fertilizer with good water-retention, *Int. J. Biol. Macromol.*, 310, 142890.

Cahyaningrum, S.E., Lusiana, R.A., Natsir, T.A., Muhaimin, F.I., Wardana, A.P., Purnamasari, A.P., and Misran, M.B., 2024, Synthesis and characterization of chitosan-modified membrane for urea slow-release fertilizers, *Heliyon*, 10, e34981.

Chandrakumara, G.T.D., Dissanayake, D.M.S.N., Mantilaka, M.M.M.G.P.G., De Silva, R.T., Pitawala, H.M.T.G.A., and de Silva, K.M.N., 2019, Eco-friendly, green packaging materials from akaganeite and hematite nanoparticle-reinforced chitosan nanocomposite films, *J. Nanomater.*, 2019, 1049142.

Cheng, J., Tang, Y., Zhu, X., Cai, Q., Wang, Y., Yun, Y., Yuan, X., Zhu, W., and Wang, H., 2025, Research progress on film-coated slow-release fertilizers as well as the film materials, *Fine Chem.*, 42, 39–47.

Cho, J., Heuzey, M., Begin, A., and Carreau, P., 2006, Effect of urea on solution behavior and heat-induced gelation of chitosan-β-glycerophosphate, *Carbohydr. Polym.*, 63, 507–518.

Corradini, E., de Moura, M.R., and Mattoso, L.H.C., 2010, A preliminary study of the incorporation of NPK fertilizer into chitosan nanoparticles, *Express Polym. Lett.*, 4, 509–515.

Du, Q., Sun, J., Zhou, Y., Yu, Y., Kong, W., Chen, C., Zhou, Y., Zhao, K., Shao,

C., and Gu, X., 2023, Fabrication of ACP–CCS–PVA composite membrane for a potential application in guided bone regeneration, *RSC Adv.*, 13, 25930–25938.

Dumitru, M.V., Vintila, A.C.N., Iovu, H., Neagu, A.L., Dolana, S., Miron, A., Neblea, I.E., Gavrila, A.M., Enascuta, C.E., and Iordache, T.V., 2024, Composite materials based on chitosan for slow release of nitrogen–phosphorus–potassium fertilizers in agriculture, *Proceedings,* 90(1), 43.

Etesami, H., 2019, Enhanced phosphorus fertilizer use efficiency with microorganisms, *Nutr. Dyn. Sustain. Crop Prod.*, 215–245.

Geng, J., Ma, Q., Zhang, M., Li, C., Liu, Z., Lyu, X., and Zheng, W., 2015, Synchronized relationships between nitrogen release of controlled release nitrogen fertilizers and nitrogen requirements of cotton, *Field Crops Res.*, 184, 9–16.

Guerrero, P., Muxika, A., Zarandona, I., and Caba, K.L.D., 2019, Crosslinking of chitosan films processed by compression molding, *Carbohydr. Polym.*, 206, 820–826.

Guertal, E.A., 2009, Slow-release nitrogen fertilizers in vegetable production: a review, *HortTechnology*, 19, 16–19.

Gumelar, M.D., Hamzah, Moh, Hidayat, A.S., Saputra, D.A., and Idvan, 2020, Utilization of chitosan as coating material in making NPK slow release fertilizer, *Macromol. Symp.*, 391, 1900188.

Hu, T., Lu, Y., Peng, Y., Li, W., Zhang, Z., and Hou, X., 2021, Effect of cross-linking treatment with citric acid on enhancement of chitosan fiber, *J. Silk*, 57, .

Hussain, M.R., Devi, R.R., and Maji, T.K., 2012, Controlled release of urea from chitosan microspheres prepared by emulsification and cross-linking method, *Iran. Polym. J.*, 21, 473–479.

Ibrahim, F., Helal, M.I., Abdelkader, N.H., Hussein, M., and El-Sherbiny, I.M., 2024, Development of eco-friendly modified natural and synthetic nanozeolites, for urea efficient delivery to vegetable plants with reducing nitrogen losses to environment, *Egypt. J. Chem.*, 68(4), 103-122.

Ji, H., Abdalkarim, S.Y.H., Shen, Y., Chen, X., Zhang, Y., Shen, J., and Yu, H.Y., 2024, Facile synthesis, release mechanism, and life cycle assessment of amine-modified lignin for bifunctional slow-release fertilizer, *Int. J. Biol. Macromol.*, 278, 134618.

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.

Karakeçili, A.G., Satriano, C., Gümüşderelioğlu, M., and Marletta, G., 2007, Surface characteristics of ionically crosslinked chitosan membranes, *J. Appl. Polym. Sci.*, 106, 3884–3888.

Kashyap, P.L., Xiang, X., and Heiden, P., 2015, Chitosan nanoparticle based delivery systems for sustainable agriculture, *Int. J. Biol. Macromol.*, 77, 36–51.

Khouri, J., Penlidis, A., and Moresoli, C., 2020, Heterogeneous method of chitosan film preparation: effect of multifunctional acid on film properties, *J. Appl.*

Polym. Sci., 137, .

Kısmet, Y., and Dogan, A., 2021, Characterization of the mechanical and thermal properties of rape short natural-fiber reinforced thermoplastic composites, *Iran. Polym. J.*, 31, 143–151.

Kubavat, D., Trivedi, K., Vaghela, P., Prasad, K., Vijay Anand, G.K., Trivedi, H., Patidar, R., Chaudhari, J., Andhariya, B., and Ghosh, A., 2020, Characterization of a chitosan-based sustained release nanofertilizer formulation used as a soil conditioner while simultaneously improving biomass production of Zea mays L., *Land Degrad. Dev.*, 31, 2734–2746.

Kumar, M., Shankar, A., Chaudhary, S., and Prasad, V., 2023, Phosphate solubilizing microorganisms: multifarious applications, *Microorganisms Sustain.*, 245–262.

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*, 10, 238.

Lewu, F.B., Volova, T.G., Thomas, S., and Rakhimol, K.R., 2021, Controlled release fertilizers for sustainable agriculture, *Cambridge, Massachusetts Academic Press*.

Li, S., Zhao, K., Wei, J., Ren, T., and Lin, H., 2014, Preparation and mechanical properties of tricalcium phosphate/calcium alginate composite flat sheet membranes, *Acta Mater. Compos. Sin.*, 31, 1106–1111.

Liao, J., Li, H., Linghu, C., Luo, Z., Chen, F., Lei, T., Liu, Y., Lin, Y., Wang, B., and Yang, L., 2023, Preparation and slow-release performance of modified poly(butyleneadipate-co-terephthalate) melt-coated urea pellets, *Prog. Org. Coat.*, 184, 107830.

Liu, T., Yang, L., Zhou, B., Huang, J., Lu, Z., and Li, B., 2012, Recent advances in the applications of the interaction between chitosan and urea, *Ion Exch. Adsorpt.*, 28, 183–192.

Lusiana, R.A., Mariyono, P.W., Muhtar, H., Cahyaningrum, S.E., Natsir, T.A., and Efiyanti, L., 2024, Environmentally friendly slow-release urea fertilizer based on modified chitosan membrane, *Environ. Nanotechnol. Monit. Manag.*, 22, 100996.

Lusiana, R.A., Siswanta, D., and Mudasir, M., 2016, Preparation of citric acid crosslinked chitosan/poly(vinyl alcohol) blend membranes for creatinine transport, *Indones. J. Chem.*, 16, 144.

Ma, X., Zhang, S., Yang, Y., Tong, Z., Shen, T., Yu, Z., Xie, J., Yao, Y., Gao, B., Li, Y.C., and Mohamed, I.D.H., 2023, Development of multifunctional copper alginate and bio-polyurethane bilayer coated fertilizer: controlled-release, selenium supply and antifungal, *Int. J. Biol. Macromol.*, 224, 256–265.

Morin-Crini, N., Lichtfouse, E., Torri, G., and Crini, G., 2019, Applications of chitosan in food, pharmaceuticals, medicine, cosmetics, agriculture, textiles, pulp and paper, biotechnology, and environmental chemistry, *Environ. Chem. Lett.*, 17(4), 1667-1692.

Mujtaba, M., Khawar, K.M., Camara, M.C., Carvalho, L.B., Fraceto, L.F., Morsi,

R.E., Elsabee, M.Z., Kaya, M., Labidi, J., Ullah, H., and Wang, D., 2020, Chitosan-based delivery systems for plants: a brief overview of recent advances and future directions, *Int. J. Biol. Macromol.*, 154, 683–697.

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, e41378.

Ofokansi, K.C., 2008, Biopolymer cross-links: strategies for improving drug release and delivery, *Bentham Sci. Publ.*, 95–111.

Pang, M.H., Li, L.X., Dong, S.Q., Liu, D.S., Li, H.Y., and Liang, L.N., 2022, Research progress on nano-materials application in slow/controlled-release fertilizers, *J. Plant Nutr. Fertil.*, 28, 1708–1719.

Peng, P., Voelcker, N.H., Kumar, S., and Griesser, H.J., 2008, Concurrent elution of calcium phosphate and macromolecules from alginate/chitosan hydrogel coatings, *Biointerphases*, 3, 105–116.

Penuelas, J., Coello, F., and Sardans, J., 2023, A better use of fertilizers is needed for global food security and environmental sustainability, *Agric. Food Secur.*, 12, .

Qiao, M.J., Jiang, J.Y., and Fu, Y.L., 2015, Influence of environmental conditions on release rules of fertilizer from wood residue slow-release fertilizer shell, *Wood Fiber Sci.*, 47, 385–390.

Raimondi, G., Maucieri, C., Toffanin, A., Renella, G., and Borin, M., 2021, Smart fertilizers: what should we mean and where should we go?, *Ital. J. Agron.*, 16(2), 1794.

Rajeswari, A., Amalraj, A., and Pius, A., 2015, Removal of phosphate using chitosan-polymer composites, *J. Environ. Chem. Eng.*, 3, 2331–2341.

Ravishankar, K., Km, S., Sreekumar, S., Sivan, S., Kiran, M.S., Lobo, N.P., Jaisankar, S.N., and Raghavachari, D., 2024, Microwave-assisted synthesis of crosslinked ureido chitosan for hemostatic applications, *Int. J. Biol. Macromol.*, 260, 129648.

Samar Swify, R., Mažeika, R., Baltrušaitis, J., Drapanauskaitė, D., and Barčauskaitė, K., 2024, Review: Modified urea fertilizers and their effects on improving nitrogen use efficiency (NUE), *Sustainability*, 16, 188.

Sanyal, K., and Dhara, S., 2020, A simple microanalytical method for trace elemental determination in plutonium samples using energy dispersive X-ray fluorescence, *Spectrochim. Acta B At. Spectrosc.*, 169, 105897.

Shahrajabian, M.H., Chaski, C., Polyzos, N., Tzortzakis, N., and Petropoulos, S.A., 2021, Sustainable agriculture systems in vegetable production using chitin and chitosan as plant biostimulants, *Biomolecules*, 11, 819.

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, 5118.

Shawkat, S.M., Al-Jawasim, M., and Khaleefah, L.S., 2019, Extending shelf life of pasteurized milk via chitosan nanoparticles, *J. Pure Appl. Microbiol.*, 13, 2471–2478.

Shimamoto, Y., Matsushita, S., Yamamoto, T., Kamada, A., Nakamura, Y., Miyata,

M., and Umimoto, K., 2017, Ultraviolet absorption properties of low molecular weight uremic substances and application to monitoring of spent dialysate, *Trans. Jpn. Soc. Med. Biol. Eng.*, 55, 252–257.

Tai, H.Y., Fu, E., Cheng, L.P., and Don, T.M., 2014, Fabrication of asymmetric membranes from polyhydroxybutyrate and biphasic calcium phosphate/chitosan for guided bone regeneration, *J. Polym. Res.*, 21, .

Teterina, A.Y., Egorov, A.A., Fedotov, A.Y., Barinov, S.M., and Komlev, V.S., 2016, Strengthening of deformable bone cements in the calcium phosphates–chitosan system by tricalcium phosphate granules, *Inorg. Mater. Appl. Res.*, 7, 20–23.

Trenkel, M.E., 2010, *Slow- and controlled-release and stabilized fertilizers*, International fertilizer association, Paris.

Trinh, T.H., Dao, Q.N., Kushaari, K., Ismail, L., and Shuib, A., 2014, Study the release of urea from Agrium® coated urea using UV-Vis spectrometer, *Appl. Mech. Mater.*, 625, 745–748.

Tsai, H.S., and Wang, Y.Z., 2008, Properties of hydrophilic chitosan network membranes by introducing binary crosslink agents, *Polym. Bull.*, 60, 103–113.

Vejan, P., Khadiran, T., Abdullah, R., and Ahmad, N., 2021, Controlled release fertilizer: a review on developments, applications and potential in agriculture, *J. Control. Release*, 339, 321–334.

Wesołowska, M., Rymarczyk, J., Góra, R., Baranowski, P., Sławiński, C., Klimczyk, M., Supryn, G., and Schimmelpfennig, L., 2021, New slow-release fertilizers – economic, legal and practical aspects: a review, *Int. Agrophys.*, 35, 11–24.

Wong, W.Y., Wong, C.Y., Rashmi, W., and Khalid, M., 2018, Choline chloride:Urea-based deep eutectic solvent as additive to proton conducting chitosan films, *J. Eng. Sci. Technol.*, 13, 2995–3006.

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.

Yang, J., Zhou, C., Tian, Y., and Tian, J., 2009, Preparation of chitosan/hydroxyapatite membrane and its effect on cell culture, *Sheng Wu Yi Xue Gong Cheng Xue Za Zhi*, 26, 580–584.

Yazicioglu, N., 2024, Chitosan/teff flour active films incorporated with citric acid and beetroot leaf extract: physicochemical properties and mathematical modeling of phenolic release, *Int. J. Biol. Macromol.*, 270, 132301.

Yoo, Y., Spencer, M.W., and Paul, D.R., 2011, Morphology and mechanical properties of glass fiber reinforced Nylon 6 nanocomposites, *Polymer*, 52, 180–190.

Zhou, J., Cai, X., Cheng, K., Weng, W., Song, C., Du, P., Shen, G., and Han, G., 2011, Release behaviors of drug loaded chitosan/calcium phosphate coatings on titanium, *Thin Solid Films*, 519, 4658–4662.

Zhu, G., Sun, Y., Shakoor, N., Zhao, W., Wang, Q., Wang, Q., Imran, A., Li, M., Li, Y., Jiang, Y., Muhammad Adeel, and Rui, Y., 2023, Phosphorus-based

nanomaterials as a potential phosphate fertilizer for sustainable agricultural development, *Plant Physiol. Biochem.*, 205, 108172.