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**Starch-Derived Bioplastics: Pioneering Sustainable Solutions for Industrial Use**
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**Abstract**
The use of plastics has increased due to the increase in population and applications in various industries. However, fossil fuel-based plastics have caused environmental issues and health hazards due to their non-degradable behavior. To resolve the on-going crisis of these non-degradable polymers, biopolymers have been considered as potential substitutes. Starch is being researched as a polymer matrix to develop bioplastics. Starch is abundant, but due to its poor water barrier and mechanical properties, other materials need to be incorporated in the matrix to improve the material properties. Natural fillers, plasticizers, essential oils, nanoparticles, or polymer blends are materials that can be used in starch-based bioplastics. Adding these materials enhances the mechanical and barrier properties. This review summarizes the recent developments in starch-based bioplastics and biocomposites and discusses the types of starch used, fillers, essential oils, and nanoparticles, explaining how they improve the mechanical, barrier, antibacterial, and biodegradability properties. Furthermore, many of the research products show potential to be used in industrial applications like packaging and agriculture. This review also discusses the potential of starch bioplastics in industrial applications like packaging, automotive applications, biomedical applications, electronics, construction, textiles, and consumer goods. This review also discusses the environmental impact of starch-derived bioplastic products, the life cycle, biodegradation, and recycling process. The circular economy of bioplastics, the economic feasibility of large-scale products, and regulation were also discussed, along with their challenges and the future perspectives of starch-based bioplastics. © 2025 by the authors.

**Author Keywords**
applications; biodegradability; essential oils; nanoparticles; natural fillers; properties; starch-based bioplastic; sustainability

**Index Keywords**
Agricultural products, Labeling, Medical nanotechnology, Plastics applications, Polymer matrix composites, Textile blends; Bio-plastics, Degradable polymers, Environmental health, Environmental issues, Industrial use, Natural fillers, Property, Starch-based, Starch-based bioplastic, Sustainable solution; Biodegradability

**References**

- Geyer, R.
  **A Brief History of Plastics**
  (2020) *Mare Plasticum—The Plastic Sea: Combatting Plastic Pollution Through Science and Art*, pp. 31-47.
  Springer, Cham, Switzerland
- Agamuthu, P., Mehran, S.B., Norkhairah, A., Norkhairiyah, A.
  **Marine Debris: A Review of Impacts and Global Initiatives**
  (2019) *Waste Manag. Res. J. Sustain. Circ. Econ*, 37, pp. 987-1002.
  31084415
- Bergmann, M., Collard, F., Fabres, J., Gabrielsen, G.W., Provencher, J.F., Rochman, C.M., van Sebille, E., Tekman, M.B.
  **Plastic Pollution in the Arctic**
  (2022) *Nat. Rev. Earth Environ*, 3, pp. 323-337.
- Dokl, M., Copot, A., Krajnc, D., Van Fan, Y., Vujanović, A., Aviso, K.B., Tan, R.R., Čuček, L.
  **Global Projections of Plastic Use, End-of-Life Fate and Potential Changes in**

**Consumption, Reduction, Recycling and Replacement with Bioplastics to 2050**
(2024) *Sustain. Prod. Consum*, 51, pp. 498-518.

- Prata, J.C., da Costa, J.P., Lopes, I., Duarte, A.C., Rocha-Santos, T.
**Environmental Exposure to Microplastics: An Overview on Possible Human Health Effects**
(2020) *Sci. Total Environ*, 702.

- Shen, M., Huang, W., Chen, M., Song, B., Zeng, G., Zhang, Y.
**(Micro)Plastic Crisis: Un-Ignorable Contribution to Global Greenhouse Gas Emissions and Climate Change**
(2020) *J. Clean. Prod*, 254.

- Alobi, N., Sunday, E., Magu, T., Oloko, G., Nyong, B.
**Analysis of Starch from Non- Edible Root and Tubers as Sources of Raw Materials for the Synthesis of Biodegradable Starch Plastics**
(2017) *J. Basic. Appl. Res. Biomed*, 3, pp. 27-32.

- Brockhaus, S., Petersen, M., Kersten, W.
**A Crossroads for Bioplastics: Exploring Product Developers' Challenges to Move beyond Petroleum-Based Plastics**
(2016) *J. Clean. Prod*, 127, pp. 84-95.

- Xie, D., Zhang, R., Zhang, C., Yang, S., Xu, Z., Song, Y.
**A Novel, Robust Mechanical Strength, and Naturally Degradable Double Crosslinking Starch-Based Bioplastics for Practical Applications**
(2023) *Int. J. Biol. Macromol*, 253.

- Otache, M.A., Duru, R.U., Achugasim, O., Abayeh, O.J.
**Advances in the Modification of Starch via Esterification for Enhanced Properties**
(2021) *J. Polym. Environ*, 29, pp. 1365-1379.

- Tan, S.X., Andriyana, A., Ong, H.C., Lim, S., Pang, Y.L., Ngoh, G.C.
**A Comprehensive Review on the Emerging Roles of Nanofillers and Plasticizers towards Sustainable Starch-Based Bioplastic Fabrication**
(2022) *Polymers*, 14.

- Jayarathna, S., Andersson, M., Andersson, R.
**Recent Advances in Starch-Based Blends and Composites for Bioplastics Applications**
(2022) *Polymers*, 14.
36365555

- Rahardiyan, D., Moko, E.M., Tan, J.S., Lee, C.K.
**Thermoplastic Starch (TPS) Bioplastic, the Green Solution for Single-Use Petroleum Plastic Food Packaging—A Review**
(2023) *Enzym. Microb. Technol*, 168.
37224591

- Pérez, S., Bertoft, E.
**The Molecular Structures of Starch Components and Their Contribution to the Architecture of Starch Granules: A Comprehensive Review**
(2010) *Starch Stärke*, 62, pp. 389-420.

- Nafchi, A.M., Moradpour, M., Saeidi, M., Alias, A.K.
**Thermoplastic Starches: Properties, Challenges, and Prospects**
(2013) *Starch Stärke*, 65, pp. 61-72.

- Cristofoli, N.L., Lima, A.R., Tchonkouang, R.D.N., Quintino, A.C., Vieira, M.C.
**Advances in the Food Packaging Production from Agri-Food Waste and By-**

**Products: Market Trends for a Sustainable Development**
(2023) *Sustainability*, 15.

- Marichelvam, M.K., Jawaid, M., Asim, M.
**Corn and Rice Starch-Based Bio-Plastics as Alternative Packaging Materials**
(2019) *Fibers*, 7.

- Sultan, N.F.K., Johari, W.L.W.
**The Development of Banana Peel/Corn Starch Bioplastic Film: A Preliminary Study**
(2017) *Bioremediation Science and Technology Research*, 5, pp. 12-17.
Public Knowledge Project, Drive Burnaby, BC, Canada

- Lenz, D.M., Tedesco, D.M., Camani, P.H., dos Santos Rosa, D.
**Multiple Reprocessing Cycles of Corn Starch-Based Biocomposites Reinforced with Curauá Fiber**
(2018) *J. Polym. Environ*, 26, pp. 3005-3016.

- Romani, V.P., Prentice-Hernández, C., Martins, V.G.
**Active and Sustainable Materials from Rice Starch, Fish Protein and Oregano Essential Oil for Food Packaging**
(2017) *Ind. Crops Prod*, 97, pp. 268-274.

- Syafri, E., Kasim, A., Abral, H., Asben, A.
**Effect of Precipitated Calcium Carbonate on Physical, Mechanical and Thermal Properties of Cassava Starch Bioplastic Composites**
(2017) *Int. J. Adv. Sci. Eng. Inf. Technol*, 7.

- Abral, H., Dalimunthe, M.H., Hartono, J., Efendi, R.P., Asrofi, M., Sugiarti, E., Sapuan, S.M., Kim, H.J.
**Characterization of Tapioca Starch Biopolymer Composites Reinforced with Micro Scale Water Hyacinth Fibers**
(2018) *Starch Stärke*, 70.

- Zuraida, A., Nur Humairah, A.R., Nur Izwah, A.W., Siti Naqiah, Z.
**The Study of Glycerol Plasticized Thermoplastic Sago Starch**
(2012) *Proceedings of the Advanced Materials Research*, 576, pp. 289-292.
AMR, Greenwood Village, CO, USA

- Podshivalov, A., Zakharova, M., Glazacheva, E., Uspenskaya, M.
**Gelatin/Potato Starch Edible Biocomposite Films: Correlation between Morphology and Physical Properties**
(2017) *Carbohydr. Polym*, 157, pp. 1162-1172.
27987819

- Faruk, O., Bledzki, A.K., Fink, H.P., Sain, M.
**Biocomposites Reinforced with Natural Fibers: 2000–2010**
(2012) *Prog. Polym. Sci*, 37, pp. 1552-1596.

- Sienkiewicz, N., Dominic, M., Parameswaranpillai, J.
**Natural Fillers as Potential Modifying Agents for Epoxy Composition: A Review**
(2022) *Polymers*, 14.
35054672

- Lopes, J., Pettersen, M.K., Grøvlen, M.S., Sharmin, N., Li, K.D., Wetterhus, E., Ferreira, P., Gonçalves, I.
**Heat-Sealable Bioplastic Films of Blended Locust Bean and Potato Byproducts for Active Packaging of Fatty Foods: Cheese and Oat Cookies as Case Studies**
(2024) *Food Hydrocoll*, 147.

- Hazrol, M.D., Sapuan, S.M., Zainudin, E.S., Wahab, N.I.A., Ilyas, R.A.
**Effect of Kenaf Fibre as Reinforcing Fillers in Corn Starch-Based Biocomposite Film**

(2022) *Polymers*, 14.

- Majamo, S.L., Amibo, T.A.
**Study on Extraction and Characterization of Anchote (Coccinia abyssinica) Starch and Reinforced Enset (Ensete ventricosum) Fiber for the Production of Reinforced Bioplastic Film**
(2024) *Heliyon*, 10.

- (2017) *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*,
ASTM International, West Conshohocken, PA, USA

- Chaffa, T.Y., Meshesha, B.T., Mohammed, S.A., Jabasingh, S.A.
**Production, Characterization, and Optimization of Starch-Based Biodegradable Bioplastic from Waste Potato (Solanum tuberosum) Peel with the Reinforcement of False Banana (Ensete ventricosum) Fiber**
(2022) *Biomass Convers. Biorefinery*, 14, pp. 27365-27377.

- Santana, I., Felix, M., Bengoechea, C.
**Sustainable Biocomposites Based on Invasive Rugulopteryx Okamurae Seaweed and Cassava Starch**
(2024) *Sustainability*, 16.

- Ekielski, A., Żelaziński, T., Kulig, R., Kupczyk, A.
**Properties of Biocomposites Made of Extruded Apple Pomace and Potato Starch: Mechanical and Physicochemical Properties**
(2024) *Materials*, 17.

- Zdanowicz, M., Rokosa, M., Pieczykolan, M., Antosik, A.K., Chudecka, J., Mikiciuk, M.
**Study on Physicochemical Properties of Biocomposite Films with Spent Coffee Grounds as a Filler and Their Influence on Physiological State of Growing Plants**
(2023) *Int. J. Mol. Sci*, 24.

- Dilkushi, H.A.S., Jayarathna, S., Manipura, A., Chamara, H.K.B.S., Edirisinghe, D., Vidanarachchi, J.K., Priyashantha, H.
**Development and Characterization of Biocomposite Films Using Banana Pseudostem, Cassava Starch and Poly (Vinyl Alcohol): A Sustainable Packaging Alternative**
(2024) *Carbohydr. Polym. Technol. Appl*, 7.

- Aaliya, B., Sunooj, K.V., Vijayakumar, A., Krina, P., Navaf, M., Parambil Akhila, P., Raviteja, P., George, J.
**Fabrication and Characterization of Talipot Starch-Based Biocomposite Film Using Mucilages from Different Plant Sources: A Comparative Study**
(2024) *Food Chem*, 438.
37984000

- Oluba, O.M., Owoso, T.O., Bayo-Olorunmeke, A.O., Erifeta, G.O., Josiah, S.J., Ojeaburu, S.I., Subbiah, N., Palanisamy, T.
**Probing the Role of Ginger Starch on Physicochemical and Thermal Properties of Gum Arabic Hybrid Biocomposite for Food Packaging Applications**
(2025) *Carbohydr. Polym. Technol. Appl*, 9.

- Lounis, F.M., Benhacine, F., Hadj-Hamou, A.S.
**Improving Water Barrier Properties of Starch Based Bioplastics by Lignocellulosic Biomass Addition: Synthesis, Characterization and Antibacterial Properties**
(2024) *Int. J. Biol. Macromol*, 283.

- Torres-Vargas, O., Campos Paéz, M., Lema González, M.
**Corn Starch Based Biocomposite Films Reinforced with Cellulosic Nanocrystals Extracted from Corn Husks (Zea mays L.): Characterization and Application in**

**Cherry Tomato Packaging**
(2025) *Ind. Crops Prod*, 225.

- Charles, A.L., Nero, Z., Sulmartiwi, L., Triningtyas, P.H., Putra, N.R., Abdillah, A.A., Alamsjah, M.A.
**Characterization of a Biocomposite Film Using Coconut Jelly Powder to Improve Arrowroot Starch and Sodium Alginate Film Forming Properties**
(2025) *Int. J. Biol. Macromol*, 292.

- Guno, F.J.R., Mopera, L., Santiago, D.M., Elegado, F., Galeon, P.L.
**Optimization of Biocomposite Taro (Colocasia esculenta (L.) Schott) Starch and Aloe Vera (Aloe barbadensis (L.) Burm.f.) Gel Based Film-Using Response Surface Methodology**
(2025) *Int. J. Biol. Macromol*, 305.

- Kedir, W.M., Geletu, A.K., Weldegirum, G.S.
**Spider Web-Reinforced Chitosan/Starch Biopolymer for Active Biodegradable Food Packaging**
(2024) *Appl. Food Res*, 4.

- Behera, L., Mohanta, M., Thirugnanam, A.
**Intensification of Yam-Starch Based Biodegradable Bioplastic Film with Bentonite for Food Packaging Application**
(2022) *Environ. Technol. Innov*, 25.

- Singh, P., Kaur, G., Singh, A., Kaur, P.
**Starch Based Bio-Nanocomposite Films Reinforced with Montmorillonite and Lemongrass Oil Nanoemulsion: Development, Characterization and Biodegradability**
(2023) *J. Food Meas. Charact*, 17, pp. 527-545.

- Ren, J., Dang, K.M., Pollet, E., Avérous, L.
**Preparation and Characterization of Thermoplastic Potato Starch/Halloysite Nano-Biocomposites: Effect of Plasticizer Nature and Nanoclay Content**
(2018) *Polymers*, 10.
30960733

- Mutmainna, I., Tahir, D., Gareso, P.L., Ilyas, S., Saludung, A.
**Improving Degradation Ability of Composite Starch/Chitosan by Additional Pineapple Leaf Microfibers for Food Packaging Applications**
(2019) *IOP Conf. Ser. Mater. Sci. Eng*, 593.

- Jaafar, J., Siregar, J.P., Oumer, A.N., Hamdan, M.H.M., Tezara, C., Salit, M.S.
**Experimental Investigation on Performance of Short Pineapple Leaf Fiber Reinforced Tapioca Biopolymer Composites**
(2019) *Bioresources*, 13, pp. 6341-6355.

- Yusof, F.M., Wahab, N.'.A., Abdul Rahman, N.L., Kalam, A., Jumahat, A., Mat Taib, C.F.
**Properties of Treated Bamboo Fiber Reinforced Tapioca Starch Biodegradable Composite**
(2019) *Mater. Today Proc*, 16, pp. 2367-2373.

- Lomelí Ramírez, M.G., Satyanarayana, K.G., Iwakiri, S., De Muniz, G.B., Tanobe, V., Flores-Sahagun, T.S.
**Study of the Properties of Biocomposites. Part I. Cassava Starch-Green Coir Fibers from Brazil**
(2011) *Carbohydr. Polym*, 86, pp. 1712-1722.

- Fitch-Vargas, P.R., Camacho-Hernández, I.L., Rodríguez-González, F.J., Martínez-Bustos, F., Calderón-Castro, A., Zazueta-Morales, J., Aguilar-Palazuelos, E.
**Effect of Compounding and Plastic Processing Methods on the Development of**

**Bioplastics Based on Acetylated Starch Reinforced with Sugarcane Bagasse Cellulose Fibers**
(2023) *Ind. Crops Prod*, 192.

- Collazo-Bigliardi, S., Ortega-Toro, R., Boix, A.C.
**Reinforcement of Thermoplastic Starch Films with Cellulose Fibres Obtained from Rice and Coffee Husks**
(2018) *J. Renew. Mater*, 6, pp. 599-610.

- Zamrud, Z., Ng, W.M., Salleh, H.M.
**Effect of Bentonite Nanoclay Filler on the Properties of Bioplastic Based on Sago Starch**
(2021) *IOP Conf. Ser. Earth Environ. Sci*, 765.

- Oluwasina, O.O., Akinyele, B.P., Olusegun, S.J., Oluwasina, O.O., Mohallem, N.D.S.
**Evaluation of the Effects of Additives on the Properties of Starch-Based Bioplastic Film**
(2021) *SN Appl. Sci*, 3.

- Tarique, J., Sapuan, S.M., Khalina, A., Ilyas, R.A., Zainudin, E.S.
**Thermal, Flammability, and Antimicrobial Properties of Arrowroot (Maranta arundinacea) Fiber Reinforced Arrowroot Starch Biopolymer Composites for Food Packaging Applications**
(2022) *Int. J. Biol. Macromol*, 213, pp. 1-10.

- Campos, A., Sena Neto, A.R., Rodrigues, V.B., Luchesi, B.R., Mattoso, L.H.C., Marconcini, J.M.
**Effect of Raw and Chemically Treated Oil Palm Mesocarp Fibers on Thermoplastic Cassava Starch Properties**
(2018) *Ind. Crops Prod*, 124, pp. 149-154.

- Ibrahim, M.M., Moustafa, H., El Rahman, E.N.A., Mehanny, S., Hemida, M.H., El-Kashif, E.
**Reinforcement of Starch Based Biodegradable Composite Using Nile Rose Residues**
(2020) *J. Mater. Res. Technol*, 9, pp. 6160-6171.

- Ilyas, R.A., Sapuan, S.M., Ibrahim, R., Abral, H., Ishak, M.R., Zainudin, E.S., Atikah, M.S.N., Ansari, M.N.M.
**Effect of Sugar Palm Nanofibrillated Cellulose Concentrations on Morphological, Mechanical and Physical Properties of Biodegradable Films Based on Agro-Waste Sugar Palm (Arenga pinnata (Wurmb.) Merr) Starch**
(2019) *J. Mater. Res. Technol*, 8, pp. 4819-4830.

- Sarsari, N.A., Pourmousa, S., Tajdini, A.
**Physical and Mechanical Properties of Walnut Shell Flour-Filled Thermoplastic Starch Composites**
(2016) *Bioresources*, 11, pp. 6968-6983.

- Lenhani, G.C., dos Santos, D.F., Koester, D.L., Biduski, B., Deon, V.G., Machado Junior, M., Pinto, V.Z.
**Application of Corn Fibers from Harvest Residues in Biocomposite Films**
(2021) *J. Polym. Environ*, 29, pp. 2813-2824.

- Sakhare, K.M., Borkar, S.P., Kale, R.D.
**Fabrication and Characterization of Bio Composite Based on Jute Fiber and Pine Rosin Modified Potato Starch**
(2023) *J. Chem. Health Risks*, 13, pp. 258-271.

- Cheng, W.
**Preparation and Properties of Lignocellulosic**

**Fiber/CaCO<sub>3</sub>/Thermoplastic Starch Composites**
(2019) *Carbohydr. Polym*, 211, pp. 204-208.

- Guleria, A., Singha, A.S., Rana, R.K.
**Mechanical, Thermal, Morphological, and Biodegradable Studies of Okra Cellulosic Fiber Reinforced Starch-Based Biocomposites**
(2018) *Adv. Polym. Technol*, 37, pp. 104-112.

- Zubair, M., Shahzad, S., Hussain, A., Pradhan, R.A., Arshad, M., Ullah, A.
**Current Trends in the Utilization of Essential Oils for Polysaccharide-and Protein-Derived Food Packaging Materials**
(2022) *Polymers*, 14.

- Syafiq, R., Sapuan, S.M., Zuhri, M.Y.M., Ilyas, R.A., Nazrin, A., Sherwani, S.F.K., Khalina, A.
**Antimicrobial Activities of Starch-Based Biopolymers and Biocomposites Incorporated with Plant Essential Oils: A Review**
(2020) *Polymers*, 12.

- Souza, A.G., Ferreira, R.R., Paula, L.C., Mitra, S.K., Rosa, D.S.
**Starch-Based Films Enriched with Nanocellulose-Stabilized Pickering Emulsions Containing Different Essential Oils for Possible Applications in Food Packaging**
(2021) *Food Packag. Shelf Life*, 27.

- Hernando, H., Marpongahtun, Julianti, E., Nuryawan, A., Amaturrahim, S.A., Piliang, A.F.R., Yanhar, M.R., Saputra, A.M.A.
**Impact of Glycerol on Oil Palm Trunk Starch Bioplastics Enhanced with Citric-Acid Epoxidized Palm Oil Oligomers**
(2024) *Case Stud. Chem. Environ. Eng*, 10.

- Enidiok, E.S., Enidiok, S.E., Anakor, D.O., Erifeta, G.O., Thanikaivelan, P., Oluba, O.M.
**Development and Characterization of Chia Oil-Activated Ginger Starch-Feather Keratin Biocomposite for Prolonged Post-Harvest Preservation of Tomato Fruits**
(2024) *Carbohydr. Polym. Technol. Appl*, 7.

- Criollo-Feijoo, J., Salas-Gomez, V., Cornejo, F., Auras, R., Salazar, R.
**Cassava Bagasse Starch and Oregano Essential Oil as a Potential Active Food Packaging Material: A Physicochemical, Thermal, Mechanical, Antioxidant, and Antimicrobial Study**
(2024) *Heliyon*, 10.

- Mao, S., Li, F., Zhou, X., Lu, C., Zhang, T.
**Characterization and Sustained Release Study of Starch-Based Films Loaded with Carvacrol: A Promising UV-Shielding and Bioactive Nanocomposite Film**
(2023) *Lebensm. Wiss. Technol*, 180.

- Srivastava, V., Singh, S., Das, D.
**Development and Characterization of Peppermint Essential Oil/Rice Husk Fibre/ Corn Starch Active Biocomposite Film and Its Performance on Bread Preservation**
(2024) *Ind. Crops Prod*, 208.

- Yang, Q., Zheng, F., Chai, Q., Li, Z., Zhao, H., Zhang, J., Nishinari, K., Cui, B.
**Effect of Emulsifiers on the Properties of Corn Starch Films Incorporated with Zanthoxylum Bungeanum Essential Oil**
(2024) *Int. J. Biol. Macromol*, 256.

- Parada-Quinayá, C., Garces-Porras, K., Flores, E.
**Development of Biobased Films Incorporated with an Antimicrobial Agent and Reinforced with Stipa Obtusa Cellulose Microfibers, via Tape Casting**
(2024) *Results Mater*, 24.

- Castro, D., Podshivalov, A., Ponomareva, A., Zhilenkov, A.
  **Study of the Reinforcing Effect and Antibacterial Activity of Edible Films Based on a Mixture of Chitosan/Cassava Starch Filled with Bentonite Particles with Intercalated Ginger Essential Oil**
  (2024) *Polymers*, 16.

- Yang, J., Chen, Y., Li, C., Ching, Y.C., Wang, R., Wei, Y., Liang, G., Xu, S.
  **Synthesis and Characterization of Bioplastics Based on Silyated Starch and Acrylated Epoxidized Soybean Oil**
  (2024) *Ind. Crops Prod*, 222.

- Yang, J., Xu, S., Ching, Y.C., Chuah, C.H., Wang, R., Li, C., Wei, Y., Liang, G.
  **Effects of Silane Hydrolysis Time on the Physicochemical Properties of Bioplastics Based on Starch and Epoxidized Soybean Oil**
  (2024) *Food Chem*, 460.
  39089044

- Enwere, C.F., Okafor, I.S., Adeleke, A.A., Petrus, N., Jakada, K., Olosho, A.I., Ikubanni, P.P., Ayuba, S.
  **Production of Bioplastic Films from Wild Cocoyam (Caladium bicolor) Starch**
  (2024) *Results Eng*, 24.

- He, X., Li, M., Gong, X., Niu, B., Li, W.
  **Biodegradable and Antimicrobial CSC Films Containing Cinnamon Essential Oil for Preservation Applications**
  (2021) *Food Packag. Shelf Life*, 29.

- Song, X., Zuo, G., Chen, F.
  **Effect of Essential Oil and Surfactant on the Physical and Antimicrobial Properties of Corn and Wheat Starch Films**
  (2018) *Int. J. Biol. Macromol*, 107, pp. 1302-1309.

- Al-Hashimi, A.G., Ammar, A.B., Lakshmanan, G., Cacciola, F., Lakhssassi, N.
  **Development of a Millet Starch Edible Film Containing Clove Essential Oil**
  (2020) *Foods*, 9.

- do Evangelho, J.A., da Silva Dannenberg, G., Biduski, B., el Halal, S.L.M., Kringel, D.H., Gularte, M.A., Fiorentini, A.M., da Rosa Zavareze, E.
  **Antibacterial Activity, Optical, Mechanical, and Barrier Properties of Corn Starch Films Containing Orange Essential Oil**
  (2019) *Carbohydr. Polym*, 222.

- Jamróz, E., Juszczak, L., Kucharek, M.
  **Investigation of the Physical Properties, Antioxidant and Antimicrobial Activity of Ternary Potato Starch-Furcellaran-Gelatin Films Incorporated with Lavender Essential Oil**
  (2018) *Int. J. Biol. Macromol*, 114, pp. 1094-1101.

- Akhter, R., Masoodi, F.A., Wani, T.A., Rather, S.A.
  **Functional Characterization of Biopolymer Based Composite Film: Incorporation of Natural Essential Oils and Antimicrobial Agents**
  (2019) *Int. J. Biol. Macromol*, 137, pp. 1245-1255.

- Silveira, M.P., Silva, H.C., Pimentel, I.C., Poitevin, C.G., da Costa Stuart, A.K., Carpiné, D., de Matos Jorge, L.M., Jorge, R.M.M.
  **Development of Active Cassava Starch Cellulose Nanofiber-Based Films Incorporated with Natural Antimicrobial Tea Tree Essential Oil**
  (2020) *J. Appl. Polym. Sci*, 137.

- Bharti, S.K., Pathak, V., Alam, T., Arya, A., Singh, V.K., Verma, A.K., Rajkumar, V.
  **Starch Bio-Based Composite Active Edible Film Functionalized with Carum carvi L.**

**Essential Oil: Antimicrobial, Rheological, Physic-Mechanical and Optical Attributes**
(2022) *J. Food Sci. Technol*, 59, pp. 456-466.

- Anugrahwidya, R., Armynah, B., Tahir, D.
**Bioplastics Starch-Based with Additional Fiber and Nanoparticle: Characteristics and Biodegradation Performance: A Review**
(2021) *J. Polym. Environ*, 29, pp. 3459-3476.

- Iacovone, C., Yulita, F., Cerini, D., Peña, D., Candal, R., Goyanes, S., Pietrasanta, L.I., Famá, L.
**Effect of TiO<sub>2</sub> Nanoparticles and Extrusion Process on the Physicochemical Properties of Biodegradable and Active Cassava Starch Nanocomposites**
(2023) *Polymers*, 15.
36771837

- Santos, J.D.C., Brites, P., Martins, C., Nunes, C., Coimbra, M.A., Ferreira, P., Gonçalves, I.
**Starch Consolidation of Calcium Carbonate as a Tool to Develop Lightweight Fillers for LDPE-Based Plastics**
(2023) *Int. J. Biol. Macromol*, 226, pp. 1021-1030.
36436608

- Oluwasina, O., Aderibigbe, A., Ikupoluyi, S., Oluwasina, O., Ewetumo, T.
**Physico-Electrical Properties of Starch-Based Bioplastic Enhanced with Acid-Treated Cellulose and Graphene Oxide Fillers**
(2024) *Sustain. Chem. Environ*, 6.

- Arezoo, E., Mohammadreza, E., Maryam, M., Abdorreza, M.N.
**The Synergistic Effects of Cinnamon Essential Oil and Nano TiO<sub>2</sub> on Antimicrobial and Functional Properties of Sago Starch Films**
(2020) *Int. J. Biol. Macromol*, 157, pp. 743-751.

- Abdullah, A.H.D., Putri, O.D., Fikriyyah, A.K., Nissa, R.C., Hidayat, S., Septiyanto, R.F., Karina, M., Satoto, R.
**Harnessing the Excellent Mechanical, Barrier and Antimicrobial Properties of Zinc Oxide (ZnO) to Improve the Performance of Starch-Based Bioplastic**
(2020) *Polym. Plast. Technol. Mater*, 59, pp. 1259-1267.

- Sapei, L., Padmawijaya, K.S., Sijayanti, O., Wardhana, P.J.
**Study of the Influence of ZnO Addition on the Properties of Chitosan-Banana Starch Bioplastics**
(2017) *Proceedings of the IOP Conference Series: Materials Science and Engineering*, 223.
Institute of Physics Publishing, Bristol, UK

- de Azêvedo, L.C., Rovani, S., Santos, J.J., Dias, D.B., Nascimento, S.S., Oliveira, F.F., Silva, L.G.A., Fungaro, D.A.
**Study of Renewable Silica Powder Influence in the Preparation of Bioplastics from Corn and Potato Starch**
(2021) *J. Polym. Environ*, 29, pp. 707-720.

- Amin, M.R., Chowdhury, M.A., Kowser, M.A.
**Characterization and Performance Analysis of Composite Bioplastics Synthesized Using Titanium Dioxide Nanoparticles with Corn Starch**
(2019) *Heliyon*, 5.

- Dawale, S.A., Bhagat, M.M., Scholar, R.
**Preparation and Characterization of Potato Starch Based Film Blended with CaCO<sub>3</sub> Nanoparticles**
(2018) *Int. J. Eng. Sci. Comput*, 8.

- Alves, Z., Ferreira, N.M., Ferreira, P., Nunes, C.
**Design of Heat Sealable Starch-Chitosan Bioplastics Reinforced with Reduced Graphene Oxide for Active Food Packaging**
(2022) *Carbohydr. Polym*, 291.

- López, O.V., Villanueva, M.E., Copello, G.J., Villar, M.A.
**Flexible Thermoplastic Starch Films Functionalized with Copper Particles for Packaging of Food Products**
(2020) *Funct. Compos. Mater*, 1.

- Collazo-Bigliardi, S., Ortega-Toro, R., Chiralt, A.
**Using Grafted Poly(ε-Caprolactone) for the Compatibilization of Thermoplastic Starch-Polylactic Acid Blends**
(2019) *React. Funct. Polym*, 142, pp. 25-35.

- Estrada-Girón, Y., Fernández-Escamilla, V.V.A., Martín-del-Campo, A., González-Nuñez, R., Canché-Escamilla, G., Uribe-Calderón, J., Tepale, N., Moscoso-Sánchez, F.J.
**Characterization of Polylactic Acid Biocomposites Filled with Native Starch Granules from Dioscorea Remotiflora Tubers**
(2024) *Polymers*, 16.

- Baniasadi, H., Äkräs, L., Madani, Z., Silvenius, F., Fazeli, M., Lipponen, S., Vapaavuori, J., Seppälä, J.
**Development and Characterization of Polylactic Acid/Starch Biocomposites—From Melt Blending to Preliminary Life Cycle Assessment**
(2024) *Int. J. Biol. Macromol*, 279.

- Abdollahi Moghaddam, M.R., Hesarinejad, M.A., Javidi, F.
**Characterization and Optimization of Polylactic Acid and Polybutylene Succinate Blend/Starch/Wheat Straw Biocomposite by Optimal Custom Mixture Design**
(2023) *Polym. Test*, 121.

- Kurup, G., Fadzillah, M.F.F.B.M., Royan, N.R.R., Radzuan, N.A.M., Sulong, A.B.
**Impact of Processing Parameters on the Compatibility and Performance of PLA/Tapioca Starch Biocomposites for Short-Term Food Packaging Applications**
(2025) *Mater. Today Commun*, 43.

- Oluwasina, O.O., Adebayo, M.A., Akinsola, M.O., Olorunfemi, T.E., Olajide, J.D.
**Influence of 2-Hydroxyethyl Terephthalate from Waste Polyethylene Plastic on the Properties of Starch-BHET Bioplastics**
(2024) *Waste Manag. Bull*, 2, pp. 203-213.

- Mohammed, A.A.B.A., Hasan, Z., Borhana Omran, A.A., Elfaghi, A.M., Ali, Y.H., Akeel, N.A.A., Ilyas, R.A., Sapuan, S.M.
**Effect of Sugar Palm Fibers on the Properties of Blended Wheat Starch/Polyvinyl Alcohol (PVA)-Based Biocomposite Films**
(2023) *J. Mater. Res. Technol*, 24, pp. 1043-1055.

- Noivoil, N., Yoksan, R.
**Oligo (Lactic Acid)-Grafted Starch: A Compatibilizer for Poly (Lactic Acid)/Thermoplastic Starch Blend**
(2020) *Int. J. Biol. Macromol*, 160, pp. 506-517.

- Ortega-Toro, R., López-Córdoba, A., Avalos-Belmontes, F.
**Epoxidised Sesame Oil as a Biobased Coupling Agent and Plasticiser in Polylactic Acid/Thermoplastic Yam Starch Blends**
(2021) *Heliyon*, 7.

- Palai, B., Biswal, M., Mohanty, S., Nayak, S.K.
**In Situ Reactive Compatibilization of Polylactic Acid (PLA) and Thermoplastic**

**Starch (TPS) Blends; Synthesis and Evaluation of Extrusion Blown Films Thereof**
(2019) *Ind. Crops Prod*, 141.

- Chang, B.P., Mohanty, A.K., Misra, M.
**Studies on Durability of Sustainable Biobased Composites: A Review**
(2020) *RSC Adv*, 10, pp. 17955-17999.
35517220

- Formela, K., Zedler, Hejna, A., Tercjak, A.
**Reactive Extrusion of Bio-Based Polymer Blends and Composites–Current Trends and Future Developments**
(2018) *Express Polym. Lett*, 12, pp. 24-57.

- Gamage, A., Thiviya, P., Mani, S., Ponnusamy, P.G., Manamperi, A., Evon, P., Merah, O., Madhujith, T.
**Environmental Properties and Applications of Biodegradable Starch-Based Nanocomposites**
(2022) *Polymers*, 14.

- Tang, K.H.D., Zhou, J.
**Ecotoxicity of Biodegradable Microplastics and Bio-Based Microplastics: A Review of in Vitro and in Vivo Studies**
(2024) *Environ. Manag*, 75, pp. 663-679.

- Martins, P., Brito-Pereira, R., Ribeiro, S., Lanceros-Mendez, S., Ribeiro, C.
**Magnetoelectrics for Biomedical Applications: 130 Years Later, Bridging Materials, Energy, and Life**
(2024) *Nano Energy*, 126.

- Khoo, P.S., Ilyas, R.A., Uda, M.N.A., Hassan, S.A., Nordin, A.H., Norfarhana, A.S., Ab Hamid, N.H., Norrrahim, M.N.F.
**Starch-Based Polymer Materials as Advanced Adsorbents for Sustainable Water Treatment: Current Status, Challenges, and Future Perspectives**
(2023) *Polymers*, 15.

- Ebrahimzade, I., Ebrahimi-Nik, M., Rohani, A., Tedesco, S.
**Towards Monitoring Biodegradation of Starch-Based Bioplastic in Anaerobic Condition: Finding a Proper Kinetic Model**
(2022) *Bioresour. Technol*, 347.

- Dutta, D., Sit, N.
**A Comprehensive Review on Types and Properties of Biopolymers as Sustainable Bio-based Alternatives for Packaging**
(2024) *Food Biomacromolecules*, 1, pp. 58-87.

- Wang, X., Tarahomi, M., Sheibani, R., Xia, C., Wang, W.
**Progresses in Lignin, Cellulose, Starch, Chitosan, Chitin, Alginate, and Gum/Carbon Nanotube (Nano) Composites for Environmental Applications: A Review**
(2023) *Int. J. Biol. Macromol*, 241.

- El-Beltagi, H.S., Basit, A., Mohamed, H.I., Ali, I., Ullah, S., Kamel, E.A.R., Shalaby, T.A., Ghazzawy, H.S.
**Mulching as a Sustainable Water and Soil Saving Practice in Agriculture: A Review**
(2022) *Agronomy*, 12.

- Salama, K., Geyer, M.
**Plastic Mulch Films in Agriculture: Their Use, Environmental Problems, Recycling and Alternatives**
(2023) *Environments*, 10.

- Shelar, A., Nile, S.H., Singh, A.V., Rothenstein, D., Bill, J., Xiao, J., Chaskar, M., Patil, R.
**Recent Advances in Nano-Enabled Seed Treatment Strategies for Sustainable Agriculture: Challenges, Risk Assessment, and Future Perspectives**
(2023) *Nanomicro Lett*, 15.

- Quilez-Molina, A.I., Chandra Paul, U., Merino, D., Athanassiou, A.
**Composites of Thermoplastic Starch and Lignin-Rich Agricultural Waste for the Packaging of Fatty Foods**
(2022) *ACS Sustain. Chem. Eng*, 10, pp. 15402-15413.

- Grancarić, A.M., Jerković, I., Tarbuk, A.
**Bioplastics in Textiles**
(2013) *Polim. Časopis Plast. Gumu*, 34, pp. 9-14.

- Drzal, L.T., Mohanty, A.K., Misra, M.
**Bio-Composite Materials as Alternatives to Petroleum-Based Composites for Automotive Applications**
(2001) *Magnesium*, 40, pp. 1-3.

- Rungruangkitkrai, N., Phromphen, P., Chartvivatpornchai, N., Srisa, A., Laorenza, Y., Wongphan, P., Harnkarnsujarit, N.
**Water Repellent Coating in Textile, Paper and Bioplastic Polymers: A Comprehensive Review**
(2024) *Polymers*, 16.

- Zhara, H., Adeel, S., Özomay, Z., Mia, R.
**Properties and Performance Relationship of Biopolymers in Textile Industry**
(2024) *Biopolymers in the Textile Industry: Opportunities and Limitations*, pp. 87-121.
Springer, Berlin/Heidelberg, Germany

- Biehl, P., Zhang, K.
**Introduction to Advances in Bio-Based Polymers: Chemical Structures and Functional Properties at the Interface**
(2024) *Green by Design: Harnessing the Power of Bio-Based Polymers at Interfaces*, pp. 1-69.
IOP Publishing, Bristol, UK

- Schutz, G.F., de Ávila Gonçalves, S., Alves, R.M.V., Vieira, R.P.
**A Review of Starch-Based Biocomposites Reinforced with Plant Fibers**
(2024) *Int. J. Biol. Macromol*, 261.

- Oh, E., Godoy Zúniga, M.M., Nguyen, T.B., Kim, B.-H., Trung Tien, T., Suhr, J.
**Sustainable Green Composite Materials in the Next-Generation Mobility Industry: Review and Prospective**
(2024) *Adv. Compos. Mater*, 33, pp. 1368-1419.

- Thapliyal, D., Verma, S., Sen, P., Kumar, R., Thakur, A., Tiwari, A.K., Singh, D., Arya, R.K.
**Natural Fibers Composites: Origin, Importance, Consumption Pattern, and Challenges**
(2023) *J. Compos. Sci*, 7.

- Hossain, M.T., Shahid, M.A., Akter, S., Ferdous, J., Afroz, K., Refat, K.R.I., Faruk, O., Samad, M.A.
**Bin Cellulose and Starch-Based Bioplastics: A Review of Advances and Challenges for Sustainability**
(2024) *Polym. Plast. Technol. Mater*, 63, pp. 1329-1349.

- Aslam, J., Parray, H.A.
(2024) *Biomimetic Coatings for Bone Regeneration. Smart Biomimetic Coatings: Design, Properties, and Biomedical Applications*, pp. 147-171.
Woodhead Publishing, Sawston, UK

- Rai, M., Dos Santos, C.A.
(2021) *Biopolymer-Based Nano Films: Applications in Food Packaging and Wound Healing*,
Elsevier, Amsterdam, The Netherlands

- Megha, M., Kamaraj, M., Nithya, T.G., GokilaLakshmi, S., Santhosh, P., Balavaishnavi, B.
**Biodegradable Polymers Research and Applications**
(2024) *Phys. Sci. Rev*, 9, pp. 949-972.

- Bozó, É., Ervasti, H., Halonen, N., Shokouh, S.H.H., Tolvanen, J., Pitkanen, O., Jarvinen, T., Sápi, A.
**Bioplastics and Carbon-Based Sustainable Materials, Components, and Devices: Toward Green Electronics**
(2021) *ACS Appl. Mater. Interfaces*, 13, pp. 49301-49312.
34609829

- Xie, D., Zhang, R., Song, S., Yang, S., Yang, A., Zhang, C., Song, Y.
**Nacre-Inspired Starch-Based Bioplastic with Excellent Mechanical Strength and Electromagnetic Interference Shielding**
(2024) *Carbohydr. Polym*, 331.

- Si, W., Zhang, S.
**The Green Manufacturing of Thermoplastic Starch for Low-Carbon and Sustainable Energy Applications: A Review on Its Progress**
(2024) *Green. Chem*, 26, pp. 1194-1222.

- Muñoz-Gimena, P.F., Oliver-Cuenca, V., Peponi, L., López, D.
**A Review on Reinforcements and Additives in Starch-Based Composites for Food Packaging**
(2023) *Polymers*, 15.

- Lepak-Kuc, S., Kądziela, A., Staniszewska, M., Janczak, D., Jakubowska, M., Bednarczyk, E., Murawski, T., Żołek-Tryznowska, Z.
**Sustainable, Cytocompatible and Flexible Electronics on Potato Starch-Based Films**
(2024) *Sci. Rep*, 14.

- Gawande, G., Khiratkar, T., Urkude, Y., Bombarde, S., Sonwane, U., Nikhade, S., Sanap, J.
(2024) *Bioplastic Production from Corn and Potato Starch and Its Industrial Applications*,
Vishwakarma Institute of Technology, Maharashtra, India

- Kong, U., Mohammad Rawi, N.F., Tay, G.S.
**The Potential Applications of Reinforced Bioplastics in Various Industries: A Review**
(2023) *Polymers*, 15.

- Vitola, L., Pundiene, I., Pranckeviciene, J., Bajare, D.
**Innovative Hemp Shive-Based Bio-Composites: Part I: Modification of Potato Starch Binder by Sodium Meta-Silicate and Glycerol**
(2024) *Materials*, 17.

- Spierling, S., Knüpffer, E., Behnsen, H., Mudersbach, M., Krieg, H., Springer, S., Albrecht, S., Endres, H.J.
**Bio-Based Plastics—A Review of Environmental, Social and Economic Impact Assessments**
(2018) *J. Clean. Prod*, 185, pp. 476-491.

- Mastrolia, C., Giaquinto, D., Gatz, C., Pervez, M.D., Hasan, S., Zarra, T., Li, C.-W., Naddeo, V.
**Plastic Pollution: Are Bioplastics the Right Solution?**
(2022) *Water*, 14.

- Lizundia, E., Luzi, F., Puglia, D.
  **Organic Waste Valorisation towards Circular and Sustainable Biocomposites**
  (2022) *Green. Chem*, 24, pp. 5429-5459.

- Mohanty, A.K., Misra, M., Drzal, L.T.
  **Sustainable Bio-Composites from Renewable Resources: Opportunities and Challenges in the Green Materials World**
  (2002) *J. Polym. Environ*, 10, pp. 19-26.

- Hussain, A.A., Lin, C., Nguyen, M.K., Ahsan, W.A., Hussain, A., Lin, C., Nguyen, M.K., Program, P.D.
  **Biodegradation of Different Types of Bioplastics through Composting—A Recent Trend in Green Recycling**
  (2023) *Catalysts*, 13.

- Igliński, B.
  **Valorization of Bioplastic Waste: A Review on Effective Recycling Routes for the Most Widely Used Biopolymers**
  (2023) *Int. J. Mol. Sci*, 24.

- Emadian, S.M., Onay, T.T., Demirel, B.
  **Biodegradation of Bioplastics in Natural Environments**
  (2017) *Waste Manag*, 59, pp. 526-536.

- Fonseca, A., Ramalho, E., Gouveia, A., Figueiredo, F., Nunes, J.
  **Life Cycle Assessment of PLA Products: A Systematic Literature Review**
  (2023) *Sustainability*, 15.

- Rosenboom, J.G., Langer, R., Traverso, G.
  **Bioplastics for a Circular Economy**
  (2022) *Nat. Rev. Mater*, 7, pp. 117-137.

- **Comprehensive Analysis of Bioplastics: Life Cycle Assessment**
  (2024) *Waste Manag. Circ. Econ*, 12.

- Boeve, M., de Waal, I.M.
  **Global Plastic Pollution and the Transition Towards a Circular Economy: Lessons from the EU's Legal Framework on Plastics**
  (2024) *Environ. Policy Law*, 53, pp. 461-472.

- Available online

- Pathak, S., Sneha, C., Mathew, B.B.
  **Bioplastics: Its Timeline Based Scenario & Challenges**
  (2014) *J. Polym. Biopolym. Phys. Chem*, 2, pp. 84-90.

- Negrete-Bolagay, D., Guerrero, V.H.
  **Opportunities and Challenges in the Application of Bioplastics: Perspectives from Formulation, Processing, and Performance**
  (2024) *Polymers*, 16.
  39339026

- Moshood, T.D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M.H., AbdulGhani, A.
  **Sustainability of Biodegradable Plastics: New Problem or Solution to Solve the Global Plastic Pollution?**
  (2022) *Curr. Res. Green. Sustain. Chem*, 5.

- Ghasemlou, M., Barrow, C.J., Adhikari, B.
  **The Future of Bioplastics in Food Packaging: An Industrial Perspective**
  (2024) *Food Packag. Shelf Life*, 43.

- Lenzi, L., Degli Esposti, M., Braccini, S., Siracusa, C., Quartinello, F., Guebitz, G.M., Puppi, D., Fabbri, P.
**Further Step in the Transition from Conventional Plasticizers to Versatile Bioplasticizers Obtained by the Valorization of Levulinic Acid and Glycerol**
(2023) *ACS Sustain. Chem. Eng*, 11, pp. 9455-9469.

- Pellis, A., Malinconico, M., Guarneri, A., Gardossi, L.
**Renewable Polymers and Plastics: Performance beyond the Green**
(2021) *New Biotechnol*, 60, pp. 146-158.

- Siddiqui, S.A., Yang, X., Deshmukh, R.K., Gaikwad, K.K., Bahmid, N.A., Castro-Muñoz, R.
**Recent Advances in Reinforced Bioplastics for Food Packaging—A Critical Review**
(2024) *Int. J. Biol. Macromol*, 263.

- Bin Abu Sofian, A.D.A., Lim, H.R., Manickam, S., Ang, W.L., Show, P.L.
**Towards a Sustainable Circular Economy: Algae-Based Bioplastics and the Role of Internet-of-Things and Machine Learning**
(2024) *ChemBioEng Rev*, 11, pp. 39-59.


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