International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Algae As A Source For Biopolymer Film Production: Methods, Characterization, and Applications - A Review

Chandran Masi[1], Prithika U[2], Yuvasree A[2] and Nagaraj T[1]

[1] Department of Food Technology, Dhanalakshmi Srinivasan Engineering College, Perambalur, Tamil Nadu, India.

[2]. Department of Biotechnology, Dhanalakshmi Srinivasan Engineering College, Perambalur, Tamil Nadu, India.
ORCID: 0000-0002-6870-4798

Abstract - Microalgae and macroalgae are considered promising and sustainable sources of biopolymers because of their rapid biomass production, efficient carbon dioxide sequestration, and renewable nature. Growing environmental concerns associated with petroleum-based plastics have accelerated the search for biodegradable and eco-friendly alternatives, making algae an attractive feedstock for biopolymer production. Algae produce valuable biopolymers such as agar, alginate, carrageenan, cellulose, proteins, and lipids, which possess unique physicochemical properties suitable for diverse industrial applications. These biopolymers have gained significant attention in food packaging, agriculture, cosmetics, textiles, bioremediation, biomedical engineering, and drug delivery due to their biodegradability, biocompatibility, and low environmental impact. Recent advancements in biotechnology and biorefinery technologies have improved the efficient conversion of algal biomass into value-added products, including biofuels, biodegradable films, hydrogels, and functional biomaterials. In particular, microalgae exhibit greater potential than conventional oil crops because of their high photosynthetic efficiency, superior lipid productivity, and ability to utilize carbon dioxide and wastewater, thereby contributing to greenhouse gas mitigation and sustainable resource management. However, large-scale commercialization remains challenging due to the small cell size, negatively charged cell surface, and high harvesting and extraction costs associated with microalgae. Therefore, the development of efficient, cost-effective, and environmentally friendly extraction and processing technologies is essential. This review summarizes the major algal sources of biopolymers, extraction and characterization methods, and the wide range of industrial applications of algae-derived biopolymer films.

KEYWORDS*: Algae, Biopolymers, Biodegradable Films, Microalgae, Macroalgae, Sustainable packaging*.

1. INTRODUCTION

We use polymer in many aspects of our lives. These days, the sustainability of polymers is becoming a more significant characteristic. If a polymer is made from waste, biological renewable resources or recycled material, and whether at the end of its life, it can remain in the technical or biological cycle of a circular economy(Mohanty,etal.,2020).Each application requires a different polymer due to their wide range of chemical and physical characteristics (Spicer,C.D.et al.,2020).The energy efficient process for turning biomass into biofuel can used on a commercial scale, the yield of biodiesel is 20 times greater than that of other oil crops, and there has been recent progress on a unified framework for policy producing biofuel are thoroughly explained(Chisti,2007; Gasparatos et al., 2013).

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Microalgae were the first photosynthetic organisms on ancient Earth. Unicellular microorganisms contribute to the reduction of greenhouse gases in the atmosphere by lowering substantial amounts of carbon dioxide through photosynthesis. As a result, algae are regarded as a practical method of carbon capture (Yu et al., 2017).

By absorbing atmospheric carbon dioxide (CO2), microalgae store carbon as lipids (autographically) and carbohydrates (cellulose and starch) (Shokrkar et al., 2018). Microalgae mass culture has been increasingly popular in recent decades. Utilized in a wide range of applications, from the extraction of proteins and carbohydrates (L.M.L.Laurens et al., 2012). The process of producing microalgae is well known, but its small size (5-50 m), highly negative surface charge, and occasionally motility lead to stable suspensions, making its large-scale separation difficult and unfeasible from an economic standpoint. According to(H.P. Jarvie et al,. 2002) algae are common single-to multicellular organisms that contain chlorophyll but lack actual roots, stems, and leaves. Complex communities of microorganisms known as biofilms develop on solid surfaces and are encased in an extracellular polymeric substance (EPS) matrix. legal biofilm cultivation as a nutrient removal method for wastewater treatment could offer both an efficient nutrient process for producing bioproducts and a source of algae biomass (P. Splauore et al., 2006).

Due to their higher growth rate, high photosynthetic efficiency, and significant potential for fixing carbon dioxide, algae are a great choice for renewable energy sources (Noreen,A., et al., 2016). Among the many products that algae can produce are proteins, carbohydrates, polymers, oils, and additional bioproducts. Because of their affordability and sustainability, algae are a useful tool for creating a range of bioproducts, The quantity of proteins, lipids, carbohydrates, and fats that the algae contains determines how useful it is as a feedstock for different processes with the cosmetics all make extensive use of biopolymers (Ranganadhareddy, A. el al., 2022).

Three generations of biopolymers can be distinguished in their historical development: petrochemical feedstocks derived from plant biomass (Karan et al., 2019). Numerous studies have documented the advantages of microalgae as a substitute for plant-based resources because of its high biomass productivity, capacity to absorb 1.8 lb of CO2, and capacity to release over 75% of the oxygen (O2) in the atmosphere (G.M. Elrayies et al., 2018). Moreover, compatibilizers, plasticizers, and additives can be added to algae-based biopolymer to improve the intermolecular force of contact between constituents and increase material strength, flexibility, and durability (Cinar, S.O. et al., 2020). This biomaterial products are categorized to function similarly to biological systems, allowing it for interactions that may results in better ecological results. Biomaterials are increasingly being incorporated into industrial processes because they successfully achieved and reduced the environmental impact of goods, supporting a manufacturing protocols / paradigm, that is more ecologically friendly. Because of their structural and functional environmental roles in living organisms, biopolymers are crucial in a variety of applications (Bugarcic,M. et., 2024). Biopolymers, polypeptides, are longer chains created by covalently bonding monomeric - subunits.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Industry. Agar, alginate and carrageenan are among the polysaccharides, produced by a range of macroalgal divisions. Biopolymers have become more and more popular in recent years investigated for cutting-edge uses in electrical devices and optical thin films (A. Badawi el al., 2017). Because of their special material qualities, flexibility, and sustainability (Ashour et al., 2025). These algal compounds have the ability to alter the rates at which other nutrients are a Polymers known as polysaccharides have drawn a lot of interest from the packaging absorbed, and these polysaccharides can alter intestinal activity by modifying the intestinal microbiota. The ability results from the large intestine's full or partial fermentation (Chen,P. et al., 2018).

1.1 SOURCES OF BIOPOLYMER -BASED ALGAE

Bio based polymer originate from renewable biological sources such as plants, algae, bacteria and other microorganisms. They may be synthesized by polymerizing monomers obtained from these resources or extracted directly from the organisms themselves (Dimri,et al.,2023).In materials of biobased origin including bioplastic ,biopolymer and biobased polyurethanes the primary building blocks are proteins, lipids and carbohydrates which microalgae (and certain cyanobacteria) can produce in substantial amounts (Madadi, et al.,2021).Microalgae have also emerged as a promising sustainable biomass feedstock , with applications in co2 reduction ,nitrogen fixation, wastewater treatment ,biofertilizer development ,bioenergy generation and both animal and human nutrition.

The most important components in the primary composition of products of biobased origin, such as bioplastic biopolymers, and biobased polyurethane are lipids, proteins and carbohydrates, all of which can be produced in large quantities by microalgae (and some cyanobacteria) (Madadi,R.,et al.,2021).polymer that are extracted from seaweed that includes agar, carrageenan, and alginate are crucially and highly used in various industries. In the food industries their functional properties that covers their efficiency to form gels , retain moisture , and act as emulsifiers make them specifically rich and cause effective results to their effective economic importance (C. Lim.,et al.,2021).According to seaweeds are generally classified into three major groups. That is green (chlorphyta), brown (phaeophyta) and Red (rhodophyta).Based on their pigmentation algae are also categorized into these colour groups , and approximately 50 species are known to be edible for human consumption (Ruperez,et al.,2002).

1.2 RED ALGAE

The Rhodophyta or red algae are a diverse group of aquatic photoautotrophic plants that range in size from unicellular to multicellular (Shoaib,A.G.,et al.,2020). According to phylogenetic analysis, red algae are considered plants since they have a single common ancestor with the green lineage which includes higher plants and green algae (Gurgel, C.F.D.,et a;.2007). The pigments that give them their red hue—phycoerythrin, phycocyanin, chlorophyll a, d, carotene, and xanthophylls—are what define the Rhodophyceae (Red Algae), which are primarily marine algae. They store food in the form of Floridean starch, and their cells have lower forms of pyrenoid-like bodies and chromatophores. The cell wall is composed of an inner cellulosic layer and an outer pectic layer. These multicellular algae

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

can have either a uniaxial or multiaxial structure, and because they lack flagella, their cells cannot move. Sexual reproduction usually takes the form of oogamous reproduction.

Fig 1: Rhodophyta

1.3 BROWN ALGAE

Up to 40% of the dry weight of brown algae may be made up of the alginate component of their cell walls. Porphyra purpurea and Undaria pinnatifida, two brown algae ,have a high protein content among them (Wang, J,.et al.,2019). The flexibility of the algae's tissue structure is facilitated by the alginate content of their cell walls. Only a small number of brown algae species are researched and processed to create alginate product, despite the fact that all brown algae contain alginate (PERMATASARI,A.A.A.P.,et al.,2022) .Alginate can also be found as insoluble calcium, magnesium and sodium salts. Species, harvest season and other variables affect the amount and quality of alginate produced by brown seaweed (M. Rinaudo,et al.,2014).One potential solution to the rapidly depleting conventional energy resources is the production of biodiesel from microalgae. Both freshwater and marine habitats are home to cryptophyceae, or nearly brown algae. They have pigments like phycocyanin and phycoerythrin, different xanthophylls like diatoxanthin, and chlorophyll a and c. Although they exist, pyrenoid-like bodies do not join the chromatophores. They use starch and occasionally oil as a reserve food source. These algae usually have an anterior groove or pocket and are unicellular in nature, lacking a true cell wall. They have two hairy flagella, which can be equal or unequal and can emerge from the lateral side or apex. Binary fission is the primary method of reproduction, whereas sexual reproduction is uncommon and, when it does occur, is isogamous.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Fig 2: Rockweed or Bladderwrack

1.4 GREEN ALGAE

Prokaryotic cyanobacteria ,which are blue and green in colour and eukaryotic microalgae which include the brown Phaeophyto , green Chorophyta and gold Chrysophyceae are the categories of microalgae (Nitsos, C.,et al.,2020).The majority of phylogenies strongly support the plantae or Archeoplastida eukaryotic kingdom which include nucleic acid. Green algae, or chlorophyta, are members of Phylum I and have starch as a backup food source. They also contain chlorophyll a and b. Several orders with distinct traits are included in the class Chlorophyceae. Volvocales exhibit both isogamy and oogamy in their reproduction and have motile cells. Tetrasporales reproduce isogamously and are primarily unicellular and gelatinous, with motile reproductive cells and occasionally motile vegetative cells. Ulotrichales exhibit either isogamous or anisogamous reproduction and are filamentous with unbranched filaments, a parietal chloroplast, and a single-section cell wall. In addition to having unbranched filaments with a parietal chloroplast, microsporales can reproduce either isogamously or anisogamously and have a two-sectioned cell wall. Cylindrocapsales reproduce oogamously and have unbranched filaments with a large chloroplast. Their cells are encased in lamellar mucilage. Sphaeropleales are filamentous and unbranched.

Fig 3:Sea lettuce

2. EXTRACTION AND PROCCESSING METHOD

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Edible algae are a staple food in China, Japan, South Korea and other Southeast Asian nations. The ocean is home to a thousand different types of algae. The problems with traditional edible algae processing technology include low sensory quality, nutritional loss, and inefficiency processing and use. Efficient processing technologies play an essential role in advancing this field (Wang,et al.,2019).When both environment and economic sustainability are considered bioenergy becomes a key strategy for reducing long-term co2 emission and providing a practical substitute for petroleum-based transportation fuels. Biofuels refer to liquid or gaseous fuels produced mainly from biomass and intended for transport applications. Various biomass sources can be converted into multiple fuel types, including gaseous options such as biogas and biohydrogen as well as liquid fuels like ethanol, methanol, biodiesel and Fischer-Tropsch diesel.

Since nearly 80% of energy currently comes from fossil fuels , the rapid depletion of conventional energy resources has prompted a global search for renewable fuel sources (M.F. Demirbas,2011).One potential solution to the rapidly depletion conventional energy resources is the production of biodiesel from microalgae (D.Vandamme et al.,2013).Since algal lipid-derived biodiesel has been shown to be comparable to conventional biodiesel ,it can be used straight away with little to no modification(Z.Wu et al.,2012).Because of this harvesting such small cells using traditional techniques like centrifugation or filtration requires a lot of energy and is therefore too costly for low-value products like biodiesel (E.Molina Grima et al.,).

3. ENVIRONMENTAL BENEFITS

The use of traditional synthetic polymers derived from petroleum has significantly increased. Because of the increase in population over the past 20 years. The emission of greenhouse dases (GHGs),their nonbiodegradability their detrimental effects on the land and marine ecosystem and environmental persistence(Devadas, V.V., et al.,2021).According to recent studies ,Algal based biopolymers have superior properties to petroleum -based polymers(Beckstrom, B.D., et al.,2020).

Advanced biopolymer such as chitosan has huge developed procedure involving drug delivery and tissue regeneration(Negam, N.A., et al.,2020).Along with ,emerging technologies like 3D printing depend comprehensively materials(Kolan,K,.,et al.,2017).Contemporary biotechnology is also being discovered as a means to improve the commercial feasibility of algae-derived biofuels(Adenle, A.A., et al.,2013).In addition, several studies have examine the efficacy of algae in bioremediation and in mass produce high value outputs such as biochar, bio-oil, syngas and diverse biopolymer(Roy Chong,J.W.,et al.,2022).

Biochar is a carbonaceous material that is synthesized using heat breaking done algal biomass in an oxygen-free surrounding. Numerous methods have been developed to produce biochar from microalgae using thermochemical reactions; these methods are preferred due to their high efficiency, quality and yield(Alazaiza, M.Y.,et al.,2023) .Because of their wide range of chemical and physical properties, each application requires a different polymer(Joshi ,J.S .,et al .,2024).One of the current uses of polymers is in batteries(Muldoon ,J., et al,.2015).Electrochemical active polymers that involves polyaniline, polypyrrole , several

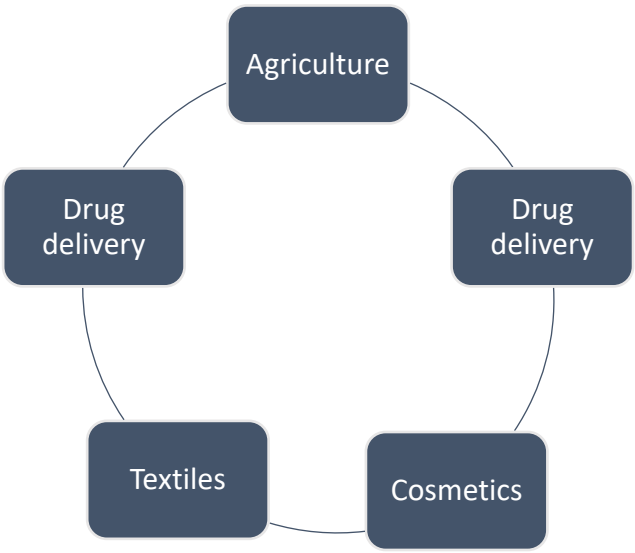
(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

redox polymers and other are used in rechargeable batteries. Because of their possible advantages for the environments and potential health risks to humans, biopolymers have attracted a lot of interest from scientists and researchers. These polymers have special qualities like renewability , biocompatibility and biodegradability because they are derived from living things(Baranwal J, et al.,2022).The search for eco-friendly materials has been sparked by the widespread production of synthetic polymers. Although they are thought to be promising substitute for polymeric materials derived from fossil fuels their growing use their growing use has brought up some environmental concerns (K,Kuranska M,.et al.,2022).Because of their distinct metabolisms, algae can live in a wide range of biological environments with extreme temperatures and pH levels and effluents that

Contain large amounts of both organic and inorganic materials. Algal biochar is a low-cost, eco-friendly biochar technology that has been the subject of numerous studies for wastewater remediation and other practical uses. Furthermore because they are petroleum-based, synthetic and nonbiodegradable they cause major ecological issues primarily because of environmental pollution, as waste is generated and incineration. Searching for alternative materials to synthetic polymers is necessary to find a new route in the shape of biopolymers. Over the last few decades there has been growing demand for environmentally friendly products that promote the development of
biodegradable materials based on biopolymer such as lipids, polysaccharides and protein which are inexpensive renewable raw materials considered as an alternative to plastic nonbiodegradable products based on petroleum(Yaashika PR,et al.,2022).

3.1APPLICATIONS



3.2 ALGAE IN FOOD INDUSRY

Conventional food packaging significantly leans on petroleum-based polymeric materials, generally called as plastics. However plastic packaging going through numerous restrictions that consists poor biodegradability , controlled recyclability, reduced biocompatibility and restricted reusability(Adrah ,et al.,2020).To explain these issues , marine-derived polysaccharides have manifested assuring materials for developing enduring packaging solutions that improves microbial safety and long last the shelf life of foods(De la Caba ,K

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

.,et al.,2019).In between these biopolymer, alginates -naturally existing, nondigestible polysaccharides-are crucially beneficial for forming films and coatings. As noted by (Senturk Parreidt , et al.,2019),alginates can be utilized from the cell walls of brown algae. Their effectiveness has been demonstrated in applications such as maintain the quality of fresh-cut apples and potato strips (Rios do Amaral .L., 2017).

Edible food packaging

Fresh produce wrapping

Biodegradable food Packaging film

Fig 4: Algae-based bioplastic films in the food industry

3.3 ALGAE IN AGRICULTURE

12.5millions tons of plastic materials are used in agriculture (Rome et al., 2021). Known as “plasticulture,” polyethylene and polypropylene and are primarily found in much, low tunnels, greenhouse covers, solarization film, fumigation film, and packaging (Ray et al., 2005). One of the major sectors that produces waste in the agro-industry. Which also produces a lot of waste from production processing (Yu X. et al., 2021). Poor environmental state can result from immoderate resource use and waste production. Global environmental strength may be upset by such factors (Tusher T.R., Pondit T., ET AL., 2020).

Biodegradable mulch film

Seed coating

Controlled-release Fertilizer film

Fig 5: Algae-based bioplastic films in the agriculture

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

3.4 ALGAE IN COSMETICS

Biopolymers are typically non-toxic, safe for living tissue and break down naturally. They are easy to extract come from many sources and are often inexpensive. Unlike synthetic polymers, biopolymers are not made through chemicals synthetic and do not keep exact shapes or structures. Most play essential roles in metabolic or structural pathways in living organisms where their structure has a more specific sequence (Hassan ME, et al.,2019).They can be classified two main types: polysaccharide based and protein based(Mohan S, et al.,2016).Their metabolic activity on skin and skin appendages, biopolymers are crucial components in cosmetic formulations , acting as rheological modifiers, emulsifiers, conditioners, film-formers, fixing agents, foam stabilisers, moisturisers and antimicrobials(Gawade RP, et al.,2020).The term biopolymer is refers to chain-like, covalent constructions of monomers. The prefix bio" has historically been used to describe biodegradable materials made by living things but it also includes polymers that describe biodegradable materials made by living things but it also includes polymers that are derived from biological sources through chemicals synthesis (Olatunji,et al.,2015)

Biopolymer face mask | Hydrogel cosmetic patch | Biodegradable cosmetic packaging

Fig 6: Algae-based bioplastic films in the cosmetics

3.5 ALGAE IN TEXTILES INDUSTRY

However, the high level of environmental pollution brought on by this industrial activity stands in stark contrast to the potential for innovation and development (Zhang,H.,et al.,2021). However, the high environmental pollution brought on by the industrial production of polyamide (PA) and polypropylene (PP) for fabric and yarn stands in stark contrast to the potential for innovation and development(Patti,A., et al.,2021). By giving textile substates a variety of potential functionalities, including antibacterial and flameretardant activity, UV protection, electric conductivity, and hydrophobicity, biopolymers can be utilised in the textile industry as the constituent base material for the production of filaments and yarns or to replace hazardous chemicals in pre-treatment and finishing operations (Abdellatif,F.H.H;.et al.,2021). Because plastics have many inherent qualities, including being lightweight, inexpensive, long-lasting, and chemical-resistant, their production is steadily rising worldwide. Other factors thought to be responsible for the rising demand for plastic products

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

include the growing human population, rapid economic growth, ongoing urbanisation, and changes in lifestyle (Themelis, N.J.,et al.,2021). The production of textile and chemical fibres more than quadrupled in less than 40 years, from 23.94 million metric tonnes to 105.6 million metric tonnes, between 1975 and 2018. As the demand for textiles has grown, so too have worries about the environmental effects of fibre production and the disposal processes that follow. According to a number of recent studies, the textile industry uses toxic and industrially harmful chemicals during the manufacturing process, and the release of these chemicals puts freshwater and atmosphere microsystems at risk (Roy Choudhury,A.K.et al.,2014).

Biopolymer coated fabric | Antimicrobial textile | Eco-friendly textile Finishing

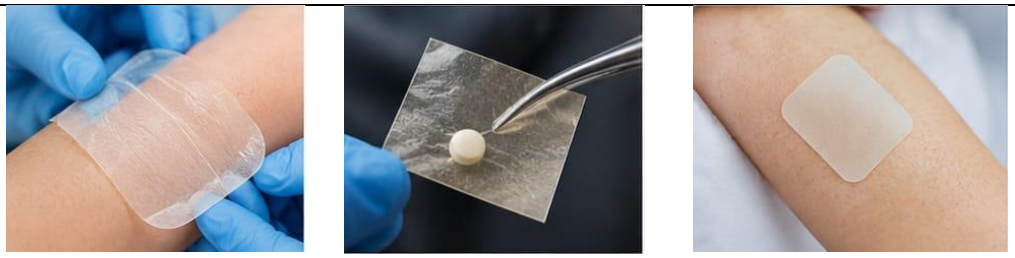
Fig 7: Algae-based bioplastic films in the textiles industry

3.6 ALGAE IN DRUG DELIVERY

Biopolymers are being used in novel formulations because of their unique qualities, such as their biodegradability, availability, and potential for physicochemical engineering. Particularly, while moving towards a green sustainable life, biopolymers offer a platform that fits into the paradigm of achieving an eco-friendly environment. Recently biopolymers have received special attention for designing and fabricating DDS (DDS).(S.Telebian,et al.,2018). Although chitosan is poorly soluble in neutral and basic media, it is soluble in aqueous acids like lactic and acetic acids. The degree of deacetylation, molecular weight, pH, temperature, and polymer crystallinity all affect how soluble chitosan is; a high degree of deacetylation and a low molecular weight increase solubility (Mourya, V.K.;et al.,2011). Crustacean shells continue to be the primary source of chitin. Because crab and shrimp shells can be obtained as waste or byproducts from the sea food industries, the source is inexpensive. In addition to proteins, calcium, and a trace amount of pigments, these shells contain 20–40% chitin. However, these supplies are only available during specific seasons and are restricted to fishing industry sites.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026



Wound dressing film | Controlled drug Release film | Transdermal patch

Fig 8: Algae-based bioplastic films in the drug delivery

Table 1: Life Cycle of Algae-Derived Bioplastic Production

Stages	**Process**
Wastewater	Provides nutrients (Nitrogen & Phosphorus)
Algae Cultivation	Microalgae grow using wastewater, CO_2, and sunlight
Biomass Harvesting	Algal biomass is collected
Biopolymer Extraction	PHAs, PHBs, lipids, starch, cellulose, and lactic acid are obtained
Bioplastic Production	Biopolymers are converted into bioplastics
Usage	Bioplastic products are utilized
Disposal	Organic recycling/composting
Degradation	Bioplastics biodegrade naturally
Nutrient Recovery	Nutrients return to wastewater, restarting the cycle

CONCLUSION

Biopolymers derived from algae show much promise, providing an effective and sustainable alternative to traditional petroleum-based polymers with significant environmental, economic and industrial benefits. As illustrated by the literature reviewed, microalgae and macroalgae have exceptional biodiversity and biochemical richness, representing a major source of

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

polysaccharides such as agar, alginate and carrageenan in addition to proteins, lipids, and other functional biomolecules. Their high photosynthetic efficiency and ability to capture high amounts of carbon dioxide, makes them ideal feedstocks for a circular bioeconomy. Advances in extraction processing and biorefinery technologies have further increased the feasibility of producing superior biopolymers from algae. Due to their exceptional biodegradability, biocompatibility an tunable mechanical properties these materials can be utilized in a wide range of industries including food packaging, agriculture, biomedical engineering, cosmetics, textiles, drug delivery and environmental remediation. Algal biopolymers also aid in reducing greenhouse gas emissions and offer solutions to the escalating issues of plastic pollution and fossil fuel dependence. Overall, algae-based biopolymers hold significant potential for driving sustainable innovation and research on cost-effective cultivation, supporting a greener and more resilient future.

REFERENCE

1. Mohanty, A.K.; Wu, F.; Mincheva, R.; Hakkarainen, M.; Raquez, J.-M.; Mielewski, D.F.; Narayan, R.; Netravali, A.N.; Misra
2. , M. Sustainable Polymers. Nat. Rev. Methods Primers 2022, 2, 46.
3. Spicer, C.D. Hydrogel Scaffolds For Tissue Engineering: The Importance Of Polymer Choice. Polym. Chem. 2020, 11, 184–219.
4. Elizarova, I.S.; Luckham, P.F. Layer-By-Layer Adsorption: Factors Affecting The Choice Of Substrates And Polymers. Adv. Colloid Interface Sci. 2018, 262, 1–20.
5. Yadav, Anupama. 2007 Chisti Biodiesel From Microalgae. Https://Doi.Org/10.1016/J.Biotechadv.2007.02.001
6. Yu, K.L.; Lau, B.F.; Show, P.L.; Ong, H.C.; Ling, T.C.; Chen, W.H.; Ng, E.P.; Chang, J.S. Recent Developments On Algal Biochar Production And Characterization. Bioresour. Technol. 2017, 246, 2–11.
7. L.M.L. Laurens, T.A. Dempster, H.D.T. Jones, E.J. Wolfrum, S.V. Wychen, J.S.P. Mcallister, M. Rencenberger, K.J. Parchert, L.M. Gloe, Anal. Chem. 84 (2012) 1879–1887.
8. H.P. Jarvie Et Al.Phosphorus Uptake Into Algal Biofilms In A Lowland Chalk River Sci. Total Environ.(2002)
9. P. Spolaore Et Al.Commercial Applications Of Microalgaej. Biosci. Bioeng.(2006)
10. Noreen, A., Zia, K. M., Zuber, M., Ali, M., & Mujahid, M. (2016). A Critical Review Of Algal Biomass: A Versatile Platform Of Bio-Based Polyesters From Renewable Resources. International Journal Of Biological Macromolecules, 86, 937-949.
11. Ranganadhareddy, A., & Chandrsekhar, C. (2022). Polyhydroxyalkanoates, The Biopolymers Of Microbial Origin-A Review. Journal Of Biochemical Technology, 13(3-2022), 1-6.
12. H. Karan Et Al.Green Bioplastics As Part Of A Circular Bioeconomytrends Plant Sci.(2019)
13. (Elrayies, 2018),G.M. Elrayies.,Microalgae: Prospects For Greener Future Building
14. Cinar, S.O.; Chong, Z.K.; Kucuker, M.A.; Wieczorek, N.; Cengiz, U.; Kuchta, K. Bioplastic Production From Microalgae: A Review. Int. J. Environ. Res. Public Health 2020, 17, 3842. [Google Scholar] [Crossref]
15. Bugarčić, M.; Jovanović, A.; Petrović, J.; Mišić, M.; Sokić, M.; Milivojević, M. Advances In Biopolymer Production And Applications: A Comprehensive Review Of Key Biomaterials. Metall. Mater. Data 2024, 2, 81–98.
16. Tagliaferri, S.; Gaspard, L.; Au, H.; Mattevi, C.; Titirici, M.-M.; Ribadeneyra, M. Nature-Inspired Batteries: From Biomaterials To Biomimetic Design Strategies. Green Chem. 2024, 26, 6944–6958.
17. Badawi, E.M. Ahmed, N.Y. Mostafa, F. Abdel-Wahab, S.E. Alomairy, Enhancement Of The Optical And Mechanical Properties Of Chitosan Using Fe2o3 Nanoparticles, Journal Of Materials Science: Materials In Electronics 28(15) (2017) 10877-10884.
18. Ashour, N., El-Shoubaky, G. A., Saleh, M. M., & Mostafa, N. M. (2025). Extraction And Characterization Of Alginate Biopolymer From Abundant Brown Seaweeds, Hurghada, Red Sea, Egypt. Egyptian Journal Of Chemistry, 68(10), 441449.
19. Chen, L.; Xu, W.; Chen, D.; Chen, G.; Liu, J.; Zeng, X.; Shao, R.; Zhu, H. Digestibility Of Sulfated Polysaccharide From The Brown Seaweed Ascophyllum Nodosum And Its Effect On The Human Gut Microbiota In Vitro. Int. J. Biol. Macromol. 2018, 112, 1055–1061.
20. Dimri, R., Mall, S., Sinha, S., Joshi, N. C., Bhatnagar, P., Sharma, R., ... & Gururani, P. (2023). Role Of Microalgae As A Sustainable Alternative Of Biopolymers And Its Application In Industries. Plant Science Today, 10(Sp2), 8-18.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

21. Madadi, R., Maljaee, H., Serafim, L. S., & Ventura, S. P. (2021). Microalgae As Contributors To Produce Biopolymers. Marine Drugs, 19(8), 466.
22. Zetterholm, J.; Bryngemark, E.; Ahlström, J.; Söderholm, P.; Harvey, S.; Wetterlund, E. Economic Evaluation Of Large-Scale Biorefinery Deployment: A Framework Integrating Dynamic Biomass Market And Techno-Economic Models. Sustainability 2020, 12, 7126.
23. C. Lim, S. Yusoff, C. G. Ng, P. E. Lim And Y. C. Ching, Bioplastic Made From Seaweed Polysaccharides With Green Production Methods, J. Environ. Chem. Eng., 2021, 9(5), 105895
24. Gurgel, C. F. D., & Lopez-Bautista, J. (2007). Red Algae. Encyclopedia Of Life Sciences, 1-5.
25. Shoaib, A. G., El-Sikaily, A., El Nemr, A., Mohamed, A. E. D. A., & Hassan, A. A. (2022). Preparation And Characterization Of Highly Surface Area Activated Carbons Followed Type Iv From Marine Red Alga (Pterocladia Capillacea) By Zinc Chloride Activation. Biomass Conversion And Biorefinery, 12(6), 2253-2265.
26. Permatasari, A. A. A. P., Rosiana, I. W., Wiradana, P. A., Lestari, M. D., Widiastuti, N. K., Kurniawan, S. B., & Widhiantara, I. (2022). Extraction And Characterization Of Sodium Alginate From Three Brown Algae Collected From Sanur Coastal Waters, Bali As Biopolymer Agent. Biodiversitas: Journal Of Biological Diversity, 23(3).
27. M. Rinaudo, Biomaterials Based On A Natural Polysaccharide: Alginate, Tip. Revista Especializada En Ciencias Químico Biológicas 17(1) (2014) 9
28. Nitsos, C.; Filali, R.; Taidi, B.; Lemaire, J. Current And Novel Approaches To Downstream Processing Of Microalgae: A Review. Biotechnol. Adv. 2020, 45, 107650.
29. Wang, J., Zhang, M., & Fang, Z. (2019). Recent Development In Efficient Processing Technology For Edible Algae: A Review. Trends In Food Science & Technology, 88, 251-259.
30. Ramaraj, R., & Dussadee, N. (2015). Biological Purification Processes For Biogas Using Algae Cultures: A Review. International Journal Of Sustainable And Green Energy, 4(1), 20-32.
31. Kim Sk, Chojnacka K. Marine Algae Extracts Chapter 26, 2015; 454-456.
32. Özdemir, N., & Erkmen, J. (2013). Use Of Algae In The Production Of Renewable Bioplastics. Black Sea Journal Of Science, 3(8), 89-104.
33. M.F. Demirbas ,Biofuels From Algae For Sustainable Development Appl Energy (2011)
34. D. Vandamme Et Al.Flocculation As A Low-Cost Method For Harvesting Microalgae For Bulk Biomass Productiontrends Biotechnol.(2013)
35. Z. Wu Et Al.Evaluation Of Flocculation Induced By Ph Increase For Harvesting Microalgae And Reuse Of Flocculated Mediumbioresour Technol(2012)
36. E. Molina Grima Et Al.Recovery Of Microalgal Biomass And Metabolites: Process Options And Economicsbiotechnol Adv(2003)
37. Devadas, V. V., Khoo, K. S., Chia, W. Y., Chew, K. W., Munawaroh, H. S. H., Lam, M. K., ... & Show, P. L. (2021). Algae Biopolymer Towards Sustainable Circular Economy. Bioresource Technology, 325, 124702.
38. Beckstrom, B.D.; Wilson, M.H.; Crocker, M.; Quinn, J.C. Bioplastic Feedstock Production From Microalgae With Fuel Co-Products: A Techno-Economic And Life Cycle Impact Assessment. Algal Res. 2020, 46, 101769.
39. Negm, N.A.; Hefni, H.H.H.; Abd-Elaal, A.A.A.; Badr, E.A.; Abou Kana, M.T.H. Advancement On Modification Of Chitosan Biopolymer And Its Potential Applications. Int. J. Biol. Macromol. 2020, 152, 681–702.
40. Kolan, K.; Liu, Y.; Baldridge, J.; Murphy, C.; Semon, J.; Day, D.; Leu, M. Solvent Based 3d Printing Of Biopolymer/Bioactive Glass Composite And Hydrogel For Tissue Engineering Applications. Procedia Cirp 2017, 65, 38–43.
41. Adenle, A. A., Haslam, G. E., & Lee, L. (2013). Global Assessment Of Research And Development For Algae Biofuel Production And Its Potential Role For Sustainable Development In Developing Countries. Energy Policy, 61, 182-195.
42. Roy Chong, J.W.; Tan, X.; Khoo, K.S.; Ng, H.S.; Jonglertjunya, W.; Yew, G.Y.; Show, P.L. Microalgae-Based Bioplastics: Future Solution Towards Mitigation Of Plastic Wastes. Environ. Res. 2022, 206, 112620.
43. Alazaiza, M. Y., Albahnasawi, A., Eyvaz, M., Al Maskari, T., Nassani, D. E., Abu Amr, S. S., ... & Bashir, M. J. (2023). An Overview Of Green Bioprocessing Of Algaederived Biochar And Biopolymers: Synthesis, Preparation, And Potential Applications. Energies, 16(2), 791.
44. Joshi, J. S., Langwald, S. V., Ehrmann, A., & Sabantina, L. (2024). Algae-Based Biopolymers For Batteries And Biofuel Applications In Comparison With Bacterial Biopolymers—A Review. Polymers, 16(5), 610.
45. Muldoon, J.; Bucur, C.B.; Boaretto, N.; Gregory, T.; Di Noto, V. Polymers: Opening Doors To Future Batteries. Polym. Rev. 2015, 55, 208–246.
46. Adrah, K.; Ananey-Obiri, D.; Tahergorabi, R. Development Of Bio-Based And Biodegradable Plastics. In Handbook Of Nanomaterials And Nanocomposites For Energy And Environmental Applications; Kharissova, O.V., Martínez, L.M.T., Kharisov, B.I., Eds.; Springer International Publishing: Cham, Switzerland, 2020; Pp. 1–25.
47. De La Caba, K.; Guerrero, P.; Trung, T.S.; Cruz-Romero, M.; Kerry, J.P.; Fluhr, J.; Maurer, M.; Kruijssen, F.; Albalat, A.; Bunting, S.; Et Al. From Seafood Waste To Active Seafood Packaging: An Emerging Opportunity Of The Circular Economy. J. Clean. Prod. 2019, 208, 86–98.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

48. Senturk Parreidt, T.; Lindner, M.; Rothkopf, I.; Schmid, M.; Müller, K. The Development Of A Uniform Alginate-Based Coating For Cantaloupe And Strawberries And The Characterization Of Water Barrier Properties. Foods 2019, 8, 203.

49. Rios Do Amaral, L.; Achaerandio Puente, M.I.; Benedetti, B.C.; Pujolà Cunill, M. The Influence Of Edible Coatings, Blanching And Ultrasound Treatments On Quality Attributes And Shelf-Life Of Vacuum Packaged Potato Strips. Lwt Food Sci. Technol. 2017, 85, 449–455.

50. Baranwal, J., Barse, B., Fais, A., Delogu, G. L., & Kumar, A. (2022). Biopolymer: A Sustainable Material For Food And Medical Applications. Polymers, 14(5), 983.

51. Stoppel, W. L., Ghezzi, C. E., Mcnamara, S. L., Iii, L. D. B., & Kaplan, D. L. (2015). Clinical Applications Of Naturally Derived Biopolymer-Based Scaffolds For Regenerative Medicine. Annals Of Biomedical Engineering, 43(3), 657-680.

52. Nathanael, A. J., & Oh, T. H. (2020). Biopolymer Coatings For Biomedical Applications. Polymers, 12(12), 3061.

53. Ray, S.S.; Bousmina, M. Biodegradable Polymers And Their Layered Silicate Nanocomposites: In Greening The 21st Century Materials World. Prog. Mater. Sci. 2005, 50, 962–1079.

54. Yu X., Zhou H., Ye X., Wang H. From Hazardous Agriculture Waste To Hazardous Metal Scavenger: Tobacco Stalk Biochar-Mediated Sequestration Of Cd Leads To Enhanced Tobacco Productivity. Journal Of Hazardous Materials 2021:413:125303.

55. Tusher T. R., Pondit T., Hasan M., Latif M. B., Binyamin Md. Impacts Of Resource Consumption And Waste Generation On Environment And Subsequent Effects On Human Health: A Study Based On Ecological Footprint Analysis. Springer, 2020.

56. Baranwal J, Barse B, Fais A, Delogu Gl, Kumar A. Biopolymer: A Sustainable Material For Food And Medical Application Polymer.2022 Feb 28;14(5):983.

57. Formela K, Kurańska M, Barczewski M. Recent Advances In Development Of Waste Based Polymer Materials: A Review.Polymers. 2022 Mar 6;14(5):1050.

58. Yaashikaa Pr, Kumar Ps, Karishma Sj. Review On

59. Biopolymers And Composites–Evolving Material As Adsorbents In Removal Of Environmental Pollutants.Environmental Research. 2022 Sep 1;212:113114.

60. Yaashikaa Pr, Kumar Ps, Karishma Sj. Review On Biopolymers And Composites Evolving Material As Adsorbents In Removal Of Environmental Pollutants.Environmental Research. 2022 Sep 1;212:113114.

61. Hassan Me, Bai J, Dou Dq. Biopolymers; Definition, Classification And Applications. Egypt J Chem. 2019; 62(9): 1725–1737.

62. Gawade Rp, Chinke Sl, Alegaonkar Ps. Polymers In Cosmetics. Polymer Science And Innovative Applications. Amsterdam: Elsevier; 2020. P. 545–565.

63. Zhang, H.; Themelis, N.J.; Bourtsalas, A. Environmental Impact Assessment Of Emissions From Non-Recycled Plastic-To-Energy Processes. Waste Dispos. Sustain. Energy 2021, 1, 3.

64. Patti, A.; Costa, F.; Perrotti, M.; Barbarino, D.; Acierno, D. Polyurethane Impregnation For Improving The Mechanical And The Water Resistance Of Polypropylene-Based Textiles. Materials 2021, 14, 1951.

65. Abdellatif, F.H.H.; Abdellatif, M.M. Utilization Of Sustainable Biopolymers In Textile Processing. In Green Chemistry For Sustainable Textiles; Woodhead Publishing: Cambridge, Uk, 2021; Pp. 453–469.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)