



Research Paper

Bioplastic Production from Microalgae: A Green Technology Approach

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Received: 03/01/2026

Revised: 10/02/2026

Accepted: 22/03/2026

Published: 01/04/2026

Abstract: Marine Microalgae such as *O. salina*, *S. peavaleikii* are a potential source for the production of bioplastic. Petroleum based plastic pollution is the accumulation of plastic in the environment, which can harm humans, marine life, and their habitats. It's a global issue that's linked to other environmental challenges like climate change and biodiversity loss. Microalgae based bioplastics has gained attention as a sustainable alternative to traditional petroleum-based plastics. Microalgae have become one of the more promising and environmentally safe feedstocks to produce bioplastics. The production and extraction of poly hydroxy butyrate's from marine algal species (*O. salina*, *S. peavaleikii*) by solvent extraction method. Solvent extraction process is often considered the most common method for PHB extraction due to its high yield, purity low cost. The extracted PHB were characterized through UV-SPECTROPHOTOMETER. In Bioplastic used in different fields like food packaging, pharmaceuticals, agricultural and medicinal industries.

Keywords: Marine microalgae, Photoautotrophic, PHB (Poly hydroxy butyrates) and Bioplastic.

1. Introduction

Global consumption of plastic amounts to about 140 million tons annually, which requires the processing of 150 million tons of fossil fuels and generates massive amounts of waste that, if they degrade at all, may take thousands of years to naturally occur. The demand for products made of plastic is rising dramatically over the world, placing a strain on the infrastructure that is already in place and adding to the workload. Currently, the world produces about 750,000 tonnes of bioplastic annually, and major industries like Nature Works [1]. The environment and marine ecosystem are at significant risk as the number of materials derived from petroleum rises. As a result, bioplastic is made from renewable sources (derived from petroleum-based plastics but biodegradable), and hybrid bioplastics (a combination of both petroleum and biological source) [2].

On recent studies, its insights into several techniques for producing microalgae-based bioplastics, as well as difficulties and upcoming work to improve the economic viability of microalgae-based bioplastics [3] Microalgae use atmospheric carbon dioxide (CO₂) and sunlight to produce biomass. Microalgae can flourish in a range of agricultural waste material as substrate media [4].

For the treatment of a different of agricultural wastes, microalgal Agri-based waste treatment systems provide an

elegant and affordable bioremediation option. Microalgae have a well-established ability to simultaneously produce biomass, which can be used to produce a variety of end products, including bioplastic, biofuel, and fertilizer. They can also efficiently assimilate different nutrients that are typically present in agricultural waste [5]

In addition, it has been demonstrated that microalgae grown from treated and depleted nutrient effluent is safe for possible recycling or discharge. Furthermore, during the growth process in agricultural waste, microalgae photosynthesis sequesters carbon dioxide and produces oxygen, reducing greenhouse gas emissions and mitigating climate change favourable effects [6]. Because microalgae have a remarkable capacity for recovering nutrients and energy, phytoremediation employing them is a sustainable method for treating agricultural waste [7]. Microalgae are an abundant producer of primary metabolites, so in addition to their capacity to treat Agri-waste on a large scale, there are potential benefits to valorizing their biomass and turning it into value-added products [8].

PHB from microalgae as same as polypropylene (synthetic plastic) but PHB degrades faster and safe to environment when compared to polypropylene. PHB is also produced by macroalgae through fermentation technique [9].



Oscillatoria salina, *Synechococcus peveleikii* is one of the species of marine microalgae with a high growth rate, easy of cultivation, and simple extraction process to obtain PHB. Cultivation of *Oscillatoria salina* BDU 20631, *Synechococcus peveleikii* BDHCU 35101 is done in an autotroph condition. The amount of accumulated PHB on average is 1-2% of the total wet biomass, this can be improved by 2-3 times through the modification of nitrogen and carbon level in the ASN-III growth medium [10].

The extensive use of petroleum-based plastics has resulted in serious environmental pollution due to their non-biodegradable nature. Global plastic consumption continues to rise, placing pressure on waste management systems and marine ecosystems. Bioplastics derived from renewable sources have emerged as sustainable alternatives. Polyhydroxybutyrate (PHB) is a biodegradable and biocompatible polymer with properties comparable to conventional plastics [11].

Marine microalgae utilize sunlight and carbon dioxide for growth and can be cultivated without competing for agricultural land or freshwater resources. These features make them attractive candidates for bioplastic production. This study focuses on PHB production, extraction, and characterization from marine microalgae [12].

The ASN-III media is typically used as a medium for marine microalgae *Oscillatoria salina* BDU 20631 and *Synechococcus peveleikii* BDHCU 35101 standard culture that was procured from Bharathidasan University, Tirichirapalli (National Facility for Marine Cyanobacteria-NFMC).

1.1 Bioplastic as food packaging material

PHB extracted from marine microalgae possesses a basic chemical makeup, yet its granules (resembling pseudo-organelles that rely on a diverse array of proteins for optimal functioning) exhibit high complexity. PHB materials exhibit a high level of crystallinity, are physically fragile, and possess low thermal stability. PHB plastics have

characteristics similar to polymers derived from petroleum, such as polypropylene (PP) and polyethylene (PE). Biopolymers are created using eco-friendly and renewable materials like leftover food [13].

Because of its ability to work well with living organisms and break down naturally in specific biological environments, PHB is a popular substitute for artificial polymers such as PP and PE. PHB can serve various functions in an organism, such as storing molecules and enhancing stress resistance, among other roles. A recommendation was made to use these bioplastics in the packaging sector. Exploring the changes in mechanical characteristics is necessary for utilizing them in a variety of industrial uses [14].

2 Materials And Methods

2.1 Cultivation of marine microalgae using ASN-III medium

The standard method for cultivation of *Oscillatoria salina* BDU 20631 and *Synechocystis peveleikii* BDHCU 35101 in ASN-III media solution with PH:6-8, light intensity :12000-14000lux, temperature will be maintained at:26-32°C and light and dark cycle has to be 16:8 hours.

2.3 Culturing *Oscillatoria salina* BDU 20631 & *Synechocystis peveleikii* BDHCU35101 in (Carbon, Nitrogen and Phosphate) starvation ASN-III media

In 10ml of ASN-III starvation media solution (without Carbon, Nitrogen). *Oscillatoria salina* BDU 20631 & *Synechocystis peveleikii* BDHCU 35101 inoculated and maintaining, light intensity:1400-3500lux, temperature will be maintained at:26-32°C and light and dark cycle has to be 16:8 hours for 7 -14 days of incubation period and optical density values (OD) are taken using U-V Spectrophotometer, using ASN-iii media as a blank. [15] [16]



Oscillatoria salina BDU 206311



Synechocystis peveleikii BDHCU35101

Figure 1. *Oscillatoria salina* BDU 20631 & *Synechocystis peveleikii* BDHCU35101 growth in agricultural waste substrate media

2.4 Screening of PHB from marine microalgal strains

After starvation period of 14 days thin culture taken in clean glass slide air dried in room temperature stain with Sudan black -B with 10-15minutes after incubation rinsed with distilled water later counter stain with safranin for 10

seconds again rinsed with distilled water dried for a minute at room temperature visualise the slide under microscope at 40x magnification to observe PHB granules [17].

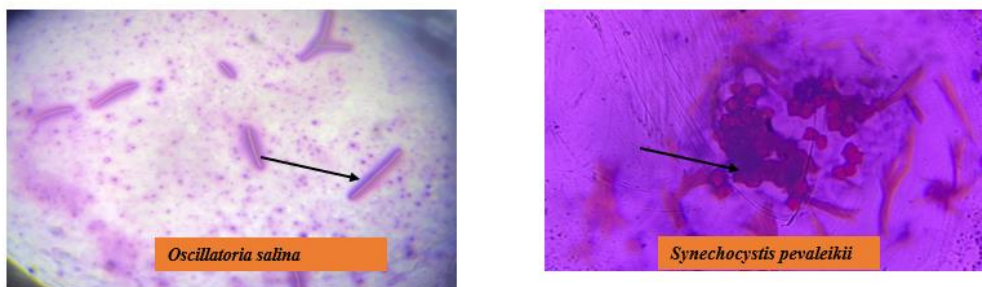


Figure 2. PHB granules under phase contrast microscope at 40x magnification

2.4 Extraction of PHB by Sodium Hypochlorite - Solvent Assay extraction method

Since PHB is produced as an intracellular product in microalgae, further the extraction of PHB from *Oscillatoria salina* BDU 20631 & *Synechocystis pevaleikii* BDHKU35101. The chosen method, solvent extraction method, is simple and cost-effective. The basic steps include pretreatment to disrupt the cell walls, precipitation of excreted PHB from culture [18] [19].

The extraction of PHB was performed following sodium hypochlorite-chloroform method. 20 ml of wet culture was centrifuged at 6900 rpm for 20 minutes and supernatant was discarded. The pellet was suspended in 2.5 ml of 4 % sodium hypochlorite for digestion and 2.5 ml of hot chloroform and was incubated at 37°C for 1 hour. The suspension was centrifuged at 1500 g for 10 minutes (The upper phase contains hypochlorite solution and the middle phase contains chloroform with cell debris). The bottom phase containing PHA with chloroform was collected and further was followed by extraction with hot chloroform and precipitated with ethanol and acetone (1:1). The precipitate was allowed to evaporate for dryness at 30°C to obtain PHB crystals [20] [21].

The extracted bioplastic from marine microalgae will be evaluated with, UV-SPECTROPHOTOMETER using sulfuric acid as a blank.

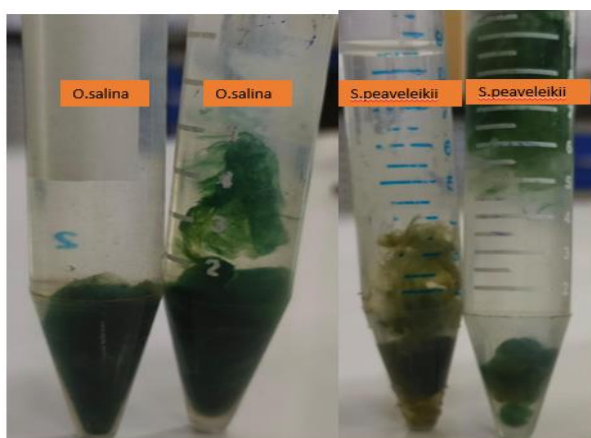


Figure 3. *Oscillatoria salina* BDU 20631 & *Synechocystis pevaleikii* BDHKU 35101 pellet after centrifugation at 4000rpm at 4°C.

3 Characterization techniques

3.1 UV-SPECTROPHOTOMETER

About 1mg of extracted PHB dissolved in 5ml of chloroform. Then scanned in range of 200-350nm against chloroform as a blank.

4 Results

4.1 UV-SPECTROPHOTOMETER

PHB exhibits a characteristic absorbance peak near 235 nm after conversion to crotonic acid by sulfuric acid digestion. The absorbance at this wavelength is proportional to PHB concentration. *O. salina* Indicates moderate PHB concentration *S. pevaleikii* showing higher PHB content compared to *O. salina* and standard PHB used for calibration and Sulphuric acid used as blank for base line stability.

Table 1. UV-spectrophotometer results of *Oscillatoria salina* BDU 20631 and *S. pevaleikii* BDHKU35101.

S.no	Sample	Absorbance at 235nm
1.	<i>O. salina</i> PHB extract	0.835
2.	<i>S. pevaleikii</i> PHB extract	1.011
3.	PHB standard (50 µg/mL)	0.940
4.	Blank (H ₂ SO ₄)	0.000–0.000

5 Discussion

The outcomes of the present investigation demonstrate that the marine cyanobacterial strains *Oscillatoria salina* BDU 20631 and *Synechocystis pevaleikii* BDHKU 35101 are capable of synthesizing and accumulating poly-β-hydroxybutyrate (PHB), indicating their suitability as potential biological resources for bioplastic production. The ability of these strains to store PHB reflects their metabolic adaptability, particularly when exposed to environmental stress conditions that favor the accumulation of intracellular reserve materials.

Experimental optimization revealed that PHB accumulation was maximized under specific physicochemical parameters, namely a pH range of 7–8, temperature between 30 and 32 °C, and light intensity of 1200–1400 lux, in combination with carbon and nitrogen limitation. Nutrient deprivation is known to restrict cellular

growth while promoting the diversion of metabolic intermediates toward storage polymer synthesis. Under such stress conditions, excess carbon and reducing equivalents are preferentially utilized for PHB biosynthesis, allowing the cells to maintain metabolic balance and energy storage.

The exploitation of marine microalgae for PHB production offers notable ecological advantages. These organisms utilize solar energy and carbon dioxide for growth, thereby enabling the conversion of greenhouse gases into biodegradable polymeric materials. Such a process not only reduces reliance on fossil-based plastics but also contributes to carbon sequestration and environmental sustainability. Furthermore, marine microalgae can be cultivated using seawater in non-arable regions, minimizing freshwater consumption and land-use competition.

Overall, the findings of this study highlight *Oscillatoria salina* BDU 20631 and *Synechocystis pevalekii* BDHKKU 35101 as promising candidates for eco-friendly PHB production. Their efficient polymer accumulation under optimized stress conditions, coupled with their ability to utilize renewable resources, supports their potential application in large-scale industrial bioplastic production. With further advancements in cultivation and downstream processing, these strains could play a significant role in the development of sustainable and biodegradable plastic alternatives.

6 Conclusion

PHB accumulation was demonstrated by the microalgae strains isolated in this investigation, confirming *Oscillatoria salina* and *Syncooccus peavelekii* sp. are both excellent sources of PHB. For PHB accumulation, the optimal physicochemical parameters were pH 7-8, a temperature range of 30°C to 32°C, and light intensity of 1200 lux to 1400 lux while denying carbon and nitrogen (C and N) sources to *O. salina* and *Syncooccus peavelekii* sp. The isolated polymer's identity as PHB was verified by UV spectroscopy. The advantage of using marine microalgae as PHB producers is that they can convert waste carbon dioxide and other greenhouse gases into environmentally friendly plastics by harnessing solar energy. Therefore, it can be said that *Syncooccus peavelekii* sp. and *Oscillatoria salina* can be used to produce PHB on a larger scale and for various industrial uses.

Future Directions:

1. Optimization of Culture Conditions

Further studies can focus on optimizing nutrient concentrations, light intensity, salinity, and carbon sources to maximize PHB yield in *O. salina* and *S. pevalekii*.

2. Blending and Biocomposite Development

PHB can be blended with other biopolymers or natural fibers to improve its mechanical properties and broaden its utility in packaging and biomedical fields.

Ethical Approval: No animal and human studies are carried out in my experimental work.

Funding: No Funding

References

- [1] Mei Shan Lee, [Kushairi Mohd Salleh](#) An overview on microalgal polyhydroxybutyrate (PHB) production and improvement of mechanical properties. [International Journal of Biological Macromolecules Volume 320, Part 4](#), August 2025, 146056.
- [2] Martina Franchini, Mara Simonazzi, Federica Costantini et.al, More than meets the eye: microalgal-bacterial association in polyhydroxybutyrate (PHB) accumulating cultures of *Desmodesmus communis*. [New Biotechnology Volume 91](#), 25 March 2026, Pages 192-200.
- [3] F. M. de Souza and R. K. Gupta, "Bacteria for bioplastics: Progress, applications, and challenges," *ACS Omega*, vol. 9, no. 8, pp. 8666–8686, 2024, doi: 10.1021/acsomega.3c08478.
- [4] A. Sakhamuru and S. Vasireddy, "AI-Enabled Cross-Layer QoS Routing Framework for Mission-Critical 5G/6G-Integrated MANETs and UAV Swarms," 2025 International Conference on Sustainable Communication Networks and Application (ICSCN), pp. 787–794, Oct. 2025, doi: 10.1109/icscn67106.2025.11308381.
- [5] C. Nef, S. Dittami, R. Kaas, E. Briand, C. Noël, F. Mairet, and M. Garnier, "Sharing vitamin B12 between bacteria and microalgae does not systematically occur: Case study of the haptophyte *Tisochrysis lutea*," *Microorganisms*, vol. 10, no. 2, p. 247, 2022, doi: 10.3390/microorganisms10020247.
- [6] R. R. L. Guillard and J. H. Ryther, "Studies on marine planktonic diatoms. I. *Cyclotella nana* Hustedt and *Detonula confervacea* (Cleve) Grunow," *Can. J. Microbiol.*, vol. 8, no. 2, pp. 229–239, 1962, doi: 10.1139/m62-029.
- [7] S. A. Huntsman and W. G. Sunda, "The role of trace metals in regulating phytoplankton growth with emphasis on Fe, Mn and Cu," in *The Physiological Ecology of Phytoplankton*, J. Morris, Ed., Berkeley, CA, USA: Univ. California Press, 1978, pp. 285–315.
- [8] Abhishake Reddy Onteddu, Dr. V Jagan Naveen, "Privacy-Centric IoT Systems: A Framework for Secure Data Handling", *Journal of Computational Analysis and Applications (JoCAAA)*, vol. 28, no. 5, pp. 1–8, May 2020.
- [9] Xiong, Y.C.; Yao, Y.C.; Zhan, X.Y.; Chen, G.Q. Application of polyhydroxyalkanoates nanoparticles as intracellular sustained drug-release vectors. *J. Biomater. Sci. Polym. Ed.* 2010, 21, 127–140.
- [10] Burdon, K.L. Fatty materials in bacteria and fungi revealed by staining dried, fixed slide preparations. *J. Bacteriol.* 1946, 52, 665–678.
- [11] Hartmann, R.; Hany, R.; Witholt, B.; Zinn, M. Simultaneous biosynthesis of two copolymers in *Pseudomonas putida* GPol using a two-stage continuous culture system. *Biomacromolecules* 2010, 11, 1488–1493.
- [12] A. Sakhamuru and S. Vasireddy, "A comprehensive review of state-of-the-art generative AI models in natural language processing: Architectures, innovations, applications, and future directions,"

- Frontiers in Health Informatics, vol. 13, no. 3, pp. 9498–9506, 2024.
- [13] A. D. Alphonse and K. G. Kishore, “Microalgae: An emerging source of bioplastics production,” *Discover Sustainability*, vol. 5, no. 1, 2024, doi: 10.1007/s44274-024-00038-0.
- [14] D. Ismail, K. Alifia, and P. R. Sari, “Solvent extraction of polyhydroxybutyrate with NaClO from *Spirulina platensis* for capsule ingredients,” *AIP Conf. Proc.*, vol. 2193, no. 1, p. 030005, 2019, doi: 10.1063/1.5139353.
- [15] Srinivasarao Goda, Pratap Pachipulusu, Sakhamuru Amulya, and Pathan Hussian Basha, “Secure Blockchain-Based Consumer Electronics Platform for Smart Homes with Efficient Access Control and Performance Evaluation”, *Synth. Multidiscip. Res. J.*, vol. 3, no. 4, pp. 54–65, Dec. 2025
- [16] F. Gironi and V. Piemonte, “VOCs removal from dilute vapour streams by adsorption onto activated carbon,” *Chem. Eng. J.*, vol. 172, no. 2–3, pp. 671–677, 2011, doi: 10.1016/j.ccej.2011.06.034.
- [17] Abhishake Reddy Onteddu, Rahul Reddy Bandhela and RamMohan Reddy Kundavaram, “Enhancing E-Commerce Product Recommendations through Data Engineering and Machine Learning,” *Economic Sciences*, vol. 20, no. 1, pp. 171–183, Mar. 2024, doi: 10.69889/vqgz857.
- [18] S. Mehariya, M. Plöhn, P. Jablonski, S. Stagge, L. J. Jönsson, and C. Funk, “Biopolymer production from biomass produced by Nordic microalgae grown in wastewater,” *Bioresour. Technol.*, vol. 376, p. 128900, 2023, doi: 10.1016/j.biortech.2023.128900.
- [19] A. Guldhe, S. Kumari, and L. Ramanna, “Prospects, recent advancements and challenges of different wastewater streams for microalgal cultivation,” *J. Environ. Manage.*, vol. 203, pt. 1, pp. 299–315, 2017, doi: 10.1016/j.jenvman.2017.08.012.
- [20] K. Afifa, K. Arshad, N. Hussain, M. H. Ashraf, and M. Z. Saleem, “Air pollution and climate change as grand challenges to sustainability,” *Sci. Total Environ.*, vol. 928, p. 172370, 2024, doi: 10.1016/j.scitotenv.2024.172370.
- [21] J. W. R. Chia, X. Tan, K. S. Khoo, H. S. Ng, W. Jonglertjunya, G. Y. Yew, and P. Loke, “Show,” *Environ. Res.*, vol. 204, p. 112019, 2022, doi: 10.1016/j.envres.2021.112019.