



Special Issue “Biotechnological Application of Photosynthetic Bacteria”

Hitoshi Miyasaka

Department of Applied Life Science, Sojo University, 4-22-1 Ikeda, Nishiku, Kumamoto 860-0082, Japan; miyasaka@bio.sojo-u.ac.jp

This Special Issue aims to contribute to the current knowledge in the field and promote the practical application of photosynthetic bacteria (PSB) biotechnology. Among various PSB, purple non-sulfur bacteria (PNSB) in particular have a wide range of biotechnological applications in agriculture [1,2], aquaculture [3], biomaterial production [4–6], renewable energy production [7,8], wastewater treatment [9], and bioremediation [10].

In this Special Issue, Koga et al. [11] reported the application of marine PNSB as probiotics for shrimp aquaculture. Segura et al. [12] used a mixture of volatile fatty acids (VFAs) as a carbon source for *Rhodospirillum rubrum* and discovered their effects on CO₂ metabolic pathways and cellular redox balance. Edreira et al. [13] reported the effects of voltage on the performance of bioelectrochemical systems to fix CO₂ with a mixed culture of PNSB and purple sulfur bacteria (PSB).

The most widely used application of PNSB is to promote plant growth and improve the quality of food crops in agriculture. This Special Issue includes two reviews on PNSB applications in agriculture. Lee et al. [14] provided a comprehensive overview of the beneficial effects of PNSB in agriculture, as well as their accomplishments in developing elite PNSB for agriculture. Maeda [15] gave an in-depth analysis of the mechanisms and regulations of nitrogen fixation by nitrogenase of PNSB, and he also provided field data on PNSB's contribution to nitrogen fixation in rice fields.

Hayashi et al. [16] reported the growth-promoting effect of lipopolysaccharide (LPS) from PNSB in plants for the first time, and the effective concentration of LPS from *Rhodobacter sphaeroides* was 10 pg/mL. In mammals, LPS acts as an endotoxin through the Toll-like receptor 4 (TLR4) signaling pathway at a concentration of pg/mL to ng/mL, causing inflammatory responses. In plants, LPS also acts as an inducer of immune response, but the effective concentration of LPS from various Gram-negative bacteria in plants reportedly ranged from 10 µg to 100 µg/mL [17,18]. The effective concentration of *R. sphaeroides* LPS for the plant was therefore approximately millions of times lower than those reported in previous studies. Iwai et al. [19] reported that biopriming by LPS from *R. sphaeroides* at a concentration of 5 ng/mL improved the root growth of rice seedlings, providing further evidence of the effectiveness of LPS from PNSB in plants at low concentrations. The much lower effective concentration of PNSB LPS than those of other bacteria is likely attributable to its unique lipid A property. Lipid A, a domain of LPS, is a hydrophobic molecule that anchors LPS to the outer membrane of Gram-negative bacteria [20]. Lipid A acts as the active component of the endotoxicity of LPS. The LPS of *R. sphaeroides* and its lipid A are known to exhibit unique properties in mammals [21]. They show no endotoxic activity but have an endotoxin-antagonistic activity for TLR4. The chemically synthesized lipid A of *R. sphaeroides*, named eritoran (E5564; Eisai), has also been developed for therapeutic application [22], and eritoran has been shown to protect animals from inflammation by blocking the TLR4 signaling pathway [23,24]. In view of these facts, it will be of great interest to investigate the effects of lipid A from *R. sphaeroides*, as well as eritoran, on plant growth in the future.

Citation: Miyasaka, H. Special Issue “Biotechnological Application of Photosynthetic Bacteria”. *Microorganisms* **2023**, *11*, 619. <https://doi.org/10.3390/microorganisms11030619>

Received: 21 February 2023

Accepted: 27 February 2023

Published: 28 February 2023



Copyright: © 2023 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Funding: This research received no external funding.

Acknowledgments: I would like to thank all the authors who contributed their papers to this Special Issue, as well as the reviewers for their invaluable revisions. I am also grateful to all the members of the Editorial Office of *Microorganisms* for their continuous support.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Sakarika, M.; Spanoghe, J.; Sui, Y.; Wambacq, E.; Grunert, O.; Haesaert, G.; Spiller, M.; Vlaeminck, S.E. Purple non-sulphur bacteria and plant production: Benefits for fertilization, stress resistance and the environment. *Microb. Biotechnol.* **2020**, *13*, 1336–1365. <https://doi.org/10.1111/1751-7915.13474>.
2. Wong, W.-T.; Tseng, C.-H.; Hsu, S.-H.; Lur, H.-S.; Mo, C.-W.; Huang, C.-N.; Hsu, S.-C.; Lee, K.-T.; Liu, C.-T. Promoting effects of a single *Rhodopseudomonas palustris* inoculant on plant growth by *Brassica rapa chinensis* under low fertilizer input. *Microbes Environ.* **2014**, *29*, 303–313. <https://doi.org/10.1264/jsme2.me14056>.
3. Qi, Z.; Zhang, X.H.; Boon, N.; Bossier, P. Probiotics in aquaculture of China—Current state, problems and prospect. *Aquaculture* **2009**, *290*, 15–21. <https://doi.org/10.1016/j.aquaculture.2009.02.012>.
4. George, D.M.; Vincent, A.S.; Mackey, H.R. An overview of anoxygenic phototrophic bacteria and their applications in environmental biotechnology for sustainable Resource recovery. *Biotechnol. Rep.* **2020**, *28*, e00563. <https://doi.org/10.1016/j.btre.2020.e00563>.
5. Higuchi-Takeuchi, M.; Numata, K. Marine purple photosynthetic bacteria as sustainable microbial production hosts. *Front. Bioeng. Biotechnol.* **2019**, *7*, 258.
6. Kikuchi, Y.; Umekage, S. Extracellular nucleic acids of the marine bacterium *Rhodovulum sulfidophilum* and recombinant RNA production technology using bacteria. *FEMS Microbiol. Lett.* **2018**, *365*, fnx268. <https://doi.org/10.1093/femsle/fnx268>.
7. Ghosh, S.; Dairkee, U.K.; Chowdhury, R.; Bhattacharya, P. Hydrogen from food processing wastes via photofermentation using Purple Non-sulfur Bacteria (PNSB)—A review. *Energy Convers. Manag.* **2017**, *141*, 299–314. <https://doi.org/10.1016/j.enconman.2016.09.001>.
8. Sagir, E.; Alipour, S. Photofermentative hydrogen production by immobilized photosynthetic bacteria: Current perspectives and challenges. *Renew. Sustain. Energy Rev.* **2021**, *141*, 110796. <https://doi.org/10.1016/j.rser.2021.110796>.
9. Lu, H.; Zhang, G.; He, S.; Zhao, R.; Zhu, D. Purple non-sulfur bacteria technology: A promising and potential approach for wastewater treatment and bioresources recovery. *World J. Microbiol. Biotechnol.* **2021**, *37*, 1–15. <https://doi.org/10.1007/s11274-021-03133-z>.
10. Nookongbut, P.; Kantachote, D.; Krishnan, K.; Megharaj, M. Arsenic resistance genes of As-resistant purple nonsulfur bacteria isolated from As-contaminated sites for bioremediation application. *J. Basic Microbiol.* **2017**, *57*, 316–324. <https://doi.org/10.1002/jobm.201600584>.
11. Koga, A.; Goto, M.; Hayashi, S.; Yamamoto, S.; Miyasaka, H. Probiotic effects of a marine purple non-sulfur bacterium, *Rhodovulum sulfidophilum* KKMI01, on kuruma shrimp (*Marsupenaeus japonicus*). *Microorganisms* **2022**, *10*, 244. <https://doi.org/10.3390/microorganisms10020244>.
12. Segura, P.C.; De Meur, Q.; Tanghe, A.; Onderwater, R.; Dewasme, L.; Wattiez, R.; Leroy, B. Effects of mixing volatile fatty acids as carbon sources on *Rhodospirillum rubrum* carbon metabolism and redox balance mechanisms. *Microorganisms* **2021**, *9*, 1996. <https://doi.org/10.3390/microorganisms9091996>.
13. Edreira, S.D.R.; Barba, S.; Vasiliadou, I.A.; Molina, R.; Melero, J.A.; Espada, J.J.; Puyol, D.; Martínez, F. Assessment of voltage influence in carbon dioxide fixation process by a photo-bioelectrochemical system under photoheterotrophy. *Microorganisms* **2021**, *9*, 474. <https://doi.org/10.3390/microorganisms9030474>.
14. Lee, S.K.; Lur, H.S.; Liu, C. Te From lab to farm: Elucidating the beneficial roles of photosynthetic bacteria in sustainable agriculture. *Microorganisms* **2021**, *9*, 2453. <https://doi.org/10.3390/microorganisms9122453>.
15. Maeda, I. Potential of phototrophic purple nonsulfur bacteria to fix nitrogen in rice fields. *Microorganisms* **2022**, *10*, 28. <https://doi.org/10.3390/microorganisms10010028>.
16. Hayashi, S.; Iwamoto, Y.; Hirakawa, Y.; Mori, K.; Yamada, N.; Maki, T.; Yamamoto, S.; Miyasaka, H. Plant-growth-promoting effect by cell Components of purple son-Sulfur photosynthetic bacteria. *Microorganisms* **2022**, *10*, 771. <https://doi.org/10.3390/microorganisms10040771>.
17. Zeidler, D.; Zähringer, U.; Gerber, I.; Dubery, I.; Hartung, T.; Bors, W.; Hutzler, P.; Durner, J. Innate immunity in *Arabidopsis thaliana*: Lipopolysaccharides activate nitric oxide synthase (NOS) and induce defense genes. *Proc. Natl. Acad. Sci. USA* **2004**, *101*, 15811–15816. <https://doi.org/10.1073/pnas.0404536101>.
18. Shang-Guan, K.; Wang, M.; Htwe, N.M.P.S.; Li, P.; Li, Y.; Qi, F.; Zhang, D.; Cao, M.; Kim, C.; Weng, H.; et al. Lipopolysaccharides trigger two successive bursts of reactive oxygen species at distinct cellular locations. *Plant Physiol.* **2018**, *176*, 2543–2556. <https://doi.org/10.1104/pp.17.01637>.
19. Iwai, R.; Uchida, S.; Yamaguchi, S.; Sonoda, F.; Tsunoda, K.; Nagata, H.; Nagata, D.; Koga, A.; Goto, M.; Maki, T.; et al. Effects of seed bio-priming by purple non-sulfur bacteria (PNSB) on the root development of rice. *Microorganisms* **2022**, *10*, 2197. <https://doi.org/10.3390/microorganisms10112197>.

20. Raetz, C.R.H.; Whitfield, C. Lipopolysaccharide endotoxins. *Annu. Rev. Biochem.* **2002**, *71*, 635–700. <https://doi.org/10.1146/annurev.biochem.71.110601.135414>.
21. Christ, W.J.; McGuinness, P.D.; Asano, O.; Wang, Y.; Mullarkey, M.A.; Perez, M.; Hawkins, L.D.; Blythe, T.A.; Dubuc, G.R.; Robidoux, A.L. Total synthesis of the proposed structure of *Rhodobacter sphaeroides* lipid A resulting in the synthesis of new potent Lipopolysaccharide antagonists. *J. Am. Chem. Soc.* **1994**, *116*, 3637–3638. <https://doi.org/10.1021/ja00087a075>.
22. Rossignol, D.P.; Lynn, M. TLR4 antagonists for endotoxemia and beyond. *Curr. Opin. Investig. Drugs* **2005**, *6*, 496–502.
23. Shirey, K.A.; Lai, W.; Scott, A.J.; Lipsky, M.; Mistry, P.; Pletneva, L.M.; Karp, C.L.; McAlees, J.; Gioannini, T.L.; Weiss, J.; et al. The TLR4 antagonist Eritoran protects mice from lethal influenza infection. *Nature* **2013**, *497*, 498–502. <https://doi.org/10.1038/nature12118>.
24. Hsieh, Y.C.; Lee, K.C.; Wu, P.S.; Huo, T.I.; Huang, Y.H.; Hou, M.C.; Lin, H.C. Eritoran attenuates hepatic inflammation and fibrosis in mice with chronic liver injury. *Cells* **2021**, *10*, 1562. <https://doi.org/10.3390/cells10061562>.

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.