UDK 579.69

Nataliia Tkachuk[1]

Liubov Zelena[2]

Pavlo Mazur[1]

PROSPECTS OF APPLICATION DIHYDROXYBENZOATE-CAPPED SIDEROPHORES IN SOLVING SOME ECOLOGICAL PROBLEMS

[1]T.H. Shevchenko National University "Chernihiv Colehium",
[2]Danylo Zabolotny Institute of Microbiology and Virology, NAS of Ukraine

Анотація

За літературними джерелами проаналізовано можливості застосування дигідроксибензоат-кепованих сидерофорів для вирішення деяких екологічних проблем. Зазначено, що перспективними сполуками для ремедіації ґрунтів, забруднених важкими металами, є бацилібактин та петробактин; як зелені-розумні інгібітори корозії розглядаються бацилібактин та ентеробактин.

Ключові слова: дигідроксибензоат-кеповані сидерофори, біологічний контроль, екологія, зелені розумні-інгібітори корозії.

Abstract

According to the literature, the possibilities of using dihydroxybenzoate-capped siderophores to solve some environmental problems have been analyzed. It is noted that promising compounds for remediation of soils contaminated with heavy metals are bacillibactin and petrobactin; bacillibactin and enterobactin are considered as green-smart corrosion inhibitors.

Keywords: dihydroxybenzoate-capped siderophores, biological control, ecology, green smart-corrosion inhibitors.

Introduction

Siderophores are low molecular weight compounds that chelate Fe (III) ions, convert insoluble Fe (III) to the bioavailable form of Fe (II), and are synthesized by some bacteria, fungus, and plants with iron ion deficiency in the medium [1-2]. Siderophores are non-toxic, environmentally unobjectionable compounds [3], which exhibit a number of useful properties to solve some agriculture, environmental, technical problems and can determine the development of bacterial infections [3-5]. Their use is a biological control approach [1]. Currently, dihydroxybenzoate-capped (DHB-capped) siderophores deserve attention, which in the chemical structure contain a fragment that effectively chelates iron – 2,3-dihydroxybenzoate, and in the case of petrobactin 3,4-dihydroxybenzoate [6]. In the processes of biosynthesis of such siderophores there is a stage of dihydroxybenzoate adenylation, for which inhibitors are being developed [4]. In addition, there are reports that 2,3-dihydroxybenzoate and bacillibactin play an essential role in biofilm formation [7].

The aim of this study was to analyze and summarize information on DHB-capped siderophores with a view to using them to address some practical issues of ecology.

Presentation of the main material

DHB-capped siderophores are, in particular, acinetobactin, bacillibactin, enterobactin, petrobactin, salmochelins, trivanchrobactin, vanchrobactin, vibriobactin. DHB-capped siderophores are represented in the group of catecholate siderophores and the group of siderophores of mixed type [2, 4, 8-9]. Their producers are both pathogenic and non-pathogenic microorganisms [1, 3-7, 10-11].

Siderophores can be involved in solving some environmental problems [10]. The publications discuss the possibility of using enterobactin for gold detection and extraction [10]. Also noteworthy is bacillibactin, which effectively binds Fe (III) at a 1:1 ratio [12]. Possibilities of siderophores for complexation of heavy metal and use in bioremediation are discussed [5, 10, 13]. In our opinion, non-pathogenic bacteria *B. velezensis*, which produce bacillibactin, and siderophore itself can be considered as promising bioremediation agents. Currently, there are no reports on the use of bacillibactin and/or its non-pathogenic producers for bioremediation in the available scientific and methodological base.

The involvement of some siderophores produced by marine bacteria (particularly petrobactin), in the biogeochemical cycling of Fe, in the remediation of petroleum hydrocarbons in the marine environment is discussed [3, 5].

Siderophores are environmentally unobjectionable compounds with high corrosion inhibitory properties of steel [14-17], promoting passivation of metals [18-20]. They are classified as green corrosion inhibitors [14]. It was found that bacillibactin-producing strains of *Bacillus velezensis* inhibit the formation of sulfate-reducing bacteria (the main agents of microbiologically influenced corrosion) biofilms on the polymeric material poly(ethylene terephthalate) [21]. It is likely that bacillibactin-producing strains or bacillibactin will inhibit the process of microbiologically influenced corrosion of steel, which is a prospect for further research.

Conclusion

The application of DHB-capped siderophores is promising for solving the problem of remediation of soils contaminated with heavy metals (bacillibactin and petrobactin), the use of green smart-corrosion inhibitors (bacillibactin and enterobactin) instead of toxic corrosion inhibitors.

REFERENCES

1. Saha M., Sarkar S., Sarkar B. et al. Microbial siderophores and their potential applications: a review. *Environ. Sci. Pollut. Res.* 2015. Issue 23. P. 3984–3999. DOI: 10.1007/s11356-015-4294-0.

2. Leonov V.V., Mironov A.Yu., Anan′ina I.V., Rubal′skaya E.E., Sentyurova L.G. Mikrobnye siderofory: struktura, svojstva, funkcii [Siderophores of microbes: structure, properties and functions]. *Astrakhan Medical Journal*. 2016. Vol. 11, No 4. C. 24-37 (in Russian).

3. Ahmed E., Holmström S.J.M. Siderophores in environmental research: roles and applications. *Microbial Biotechnology*. 2014. Vol. 7, Issue 3. P. 196–208. DOI: 10.1111/1751-7915.12117.

4. Lamb A.L. Breaking a pathogen’s iron will: Inhibiting siderophore production as an antimicrobial strategy. *Biochimica et Biophysica Acta*. 2015. Issue 1854. P. 1054–1070. DOI: 10.1016/j.bbapap.2015.05.001.

5. De Serrano L.O. Biotechnology of siderophores in high-impact scientific fields. *Biomolecular concepts*. 2017. Vol. 8, Issue 3–4. P. 169–178.

6. Yeremenko E.I. Siderofory *Bacillus anthracis* [Siderophores *Bacillus anthracis*]. *Problems of especially dangerous infections*. 2016. No 1. C. 68–74 (in Russian). DOI: 10.21055/0370-1069-2016-1-68-74.

7. Rizzi A., Roy S., Bellenger J.P., Beauregard P.B. Iron homeostasis in *Bacillus subtilis* requires siderophore production and biofilm formation. *Appl. Environ. Microbiol.* 2019. Issue 85. e02439–02418.

8. Valdebenito M., Crumbliss A. L., Winkelmann G., Hantke K. Environmental factors influence the production of enterobactin, salmochelin, aerobactin, and yersiniabactin in Escherichia coli strain Nissle 1917. *International Journal of Medical Microbiology*. 2006. Vol. 296 Issue 8. P. 513–520. DOI: 10.1016/j.ijmm.2006.06.003.

9. Timmermans M.L., Paudel Y.P., Ross A.C. Investigating the Biosynthesis of Natural Products from Marine Proteobacteria: A Survey of Molecules and Strategies. *Marine Drugs*. 2017. Vol. 15, Issue 8. P. 235. DOI: 10.3390/md15080235.

10. Khan A., Singh P., Srivastava A. Synthesis, nature and utility of universal iron chelator – siderophore: a review. *Microbiological Research*. 2018. Vol. 212–213. P. 103–111. DOI: 10.1016/j.micres.2017.10.012.

11. Kramer J., Özkaya Ö., Kümmerli R. Bacterial siderophores in community and host interactions. *Nat. Rev. Microbiol.* 2020. Issue 18. P. 152–163. DOI: 10.1038/s41579-019-0284-4.

12. Dertz E.A., Stintzi A., Stintzi A., Raymond K.N. Siderophore-mediated iron transport in *Bacillus subtillis* and *Corynebacterium glutamicum*. J. *Biol. Inorg. Chem.* 2006. Issue 11: P. 1087–1097. DOI: 10.1007/s00775-006-0151-4.

13. Rajkumar M., Ae N., Prasad M.N.V., Freitas H. Potential of siderophore-producing bacteria for improving heavy metal phytoextraction. *Trends in Biotechnology*. 2010. Vol. 28, Issue 3. P. 142–149. DOI:10.1016/j.tibtech.2009.12.002.

14. Pérez-Miranda S., Zamudio-Rivera L.S., Cisneros-Dévora R., George-Téllez R., Fernández F.J. Theoretical insight and experimental elucidation of desferrioxamine B from *Bacillus* sp. AS7 as a green corrosion inhibitor. *Corros. Eng. Sci. Technol.* 2020. Vol. 56, Issue 1. P. 93–101. DOI: 10.1080/1478422X.2020.1824441.

15. Little B., Mansfeld F. Passivity of stainless steels in natural seawater. In Uhlig, H.H. *Memorial Symposium: Corrosion monograph series. Proceeding.* Mansfeld F., Asphahani A., Bohni H., Latansion R., Eds. New Jersey: The Electrochemical Society, Inc., 1995. Vol. 94–26. P. 42–52.

16. McCafferty E., McArdle J.V. Corrosion inhibition of iron in acid solutions by biological siderophores. *J. Electrochem. Soc.* 1995. Issue 142. P. 1447–1453.

17. Rajala P. Microbially-induced corrosion of carbon steel in a geological repository environment. Helsinki: Julkaisija – Utgivare Publisher, 2017. 83 p.

18. Little B.J., Lee J.S., Ray R.I. The influence of marine biofilms on corrosion: A concise review. *Electrochim. Acta.* 2008. Issue 54. P. 2–7. DOI: 10.1016/j.electacta.2008.02.071.

19. Javaherdashti R., Alasvand K. *Biological Treatment of Microbial Corrosion: Opportunities and Challenges.* Saint Louis, Missouri: Elsevier Science, 2019. 156 p.

20. Zanna S., Seyeux A., Allion-Maurer A., Marcus Ph. *Escherichia coli* siderophore-induced modification of passive films on stainless steel. *Corros. Sci.* 2020. Issue 175. P. 1–11. DOI: 10.1016/j.corsci.2020.108872.

21. Tkachuk N., Zelena L., Lukash O., Mazur P. Microbiological and genetic characteristics of *Bacillus velezensis* bacillibactin-producing strains and their effect on the sulfate-reducing bacteria biofilms on the poly(ethylene terephthalate) surface. *Ecological Questions*. 2021. Vol. 32, Issue 2. P.119-129.

Ткачук Наталія Василівна – канд. біол. наук, доцент кафедри біології, Національний університет «Чернігівський колегіум» імені Т.Г.Шевченка, Чернігів, e-mail: nataliia.smykun@gmail.com

Зелена Любов Борисівна – канд. біол. наук, старший науковий співробітник відділу фізіології промислових мікроорганізмів, Інститут мікробіології і вірусології ім. Д.К.Заболотного НАН України, Київ, e-mail: zelenalyubov@gmail.com.

Мазур Павло Дмитрович – аспірант кафедри біології, Національний університет «Чернігівський колегіум» імені Т.Г.Шевченка, Чернігів, e-mail: MazurP@i.ua

Tkachuk Nataliia – Cand. Sc. (Bio), Associate Professor of Department of Biology, T.H. Shevchenko National University "Chernihiv Colehium", Chernihiv, e-mail: nataliia.smykun@gmail.com

Zelena Liubov – Cand. Sc. (Bio), Senior Resercher, Department of physiology of industrial microorganisms, Danylo Zabolotny Institute of Microbiology and Virology, NAS of Ukraine, Kyiv, e-mail: zelenalyubov@gmail.com.

Mazur Pavlo – graduate student of the Department of Biology, T.H. Shevchenko National University "Chernihiv Colehium", Chernihiv, e-mail: MazurP@i.ua