Aplicación de herramientas biotecnológicas para la obtención de pigmento bacteriano con potencial industrial

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RESUMEN

El uso indiscriminado de colorantes sintéticos en la industria alimentaria, cosmética y textil ha generado preocupaciones ambientales y sanitarias debido a su baja degradabilidad y potencial toxicidad (Dutta et al., 2024; Tkaczyk et al., 2020). En este contexto, los pigmentos bacterianos emergen como alternativas sostenibles por su origen natural, biodegradabilidad y propiedades bioactivas (Nigam & Luke, 2016; Venil et al., 2020). El presente estudio tuvo como objetivo aislar, caracterizar y evaluar un pigmento bacteriano con potencial industrial obtenido a partir de una cepa nativa del suelo agrícola del Caribe colombiano.

La cepa fue aislada de la rizosfera de maíz del municipio de Juan de Acosta (Atlántico, Colombia) y cultivada en medio Luria-Bertani. La identificación molecular, basada en la secuenciación del gen 16S rRNA, mostró un 89 % de identidad con secuencias de referencia del género *Serratia*, lo que sugiere la presencia de una cepa ambiental divergente o la posible existencia de un linaje local. Aun así, las características morfológicas y fisiológicas permitieron su tratamiento experimental como *Serratia marcescens*. El pigmento extraído con etanol presentó un máximo de absorbancia a 525 nm, consistente con el espectro característico de la prodigiosina, e indicó la presencia de grupos funcionales –OH y C=O en el análisis FTIR, propios de compuestos tripirrólicos (Choi et al., 2021; Narsing Rao et al., 2017). De manera

destacable, el pigmento mostró solubilidad parcial en agua, un comportamiento inusual frente a la prodigiosina tradicionalmente descrita como hidrofóbica (Choi et al., 2021), lo que podría representar una ventaja tecnológica para su incorporación en matrices acuosas o productos alimentarios. Además, los ensayos de difusión en disco revelaron actividad antimicrobiana selectiva frente a bacterias Gram positivas, especialmente *Bacillus spizizenii*, incluso con extractos diluidos (1/100), evidenciando la potencia biológica del metabolito.

Estos resultados demuestran el potencial biotecnológico de cepas nativas productoras de pigmentos como alternativa ecológica frente a los colorantes sintéticos. La capacidad de producir un pigmento ópticamente similar a la prodigiosina, con propiedades de solubilidad mejoradas y actividad antimicrobiana a bajas concentraciones, posiciona a este aislado como un recurso prometedor para el desarrollo de bioprocesos sostenibles en la industria. En conjunto, este estudio contribuye al conocimiento científico sobre los pigmentos bacterianos y promueve la valorización de microorganismos autóctonos del Caribe colombiano como fuente de compuestos funcionales con aplicación industrial y ambiental (Grewal et al., 2022; Lyu et al., 2022; Kumar et al., 2022).

Palabras clave: *Serratia marcescens*, prodigiosina, pigmentos bacterianos, biotecnología, antimicrobiano natural, sostenibilidad.

ABSTRACT

The indiscriminate use of synthetic dyes in the food, cosmetic, and textile industries has raised environmental and health concerns due to their low degradability and potential toxicity (Dutta et al., 2024; Tkaczyk et al., 2020). In this context, bacterial pigments have emerged as sustainable alternatives due to their natural origin, biodegradability, and bioactive properties (Nigam & Luke, 2016; Venil et al., 2020). This study aimed to isolate, characterize, and evaluate a bacterial pigment with industrial potential obtained from a native strain of agricultural soil in the Colombian Caribbean.

The strain was isolated from the rhizosphere of maize crops in Juan de Acosta (Atlántico, Colombia) and cultivated in Luria-Bertani medium. Molecular identification based on 16S rRNA gene sequencing revealed 89% identity with *Serratia* reference sequences, suggesting either a divergent environmental strain or the existence of a local lineage. Nonetheless, morphological and physiological traits supported its experimental classification as *Serratia marcescens*. The ethanol-extracted pigment exhibited a maximum absorbance at 525 nm, consistent with the characteristic spectrum of prodigiosin, and FTIR analysis showed –OH and C=O functional groups typical of tripyrrolic compounds (Choi et al., 2021; Narsing Rao et al., 2017). Remarkably, the pigment exhibited partial solubility in water, an unusual behavior compared to the traditionally hydrophobic prodigiosin (Choi et al., 2021), which could represent a technological advantage for its incorporation into aqueous or food matrices. Furthermore, disk diffusion assays revealed selective antimicrobial activity against Gram-positive bacteria, particularly *Bacillus spizizenii*, even at low extract concentrations (1/100), highlighting the compound's biological potency.

These findings demonstrate the biotechnological potential of native pigment-producing strains as ecological alternatives to synthetic dyes. The ability to produce a pigment optically similar to prodigiosin, with improved solubility and antimicrobial activity at low concentrations, positions this isolate as a promising resource for the development of sustainable bioprocesses. Overall, this study contributes to scientific knowledge on bacterial pigments and promotes the valorization of native microorganisms from the Colombian Caribbean as sources of functional compounds with industrial and environmental applications (Grewal et al., 2022; Lyu et al., 2022; Kumar et al., 2022).

Keywords: *Serratia marcescens*, prodigiosin, bacterial pigments, biotechnology, natural antimicrobial, sustainability.

REFERENCIAS

1. Alfonso Pellicer, M. (2021). Revisión bibliográfica sobre los efectos adversos de los colorantes sintéticos de 2008 a 2021. Retrieved from https://riucv.ucv.es/handle/20.500.12466/1903

2. Al-Tohamy, R., Ali, S. S., Li, F., Okasha, K. M., Mahmoud, Y. A. G., Elsamahy, T., Jiao, H., Fu, Y., & Sun, J. (2022). A critical review on the treatment of dye-containing wastewater: Ecotoxicological and health concerns of textile dyes and possible remediation approaches for environmental safety. Ecotoxicology and Environmental Safety, 231, 113160. doi: 10.1016/J.ECOENV.2021.113160

3. Amchova, P., Kotolova, H., & Ruda-Kucerova, J. (2015). Health safety issues of synthetic food colorants. Regulatory Toxicology and Pharmacology, 73(3), 914–922. doi: 10.1016/J.YRTPH.2015.09.026

4. Ardila-Leal, L. D., Poutou-Piñales, R. A., Pedroza-Rodríguez, A. M., Quevedo-Hidalgo, B. E., Capela, I., Kamali, M., & Zuorro, A. (2021). A Brief History of Colour, the Environmental Impact of Synthetic Dyes and Removal by Using Laccases. Molecules 2021, Vol. 26, Page 3813, 26(13), 3813. doi: 10.3390/MOLECULES26133813

5. Choi, S. Y., Lim, S., Yoon, K. hye, Lee, J. I., & Mitchell, R. J. (2021). Biotechnological Activities and Applications of Bacterial Pigments Violacein and Prodigiosin. Journal of Biological Engineering 2021 15:1, 15(1), 1–16. doi: 10.1186/S13036-021-00262-9

6. Golka, K., Kopps, S., & Myslak, Z. W. (2004). Carcinogenicity of azo colorants: influence of solubility and bioavailability. Toxicology Letters, 151(1), 203–210. doi: 10.1016/J.TOXLET.2003.11.016

7. Grewal, J., Wołącewicz, M., Pyter, W., Joshi, N., Drewniak, L., & Pranaw, K. (2022). Colorful Treasure From Agro-Industrial Wastes: A Sustainable Chassis for Microbial Pigment Production. Frontiers in Microbiology, 13, 832918. doi: 10.3389/FMICB.2022.832918/XML

8. Kumar, S., Kumar, V., Ambika, Nag, D., Kumar, V., Darnal, S., Thakur, V., Patial, V., & Singh, D. (2022). Microbial pigments: learning from the Himalayan perspective to industrial applications. Journal of Industrial Microbiology & Biotechnology, 49(5), kuac017. doi: 10.1093/JIMB/KUAC017
9. Lyu, X., Lyu, Y., Yu, H., Chen, W. N., Ye, L., & Yang, R. (2022). Biotechnological advances for improving natural pigment production: a state-of-the-art review. Bioresources and Bioprocessing, 9(1), 1–38. doi: 10.1186/S40643-022-00497-4/TABLES/1

10. Narsing Rao, M. P., Xiao, M., & Li, W. J. (2017). Fungal and bacterial pigments: Secondary metabolites with wide applications. Frontiers in Microbiology, 8(JUN), 250699. doi: 10.3389/FMICB.2017.01113/XML

11. Neves, M. I. L., Silva, E. K., & Meireles, M. A. A. (2019). Trends and Challenges in the Industrialization of Natural Colorants. Food and Public Health, 9(2), 33–44. doi: 10.5923/J.FPH.20190902.01

12. Nigam, P. S., & Luke, J. S. (2016). Food additives: production of microbial pigments and their antioxidant properties. Current Opinion in Food Science, 7, 93–100. doi: 10.1016/J.COFS.2016.02.004

13. Tkaczyk, A., Mitrowska, K., & Posyniak, A. (2020). Synthetic organic dyes as contaminants of the aquatic environment and their implications for ecosystems: A review. Science of The Total Environment, 717, 137222. doi: 10.1016/J.SCITOTENV.2020.137222

14. Venil, C. K., Dufossé, L., & Renuka Devi, P. (2020). Bacterial Pigments: Sustainable Compounds With Market Potential for Pharma and Food Industry. Frontiers in Sustainable Food Systems, 4, 554584. doi: 10.3389/FSUFS.2020.00100/XML

15. Choi, S. Y., Lim, S., Yoon, K. H., Lee, J. I., & Mitchell, R. J. (2021). *Biotechnological activities and applications of bacterial pigments violacein and prodigiosin*. Journal of Biological Engineering, 15(1), 1–16. https://doi.org/10.1186/s13036-021-00262-9

16. Grewal, J., Wołącewicz, M., Pyter, W., Joshi, N., Drewniak, L., & Pranaw, K. (2022). *Colorful treasure from agro-industrial wastes: A sustainable chassis for microbial pigment production*. Frontiers in Microbiology, 13, 832918. https://doi.org/10.3389/fmicb.2022.832918

17. Kumar, S., Kumar, V., Ambika, Nag, D., Kumar, V., Darnal, S., Thakur, V., Patial, V., & Singh, D. (2022). *Microbial pigments: Learning from the Himalayan perspective to industrial applications*. Journal of Industrial Microbiology & Biotechnology, 49(5), kuac017. https://doi.org/10.1093/jimb/kuac017

18. Lyu, X., Lyu, Y., Yu, H., Chen, W. N., Ye, L., & Yang, R. (2022). *Biotechnological advances for improving natural pigment production: A state-of-the-art review*. Bioresources and Bioprocessing, 9(1), 1–38. https://doi.org/10.1186/s40643-022-00497-4

19. Narsing Rao, M. P., Xiao, M., & Li, W. J. (2017). *Fungal and bacterial pigments: Secondary metabolites with wide applications*. Frontiers in Microbiology, 8, 250699. https://doi.org/10.3389/fmicb.2017.01113

20. Nigam, P. S., & Luke, J. S. (2016). *Food additives: Production of microbial pigments and their antioxidant properties*. Current Opinion in Food Science, 7, 93–100. https://doi.org/10.1016/j.cofs.2016.02.004

21. Venil, C. K., Dufossé, L., & Renuka Devi, P. (2020). *Bacterial pigments: Sustainable compounds with market potential for pharma and food industry*. Frontiers in Sustainable Food Systems, 4, 554584. https://doi.org/10.3389/fsufs.2020.00100

22. Benkhaya, S., M'rabet, S., & El Harfi, A. (2020). Classifications, properties, recent synthesis and applications of azo dyes. *Heliyon*, *6*(1), e03271. https://doi.org/10.1016/J.HELIYON.2020.E03271

23. Dutta, S., Adhikary, S., Bhattacharya, S., Roy, D., Chatterjee, S., Chakraborty, A., Banerjee, D., Ganguly, A., Nanda, S., & Rajak, P. (2024). Contamination of textile dyes in aquatic environment: Adverse impacts on aquatic ecosystem and human health, and its management using bioremediation. *Journal of Environmental Management*, *353*, 120103. https://doi.org/10.1016/J.JENVMAN.2024.120103

24. Gičević, A., Hindija, L., & Karačić, A. (2020). Toxicity of azo dyes in pharmaceutical industry. *IFMBE Proceedings*, *73*, 581–587. https://doi.org/10.1007/978-3-030-17971-7_88