A Review Article on Recent Production & Application of Natural Dyes or Biocolours from Microorganisms

Ms L. Jayavani [1], Dr. Shahin Banu Z[2]

[1] II MSc, [2]Assistant Professor

[1, 2]Department of Microbiology, Dr MGR Janaki College of arts and science for women

Abstract

This review article provides a comprehensive overview of highlights on biocolours and their significance as natural alternatives to synthetic dyes across various industries. It includes food, cosmetics, textiles and pharmaceutical industries. Synthetic dyes pose number of health risk, including skin and eye irritation, respiratory problems, hormonal disruption, cancer, neurotoxicity, allergic reactions, tumors, DNA damage, white blood cell damage. Synthetic dyes can also have negative environmental consequences. Hence, biocolours are the good alternative, due to the demand for the natural source is increasing day by day because of the awareness of the positive health benefits out of natural compounds. Biocolours are derived from biological sources such as plants, fruits and microorganisms are favored for their non-toxic properties and potential health benefits. These natural dyes have antioxidant, anti-cancer, antimicrobial effects. This article comprehends the microbial pigments based on their source, colours, and solubility while study into a variety of microorganisms that produce these pigments. Organism like *bacillussp* produces zeaxanthinpigment which is brown, S*taphylococcus aureus* produces staphyloxanthin golden yellow, *pseudomonas aeruginosa* produce pyocyanin which is blue-green, *Serratiamarcescens*, produce prodiogiosin that is red in colour, *Agrobacterium* produces astaxanthin pigment pink in colour. The merits of utilizing microbial pigments in diverse application ranging from biomedical application, bioindicators, cosmetic, textile, food etc. these pigments are eco-friendly, waste management, sustainable. Ultimately the need for future research to enhance the production and application of biocolours, underlining their importance in promoting public health and environmental sustainability.

Keywords: Biocolours, Microbial Pigments, Non-Toxic dyes, Natural Dyes, Characteristics, Application

1. INTRODUCTION:

The term "Biocolour" is made up of "bio" which refers to life (living organisms) and "colour" which refers to anything that provides colour or is used for colouring purposes[22].The colours found in nature are typically obtained from fruits, vegetables, roots, and microorganisms. These are commonly referred to as biocolours because of their biological source [15].Synthetic artificial colours have been extensively utilized in various industries such as food, cosmetics, textiles, and pharmaceuticals [14].

Natural dyes serve as a safe substitute for harmful synthetic dyes. Recently, there has been an increase in the use of natural pigments in various industries, including food, dye, cosmetics, and pharmaceuticals, due to their non-toxic characteristics. Furthermore, their eco-friendly, antioxidant, anti-cancer, and antimicrobial qualities enhance their positive effects [15].

2. ORIGINS OF BIOCOLOURS:

A wide range of biological materials, including plants, fruits, vegetables, flowers, insects, and microorganisms, can be utilized to derive bio-colours. These sources possess unique colour compounds that can be extracted for the creation of natural dyes. Instances of bio-colour sources are commonly encountered in everyday products[10].

3. COLOURING AGENTS MADE FROM FRUITS, VEGETABLES AND PLANTS:

Indigo, turmeric, madder, and henna are instances of plants that contain natural pigments, which can be extracted for use in dyeing fabrics and various other materials. Berries, beets, onions, and spinach are abundant in vivid pigments that can be extracted and employed as natural colorants in food, cosmetics, and textiles [7].

4. MICROBIAL PIGMENTS CATEGORIZATION :

Microbial pigments can be classified into three main categories.

1) They can be classified by their source, which includes pigments derived from algae, fungi, and bacteria.

2) They can also be categorized by their dominant color, such as:

- Yellow pigments (Riboflavin, Carotenoids)

- Red pigments (Prodigiosin, Carotenoids)

- Blue pigments (Indigiodine, Violacein).Furthermore, they can be grouped based on their solubility, either as water-soluble or fat-soluble[7].

5. THE HABITATS AND ECOLOGY OF PIGMENTED MICROORGANISMS:

Numerous scientific investigations have recorded the presence of vibrant microorganisms, including bacteria, fungi, and yeast, residing in both land and water ecosystems. These microorganisms are found across a wide range of geographic areas, spanning from polar zones to tropical regions and from lofty altitudes to deep-sea environments. It is thought that microbes from various regions withstand extreme conditions by synthesizing pigments. Some microorganisms with pigments, including specific bacteria (e.g., Stenotrophomonas) and yeasts (like Rhodotorula), that come from terrestrial sources have been observed to move to coastal ecosystems via sewage releases from medical facilities and residences, thus adjusting to marine environments. An examination of existing literature shows that pigmented bacteria can be classified into two groups: true marine pigmented bacteria, which are mainly sourced from marine habitats, and adaptive pigmented bacteria, which are from terrestrial ecosystems and can endure and flourish in coastal regions. Significant amounts of pigmented bacteria have been observed in various sites, such as air-water interfaces, glaciers, ice cores, the bacterial neuston (the sea surface microlayer) along with the water beneath it, salt lakes, deep-sea hydrothermal vents, and abyssal hot springs (including Thermus). Furthermore, various communities of colorued bacteria have recently been found in lava caves. In addition, the pigmented bacteria P. aeruginosa has been found in the wounds and skin of both humans and animals[25].

6. MICROBIAL PIGMENTS:

Pigments are colourful secondary metabolites produced by microorganisms. Since ancient times, pigments have been used as colouring agents[16].

6.1.RIBOFLAVIN:

Riboflavin is a yellow pigment that dissolves in water and is generated by ascomycetes, including Candida fermata, Ashby gossypii, and Bacillus subtilis[11].

6.2.BETA-CAROTENE:

Beta-carotene is a pigment that dissolves in fat and is found in various fruits and vegetables, as well as in specific microorganisms like Trispora[18].

6.3.CAROTENOIDS:

Carotenoids are pigments that exhibit colors ranging from red to yellow and orange, generated by certain species of Halobacterium[21].

6.4.PRODIGIOSIN:

Prodigiosin is a vibrant red pigment produced by specific strains of Serratia marcescens. It has been noted for its antibacterial, antifungal, immunosuppressive, and antiproliferative properties[5].

6.5.PYOCYANIN:

Pyocyanin is a pigment with a blue-green colour that is water-soluble and generated by certain strains of Pseudomonas aeruginosa. It possesses antifungal, antibacterial, and antioxidant characteristics[4].

6.6.VIOLACEIN:

Violacein is anon-water-soluble pigment that is purplein colour and produced by specific strains of chromobacterium violaceum. It has properties that are antibacterial, antifungal, and antioxidant[19].

6.7.INDIGIODINE:

Indigiodine is a blue pigment synthesized by E. coli, and it has antioxidant and antimicrobial characteristics[1].

6.8.ASTAXANTHIN:

Astaxanthin is a red pigment located in several types of seafood, including salmon, trout, red sea bream, shrimp, and lobster. This pigment, generated by the algae Haematococcuspluvialis, has antioxidant characteristics[9].

7. CHARACTERISTICS OF BIOCOLOURS:

- Dyeing ability
- Anti parasitic
- UV protection
- Anti microbial
- Anti cancer
- Anti oxidative[3].

8. SOURCES OF BIOCOLOURS:

8.1. VARIOUS SOURCES OF MICROORGANISMS AND THEIR PIGMENTS:

MICROORGANISMS	PIGMENTS AND APPEARANCE
• *Agrobacterium Aurantiacum* • *ParacoccusCarotinifaciens*	Astaxanthin Pink-Red
• *BradyrhizobiumSp* • *Haloferax Alexandrine*	Canthaxantin Dark -Red
• *CorynebacteriumInsidiosum*	Indigiodine Blue
• *Roseomonas Rubra* • *Streptomyces Luteireticuli* • *Vibrio Aerogenes* • *Alteromonas Rubra* • *Serratia Marcescens* • *Serratia Rubidaea*	Prodigiosin Red
• *Pseudomonas Aeruginosa*	Pyocyanin Blue-Green
• *Staphylococcus Aureus*	Staphyloxantin Golden Yellow
• *JanthinobacteriumLividum,* • *Chromobacterium Violaceum*	Violacein Purple
• *Xanthomonas Oryzae*	Xanthomonadin Yellow
• *Flavobacterium Sp.,* • *ParacoccusZeaxanthinifaciens*	Zeaxanthin Yellow
• *Monascus Sp.*	Ankaflavin Yellow
• *Ashbya Gossypii*	Riboflavin Yellow
• *XanthophyllomycesDendrorhous (PhaffiaRhodozyma)*	Astaxantin Pink-Red
• *Cryptococcus Sp.* • *Red Saccharomyces* *Neoformans Var*	Melanin Black

• *Rhodotorula Sp.* *RhodotorulaGlutinis*	Torularhodin Orange- Red

Table 1: various sources of microorganisms and their pigments[17].

9. VARIOUS MEDIA AND SUPPLEMENTS REQUIRED FOR EXTRACTION OF SPECIFIC PIGMENTS FROM DIFFERENT MICROORGANISMS:

Media/Supplement	**Pigments**
Casein hydrolysate agar	Prodigiosin
Lactose and tryptophan	Violacein
Potato-glucose-peptone agar, Phosphate agar— incorporation of 2-hydroxypyridine and/or Tryptophan	Indigo
Glycerol, leucine, glycine, alanine, and mineral salts	Pyocyanine
Cornsteep liquor, corn oil, and glycine	Riboflavin
Tyrosine agar, Peptone-yeast extract iron agar, Tyrosine, Zn, Cu, Co, and 3-chlorobenzoate	Melanin
Mevalonic acid, trisporic acid, and Isopentenyl pyrophosphate	Carotenoids
Sucrose, molasses, corn extract, yeast extract, zinc sulfate, and magnesium sulphate	Anthraquinones

Table 2: various media and supplements required for extraction of specific pigments from different microorganisms [6]

10. EXTRACTION OF PIGMENT FROM ISOLATED BACTERIA:

- The isolated bacterial cultures were suspended in flasks containing plain sterile Nutrient broth
- The flasks were incubated at 37°C for 7 days for observation of maximum pigment production.
- extraction of pigment: After incubation, the culture broth was centrifuged at 3000 rpm for 10 minutes.
- The colourless supernatant was discarded. The pellet was mixed with the different solvents via vortex mixing repeatedly until the pellet turned colourless.
- The supernatant was separated and filtered through Whatman No.1 filter paper and kept in a hot air oven for solvent evaporation.

- The dry pigment residues left after evaporation were suspended in the solvent and then re-evaporated, this step was repeated 2-3 times so that pure pigments were obtained[23].

11. METHODS USED FOR THE EXTRACTION OF NATURAL DYES:

- Conventional method
- Ultrasound assisted extraction
- Microwave extraction
- Enzyme based extraction[20].

12. HAZARDS OF CHEMICAL OR SYNTHETIC COLOURS:

Toxicity: Artificial dyes may have harmful substances such as mercury, lead, chromium, copper, sodium chloride, toluene, and benzene. Being exposed to high levels of these chemicals can lead to serious health issues in humans[26].

Cancer: Certain synthetic dyes, such as Red 3, have been shown to cause cancer in animals. Other dyes, including Red 40, Yellow 5, and Yellow 6, have been found to contain cancer-causing substances[26].

Neurological issues: Research indicates that artificial colourings may lead to hyperactivity, lack of focus, and other behaviour concerns in children[26].

Gastrointestinal and respiratory issues: Artificial colors may lead to gastrointestinal and respiratory complications[28].

13. MERITS OF BACTERIAL PIGMENTS:

- ➢ The selection is extensive and easy to handle.
- ➢ The quality is extremely high and it is also effective in various other sources.
- ➢ The fermentation process is simple to conduct and is also highly efficient as it can be integrated with other chemical processes.
- ➢ ▪ Genes can be easily controlled.
- ➢ ▪ The method of teaching and learning is quick and simple, enabling the operation of a bioreactor to be pursued.
- ➢ ▪ To reduce operation time, bacterial components are eliminated through a simple liquid-liquid extraction method[14].

14. APPLICATIONOFMICROBIAL PIGMENTS IN VARIOUS FIELDS:

BIOMEDICAL APPLICATION	MISCELLANEOUS APPLICATION	INDUSTRIALS APPLICATION
ANTIMICROBIAL ACTIVITY: Antibacterial Antifungal Antiviral	BIO INDICATORS: Pollution Indicators	TEXTILE: Dyeing fibers

ANTIOXIDANT ACTIVITY: Neutralize free radicals	ELECTRON SOURCE: Dyesensitizedsolarcells COSMETICS: Sun block Creams	FOOD INDUSTRY: Food preservative Food colorants

Table 3: applicationof microbial pigments in various fields [16].

14.1 COSMETICS:

Microbial melanin is a naturally occurring “sunscreen” that captures a wide range of UV and visible light. Besides its ability to block UV radiation, this pigment also serves as a potent antioxidant[2].

14.2 THERAPEUTIC USES OF PIGMENTS:

Therapeutic Uses of Pigments: The cytotoxic effectiveness of prodigiosin pigment has been examined in standard 60 cell line panels of human tumor cells. Violacein, a pigment derived from *C. violaceum*, has been shown to induce cell death in human Leukemia. Violacein triggers apoptosis by activating the TNF receptor 1 signal transduction pathway and represents a novel category of cytotoxic medications. Immunosuppressant medications are a type of drug that diminishes, or lowers, the activity of the body's immune system. Certain of these drugs are utilized to reduce the likelihood of organ rejection in transplants, such as those of the liver, heart, or kidney [24].

14.3 TEXTILE INDUSTRY:

In the textile industry, synthetic dyes have been extensively utilized as they meet the preferences of both dyers and consumers. Bacterial species include Serratia marcescens, Vibrio sp, and Chromobacterium violaceum. The pigments produced are prodigiosin and violacein. Fabrics that have been dyed include acrylic, polyester, microfiber, silk, cotton, wool, nylon, and others, particularly with violacein[27].

14.4 LEATHER AND TANNING:

The majority of leather dyeing processes utilize azo dyes or metal complex dyes. Nonetheless, the dye structures can differ from those used in textile dyeing [12].

14.5 DAIRY INDUSTRY:

Monascus species are recognized for generating non-toxic pigments that can serve as food colorants, flavor enhancers, and preservatives. Monascus ruber is employed to create flavored milk by metabolizing carbohydrates from rice, leading to the production of pigments as a secondary metabolite. The fermentation of rice in solid state results in pigments that can be red, orange, or yellow[8].

15. FUTURE PERSPECTIVES:

There has been an increasing level of public interest in natural colors, mainly due to their safety for health and environmentally friendly properties. Microbial pigments, which are a key source for natural colors, provide a range of medicinal advantages. There is a necessity for more focused efforts to discover cost-effective organic substrates that support the growth of microorganisms producing these pigments. Research should increasingly aim to clarify the mechanisms that underlie the pharmacological benefits of microbial pigments, as this could contribute to the development of innovative strategies for treating serious conditions like cancer. Future research should prioritize a deeper understanding of the chemical structures of microbial pigments and the correlation between their structure and function.

16. CONCLUSION:

Synthetic pigments have been extensively used across numerous applications, despite their carcinogenic properties and non-biodegradability. Consequently, it is essential to create alternative natural pigments that are more cost-effective and biodegradable. Bacterial pigments serve as promising sources for dyes, food coloring, anticancer agents, biological imaging, and various other commercial uses.

REFERENCES:

1. Abhishek kumar."Microbial pigments: production and their applications in various industries"(2015, ed.) [review of microbial pigments: production and their applications in various industries].
2. Anh n. Tran-ly. (2020). "Microbial production of melanin and its various application" [review of microbial production of melanin and its various application].
3. Ana kumar. (2022). "Bacterial secondary metabolites as biopigments for textaildeying" [review of bacterial secondary metabolites as biopigments for textaildeying].
4. Aparna joshi. (2023). "Production and characterization of pyocyanin pigment from pesudomonas aeruginosa" [review of production and characterization of pyocyanin pigment from pesudomonas aeruginosa].
5. Chandni gulani(2012). "Assessment of process parameters influencing the enhanced productiob of prodigiosin from serratia marcescens and evaluation of its antimicrobial antioxidant and dyeing potentials" [review of assessment of process parameters influencing the enhanced productiob of prodigiosin from serratia marcescens and evaluation of its antimicrobial antioxidant and dyeing potentials].
6. ChatragaddaRamesh "Multifaceted applications of microbial pigments: current knowledge, challenges and future directions for public health implications" (2019, ed.) [review of multifaceted applications of microbial pigments: current knowledge, challenges and future directions for public health implications].
7. Dhiraj patil (2024). "An overview of microbial pigment: a reliable source of biocolor" [review of an overview of microbial pigment: a reliable source of biocolor]. Www.ijprajournal.com .
8. Hrucha Vaidya. (2021). Microbial Pigments: Natural Colorants and their Industrial Applications [Review of Microbial Pigments: Natural Colorants and their Industrial Applications].
9. Jyotika dhankhar"Astaxanthin: a potential carotenoid" (2012, ed.) [review of astaxanthin: a potential carotenoid].
10. Kamla malik."Microbial pigments: a review" (2021, ed.) [review of microbial pigments: a review].

11. Kirti tiwari. (2022). A potential application of microbial pigment: an alternative to synthetic dye & colourants [review of a potential application of microbial pigment: an alternative to synthetic dye &colourants].
12. Leidy D. Ardila-Leal. (2021). ABrief History of Colour, the Environmental Impact of Synthetic Dyes and Removal by Using Laccases [Review of ABrief History of Colour, the Environmental Impact of Synthetic Dyes and Removal by Using Laccases].
13. Manisha parmar. "Biocolors: the new generation additives"(2015, ed.) [review of biocolors: the new generation additives].
14. Meenakshi(2017). "Microbes and pigments" [review of microbes and pigments]. Www.phytojournal.com.
15. Meenakshi, m., rana, n., &chauhan, a. (2018). "Extraction and characterization of biocolors from bacterial isolates of pseudomonas sp. M1 and ms2." Annals of phytomedicine an international journal, 7(1). Https://doi.org/10.21276/ap.2018.7.1.7
16. Mayuri n. Bhosale. "A survey on microbial pigments: production and applications"(2022, ed.) [review of a survey on microbial pigments: production and applications]. Gorteria journal issn: 0017-2294.
17. Monishdeep v, "A review on potential microbial sourced bio-colours from fungi"(2022, ed.) [review of a review on potential microbial sourced bio-colours from fungi].
18. Muhammad rifqi. Journal home: https://journal.sgu.ac.id/jffn 2023:4(2), pp.67-78 67 "use of beta-carotene pigment to improve food product chemical and sensory qualities" a review (2023, ed.) [review of journal home: https://journal.sgu.ac.id/jffn 2023:4(2), pp.67-use of beta-carotene pigment to improve food product chemical and sensory qualities: a review].
19. Manal jameelkiki. "Biopigments of microbial origin and their application in the cosmetic industry"(2023, ed.) [review of biopigments of microbial origin and their application in the cosmetic industry].
20. Nikhetrafiq. (2022). "Extraction techniques and utilization of natural pigments"[Review of extraction techniques and utilization of natural pigments].
21. Omayma a. Eldahshan. Journal of pharmacognosy and phytochemistry carotenoids (2013, ed.) [review of journal of pharmacognosy and phytochemistry carotenoids].
22. Priyaragini. (2017). "Microbial pigment as an alternative to synthetic dye" [review of microbial pigment as an alternative to synthetic dye].
23. Pooja ratnakaran. (2020). "Isolation and characterization of pigments producing bacteria isolated from waste" [Review of isolation and characterization of pigments producing bacteria isolated from waste].
24. Roqayyamumtaz. "Pigments from soil bacteria and their therapeutic properties: a mini review" (2018, ed.) [review of pigments from soil bacteria and their therapeutic properties: a mini review].
25. Ramesh chatragadda. "Ecological and biotechnological aspects of pigmented microbes: a way forward in development of food and pharmaceutical grade pigments"[review of ecological and biotechnological aspects of pigmented microbes: a way forward in development of food and pharmaceutical grade pigments]. Publisher's note: mdpi stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.
26. Sarah kobylewski. (2012). "Toxicology of food dyes" [review of toxicology of food dyes].

27. Vinotha m. . “Bacterial pigments and their application in textile industries using mordants” (2019, ed.) [review of bacterial pigments and their application in textile industries using mordants]. Http://www.sciensage.info/jasr .
28. Zandlemebirino de oliveira. (2024). “Synthetic colours in foods : a waening for children’s health” [review of synthetic colours in foods : a waening for children’s health].