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Marine Bacterial Pigments and Nanoparticles Synthesis - An Overview

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ABSTRACT

Over the past two decades, there have been increasing trends toward replacing synthetic colorants with natural pigments because of their harmful effects on co-workers and consumers. So bacterial pigments, due to their better biodegradability and higher compatibility with the environment, offer promising avenues for various applications. However, there is significant economic potential for anti-microbial, anti-cancer, anti-oxidant, anti-inflammatory, and anti-allergic characteristics. Additionally, bacterial sources provide more scope than plant sources for the quick and affordable production of natural colorants all through the year. The current review study gives an outline of the naturally pigmented compounds derived from marine bacteria and nanoparticles based on information learned from the literature.

Introduction

Pigments are one of many bioproducts that bacteria have the potential to produce, Several researchers have investigated the production and use of bacterial pigments as natural colorants (Ahmad *et al.*, 2012; Joshi *et al.*, 2003). Nearly 300,000 marine organisms have been studied, representing a tiny fraction of the total number of bacterial species that may be explored and produce pigment. These molecules, also known as "bioactive pigmented molecules," come in a wide variety and can be produced by both gram-positive and gram-negative bacterial species. Bacterial species, including *Streptomyces sp.*, *Pontibacter korlensis sp.*, *Pseudomonas sp.*, *Bacillus sp.*, *and Vibrio sp.*, that have been isolated from marine sediments or seawater. Pigment refers to a significant category of organic components found in bacterial protoplasm. Microorganisms are the source of some colored compounds, such as carotenoids, melanins, flavins, quinones, prodigiosin, and more precisely monastics, violacein, or indigo (Dufosse, 2009).

Bacteria can produce colors for a variety of reasons some microorganisms, such as cyanobacteria, produce the pigment phycobilin in order to perform photosynthesis (Song *et al.*, 2006). Other reasons for creating pigments include UV protection, defensive systems, secondary metabolites for energy storage, and in stressful situations to protect them from harsh conditions. Pigments such as prodigiosin (red), violacein (violet), and pyocyanin (blue-green) are known to contain active ingredients with antimicrobial, antiviral, antitumor, antiprotozoa, antioxidant, and other beneficial properties (Ferreira *et al.,* 2004).

Previous research has shown that some microorganism-produced colors can inhibit the development of other bacteria. Plants, microbes, and a variety of other sources are used to make bioactive pigments (Papageorgion and Winkler, 1979). When compared to plant-produced bioactive pigments, microbes are generally chosen due to their availability and stability (Kim *et al.,* 1999; Parekh, 2000; Cho *et al.,* 2002). The creation of bacterial pigments is one new area of study that has the potential for various industrial applications (Venil *et al.,* 2009). In addition to their well-known cytotoxic, antioxidant, antimicrobial, antimalarial, anticancer, antitumor, and antifouling properties, microbial pigments have been highlighted for their usefulness in a variety of applications, including cosmetics, food, medicines, and textiles (Venil *et al.,* 2013; Ramesh *et al., 2019*).

Natural dyes are expected to grow at a 5-10% annual rate, while synthetic dyes are expected to grow at a rate of only 3-5% (Parmar and Phutela, 2015). Microbes can grow quickly and easily in an inexpensive cultural medium, regardless of the weather (Dufosse, 2009).

Typically, unhealthy chemical components including lead, mercury, copper, chromium, sodium chloride, benzene, and toluene are used to create synthetic colors. Several synthetic colorants that the Food and Drug Administration (FDA) had previously approved for use in the creation of medications, foods, and cosmetics were later discovered to be carcinogenic (Rao *et al.,* 2017).

Nowadays, customers choose natural components over artificial ones in their meals since they are aware of the negative consequences that synthetic dyes can have on the body (Downham and Collins, 2000).This has increased the need for pigments made organically. Below is a discussion of bioactive-pigmented chemicals that were obtained from marine microorganisms.

Nanoparticles mediated by bacterial pigments

Nanoparticles with one or more dimensions of 100 nm or less have received a lot of attention because of their unique and fascinating properties (Daniel and Astruc 2004; Kato 2011). Different kinds of nanoparticles can be created using a wide range of physical, chemical, biological, and hybrid processes (Liu *et al.,* 2011; Luechinger *et al.,* 2010; Tiwari *et al.,* 2008; Mohanpuria *et al.,* 2008). Although the use of toxic chemicals severely restricts the biomedical applications of nanoparticles, particularly in the clinical fields, physical and chemical methods are still more common in the synthesis of nanoparticles. Therefore, it is crucial to develop dependable, non-toxic, and environmentally friendly methods for synthesizing nanoparticles in order to increase the scope of their biomedical applications. Using microorganisms to create nanoparticles is one way to accomplish this. Additionally, nanoparticles are employed as antimicrobial agents, targeted delivery systems, gene therapy, and cell labeling vehicles (LaVan *et al.,* 2003; J. X *et al.,* 2014).

Due to their long history of reducing the enormous amount of inorganic elements found in the ocean's depths over millions of years, marine microbes have the potential to synthesizenanoparticles. It is important to study marine microbes for the biosynthesis of nanoparticles and to elucidate biochemical pathways that lead to metal ion reduction by the different classes of microbes in order to develop nanoparticles. Standardizing these conditions for the high synthesis of nanoparticles is necessary because the biosynthesis of nanoparticles using microorganisms depends on culture conditions. Numerous marine microorganisms have been observed to produce metallic nanoparticles and nanostructured mineral crystals with characteristics resembling those of chemically synthesized materials while tightly controlling the particle's size, shape, and composition (Asmathunisha and Kathiresan, 2013). Among the biomolecules that have been well exploited in green nanotechnology are pigments obtained from microorganisms. Some possess biological properties that make them suitable for biomedical applications.

Using a flexible pigment made by *P. aeruginosa*, an eco-friendly method for synthesising silver nanoparticles that is dependable, stable and reasonably priced using the human epidermoid larynx carcinoma cell line. Biological function of the bacterial pigment-capped AgNPs toward harbouring antibiotic-resistant strains and the in vitro antiproliferative effect (Muthukrishnan *et al.,* 2019). Similarly, using canthaxanthin pigment from *Dietziamaris* to create silver nanoparticles and evaluating their therapeutic potential against a human keratinocyte cell line (Venil *et al.,* 2021). Flexirubin-type pigments from *Flavobacterium sp*. can suppress the growth of *Mycobacterium sp*. and are thus used in the treatment and prevention of tuberculosis among a variety of microbial substances (Bej, 2010). Furthermore, it reveals that have antibacterial and anticancer capabilities and can be regarded as innovative therapeutics for the treatment and prevention of microbial-mediated illnesses and cancer, for which there is an increasing demand (Shim *et al.,* 2014). Similar to this, we created gold nanorods via microwave-assisted blue pigment extraction from *Streptomyces coelicolor* klmp33.

The antibacterial and anti-biofilm properties of the melanin-derived nanoparticles could be used to regulate the growth of biofilms (Nair *et al.,* 2013). Microorganisms have been frequently exploited in biological systems to create metal nanoparticles. Nanoparticle production is mediated by microbial systems in an extracellular and cell-associated way (Rodrigues *et al.,* 2013; *Golinska et al.,* 2014; Singh *et al.,* 2016; Park *et al.,* 2015). To encapsulate bacterial pigments, nano-emulsions with droplet sizes of 100 nm or even smaller can be created. It consists of three components: water, oil, and an emulsifier. Emulsifier addition is the key stage in the development of nano-emulsions, which lessen the tension between the water and oil phases. Surfactants are the most widely used emulsifiers; however, proteins and lipids can also be used.

A larger surface area, kinetic stability, and resistance to physical or chemical change give nanoemulsions better applicability than micro- or macro-emulsions (Gupta *et al.,* 2016). Nano-emulsion is a cost-effective technology since it can reduce the amount of colorant needed to get the desired color. B-lactoglobulin, a biocompatible emulsifier, was used to report on the creation and stability of a nano-emulsion containing b-carotene (Jaiswal *et al.,* 2015). These nano-emulsions for food colorants have a number of benefits, such as being non-irritating and non-toxic, which makes them appropriate for use in the food business. Nano-emulsions have no unpleasant taste and stabilize the colorants within the emulsion (Yi *et al.,* 2014). This present review, summarise the importance of bacterial pigment and nanotechnology in a pharmacological application.

Bacteria are being studied more and more as a potential alternative source of colorants used in foods, textiles, pharmaceuticals, and other products. The oceans provide a wealth of resources for research and development, but their potential as the foundation for novel biotechnology applications is virtually untapped. Only 1% of the microbial world has reportedly been studied; the remaining 95% can be studied for bacterial-based colors. On the other hand, synthetic pigments are made using hazardous chemicals that are bad for both the environment and people. We strongly advise isolating bacterial strains from unfamiliar situations and examining them for bacterial colors as a means of overcoming them. The majority of natural colors are sufficiently complex that chemical synthesis will never be a widespread method of producing them. Particularly pigments of microbial origin, which are extremely rare but provide considerable economic availability due to the simplicity of mass manufacturing by fermentation, include poisonous and carcinogenic amines that are not environmentally benign.

Table.1 Marine Bacterial Pigments

Pigments	Microorganisms	Colour	Activity	Reference
Prodigiosin	*Vibrio spp* *S. marcescens*	Red	-	Alihosseini *et al.*, 2008; Yusof 2008
	P.rubra *Hahella chejuensis*		Antibacterial; Anticancer; Algicidal	Gerber and Gauthier, 1979; Kim *et al.*, 2007
	S.rubidaea, Rugamoas rubra, Steptoverticillium rubrireticuli		Antibacterial, Anti-malarial, Antineoplastic, and Antibiotic Activity	Khanafari *et al.*, 2006; Malik *et al.*, 2012
Violacein	*Chromobacterium violaceum Janthinobacterium vividum, Pseudoaltermonas tunicata*	Purple	Anti-bacterial, anti-viral, antileukemic, antifungal, antiparasitic, antiprotozoal, antioxidant and antiulcerogenic.	Ahmad *et al.*, 2012; Venegas *et al.*, 2019
Carotenoide (Astaxanthin)	*Deniococcus sp, Agrobacterium aurantiacum, Paracoccus Carotinifaciens, Paracoccus haeundaensis*	Pink-red	Ratio productive and Antioxidant activities, Anticancer, Antiinflammatory	Sajjad *et al.*, 2017; Ambati *et al.*, 2014; Misawa *et al.*, 1995; Lee *et al.*, 2004
	Streptomyces sp. Hymenobacter sp. and Chryseobacterium sp.	Yellow	-	Dharmaraj *et al.*, 2009; Ordenes Aenishanslins *et al.*, 2016
Melanin	*V.cholerae, Shewanella colwelliana, Alteromonas nigrifaciens, Cellulophagatyrosin oxydans, Pseudomonas guinea*	Brown-black	Antibacterial activity against antibiotic-resistant pathogens, Antioxidant activity, and cytotoxic activity	Kotob *et al.*, 1995; Ruzafa *et al.*, 1995; Ivanova *et al.*,1996; Fuqua and Weiner, 1993; Kahng *et al.*, 2009; Narsing Rao *etal.*, 2017; Tarangini, Mishra, 2013
Phenazine	*Pseudomonas aeruginosa , streptomyces sp.,*	Yellow to brown	cytotoxic activity	Li *et al.*, 2018; Liang *et al.*, 2017
Quinones	*Streptomyces*	Yellow to red	Anti-infective, antimicrobial, insecticidal, and anticancer activities,	Margalith,1992; Koyama, 2006

Fig.1 Application of Bacterial pigments

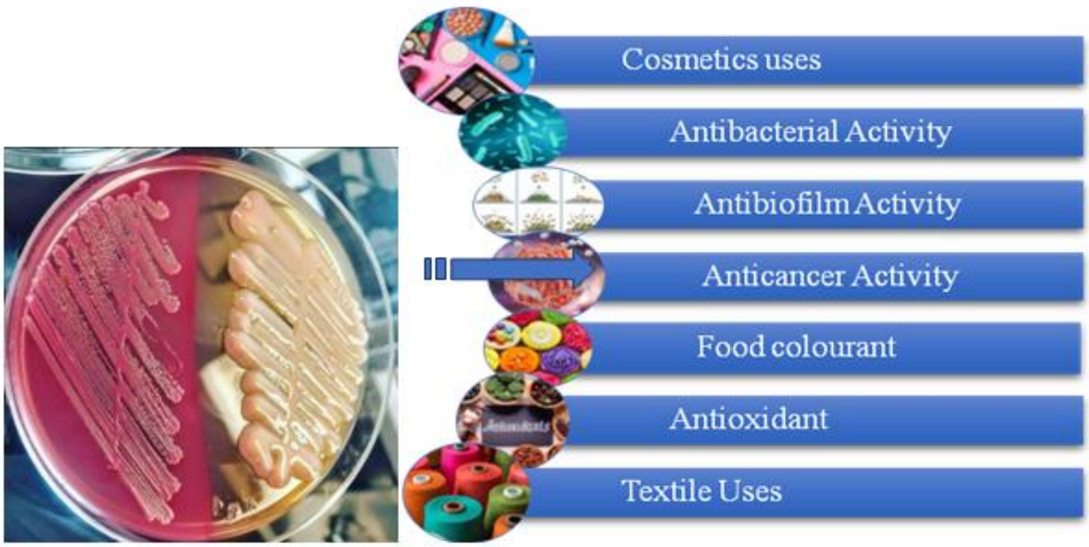
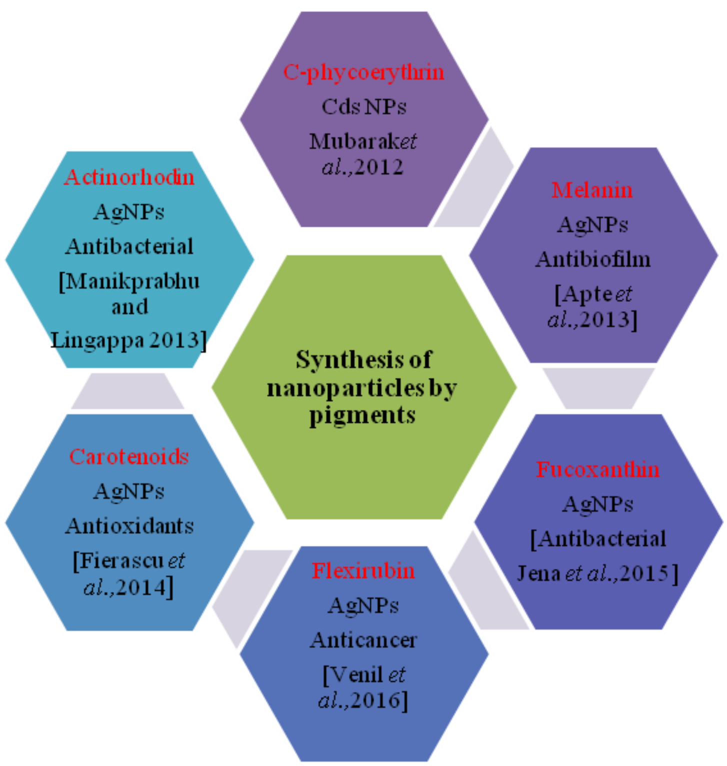


Fig.2 Pigment-mediated Nanoparticles



Extraction is straightforward and more productive since microbial fermentation is a cost-effective industrial method of producing natural colors. The development of secondary metabolites in microbial sources may be greatly improved by the contribution of contemporary science and technology. Being aware that pigments made from bacteria are often safer than their synthetic equivalents is one of the biggest obstacles to the commercialization and widespread use of these materials. The intention is to use these pigments' advantageous qualities while also completely replacing artificial color on the market. Nanoparticle-based techniques have been attempted and proven efficient in extending the stability and shelf life of pigments.

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