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Review Article

BACTERIAL PIGMENTS AND THEIR APPLICATION IN TEXTILE INDUSTRIES USING MORDANTS

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ABSTRACT

The synthetic dyes were highly used from 19th century onwards which is a reason for declining of natural dyes. In textile industry synthetic pigments are highly used which is harmful to our environments but the natural color are safe. The source for natural colors is plants, animals and microorganisms. In microbes, the bacteria produce a more number of pigments which is used as natural colorants and they used for dyeing a cloth in textile industry. These types of natural dyes are known as green dyes or biocolors which have more applications on other industries like food, pharmaceuticals and cosmetics. This review summarizes the importance of natural pigments from bacteria which can be used to dyeing the fabrics in textile industry with the help of mordant.

Keywords: Natural dyes and pigments, Bacterial pigments, Mordants and Textile industry.

1. INTRODUCTION

In this world life forms mostly depend on colors, for example- cholorophyll for plants and haemoglobin for humans. Because without chlorophyll, plants can't synthesis its own food likewise without haemoglobin, body can't carries oxygen [1]. The reciprocal action between objects and lights leads to form colors based on the physical and chemical nature of a matter. Microorganisms are able to produce extra -cellular pigments which are natural color and they were used as a dye in textile industry. The colors produced by microorganisms are known as biocolors and they used as a substitute or alternative for synthetic colors. Now-a-days, natural colors are encouraging because compare to synthetic colors it doesn't harm our environment. Based on the health environment concerns, natural dyes are shows high interest compares to synthetic dyes because it is very safe and biodegradable [2]. Microorganisms were highly effect by visible or ultraviolet (UV) rays which leads to cell death. This can be overcome by secondary metabolites like pigments produced by microbes which protect the cells from damage. Pigment produced capacities were not found in all, only in some microorganisms. So, pigment producing microorganisms are safer than non-pigmented organisms from harmful effects [3]. High amount of pigments produced by microorganisms species which includes, *Achromabacter, Bacillus, Cordyceps, Cryptococcus, Monoscus purpureus, Paecilomyces, Penicillium herquei, P. atrovenetum, Phaffia, Rhodotorula, Serratia, Streptomyces, Sarcina* and *Yarrowia* [4]. For industrial purpose, various samples were isolated to obtain a pigment producing microorganisms and they are carotenoids, melanins, flavones, quinines, prodigiosins, indigo, violacein, and monascins [5]. Low cost substrates or industrial waste can be used for microbes to produce pigments. The natural dyes productions were not developed that much because of low production from the natural sources. It can be overcome by new technology (i.e.) through fermentation, production can be increase. Advantages of fermentation using microorganisms are more and they are: yields are higher, productions are cheaper and compare to synthetic there is no lack of raw materials. Large fermentation of biocolorant plays a very important role in many fields like foods, textile, pharma, cosmetics, plastics, paint, ink, photographic and paper industries, etc. In the emerging fields of research, microbial pigments are applied in various industries.

2. HISTORY OF NATURAL COLORANTS

The people always show interested on colors because of its attractive character and it are pleasant to our eyes. Before the development of colors using microbes, our

ancestors were used various colors from natural sources and the proof of colors involving in our ancient times were given below. According to the chronological order, the history of natural colors and the development of color's using microorganisms were given in the Table 1 and 2 because of the progress of culture the coloring art were widely dispersed [6].

Table 1: History of natural colors

Periods	Using natural colors in ancient times
500 BC	The post vedic period, natural dye stuffs were introduced like saffron, indigo, kermes, recona, gairica and khanjana
2500 BC	In India, the geological period of Indus valley onwards the dyeing was carried out.
2600 BC	The earliest records show that china used natural dye for first time [7].
3500 BC	In this period colored clothes were used which is established through research on the bankrupts of Mohenjo-Daro and Harappa culture [8].

Table 2: Evolution of color using pigmented microorganisms (Source: [4])

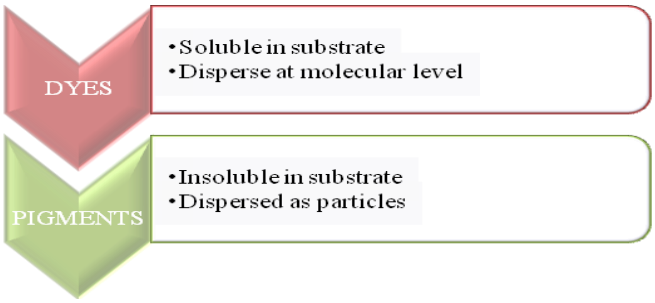
Years	Pigmented Microorganism Uses
1884	*Monascus sp*, was traditionally domesticated and used for preparing wine from red rice.
1954	The first carotenoid pigments from *Cryptococcus* were marketed.
1963	Using *Rhodotrula sp* productions of carotenoid pigments were started.
Early 1970's	Isolation of Astaxanthin from *Phaffia rhodozyma* which grown on oozes of deciduous tree in Japan and Alaska
Late 1970's and early 1980's	*Dunaliell salina* is used for beta carotene production.
1985	Natural beta carotene was produced by *D. salina* which was cultivated in large scale. It was established by Betatene Limited Corporation

3. DEFINITION FOR DYES AND PIGMENTS

The dyes are colored substances but the pigments are colored, colorless or fluorescent. The dye is soluble into solution in the time of application process but pigments are insoluble. The principle behind the color of dye is absorption of light, where the color of pigment is due to absorption / scattering of light. The coloristic properties of dye depend on its chemical structure and the properties of pigments depend on its physical characteristics of particles [8].

4. COMPARISON OF NATURAL DYES AND PIGMENTS

The pigments and dyes are used to apply color to all kinds of substances and it's important to humans subsequently the aurora of history. The conflict among the dyes and pigments are their solubility and dispersion (Table 3).



Compared to the formal pigments, the dyes render bright color but it's stability to light is less.

Table 3: Difference between the pigments and dyes (Source: [11])

Specification	Dyes	Pigments
Water solubility	70%	Insoluble
Direct affinity to textile material	Yes	No
Auxochrome groups	Present	Absent
Binding agent	Required	Not required
Diffusion in fabric	Dye	Pigment

5. NANOCOLRANTS

Nanocolorants were considered as a novel form of colorants that could bring out of quandary among dyes and pigments. The pigment colorants incline to be the majorly long lasting, static heat, tolerance to solvent, lightfast, and quick mobility. But then, they also are given difficult to process and have poor color magnificence and intensity. Dyestuff colorants are first class magnificence and color intensity, and are generally not hard to process, but it's poor in lastingness and heat. Due to the different properties of dyes and pigments, more research needs to improve the properties of these colorants. Nanocolorants are a form of nanocomposites that modify dye played as a necessary component and desirable polymeric matrix, and its aim is to incorporate

excellent chromatic properties which include good processing ability of dyes and good long lasting of pigments. Nanocolorants are novel variety of colorants that can combine advantageous properties of both dyes and pigments [12].

6. NATURAL PIGMENT SOURCES

The sources of natural pigments are like plants, animals and microbes.

6.1. Plants Pigments

Plant pigment is a type of colored substance which is produced by the plants. In plants, the function of pigment is photosynthesis (i.e.) Chlorophyll-green pigment and some carotenoids [13]. These have been extracted from fruits, flowers, leaves, vegetables, seeds and roots [14]. The color of leaves, fruits and flowers are in different color because of the different pigment production by plants.

6.2. Animals Pigments

Animals also produce some biological pigments. For example,

(i) Melanin in mammals

(ii) Red pigment from the blood of Cochineal beetle which is parasitic insect found on cactus [15].

6.3. Microbial Pigments

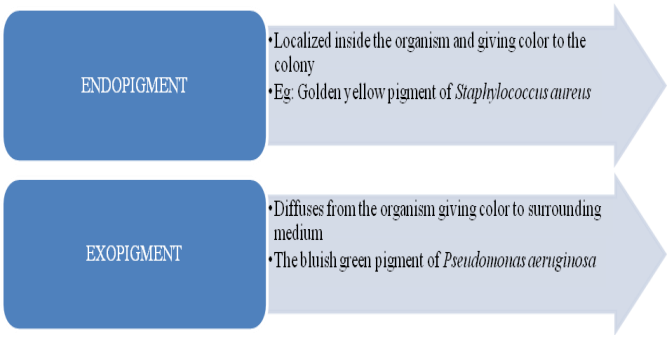
The different and more number of natural pigments were produced by microorganisms. Microbial pigment production can be increase by optimizing their growth conditions because it has more advantages on industries like dyeing fabrics in textile industry, food colorant in food industry and antibiotics preparation in pharmaceutical industry [14, 15].

Table 4: Physical appearance of bacterial strains

Bacteria	Pigment/ molecule	Color/ appearance
Agrobacterium auranticum	Astaxanthin	Pink/red
Paracoccus carotinifaciens	Astaxanthin	Pink/red
Bradyrhizobium sp	Canthaxanthin	Dark red
Haloferax alexandrius	Canthaxanthin	Dark red
Flavobacterium sp	Zeaxanthin	Yellow
Xanthomonas oryzae	Xanthomonadin	Yellow
Janthinobacterium lividum	Violacein	Purple
Chromobacterium violaceum	Violacein	Purple
Corynebacterium insidiosum	Indigoidine	Blue

6.4. Bacterial pigments

At present, the yield of bacterial pigments is one of the emerging areas in research to exhibit its possibilities of their application in diverse industries. The physical appearances of bacterial strains were shown in Table 4.



Examples of bacterial pigments

The bacterial pigments are classified based on their structural affinities and natural occurrences [16]. Some of the examples of naturally occurring bacterial pigments are:

6.4.1. Riboflavin

Bacteria are able to produce the riboflavin which is a yellow in color and their vitamins were soluble in water. Eg: *Bacillus subtilis*. The riboflavin was used in food industries (fruit drinks, enriched milk products, sauces and pastas [17].

6.4.2. Carotenoids

In bacteria, *Serratia* sp and *Streptomyces* sp are producing the carotenoids which are yellow to orange-red pigments. High amount of carotenoids producing bacteria are *Myxococcus* sp, *Streptomyces* sp, *Mycobacterium* sp, *Agrobacterium* sp and *Sulfolobus* sp [18].

6.4.3. Canthaxanthin

The *Bradyrhizobium* sp chlorophyll containing bacteria from stem nodules of *Aeschynomene* sp. Canthaxanthin inhibit the oxidation of lipids in liposomes and it's a best antioxidant [16].

6.4.4. Prodigiosin

Serratia marcescens and *Vibrio psychoerythrus* are produce prodigiosin which is a multipurpose red pigment. The prodigiosin have the antibacterial, antinopleostic and anti-malarial activity [19].

6.4.5. Pyocyanin

Pseudomonas aeruginosa produce pyocyanin which is a blue pigment and this pigment composed of two sub units of

N-methyl-1-hydroxyphenazins [20, 21]. It can be used as a biocontrol agent and also it has antibacterial and anti fungal activity [22].

6.4.6. Violacein

Chromobacterium violaceum produce violacein which exhibits several biological activities. This pigments has more application on textile industry, food industry and pharmaceutical industry [16].

6.4.7. Astaxanthin

Agrobacterium auranticum produce astaxanthin which is an orange-red pigment and it's also having more applications especially in pharmaceutical for drug production [23].

7. PRODUCTION OF BACTERIAL PIGMENTS

The fermentation is a good process for the bacterial pigment production. Two types of fermentation affect the growth and pigmentation of bacteria is solid state fermentation and submerged fermentation. In industries, mostly used fermentation process for pigment production is submerged fermentation [24]. The major disadvantage is using high cost synthetic medium for bacterial pigment production. But this problem can be overcome by introducing low cost medium like agro industrial waste Eg: Whey, crushed pasta, apple pomace, etc. [25].

7.1. Factors affecting bacterial pigment production

7.1.1. Temperature

Bacterial pigment productions are highly affected by incubating temperature. The growth of bacteria requires 23-30˚C for the production of pigment. If temperature increases production of pigment decrease which shows that temperature is indirectly proportional to the pigment production [26].

7.1.2. pH

pH are the reason for the shade of color of bacterial pigment. Depend on pH only the bacteria will produce pigment. Neutral to slight alkaline pH favors bacterial pigment production [26].

7.1.3. Nutritional sources

Depending on the source only pigment productions were varied. Some of the organism needs more carbon source and some other need nitrogen source or any other minerals for enhancing its growth. But some of minerals and nitrogen source are highly affect the bacterial pigment production. So depending upon the bacteria the limited amount of source should be used otherwise it will act as a inhibitor for their growth.

8. ADVANTAGES OF BACTERIAL PIGMENTS

The benefits of bacterial pigments are many because of its fast growth in cheap culture medium and its applications on industries [27]. The advantages of bacterial pigments are given below, they are:

- Increasingly attractive to science because of broad ranging activities.
- Easy propagation and wide strain selection.
- High versatile and productive over other sources.
- Fermentation is inherently faster and more productive compound to any other chemical process.
- Easy to manipulate genes.
- Simple and fast culturing techniques allowing continuous bioreactor operation.
- Structural complexity suits for industrial needs.
- Bacterial pigments extracted using simple liquid-liquid extraction technique minimizing operation cost.

9. APPLICATION OF BACTERIAL PIGMENTS IN TEXTILE INDUSTRY

In textile industries, the synthetic dyes were highly used because it's satisfy the dyers and consumer demands. Before 19thcentury, natural dyes only used in textile industries. After the invention of mauveine by Perkin in 1856, the synthetic dyes were popular and it's the reason for the eradication of natural dyes. Innovative ideas of the chemist in textile industry are create the synthetic dyes which satisfy all the demands. So, all over the world synthetic dyes are used. But its effect on our environment is high and the effluent from dye industry mixes in potable water which leads to cause pollution and affect people healths. Now a day the people were follow the go green way or bio way that means they demand only on natural products. Because of this reason many researcher were concentrate on the production of natural dyes with the help of natural sources like plants, animals and microbes. In microbes, bacteria, actinomycetes, fungi and algae are produce pigments. Compare to all bacteria produce least amount of pigments so many research going on bacterial pigments only to increase their pigment production through fermentation process. Some of the examples for bacterial pigments used in textile industries are given below Table 5.

Table 5: Bacterial pigments and their applications

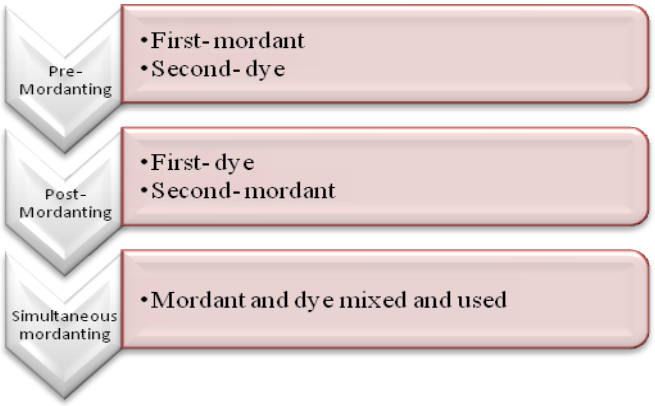
Bacteria	Pigments	Dyed cloth
Serratia marcescens	Prodigiosin	Acrylic, polysters, microfiber, silk, cotton [15] [28].
Vibrio sp	Prodigiosin	Wool, nylon, acrylics, silk [29].
Chromobacterium violaceum	violacein	Rayon, jacquard rayon and silk satin [15].
Janthinobacterium lividum	violacein	Silk, cotton, wool, nylon, vinylon [30].

The color fastness testing are used to check the pigment ability whether it's maintain the color under different conditions or not [30]. Comparing with dyes the bacterial pigments are not adhere to cloth that much. So some mordants were used to fix the pigment color on cloth.

10. MORDANT

Mordants are used for fixation of the dyestuff, increasing the fastness properties or variation in the color appearance. This last effect can be a desired effect as well as an unwanted phenomenon. Especially the use of iron mordants leads to substantial color differences and primarily results in a color shift towards dark shades.

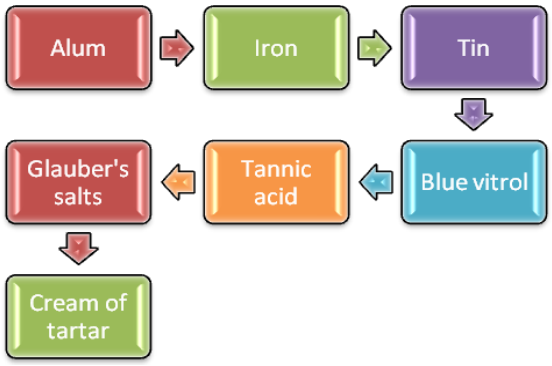
10.1. Methods of mordanting



Basically, three different types of mordanting strategies can be distinguished: pre-, after and meta-mordanting. The processes mainly vary in the time of mordant addition. While pre- and after-mordanting require an additional treatment step in a separate bath i.e., a mordant solution with defined concentration of the metal salt [31, 32].

10.2. Common mordants used in natural dyeing

Most commonly used mordants in natural dyeing is alum which is non-toxix compare to other mordants. The application of natural dyeing is a big challenge because; only few sources are available for the natural colors [33].



11. OTHER APPLICATIONS OF BACTERIAL PIGMENTS

11.1. Food colorant

The children's were mostly attracted by the color of foods. Not only children many people's were attracted by the foods through its color only. That's why the food industries were used synthetic colors in food to attract peoples but it's harmful to our health. But the bacterial pigments were used as a natural colorant in food which gives color and also many health benefits included like antioxidant, antibacterial, etc. Researchers were give food grade pigments from bacteria. Examples: Zeaxanthin (yellow) from *Flavobacterium* sp., Carotenoids (yellow) from *Streptomyces* sp., Canthaxanthin (dark red) from *Halobacterium* sp., and Astaxanthin (pink/red) from *Agrobacterium aurantiacum* [14].

11.2. Pharmaceutical industry

Bacterial pigments shows more application on pharmaceutical industry because its cure many diseases and it have some properties like antioxidant, antibiotic and immunosuppressive compounds. Compare to other sources bacteria produce many bioactive compounds [34].

12. REASON FOR NATURAL COLORATION

The superior success of synthetic colorants since their introduction in the 19th century has been described by Brian Glover as follows: 'In summary, they allowed people to make more money' [35]. The synthetic colorants show more advantages than natural colorants. The reasons are brilliant colors, depth of color, shade of

color, color fastness and handling is easy [32, 36-38]. At the sametime, the circumstances changed significantly. Several reasons for the new, increasing interest in natural dyes can be identified. To obtain a more detailed and structured impression four categories, named innovation, economics, personal and ethic reasons, have been established. Therefore the categories defined there as on sand were classified in a subjective manner. If more than one category seemed to be suitable all those categories have been marked.

The reasons for innovation and economics are the most important factors for company decisions. Market research, governmental regulations and cost analysis are of huge importance in decision-making processes in industry [39]. The successful introduction of a new product is not only dependent on the product's properties but also to a large extent on the marketing strategy used. The increasing awareness of health and environmental aspects seems to work as a catalyst when innovative products are presented. Highlighting the luxury or additional benefits of a product also serves as a driving force to attract consumer attention [40].

13. CONCLUSION

In this review, pigment production and extraction from bacteria were explained with their applications. Now a day peoples are not shows that much interest on the synthetic products, instead of this they choose natural products mostly. So most of the industries were concentrate on the natural products only. Textile industry is one of the growing fields where they use more synthetic dyes for dyeing cloth and dye effluents were discharge into the rivers or soils which leads to cause pollution to our environment. This problem can be overcome only by using natural colorants from plants, microbes, etc. Most of them go with plants for producing natural colorants because it's easy way to extract pigments from plants. Compare to plants, microbial pigment extraction is tedious procedure only. So more research and correct procedure is need for bacterial pigment production. Especially genetic engineering research is need for improving the pigment production from bacteria and also more research should do to improve the pigment production and its stability, color fastness.

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