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A Potential Application of Microbial Pigment: An Alternative to Synthetic Dye & Colourants

Kirti Tiwari[1], Dr. Murtaza Hajoori[2]
[1] MSc Microbiology Student, Bhagwan Mahavir College of Basic and Applied Sciences
[2]Assistant Professor, Bhagwan Mahavir University, Surat, Gujarat-395007

ABSTRACT: Dye pollution is becoming more and more of a worry for the environment. Dye removal from the environment is necessary because dye disposal in water resources has detrimental aesthetic and health implications. A well-known technology for all fibers, textiles, and apparel in the wet processing of textiles is the textile printing branch. When printing, colors are applied to specific areas of the fabric rather than the entire piece. Since the Stone Age, natural colorants derived from ores, insects, plants, and animals have been employed. Despite having a dangerous impact on people, animals, and the environment, synthetic dyes, which replaced natural pigments in the middle of the 19th century, continue to dominate the market to the fullest extent. Bacterial pigments provide intriguing alternatives to synthetic pigments for a variety of uses because they degrade more quickly and are more environmentally friendly. A few bacterial pigments can currently be produced by the industry for use in food, medicine, cosmetics, and textiles. The key technological problem is the extraction of bacterial pigments in reasonably pure and concentrated forms. Due to the growing consumer desire for more natural products, there has been an increasing tendency in recent decades to replace synthetic colorants with natural pigments. In many aspects of daily life, including food production, the textile and paper industries, agricultural practices and research, and water science and technology, natural pigments and synthetic colors are widely employed. Natural pigments exhibit advantageous biological properties as antioxidants and anticancer agents in addition to their capability to boost the marketability of items.

KEYWORDS: Azo dye, Direct dye, Dye, Natural dye, Pigment, Reactive dye.

I. INTRODUCTION

Industrial textile wastewater adds to the complexity by including unknown volumes and variations of many different colours, as well as low BOD/COD ratios, which can reduce biological decolorization efficacy (Sriram *et al*., 2013). Around 10000 different dyes and pigments are used in the textile industry around the world. Azodyes account for more than half of all dyes used in the industry (Wang *et al*., 2000). Rubber, textiles, cosmetics, plastics, leather, food, and other industries all employ different types of colours. Making of paper in wastewaters, the variety of these colours can be detected. "Those who have been discharged from these industries" In general, dyes have a long shelf life. They are usually non-biodegradable and are exposed to light, heat, and oxidizing chemicals"(Ngulube *et al*., 2017). They are colorless, high molecular, highly viscous, resilient, have long hydration durations, and are compatible with other printing pulp components (Ebrahim *et al*., 2021).Plants and microbes are the two most important types of life. natural pigments sources Nonetheless, the natural Plant pigments, on the other hand, have downsides, such as Instability in the presence of light, heat, or an acidic pH, for example. They have a low water solubility and are frequently unavailable(Kumar *et al.*,2015). all through the year as a result, the microbiological Because of theirversatility, pigments are of significant interest the pigments produce's stability and the Technology for cultivation is readily available. The advantages of bacterial pigment manufacturing include facile and rapid growth in a low-cost culture media, and a lack of sensitivity to changing weather conditions and the colours of various objects shades(Amin, Vikas Bhat, and Sayeed Khan 2019). Historical notes on various synthetic dyes and pigments with commercial applications (textile, cosmetics, and food) have recently been well-detailed, and their drawbacks have been well-detailed as well. Since a number of synthetic pigments and their by-products have been discovered to have hazardous properties, Natural pigments derived from bacteria have been studied for their teratogenic and carcinogenic effects. Because they are more biodegradable than synthetic competitors, they have gained popularity in recent years(Ramesh *et al*., 2019).which are utilised in the manufacturing of Synthetic pigments contain a number of carcinogenic properties. To counteract the dangers of synthetic colourants, there is a growing interest in process improvement research and development for the manufacture of pigments

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from sources of natural resources.Minerals must be present, and colour output must be acceptable. The majority of bacterial pigment synthesis is still going on. the stage of research and development as a result, work on bacterial pathogens has begun. Pigments, in particular, should be considered. locating a low-cost and acceptable growing medium in in order to lower the price while increasing the quality ability to be used in industrial manufacturing Fermentation is fundamentally a speedier and more efficient process (Malik, Tokkas, and Goyal *et al*., 2012).

Dye & Colorant:

Dyes are organic compounds with color that are used to color a variety of substrates such as cosmetics, paper, pharmaceuticals, leather, fur, greases, hair, waxes, plastics, and textiles. "Dyes are chemical substances that can attach themselves to surfaces or fabrics to give them color (Ngulube *et al*., 2017).

Basic, acid, reactive, direct, vat, and disperse dyes are among the many types of dyes used in various industries. Except for dispersion and vat dyes, all of these dyes are water-soluble. Apart from the vat and disperse dyes, colors contain quantities of metals such as chromium, copper, lead, zinc, and cobalt. Dye effluents from the industry are noted for their intense color and organic content. In addition, it is hazardous (Ngulube *et al*., 2017). Dyes are coloured compounds that may transfer their colours to a matrix, which could be fiber, paper, or any other thing. They must adhere to a cloth impregnated with their solution, and the coloured fixed dyes must be lightfast as well as resistant to water, dilute acids, alkali's, various organic solvents used in dry cleaning, soap solutions, detergent, and other chemicals (Bhatti *et al*., 2017).

Because it has absorbed some electromagnetic energy from the visual area, a compound appears coloured. Chromophores are the moiety in colouring substances that absorb electromagnetic radiation and reflect it in the visible spectrum (Bhatti *et al*., 2011). Reactive dyes are extensively used because of their favourable characteristics of bright colour and low energy consumption during application (Krupali & Butani, *et al*.,2021).

II. CLASSIFICATION OF DYE & COLOURANT

[1] Natural dye:

Colorants (dyes and pigments) generated from animal and vegetable components without the use of chemicals are known as natural dyes. Mordant dyes are the most common, but there are also vat, solvent, pigment, and acid variants. Colors generated from natural sources such as plants, animals, and minerals are known as natural colors. Natural colors, which have been used since ancient times, are primarily derived from plants, whereas synthetic dyes are created artificially from chemical compounds (Slama *et al*., 2021). Fabrics, food, cosmetics, and medications are all dyed with these colors. (Ebrahim *et al*., 2021). Natural colours, which have been used since ancient times, are primarily derived from plants, whereas synthetic dyes are created artificially from chemical compounds (Slama *et al*., 2021).

Natural dyes such as jack fruit, onion, eucalyptus, turmeric, weld, and henna were commonly utilized in the early textile business. As a result, they're largely used in the food sector nowadays (Ngulube *et al*., 2017). The Cassia singulars plant can be utilized as a natural coloring source (Guha *et al*., 2019). These dyes can provide not only a diverse range of dyes, but also a rich and diverse source of dyestuff. However, they could also be considered safe, environmentally friendly, and low-cost treatments, with the added bonus of being able to color in one step (Kasiri *et al*., 2014).

Natural dyes have several advantages, including the fact that they require no special care, are beautiful and rich in tones, act as a health cure, have no disposal issues, have no carcinogenic effect, are easily biodegradable, require a simple dye house to apply on matrix, and are extracted and applied under reaction conditions. Natural dyes have some drawbacks, such as limited color availability, poor color output, complex dyeing processes, poor fastness qualities, and difficulties combining hues (Bhatti *et al*., 2011).

[2] Synthetic dye:

Synthetic dyes are a type of brightly coloured organic compounds that are primarily used to tint textiles and attach themselves to the fiber molecules through chemical bonding synthetic dyes are divided into two categories: chemical structure and application methods. Synthetic dyes are divided into two categories: chemical structure and application methods (Bhatti *et al*., 2011). Synthetic dyes have nearly totally supplanted natural colours, particularly in the fabric and textile industries (Wang *et al*., 2016).

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Synthetic dyes are split into three categories based on the created fiber's nature. cellulose fiber dyes, protein fiber dyes, and synthetic fiber dyes are the three types.

(2.1) Cellulose fiber dyes:

Plants such as linen, cotton, ramie, rayon, lyocell, and hemp produce cellulose fiber. With reactive dyes, direct dyes, indigo dyes, and Sulphur dyes, these fabrics produce flawless results (Slama *et al*., 2021).

(2.1.1) Reactive dyes:

Chemical structures in reactive dyes are complex, forming covalent bonds. Connections formed between reactive groups of the functional groups of cellulose and agile functional groups of molecules of dye. The most common dyes are reactive dyes. Reactive dyes are nitrogen-containing heterocyclic rings with halogen substituents that undergo nucleophilic substitution with cellulose fibers. (Shyamala Gowri *et al*., 2014).

Reactive dyes are those that have groups in their ions or molecules that react with other groups in fibers to generate covalent dye-fibre interactions (Aspland *et al*., 1992). Due of theirsignificantly excellent fastness qualities and simplicity of application, reactive dyes are the most extensively used type of dyes (Siddiqua *et al*., 2017). They are noted for their excellent pigmentation, long-lasting effect, ease of manipulation over a wide temperature range, and versatility due to their versatility.

A variety of reactive groups capable of forming covalent connections with a variety of fibers (Ebrahim *et al*., 2021). Because of their brightness of shade, wide color range, versatile application processes, and all-around good colourfastness' features of the resultant dyeing reactive dyes are the most preferred dyes for dyeing cotton (Lewis *et al*., 2007).

(2.1.2) Direct dye:

Many factors, such as chromophore, fastness qualities, and application characteristics, chemical classes such as formazan, anthraquinone, quinolone, and thiazole are the most common chromophoric kinds (Benkhaya *et al*., 2017).

A number of new direct dyes were synthesized from non-genotoxic diamines and examined as prospective alternatives to certain benzidine-based dyes in prior work in our laboratories (Bae *et al*., 2003). Due to its occurrence in numerous industrial effluents such as textile, tannery, paper, soap, cosmetics, polishes, wax, and so on, direct dye was chosen for the adsorption experiment (Abdelwahab *et al*., 2005).

These are azo dyes that are applied to cotton-silk blends in neutral or slightly alkaline baths with added electrolytes. These dyes are used to colour materials such as cellulose, wool, nylon, and silk (Bhatti *et al.*, 2011). To improve their fabric binding abilities, they are coupled with inorganic electrolytes and anionic salts in the form of sodium sulphate (Na_2SO_4) or sodium chloride (NaCl) (Slama *et al*., 2021).

(2.1.3) Indigo dyes:

The colour indigo, or dark blue, is classified as a vat dye, which was formerly insoluble in water but became so after an alkaline reduction. To achieve a complete bonding of the dye to the fabric, the textile dyeing process begins with the water-soluble or leucon form of indigo, which then oxidizes under air exposure and returns to its original insoluble or keto form. Indigo dyes are primarily utilized in blue denim dyeing, which explains why they are produced in such large quantities all over the world (Slama *et al*., 2021). Because pure indigo is just slightly water-soluble, it's perfect for use as a pigment (Stasiak *et al*., 2014). Indigo was traditionally obtained from plants of the genus Indigofera, which are native to the tropics, and was utilised in the textile business (Baran *et al*., 2010)

(2.1.4) Sulfur dye:

Sulfur dyes accounted for 9.1% of total US dye production and 15.8% of dyes for use on cellulosic fibers in 1966, with global production estimated at 110,000–120,000 tones per (Benkhaya *et al*., 2017). Approximately 10–40% of sulfur dyes are lost in effluents, which contain unfixed dyestuff, residual organics, high concentrations of sulphides (1.06–1.40 g L^{-1}), and high concentrations of inorganic salts such as sodium thiosulfate (284–311 g L^{-1}) from old sulfuretingprocedures (Nguyen *et al*., 2013). In terms of fastness qualities, sulfur dyes can be thought of as spanning the gap between direct dyes and vat dyes, however they differ greatly among themselves. The most changeable property is light fastness which, as one might anticipate, decreases as the depth of shade decreases (Aspland *et al*., 1992). Cotton fibers are frequently dyed using sulfur dyes (Parvinzadeh *et al*., 2007).

Starting materials typically comprise aromatic compounds with at least one nitro, nitroso, amino, modified amino, or hydroxy groups, such as benzene, naphthalene, diphenyl, diphenylamine, azobenzene, and others. Sulfur dyes are mostly used to colour textile cellulosic materials or blends of cellulosic fibers and synthetic fibers, but they also have limited uses in the dyeing of silk and paper, as well as on certain types of leathers (Benkhaya *et al*., 2017). Cotton and rayon are dyed with these colours. Due to its water-soluble reduced form and insoluble oxidized form, the application of this dye necessitates caution (Bhatti *et al*., 2011). They have a complicated structure that includes is a disulfide (S–S) bridge (Slama *et al*., 2021).

(2.2) Protein fiber dyes:

Silk, cashmere, angora, mohair, and wool are all protein fibers derived from animals. Because they are sensitive to high pH levels, they are coloured with indigo. To obtain a molecule of an insoluble colour on the fiber, a water-soluble acid dyestuff is used (Slama *et al*., 2021).

(2.2.1) Azo dye:

These dyes contain an azo component (–N=N-), which is utilized in cotton fabric dyeing. In the dyeing procedure, the fiber is first treated with a coupler, then azo dye is applied. This type of dye responds to light quickly (Bhatti *et al*., 2017).

The global production of azo dyes is estimated to be around 1 million tons per year. There may be an azo bond connection (–N = N–). One azo linkage appears several times in mono azo dyes. Azo dyes are the most common type of synthetic dye. azo dyes account for over 70% of all dyes used in the industry. Textile, cosmetic, leather, pharmaceutical, paper, paint, and food industries all use them (Benkhaya *et al*., 2017). Azo dyes are divided into three classes based on the number of azo groups in their structure (mono, di, and poly) (Slama *et al*., 2021). Azo dyes make up the largest and most flexible group of dyes, accounting for more than half of the yearly dye production (estimated at 1 million tonnes in 1994) (Stolz *et al*., 2001). Only one natural azo compound (4–40 dihydroxy azo benzene) has been reported thus far (Pandey *et al*., 2007).

(2.2.2) Anthraquinone dyes:

Anthraquinone dyestuffs are widely employed in the textile dyeing industry; red dyestuff in particular has been used for a long time. These dyes are renowned for their exceptional fastness, bright colours, and water solubility. Junctions with azo dyes could be formed using the anthraquinone structure (Slama *et al*., 2021). Plants, animals, and insects can all produce anthraquinone-based red colours (Ebrahim *et al*., 2021). From many thousands of years ago until the late 19th century, anthraquinones were commonly found in the most prevalent red natural colourants used in textile dyeing (Shahid *et al*., 2019). The largest group of natural quinones is anthraquinone derivatives (Duval *et al*., 2016).

(2.2.3) Triarylmethane dyes:

When made composed of two groups of sulfonic acid, triphenylmethane dyes are commonly used in the textile industry for colouring wool and silk protein fibers (SO3H). If they only have one sulfonic acid (SO3H) autochrome in their chemical structure, they can be employed as indicators. The solubility of these dyestuffs in water, as well as their wide and strong colour spectrum, make them popular (Slama *et al*., 2021). Their use accounts for 30–40% of overall dye use, and they are widely used on nylon, cotton, wool, and silk (Ogugbue *et al*., 2011). Their use accounts for 30–40% of overall dye use, and they are widely used on nylon, cotton, wool, and silk (Mittal *et al.,* 2010).

(2.2.4) Phthalocyanine dye:

Green and blue hues are produced through a reaction between the 1,4- Dicyanobenzene molecule and a metallic atom (Nickel, Cobalt, Copper, etc.) in the phthalocyanine family of dyes. They have a variety of intrinsic qualities, including high lightfastness, oxidation resistance, water solubility, and chemical stability. (Slama *et al*., 2021).

(2.3) Synthetic fiber:

Fabrics made of synthetic fibers include spandex, polyester, acrylic, polyamide, polyacetal, polypropylene, ingot, and acetate. Because of their extensive application range, they are used in 60 per cent of global fiber manufacturing. Direct dyes, basic dyes, and disperse dyes are used to colour these fibers (Slama *et al.,* 2021).

(2.3.1) Disperse dyes:

These dyes are colloidal and hydrophobic fibers soluble. Polyester, nylon, acetate and triacetate fibers are commonly dyed with these dyes. They are. Usually administered as a dispersion from a dye bath using the direct colloidal absorption method (Bhatti *et al*., 2017). Disperse dyes are synthetic Colourants for hydrophobic substrates that are extensively used in textile dyeing as commercial blends. They are frequently employed in big quantities, and substantial volumes of wastewater can be generated because of the vast amounts of water needed in the dyeing procedures and the high proportion of dye that remains in the water bath. These dyes are usually intractable or only soluble in small amounts. Water-based, non-ionic, and applied to hydrophobic fibers from an aqueous dispersion (Benkhaya *et al*., 2017). The smallest molecules in all dyes are dispersed dyes. These dyes are insoluble in the

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water yet remain stable when exposed to high temperatures. High-temperature conditions A dyeing solution is a combination of dye powder and a dispersion agent (Slama *et al*., 2021).

(2.3.1) Basic dye:

Cationic dyes, such as acrylic, cationic dyeable polyester, and cationic dyeable nylon, establish ionic connections with anionic fibers. These are amino derivatives that are mostly utilized for paper applications (Bhatti *et al*., 2017). These dyes are commonly used on acrylic, paper, and nylon substrates; however, some modified polyester substrates can also benefit from their use. Due to their weak migratory capabilities at the boil, basic dyes are frequently used with retarders. Basic dyes are water-soluble and produce coloured cations in solution, which are electrostatically attracted to negative-charged substrates (Benkhaya *et al*., 2017). Because they change into colorful cationic ions that dye anionic fiber textiles, basic dyes are also known as cationic dyes. Their leader is Cyanine, triarylmethane, anthraquinone, diarylethene, diazahelicene, oxazine, hemocyanin, thiazine, and hemocyanin are some examples of structures (Slama *et al*., 2021).

III. THE HARMFUL IMPACT ON AIR, WATER, HUMAN, SOIL, PLANTS

The main impact of industrial dye effluent is on receiving water bodies. These effluents' dark hue and high turbidity prevent sunlight from passing through the water. They have an impact on the human body's vital organs (brain, kidney, liver, and heart) as well as systems (respiratory, immunological, and reproductive) (Slama *et al*., 2021).

IV. TOXICITY EFFECTS OF DYES

Dyes may reduce photosynthetic activity in aquatic life by reducing light penetration. They may also be hazardous to some aquatic species owing to metals, aromatics, and other contaminants. Dyes are teratogenic, mutagenic, and carcinogenic in numerous bacterial and fish species (Yagub *et al*., 2014).

V. PIGMENT PRODUCING MICROORGANISMS

Brevibacterium sp. (orange, yellow), *Pseudomonas sp*. (yellow), *Rhodococcus maris* (bluish red), *Achromobactin* (creamy), *Bacillus sp*. (brown), *Streptomyces sp*., and *Brevibacterium sp* (yellow, red, blue). *Molds* include the yellow, orange, and red *Monascus purpureus*, *Aspergillus sp*., and H. avenae (bronze colour). Yeasts include *Phaffia Rhodozyma* and *Cryptococcus sp.* (red) (red). Annatto, Caramel, Iron oxides, Manganese violet, and white pigments like zinc oxide and titanium dioxide are examples of synthetic colours (Waghela *et al*. 2018).The most important microorganisms in this area are bacteria, yeasts, and fungus, which are all capable of creating natural colours. Numerous fungal pigments have been described and have been used for a long time as taxonomic identifiers. Some of them are commercially available for cell staining and protein detection, and they can also be utilised as substitutes for the creation of synthetic dyes in the textile industry. (Celedón*et al*. 2021).Carotenoids, flavonoids, tetrapirroles, and other natural pigments are among the most important. The pigment that is used the most Beta-carotene is a kind of vitamin A that is widely employed in industry. is derived from *cyanobacteria* and microalgae. *Phaffia rohodozoa*-derived astaxanthin and *Haematococcus* pluviais is a powerful red pigment.

VI. CLASSIFICATION OF PIGMENTS

The two categories of pigments are natural/synthetic and organic/inorganic pigments. Biological pigments can be used in a variety of ways. Natural affinities and structural affinities were used to classify the organisms. Several examples of naturally occurring phenomena the following are pigments:

6.1 Riboflavin: riboflavin is a water-soluble vitamin that is yellow in colour. Traditional Riboflavin is increasingly being synthesised chemically. commercially viable alternatives *Ascomycetes* are used in biotechnological operations. *Candida fermata*, *Ashby gossypii*, *Ashby gossypii* or the *Bacillus subtilis* bacteria. It's found in infant foods, breakfast cereals, and other products. pasta, sauces, processed cheese, fruit drinks, and so on vitamin-fortified milk, as well as some energy beverages(Malik *et al*., 2012).

6.2 Beta-carotene: Beta-carotene can be found in *Phycomyces* and. Beta-carotene generated via Blakeslee fermentation is considered by the European Union Committee to be safe. trispora is the chemically manufactured version of trispora. substance that is employed as a food colourant and is thus approved for use in meals as a colouring agent(Malik *et al*., 2012).

6.3 Canthaxanthin:The main carotenoid pigment, canthaxanthin, is produced by orange- and dark-pink-pigmented *Bradyrhizobium* (photosynthetic) strains that were isolated from stem nodules of *Aeschynomene* species and Halobacterium spp. Canthaxanthins are strong antioxidants that prevent liposomes' lipids from oxidising (Malik *et al*., 2012).

6.4 Carotenoids:the reported organisms are*Erwinia*,*Flavobacterium*, *Brevibacterium*, *Para coccus*, Antibacterial (celadons etal., 2021). Are naturally occurring yellow to orange-red pigments. Similarly, aryl carotenoids such as isorenieratene, 3-hydroxy-isorenieratene and 3,30-di-hydroxy-isorenieratene are found in very few microorganisms, such as *Brevibacterium linens*, *Streptomyces Mediolanum*, and *Mycobacterium arum*. In general, carotenes (-carotenes and -carotenes) and *xanthophylls* (zeaxanthin, canthaxanthin, and astaxanthin) are divided into two classes. They are frequently used as food colours and are rich in antioxidants. The majority of known bacteria generate carotenoids. belongs to the *Mycobacterium*, *Streptomyces*, and *Myxococcus genera*. *Agrobacterium* and *Sulfolobussulfolobus* are two different types of bacteria. (Aberoumand 2011).the biological activity is Antibiotic, Antioxidant, Cytotoxic activity (celadons *et al*., 2021).

6.5 Prodigiosin: is a versatile red pigment generated by a variety of bacteria, including *Serratia*. *Rug monas marcescens*, *Vibrio phycoerythrin Actinomycetes* like *Streptoverticillium rubra Kanafani* discovered *rubrireticuli* and other eubacteria. It is reported to have antibacterial, anti-malarial, and antiviral properties. antibiotic and anticancer action. Infections from chromogenic biotypes found in the natural environment are uncommon, and clinical isolates are very rarer(Malik *et al*., 2012). Biological activity is Biocontrol Antibiotic, Algacidal, Anti-inflammatory, Anticancer, Antimalarial Antidiabetic, Immune system modulator. Reported organism *Serratia*, J*anthinobacterium*, *Streptomyces*,*Vibrio*,*Zooshikella*, *Pseudoalteromonas* (Celadons *et al*., 2021).

6.6 Phycocyanin and Pyoverdines: is a blue pigment made by plants. Reported organisms is *Pseudomonas.* chlorophyll-a-containing *cyanobacteria*the colour *blue Spirulina* (blue green) is the name of the colourant. alga), which also happens to be the name of a dietary supplement. It's made out of dried *cyanobacteria* and is high in protein. Pyoverdines and pyoverdines are virulence factors produced by the strain *Pseudomonas aeruginosa* and are widely known for their capacity for iron uptake from the extracellular mediums(Priya 2017).biological activity is Bioluminescence, Virulence factor, Iron uptake, Bioluminescence, Virulence factor.

6.7 Violacein: is a bacterium-derived pigment with a wide range of applications. A purple dye, is a natural compound of indelindolocarbazole formed by the condensation of two tryptophan molecules.*Chromobacterium violacein* is a bacterium that has a number of different characteristics. biological processes It is gaining popularity. In industrial markets, such as medicine, it is of critical importance. Cosmetics, food, and textiles are just a few examples(Celedón and Díaz 2021).

precursors, violacein, glaukothalin, pyocyanin, xanthomonad in, phenazine, canthaxanthin, violacein, glaukothalin, pyocyanin, xanthomonad in, phenazine, canthaxanthin, canthaxanthin, cantha Several bacteria create astaxanthin. Several synthetic colourants are being researched as anticancer and immunosuppressive medicines. Notes on various synthetic dyes and pigments from the past are of industrial interest. Applications (textiles, cosmetics, and food) have recently been well-detailed, as have their drawbacks (Tuli *et al*.,2015).

6.8 Lycopene- widely present and consumed in tomatoes, a brilliant red pigment consisting of carotenoid. It has been isolated from microbes like *Fusarium*, *Sporotrichosis's*, and *Blakes lea trispora*, and has the potential to attenuate persistent diseases such as some types of cancers and coronary heart disease. It is used in meat colouring in countries like the USA, Australia and New Zealand (Ferreira *et al*., 2004).

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VII. APPLICATIONS OF DYE & COLOURANTS

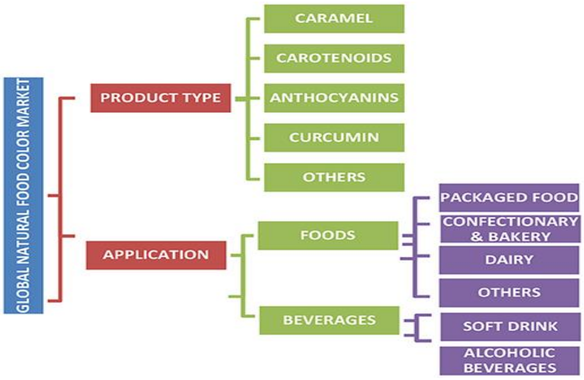

Figure1: Applications of Dye & Colourants (Sen, t. *et al*., 2019).

7.1 Pharmaceutical industry

Pharmaceutical industry uses many microbial pigments in their products. Numerous research projects are being conducted to cure various diseases like cancer, leukaemia, diabetes mellitus, etc. using several coloured secondary metabolites of the bacterium, which have great potential therapeutic uses. These pigments may function as immunosuppressive, antibacterial, anticancer, and antiploriferative substances. Some examples of such type of pigments are given below: (Kumar *et al.*, 2015).

7.1.1 Anthocyanin: Anthocyanins are water-soluble pigments. Flavonoid pigments that are soluble. They really are. involved in a wide range of biological activities antioxidant activity, for example, reduces the risk of cancer is decreasing. Inhibit the immune system's response to an insult. Anthocyanins have an inhibiting effect on It's possible that carcinogenesis and tumour growth are linked. There are two basic processes by which this can be accomplished: a) Changes in redox state; b) Interference with basic cellular functions (cell cycle, apoptosis, etc.) Inflammation, angiogenesis, and invasion are all terms that are used to describe the process of (as well as metastasis). Antioxidant action of anthocyanin due to the presence of phenolic hydroxyl groups that have a proclivity for donating hydrogen to a free radical, an atom or an electron*(*Abhishek*et al*., 2015).

7.1.2 Prodigiosin: is a possible pigment with a variety of pharmacological properties. It demonstrates a diverse set of skills. *Vibrio* produces cytotoxic activity. *S. marcescens*, *phycoerythrin Pseudomonas magnesiorubra* and other *Pseudomonas* species Prodigiosin is a tripyrrole found in *eubacteria* was the first to report it as a pigment. *marcescens* (a Gram-negative bacterium). The. It demonstrates anti-immunosuppressive activity, as well as has antiproliferative and cytotoxic properties impact on human tumour cell lines cells from the lungs, intestines, and liver, Melanoma, ovarian brain cancers, and leukaemia(Priya 2017).*S. marcescens* is known for the production of a non-diffusible red pigment, prodigiosin. *Streptomyces*crerarite are also used for its production. It shows immunosuppressing activity and also exerts antiproliferative and cytotoxic effects on 60 cell lines of human tumour cells (derived from lung colon liver ovarian brain cancers, melanoma and leukaemia (Kumar *et al*., 2015).

7.1.3 Violacein: Violacein is a violet pigment that is made up of indole derivatives. derived from microorganisms *Chromobacteriumviolaceum*, also known as *Chromobacteriumviolaceum*, is a type of bacteria antitumor, antiviral, antibacterial, antifungal, antiviral, antiviral, anti-antiparasitic, antiprotozoan35, antiparasitic, antiparasitic, antiparasitic, antipara, anticancer, antiviral, anticancer, antiviral, antiviral, antiviral, antiviral, antiviral antimicrobial, antifungal, and anti-oxidant activities(Atalah*et al*., 2020).Modern fermentation methods have made it simple to produce and isolate colour pigments. Microbial Pigments can be made by fermentation of solid substrates. or by sunk fermentation. fermentation involving a solid substrate (SSF), the growth of microbial biomass takes place on the surface of a substantial support (Tuli et al., 2015).

7.1.4 Red Yeast Rice (RYR): Red Yeast Rice is a type of rice made from yeast. (RYR) is a rice product that has been fermented (Abhisheketal., 2015).traditionally made by fermenting rice kernels boiled with yeast (*Monascusrubur*, *Monascusruberand*, *Monascus purpureus Monascuspilosus)Monascus spp*. are a type of *Monascus*. have a significant ability to create secondary metabolites yellow, orange, and polyketide structure as well as red pigmentsMonascusruberwas used to make angkak, a traditional Indonesian dish rice fermented with antimicrobial properties cholesterol oxidation RYR has proven to be effective. contain a variety of active ingredients, including statin-like substances in its composition sterols, structure, unsaturated fatty acids as well as B-complex vitamins. A variety of in addition, investigations have shown that RYR and Statins lower blood glucose levels in diabetics (Numan *et al*., 2018).

7.2 Textile Industry

About 1.3 million tonnes of pigments, dyes, and dye precursors are produced and used in the textile industry each year, costing close to US $23 billion. The majority of these are manufactured synthetically. However, synthetic dyes have a number of drawbacks, including safety issues and the production of toxic waste (Numan*et al.*, 2018). Synthetic dyes are widelyThey are available for a reasonable price and yield a wide range of colours, but they harm the skin. allergies and other hazardous conditions for humans, generates toxicity and chemical risks while Synthesis produces unwanted, dangerous, or toxic products. other compounds These potentially harmful effects of There are increased consumer demand for synthetic pigments. Considering client preference for natural or microbiological pigments (known as natural dying) (Abhishek *et at*., 2015). Despite the use of natural pigments and colourants, compounds of the anthraquinone class have been reported to have antibacterial properties and bright colours. These compounds may be a source of textiles that are resistant to bacteria. To successfully employ natural colours for any specific fibre in a commercial setting, the suitable and regulated methods for dyeing with a natural dye method for that specific fabric adoption is required. in order to acquire more recent a colour that exhibits acceptable colour fastness & consistent colour output, suitable There are to be scientific dyeing methods and procedures derived.

7.3 Food Industry

Food industry is aiming to develop food in various attractive colours. Industries are converting to natural colouring agents because of the harmful impact of synthetic colouring and additives on human health.Because there are less natural colourants available, the food business has greater demand for them. This demand for natural pigments can be fulfilled by research in finding natural coloring agents (Numan *et al*., 2018) the natural Carotenoids can sometimes work as a sun screen, preserving the quality of food by shielding it from harsh light. Corn carotenoids have been shown to prevent the formation of aflatoxin by Aspergillus flavus (90%) and most Aspergillus parasitic us (30%) strains(Aberoumand 2011). Chocolate is thought to have originated in Mesoamerica and has been consumed as a food, medicine, and beverage for over 2,000 years. Raw cocoa is high in antioxidants, which are also found in vegetables and tea, according to studies(Mazhar 2022). Additionally connected to food, they are in charge of the fermentation of food goods. Due to its availability, non-seasonality, scalability, higher output per hectare, and simple down streaming processing, microbial pigments are a superior alternative to manufactured food colours than plants. The food industry already uses microbial pigments from various bacteria to colour meals, including Monascus, AR pink Red (natural red-industrial name) from *Penicillium oxalic*, -carotene from Blakes lea trispora, and Astaxanthin(Sen, t.*etal*., 2019).

7.3.1 Arpink red production:

It is the red pigment produced by the strain *Penicilliumoxalicum* obtained from the soil. It contains chromophore of anthraquinone type (Laurent 2006). The amounts of red pigment Arpink Red in various food products was amount recommended by Codex AlimentariusCommmision (Abhishek *et al*., 20015).

7.3.2 Lycopene production:

It is a red open-chain unsaturated carotenoid, acyclic isomer of beta-carotene, and longer than any other carotenoid. Lycopene, also known as psi-carotene, is very sensitive to heat and oxidation and is insoluble in water. In a study cis-isomers of lycopene were shown to be more stable, having higher antioxidant potential compared to the all-trans lycopene. Genetically modified fungus *Fusariumsporotrichioides* was used by (Jones et. al.,) to manufacture the colourant and antioxidant lycopene. They used the cheap corn fibre material as the substrate.Cultures in lab flasks produced 0.5 mg (lycopene)/g ofdry mass within 6 days and such a production will be increased within the next years(Kumar *et al*., 2015).

7.4 Therapeutic application:

Infectious diseases are now, behind non-communicable diseases, the second leading cause of death worldwide and in wealthy nations. Today, there is a strong demand for novel antibiotics due to the growing number of resistant microorganisms. The prevalence of germs gaining resistance has increased over the past 25 years despite a drop in the number of new medications hitting the market, making it harder to deliver treatment. Pigments are a good option, and numerous studies have been done to find newer antibacterial agents. According to reports, both Gram positive and Gram-negative bacteria are resistant to the antimicrobial effects of bacterial pigments (Ferreira *et al*., 2004).

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7.4.1 Anticancer agent:

Numerous investigations have indicated that microbial pigments play a function in cell cycle inhibition and the induction of apoptosis (Montaner *et. al.*, 2000). Apoptosis ismainly characterized by a series of distinct changes incell morphology such as blebbing, loss of cell attachment,cytoplasmic contraction, DNA fragmentation andmany other biochemical changes including activation ofcaspases through extrinsic and/ or intrinsic mitochondrial pathways (Tuli *etal*., 2015).Cancer is a non-communicable disease and is one of the leading causes of morbidity and mortality in humans. To date, many anticancer drugs have been developed and are in the clinical trial stage. However, the major challenge in cancer treatment is due to the limitations, side effects and resistance towards the treatment and therapies. Current research on anticancer drugs is focused on searching for newer and effective chemotherapeutic agents with lower to non-toxic effects. Various research on bacterial pigments as anticancer agents against different types of cancer have showed the potential of bacterial pigments as a promising anticancer agent (Ferreira *et al*., 2004).

7.5 Future Perspectives:

The current novel strategies like genetic engineering, molecular biology techniques and fermentation technologies are greatly contributing to higher production of bacterial pigments. These current processes of screening new pigmented bacteria should be kept up to support the discovery and application of novel bacterial pigments that possess high activities and useful properties from less expensive sources in order to support cost-competitive and higher production of bacterial pigments.

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