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Microbial Production of Pigment and its Application in the Food and Cosmetic Industry

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Abstract: ***The negative effect of some synthetic dyes is driving up demand for natural color. A Convenient alternative supply of naturally generated colors is offered by bacterial and fungal pigment. They offer many advantages over other natural pigments, such as quick development, simple processing, and immunity to weather. The study's main objective was to separate a soil-based pigment-producing bacterium. The isolated colonies were maintained using a variety of pure culture techniques. Pigments can magnify the existing palette of colors used in numerous applications. Various parameters for maximum pigment yield were environmental and health problems, in contrast, microbial pigments are eco-friendly and used in the textile industry, the pigment from microbial sources is a good alternative that could easily be produced in high yields. Chemicals known as pigments are responsible for absorbing visible light. Compounds called pigments are frequently employed in the business. Environmentally beneficial due to their non-toxic makeup, certain microorganisms manufacture color for use in pharmaceuticals, cosmetics, Food, Dye and other industrial purposes. Natural food colorants are produced commercially by microorganisms. Fermentation offers several benefits including cheaper production and simpler extraction; Improved strain yields an ample supply of basic materials independent of season.***

Keywords: Microbial Pigments, Soil Sample, Bacteria, Textile & Dyes

1. Introduction

Synthetic colors are superior to natural pigments in stability, ease of application and cost-effectiveness. The natural pigment is isolated from Foodstuff, Dyestuff, Cosmetic and Pharmaceutical manufacturing practices has been increasing in recent years (Sanjay, *et al.*, 2007). The main source of natural pigments is obtained from Animals, Plants (Joshi, *et al.*, 2003) andMicroorganisms (Nagpal, *et al.*, 2011). Microorganisms are Biodegradable, Renewable, environmentally friendly and known for their uses in textile dyeing, food ingredients, cosmetics and pharmaceutical (Shahid *et al*., 2013). The development of microorganisms can be cultivated through a strong state and lowered ageing on characteristics of crude material or modern natural waste. Microorganisms can develop effectively and quick rate in the modest culture medium and their development is autonomous of the climate condition. Microorganisms produce a variety of pigments include Polyketides, Carotenoids, Phenazines, Acylphenols, Pyrones, and Anthraquinones but most of these pigments are toxic to humans except for carotenoids and polyketides (Stich *et al.*, 2002).

The freshness of food material is indicated by its safety and color that are also show good sensorial and aesthetic values. Bacterial pigments are used because of their harmless effects on humans as well as the environment (Ahmad, *et al.*, 2012). In food industries purified microbial pigments are used as food additives with properties such as antioxidants, color intensifiers etc. (Rymbai, *et al*., 2011). Microbes are good sources of organic acids, enzymes, vitamins, amino acids and organic acids. The extraction of pigment from microbial sources and then used it as a food colorant is an excellent alternative to synthetic dyes (Malik, *et al.2012)*. The main benefits of the creation from bacterial species are fast and easy growth in the easily available and cheap culture medium, totally free from atmospheric conditions.

In nature, color-rich and pigment producing microorganisms like Fungi, Yeast and Bacteria are quite common. The pigments were isolated from species such as Serratia phymuthica, Serratia rubidaea, Hahella chejuensis, and Vibrio gazogenes. These pigments have been reported to have antifungal, antibacterial, algicidal, antiprotozoal, antimalarial activities, immunosuppressive and anticancer activities. Carotenoids are a group of bioactive compounds which are responsible for yellow, orange and red pigments (Muneefa KI, Angayarkanni Thirumalai). One of the most commonly used additives in a variety of industries, including food and beverage, textile, leather, cosmetics, medicines, paper and dye-sensitized surfaces solar cells etc., not only to enhance the product's aesthetic appeal but also enhance its flavor, quality and durability. Between 2020 and 2027, the market for pigments and dyes will grow by 5% annually, from its current value of about 33.20 billion US dollars. (Bhagyashree Padhan, Kasturi Poddar, Debapriya Sarkar, Angana Sarkar*)

Microbes can create pigments such as Quinones, Carotenoids, Violacein and Melanins. Among the most varied natural products are carotenoids. Microbiological carotenoids are well-known for their antioxidant, and nutrition which enhance immunological response in both people and animals and prevent degenerative diseases. Pigment-producing bacteria can come from a variety of places, with soil and water sources being the most prevalent. According to Grube and Berg (2009), lichens are composite, symbiotic systems made up of two or more closely related organisms: a fungus and one or more partners known as photobionts. Lichens offer other microorganisms a stable community and habitat beneath the tissue at the epidermal cell layer without harming the host. (Turki M. Dawoud a, Naiyf S. Alharbi a, Aswani M. Theruvinthalakal b, Aswani Thekkangil b, Shine Kadaikunnan a, ⇑, Jamal M. Khaled a, Taghreed N. Almanaa a, Karthikumar Sankar b, Ganesh Moorthy Innasimuthu b, Khaled F Alanzi a, Shyam Kumar Rajaram b,)

Synthetic pigment demand increased significantly during the post-industrial revolution because of their high productivity, high stability, high intensity, low manufacturing cost and wide range of uses. However, these colours have a direct effect on people's health and well-being as well as the environment. Many governments have banned or restricted the use of synthetic pigments as a result of recent reports suggesting that carmoisine has carcinogenic activity or that Tartrazine, Allura Red, Sunset Yellow, and Brilliant Blue have Mutagenic activity, Allergy and Hyperactivity associated with them. (Bhagyashree Padhan, Kasturi Poddar, Debapriya Sarkar, Angana Sarkar*)

Endophytes have a wide variety, grow quickly under standard laboratory conditions, and generate a significant number of new chemicals. Endophytes bacteria are the new, possible sources of novel natural compounds, according to recent studies. There are currently few investigations on the standardisation of pigment synthesis from endolithic bacteria. (Turki M. Dawoud a, Naiyf S. Alharbi a, Aswani M. Theruvinthalakal b, Aswani Thekkangil b, Shine Kadaikunnan a, Jamal M. Khaled a, Taghreed N. Almanaa a, Karthikumar Sankar b, Ganesh Moorthy Innasimuthu b, Khaled F Alanzi a, Shyam Kumar Rajaram b,)

Carotenoids can scavenge the free oxygen radicals in our bodies. Free radicals can help in curing certain types of cancer and reduce the formation of tumours in cancer patients. Certain carotenoids are found to activate the antioxidant gene expression which helps in decreasing neurological disorders and diabetes. In the nervous system, an increase in oxidative stress results in several neurodegenerative diseases such as Alzheimer's, Huntington's and Parkinson's disease. The main reason for several diseases is the inability of calcium to signal the molecules. But pigments like astaxanthin, beta-carotene and lycopene are involved in calcium ion transportation in the brain. So proper dietary of carotenoid malfunction can be reduced due to improper signaling. (Muneefa KI*1, Angayarkanni Thirumalai2).

History

Dyeing was known as early as in the Indus Valley period; this knowledge has been substantiated by the finding of colored garments of cloth and traces of madder dye. So, natural dye, dyestuff and dyeing are as old as textiles themselves. The earliest written record of the use of natural dye was found in China dated 2600 BC [6]. Primitive dyeing techniques included sticking plants to fabric or rubbing crushed pigments into cloth (Zainul Akmar Zakariab). The methods became more sophisticated with time and techniques using natural dyes from crushed fruits, berries and other plants, which were boiled into the fabric and gave light and water fastness (Chidambaram Kulandaisamy Venil *et al*-2013).

The use of natural pigments in food is known from Japan in the shosoin text of the Nara period, which contains references to coloured soybean and adzuki-bean cakes, so it appears that coloured processed foods had been taken at least by people of some sections.

The art of colouring spread widely with the advancement of (Zainul Akmar Zakariab, and Wan Azlina Ahmada).

Before the advent of synthetic pigments, natural pigments were the civilization only source of colour available and were widely used and traded, providing a major source of wealth creation around the globe. It has been used for many purposes such as the colouring of natural fibres, fur and leather (Chidambaram Kulandaisamy Venila *et al*. -2013). They were also used to colour cosmetic products and to produce inks, watercolours and artist's paints. Since the introduction of synthetic dyes by Perkin in 1856, many convenient and cheap synthetic pigments have appeared, and the use of natural dyes has decreased due to the relatively cheaper synthetic pigments (Chidambaram Kulandaisamy Venila-2013).

Advanced in organic chemistry enable mass production of these compounds relatively cheaper thereby allowing them to displace natural product pigments, whose procurement is often more challenging. Current applications of synthetic pigments are in the textile industry, leather tanning industry, paper production, food technology, agricultural research, light-harvesting arras, photoelectrochemical cells and hair colouring (Chidambaram Kulandaisamy Venila, Zainul Akmar Zakariab, Wan Azlina Ahmada)

In the 1960s in US, environmental activists demonstrated against the use of such food additives and this attitude was spread widely. Activists campaigned for natural colourants highlighting their nutritional characteristics as a sales tool (Chidambaram Kulandaisamy Venila *et al*-2013). Thus a worldwide tendency to use natural colourants was generated. Because of their pharmacological properties, the number of advantages of using natural pigments, over synthetic colourants, has been further boosted.

Because of the habitat's structural affluence, forests are recognised as having a high level of biodiversity, where complex relationships among fauna, plants and microflora are preserved (Ahmad *et al.* 2009). There is a wide variety of bacteria in mangroves and these microbes are directly engaged in nutritional transformation, photosynthesis, N2 fixation, Methanogenesis and PO4 solubility, SO4 reduction and metabolite synthesis. Mangroves offer a special ecological service niche to many microorganisms that have a variety of roles in both nutrient recycling and other ecological activities (Ramanath *et al.* 2008). Although microorganisms exhibit extraordinary despite the enormous diversity of life on earth, the Sundarban mangrove forest soil is the most abundant.

Natural pigments and synthetic dyes are extensively used in various fields of everyday life such as food production, textile industries, paper production and agricultural practices. It is well known that some synthesized dye manufacturing is prohibited due to the carcinogenicity of the precursor of products and also the effect of the disposal of their industrial wastes in the ecosystem. Now industries can produce some bacterial pigments for food, cosmetics or textiles (Chidambaram Kulandaisamy Venila, Zainul Akmar Zakariab, Wan Azlina Ahmada).

Natural colourants come from biological sources and are generally safe for the environment and do not pose any issues. Natural plants, Microorganisms and other biological sources of pigments. The majority of natural colourants are derived from sustainable sources. One can acquire natural colourants, stems, bark, leaves, fruits, flowers, seeds and other components of plants, teak, paprika, annatto, henna, carrot, red cabbage, turmeric and other natural sources are used to create the colour (Kapoor *et al*-2007).

The word "Cosmetic" derives from the Greek "Kosm tikos", which means "Having the Power, Organise or Decorating skill" (Rohit Kumar Bijauliya *et al.*, 2017). Colours are crucial in cosmetics because they draw customers in and grab their attention. The use of colour in promoting any product including cosmetics. Cosmetics are now a significant element of women's lives (Fathima. A *et al.*, 2011). Taking the place of Textiles, Food items etc. Women use a variety of Cosmetics such as Lipstick, Nail polish, Hair dyes, Perfumes, Skin care products and other items.

Problem Associated with synthetic dyes:

Numerous health issues have been linked to the synthetic dyes used in cosmetics. The main class of synthetic colours, Azo dyes interact with skin flora, liver cells and gut microbes. These colours have a variety of Carcinogenic, Mutagenic and Genotoxic effects. These azo dyes are responsible for a variety of Skin issues (Bruna de Campos Ventura-Camargo *et al.*, 2013), (Shabana Sarkar *et al*., 2017). Sarkar et al. Numerous records for the Triarylmethane dyes have been provided indicated that this. When ingested through cosmetics, Triarylmethane enters the bloodstream immediately and produce a variety of various illness (Herbert Levitan *et al.*, 1977). Xanthones are widely used in Cosmetic products for the skin. Therefore, these xanthones interact with the skin's proteins when applied by cosmetic items, making the skin permanently dry (Visalakshi. M *et al*., 2013). These kinds of colours might produce numerous problems including cancer when used in other cosmetic goods like paint.

Artificial colours are regarded as xenobiotics that are particularly hazardous to the environment (Eugenia Guerra *et al*., 2018). Artificial dyes such as azo dyes, are thought to be toxic and have major negative effects on the body when combined with water. Skin irritation is brought on by 1, 4-diamino benzene, a component of azo dye. Annoyances include contact dermatitis, blindness, vomiting and hypertension dyes that can catch fire as aniline may result in numerous (Diana Kyle. J *et al*., 1996).

Natural Colourant:

People prefer to use natural colourants in cosmetics instead of synthetic dyes because of some issues with such dyes. These days more natural colourants are being used in cosmetics. Natural colourants come from biological sources and are generally safe for the environment and do not pose any issues (Manish Kumar *et al*., 2017). Natural plants, Microorganisms and other biological sources of pigments. The majority of natural colourants are derived from sustainable sources. One can acquire natural colourants, stems, bark, leaves, fruits, flowers, seeds and other components of plants, teak, paprika, annatto, henna, carrot, red cabbage, turmeric and other natural sources are used to create colour.

Figure 1: Annatto seeds
(Kapoor *et al*-2007)

Figure 2: Madder roots
(Kapoor *et al*-2007)

The benefits of natural colourants include being environmentally friendly, non-toxic, without side effects, not carcinogenic, causing less pollution and having additional health benefits such as being Vitamin-A rich anticancer and antioxidants (Rymbai. H *et al.,* 2011), (Papori Bora *et al.,* 2019).

Bacterial pigments benefits and advantages:

- Growing in appeal to science due to its wide range of activities.
- Broad strain selection and simple propagation.
- Greater flexibility and productivity than alternative sources.
- Compared to any other chemical process, fermentation is naturally faster and more productive.
- Simple and efficient culture methods allow the continued operation of the bioreactor.
- Easy to manipulate genes.
- Structural complexity suits industrial needs.
- Utilizing a straightforward liquid-liquid extraction method, bacterial pigments were recovered reducing the operation coat.
- Cheap substrates are used for bulk production.

(1) Application as Food Colourant:

The development of foods with an attractive appearance is important in the food industry. Food production is turning to natural food colours, and certain artificial colour additives have demonstrated negative health issues in their consumption. Due to the lack of availability of natural food colourants, their demand is much more especially in the food industries. Many natural colours are available, and microbial colourants play a significant role as food colouring agents, because of their production and easy streaming process. Microorganisms could be made to produce colourant in high yield by inserting genes coding for the colourant (Chidambaram Kulandaisamy Venila *et al*-2013).

Scientists have isolated food-grade pigments from bacteria and blue pigment from cultured. Food markers have increasingly been looking for alternatives to artificial food colours such as sunset yellow, Tartrazine and Quinoline yellow. Microbial colours are used in the fish industries for example to enhance the pink colour of farmed salmon. Some natural food colourants have commercial potential for use as Antioxidants (Chidambaram Kulandaisamy Venila *et al*-2013).

(2) Application of the Pharmaceutical industry:

The genus, *Streptomyces* or *Serratia* can produce a red substance of pyrrolylpyromethene skeleton, which is one of the substances: prodigiosin, metacycloprodigiosin, desmethoxy prodigiosin and prodigiosin 25-C. Prodigiosin 25-C, in particular, has been shown to have immunosuppressive activity and to have an antibacterial and antimalarial impact. Prodigiosin's immunosuppressive properties were originally noted by Nakamura and colleagues in 1989. These researchers showed the presence of prodigiosin and metacycloprodigiosin in the culture broth of *Serratia* and observed selective inhibition of polyclonal proliferation of T-cells as compared to that of B-cells. The cytotoxic potential of prodigiosin has also been studied in the conventional 60 cell line panels of human tumour cells derived from Leukaemia, melanoma, lung, colon, renal, ovarian and brain malignancies. Inhibition of cell proliferation and induction of cell death has been observed in these cell lines (Chidambaram Kulandaisamy Venila, Zainul Akmar Zakariab, Wan Azlina Ahmada).

Different prodigiosin analogues and synthetic indole derivatives of prodigiosin have been demonstrated in vitro anticancer properties. The antiproliferative and cytotoxic effects of prodigiosin have been observed not only in cultured tumour cell lines but also in human primary cancer cells from B-cell chronic lymphocytic leukaemia patients. Hwanmook et al. also reported on the usage of prodigiosin for treating diabetes mellitus and concluded that it is an effective treatment and preventative agent (Chidambaram Kulandaisamy Venila *et al*-2013).

(3) Application in the Textile industry:

The textile industry produces and uses approximately 1.3 million tons of dyes, pigments and dye precursors, valued at around U$23 billion, almost all of which is manufactured synthetically. Synthetic dyes have some limitations, primarily, (1) Their production process requires hazardous chemicals, creating worker safety concerns, (2) they may generate hazardous wastes, and (3) these dyes are not environment friendly. All dyes used in textiles up until the second half of the 19th century were made naturally. However, with the synthesis of mauveine by Perkin in 1856, the synthetic dye industry has grown at a vigorous rate and is all about eradicating the use of natural dyes. The huge range of synthetic dyes currently in use is evidence of the inventiveness and innovation of textile chemists in effectively meeting the expectations of dyers for straightforward, repeatable application methods and the demands of consumers for high-quality goods at competitive prices (Wan Azlina Ahmada).

The currently used colourants are almost exclusively made from non-renewable resources such as fossil oil. Synthetic colourants are facing challenges like Dependence on non-renewable oil resources and sustainability of current operation, environmental toxicity and human health concerns of some synthetic dyes. Thus, biosynthesis of pigments through fermentation processes can serve as major

chromophores for further chemical modification, which could lead to colourant with a broad spectrum of colour (Venila *et al*-2013).

Fermentation of microorganisms such as fungi and bacteria could be a valuable source of manufacturing colourants. Microorganisms produce a large variety of stable pigments such as carotenoids, flavonoids and rubramines and fermentation has higher yields in pigments and lower resides compared to the use of plants and animals. Some natural colourants, especially anthraquinone-type compounds have shown remarkable antibacterial activity in addition to providing bright colours, which could serve as functional dyes in producing coloured antimicrobial textiles. Ahmad et al. characterized the red pigment prodigiosin and violet pigment violacein and tested its dyeing efficiency in different fabrics i.e., pure cotton, pure silk, pure rayon, jacquard rayon, acrylic, cotton, silk satin and polyester. Their results suggested that prodigiosin could be used to dye acrylic and for violacein, intense colourations were observed in pure rayon, jacquard rayon and silk satin (Chidambaram Kulandaisamy Venila *et al*-2013).

(4) Application in Other aspects:

The potential of prodigiosin in colouring candles, paper, soap and pencil case pouch and also tested the potential of prodigiosin and violacein as ink in ballpoint pen and high lighter pen. There are two types of ballpoint-pen ink namely oil-based ballpoint-pen ink and water-based ballpoint-pen ink. The basic components in ballpoint-pen inks are a colouring agent, solvent and resin. Dyes and pigments which are soluble or dispersible in aqueous media can be used as colouring agents in inks. As a basic component, several other compounds were also added to this ink as additives that include amine derivatives as the pH-controlling agent or mildew-proofing agent. Surfactants with fluorine serve as a defoaming, rust-proofing and lubricating agent as well as increasing solvent penetrability. When the pen is not being used, the gap between the ball and the tip can cause the ink to leak out. This can be avoided by adding a shear-viscosity reducing agent, such as cross-linked acrylic resin and fatty acid metal salt (Zainul Akmar Zakariab, Wan Azlina Ahmada).

2. Conclusion

This review study highlights the natural pigment to concentrate on it. Because they contain less chemicals than synthetic dyes, natural dyes are safer. Because plants that grow abundantly can be utilised instead of the synthetic dye-making process, employing natural dyes reduces the amount of water and pollutants needed in production. The toxic compounds from dyes severely harm water, air, and soil.

References

[1] Adeel, S., Abrar, S., Kiran, S., Farooq, T., Gulzar, T., & Jamal, M. (2018). Sustainable application of natural dyes in the cosmetic industry. *Handbook of Renewable Materials for Coloration and Finishing*, 189-211.

[2] Bhat, S. H., Kaur, K., & Vyas, A. (2019). Isolation and Characterization of Pigment Producing Bacteria. *Think India Journal*, *22* (17), 1877-1892.

[3] Boo, H. O., Hwang, S. J., Bae, C. S., Park, S. H., Heo, B. G., & Gorinstein, S. (2012). Extraction and characterization of some natural plant pigments. *Industrial Crops and Products*, *40*, 129-135.

[4] Chatragadda, R., & Dufossé, L. (2021). Ecological and biotechnological aspects of pigmented microbes: A way forward in the development of food and pharmaceutical grade pigments. *Microorganisms*, *9* (3), 637.

[5] Dawoud, T. M., Alharbi, N. S., Theruvinthalakal, A. M., Thekkangil, A., Kadaikunnan, S., Khaled, J. M., . . . & Rajaram, S. K. (2020). Characterization and antifungal activity of the yellow pigment produced by a Bacillus sp. DBS4 isolated from the lichen Dirinaria agealita. *Saudi Journal of Biological Sciences*, *27* (5), 1403-1411.

[6] Gillespie, D. E., Brady, S. F., Bettermann, A. D., Cianciotto, N. P., Liles, M. R., Rondon, M. R., . . . & Handelsman, J. (2002). Isolation of antibiotics turbomycin A and B from a metagenomic library of soil microbial DNA. *Applied and environmental microbiology*, *68* (9), 4301-4306.

[7] Gjadhar, S., & Mellem, J. J. (2019). Isolation and characterization of a microbial pigment obtained from Serratia marcescens as a natural food colourant. *The Annals of the University Dunarea de Jos of Galati. Fascicle VI-Food Technology*, *43* (1), 137-154.

[8] Indra Arulselvi, P., Umamaheswari, S., Ranandkumar, S. G., Karthik, C., & Jayakrishna, C. (2014). Screening of yellow pigment-producing bacterial isolates from various eco-climatic areas and analysis of the carotenoid produced by the isolate. Indra Arulselvi, P., Umamaheswari, S., Ranandkumar, S. G., Karthik, C., & Jayakrishna, C. (2014). Screening of yellow pigment-producing bacterial isolates from various eco-climatic areas and analysis of the carotenoid produced by the isolate.

[9] Kumar, A., Vishwakarma, H. S., Singh, J., Dwivedi, S., & Kumar, M. (2015). MICROBIAL PIGMENTS: PRODUCTION AND THEIR APPLICATIONS IN VARIOUS INDUSTRIES. *International Journal of Pharmaceutical, Chemical & Biological Sciences*, *5* (1).

[10] ISLAM, M. N. PIGMENT PRODUCING SOIL BACTERIA OF SUNDARBAN MANGROVE FOREST MIHIR LAL SAHA*, SADIA AFRIN, SONIA KHAN SONY.

[11] Mansour, R. (2018). Natural dyes and pigments: Extraction and applications. *Handbook of renewable materials for colouration and finishing*, *9*, 75-102.

[12] Md Zaki, N. A., & Jai, J. (2020). Plant-based pigments: Challenges and future perspectives for natural food colourants. *Malaysian Journal of Chemical Engineering and Technology (MJCET)*, *3* (1), 44-49.

[13] Mumtaz, R., Bashir, S., Numan, M., Shinwari, Z. K., & Ali, M. (2019). Pigments from soil bacteria and their therapeutic properties: A mini review. *Current microbiology*, *76* (6), 783-790.

[14] Muneefa, K. I., & Thirumalai, A. (2021). ISOLATION AND CHARACTERIZATION OF PIGMENT PRODUCING BACTERIA AND THEIR POSSIBLE

USE IN TEXTILE INDUSTRY. *Journal of Advanced Scientific Research*, *12* (01), 132-139.

[15] Ramesh, C., Prasastha, V. R., Venkatachalam, M., & Dufossé, L. (2022). Natural Substrates and Culture Conditions to Produce Pigments from Potential Microbes in Submerged Fermentation. *Fermentation*, *8* (9), 460.

[16] Rana, B., Bhattacharyya, M., Patni, B., Arya, M., & Joshi, G. K. (2021). The realm of microbial pigments in the food color market. *Frontiers in Sustainable Food Systems*, *5*, 603892.

[17] Saha, M. L., Sadia, A., Sony, S. K., & Islam, M. N. (2017). Pigment producing soil bacteria of Sundarban Mangrove Forest. *Bangladesh Journal of Botany*, *46* (2), 717-724.

[18] Selvi, P. S., & Iyer, P. (2018). Isolation and characterization of pigments from marine soil microorganisms. *IJLSSR*, *4*, 2003-2011.

[19] Sengupta, S., & Bhowal, J. (2022). Characterization of a blue-green pigment extracted from Pseudomonas aeruginosa and its application in textile and paper dyeing. *Environmental Science and Pollution Research*, 1-15.

[20] Sen, T., Barrow, C. J., & Deshmukh, S. K. (2019). Microbial pigments in the food industry—challenges and the way forward. *Frontiers in Nutrition*, *6*, 7.

[21] Sinha, S., Choubey, S., Kumar, A. A., & Bhosale, P. (2017). Identification, characterization of pigment producing bacteria from soil and water and testing of antimicrobial activity of bacterial pigments. *Int. J. Pharm. Sci. Rev. Res*, *42* (2), 119-124.

[22] Siva, R. (2007). Status of natural dyes and dye-yielding plants in India. *Current science*, 916-925.

[23] Solehin, S. N., Kamarudin, K. R., & Badrulhisham, N. S. (2020). Production of Natural Food Colourants Using Food Grade Microbial Pigments: A New Focus in Industrial Microbiology. *Journal of Sustainable Natural Resources*, *1* (1), 1-14.

[24] Umadevi, K., & Krishnaveni, M. (2013). Antibacterial activity of pigment produced from Micrococcus luteus KF532949. *International journal of chemical and analytical science*, *4* (3), 149-152.

[25] Usman, H. M., Abdulkadir, N., Gani, M., & Maiturare, H. M. (2017). Bacterial pigments and their significance. *MOJ Bioequiv Availab*, *4* (3), 00073.

[26] Venil, C. K., Zakaria, Z. A., & Ahmad, W. A. (2013). Bacterial pigments and their applications. *Process Biochemistry*, *48* (7), 1065-1079

[27] Waghela, M., & Khan, S. (2018). Isolation, Characterization of Pigment Producing Bacteria from various food samples and testing of antimicrobial activity of bacterial Pigments. *DAV International Journal of Science*, *7* (1).

[28] Zine, A. (2022). SCREENING AND ISOLATION OF PIGMENT PRODUCING BACTERIA. *Journal of Global Biosciences Vol*, *11* (6), 9315-9326.

[29] Zokaeifar, H., Luis Balcázar, J., Kamarudin, M. S., Sijam, K., Arshad, A., & Saad, C. R. (2012). Selection and identification of non-pathogenic bacteria isolated from fermented pickles with antagonistic properties against two shrimp pathogens. *The Journal of antibiotics*, *65* (6), 289-294