International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Review of Anthraquinone Pigment Production from Soil Fungi and Their Potential Use in Calligraphy Ink and Textile Dye Applications

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Abstract

This review provides an in-depth examination of anthraquinone pigment production from soil fungi and their potential applications in calligraphy ink and textile dye. We discuss various methods for isolating fungi from soil samples, extracting anthraquinone pigments, and characterizing their properties. The review highlights the advantages of using natural pigments, including sustainability and unique color profiles. We also explore the challenges and opportunities associated with scaling up production and integrating fungal-derived anthraquinones into industrial applications. Our analysis aims to contribute to the development of innovative, eco-friendly solutions for the ink and dye industries.

Keywords: Anthraquinone pigments, Soil fungi, Isolation, Extraction, Calligraphy ink, Textile dye, Natural pigments, Fungal pigments.

1. Introduction:

This review focuses on isolating fungi from soil samples, extracting anthraquinone pigment, and producing calligraphy ink and textile dye. Fungi are a rich source of bioactive compounds, including anthraquinone pigments, which have been used for centuries in various applications such as textile dyeing, ink production (K. Singh and R. K. Singh 2019).The current study aims to separate and improve the fermentation conditions of two fungi Alternaria alternata and Curvularia lunata. In two weeks under static conditions, the highest optical density was attained in potato dextrose broth at 28ºC.Natural dyes from Alternaria alternata and Curvularia lunata are used to get pigments for textile dyeing. Silk and wool have excellent wash and rub fastness. .(SHARMA et.al) The present study is an attempt to isolate and optimize the fermentation conditions of three fungus, namely Alternaria alternata and Curvularia lunata to get pigments for the purpose of textile dyeing. Highest optical density has been achieved in potato dextrose broth at 28ºC in 25 days under static conditions. Wool and silk are dyed unmordanted with very good wash and rub fastness. Trichoderma virens has demonstrated antifungal property. There is no adverse effect on the tensile strength of the fabric and on the human skin. Paper and thin layer chromatography has revealed that the pigments are multi-component in nature.(SHARMA et al.2016). The above-cited literature suggests that unusual habitats are a good choice for investigating soil fungi that can produce novel bioactive compounds.The research on fungal pigments made through various biosynthetic processes of soil fungi received enormous usage in textile dyeing, food tinting, medical and cosmetics fields (Akilandeswari & Pradeep 2016). Microorganisms that are able to synthesize natural pigments with applications in the dye industry have been identified (Gunasekaran & Poorniammal 2008). In addition to the pigments, different pharmacologically active molecules were also isolated from soil fungi (Takahashi et al. 2008).

2. Soil Fungi as Pigment Producers

Soil inhabiting fungi generally consist of four phyla viz. Deuteromycota, Zygomycota, Basidiomycota and Ascomycota (Guiraud et al.1995, Buée et al. 2009, Richardson 2009). Soil fungi play crucial roles in the recycling and redistribution of soil nutrients (Frąc et al. 2018).Fungal hyphae form a filamentous network with rock, soil particles and roots, which secrete enzymes that can digest soil organic matter composed of lignin and cellulose (Gupta et al. 2017).Soil dwelling fungi are highly active in their metabolic processes, and hence they may provide bioactive compounds like organic acids, pigments, Intracellular Enzymes (Akilandeswari & Pradeep 2016). Even though fungi are ubiquitous, they can survive in a vast range of temperatures and pHs. Fungi prefer to live in a slightly acidic environment (Frąc et al. 2018). Initially, soil-borne fungi were investigated randomly by researchers for bioactive compounds. Jancic et al. (2016) hypothesised that extreme habitats act as hotspots of microorganisms producing novel bioactive compounds.It is suggested that the successful establishment of fungi in the extreme environment occurs because of the production of unique secondary metabolites, which have potential uses in commercial industries (Frisvad 2005)The present study is an attempt to isolate and optimize the fermentation conditions of three fungus, namely Alternaria alternata and Curvularia lunata to get pigments for the purpose of textile dyeing. Highest optical density has been achieved in potato dextrose broth at 28ºC in 25 days under static conditions. Wool and silk are dyed unmordanted with very good wash and rub fastness. Trichoderma virens has demonstrated antifungal property. There is no adverse effect on the tensile strength of the fabric and on the human skin. Paper and thin layer chromatography has revealed that the pigments are multi-component in nature.(SHARMA et al.)2016).The above-cited literature suggests that unusual habitats are a good choice for investigating soil fungi that can produce novel bioactive compounds.The research on fungal pigments made through various biosynthetic processes of soil fungi received enormous usage in textile dyeing, food tinting, medical and cosmetics fields (Akilandeswari & Pradeep 2016).Microorganisms that are able to synthesize natural pigments with applications in the dye industry have been identified (Gunasekaran & Poorniammal 2008). In addition to the pigments, different pharmacologically active molecules were also isolated from soil fungi (Takahashi et al. 2008).

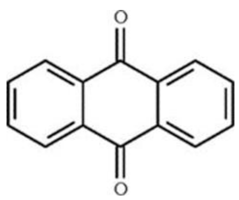
3.Natural Dye

Natural dyes are non-toxic, non-polluting and less health hazardous. Moreover, their antioxidant and antimicrobial nature further adds to their positive effects. Natural dyes can be obtained from various sources like plants, animals and microbes. SHARMA et al.2016. Microbial dyes have some advantages over plant and animal based dyes as microbes are fast growing and have the potential of being standardized commercially. Attempts have been made to synthesize bacterial and fungal pigments to be used in the textile and leather industry2-5.Microbes can produce a large amount of stable pigments such as anthraquinones SHARMA et al.2016 Fungi contain several anthraquinone compounds which have been identified as their secondary metabolites. The production and evaluation of such textile colorants are currently being investigated at The British Textile Technology Group. Earlier studies confirmed the non toxicity and biodegradability of the SHARMA et al.2016. Fungal pigments In the present work, efforts have been made to screen and isolate certain pigment producing species of fungi and optimize their fermentation conditions for maximum pigmentation. Thereafter, the substantivity of the pigment is checked on different textile substrates, and their color measurement and color fastness are ascertained. SHARMA et al.2016.

4.Anthraquinone Dyes:

Anthraquinone pigments are a class of organic compounds widely used as dyes for textiles due to their bright colors and excellent color fastness, primarily found in the textile industry; they also have applications in the paper industry, and some anthraquinone derivatives possess potential Anthraquinone dyes are an abundant group of dyes comprising a anthraquinone unit as the shared structural element. Anthraquinone itself is colourless, but red dyes are obtained by introducing electron donor groups such as hydroxy or amino groups in the 1-, 4-, 5- or 8-position. Anthraquinone dyestuffs are structurally related to indigo dyestuffs and are classified together with these in the group of carbonyl dyes. (International Agency for Research on Cancer 2013)

4.1Structural and molecular formulae and relative molecular mass .



ANTHRAQUINONE - C14H8O2 Relative molecular mass: 208.21

5. Use of Anthraquinonoid Pigment:

Anthraquinone is a versatile compound with applications in various fields, including the production of dyes, as a laxative, and in various industrial processes. It is also used as a pesticide, bird repellent, and in paper and pulp manufacturing. Furthermore, anthraquinones have biological activities like anticancer, anti-inflammatory, and antibacterial properties.

5.1. Dye Industry:

Anthraquinone is a key raw material for making vat dyes, which are water-insoluble dyes that can be reduced to a water-soluble form. These dyes are known for their brightness and good fastness on textiles.

5.2. Medical Applications:

- **Laxative:** Anthraquinones, particularly sennosides, are found in senna and rhubarb and are used as laxative agents.

- **Other therapeutic uses:** Sennosides have shown antiviral, anti-inflammatory, and antioxidant effects, and may also be useful in treating type-2 diabetes and obesity.

5.3 Industrial Processes:

- **Pulp and Paper:** Anthraquinone is used as an additive in chemical alkaline pulp processes in the paper and pulp industry.
- **Pesticide:** It is used as a pesticide in both agricultural and non-agricultural settings.
- **Seed Dressing:** Anthraquinone can be used as a seed dressing or in seed treatments, particularly for corn and rice.
- **Bird Repellent:** It is used as a bird repellent, especially for geese, and can be mixed with lanolin to protect sheep flocks against kea attacks.
- **Other Niche Uses:** Anthraquinone has been used as a gas generator in satellite balloons.

5.4. Biological Applications:

- Anticancer: Some anthraquinones have shown promise in anticancer research, particularly in overcoming cancer-therapy resistance.
- Anti-inflammatory: Anthraquinones exhibit anti-inflammatory properties and may be useful in treating conditions like arthritis.
- Antimicrobial: Many anthraquinones possess antibacterial and antifungal activities.
- Other Biological Activities: Anthraquinones have also been shown to have antiviral, antimalarial, and other biological activities.

5.5. Chemical Synthesis:

- Anthraquinone serves as a building block for synthesizing a wide range of organic compounds, including pharmaceuticals and agrochemicals. It is also used in the production of hydrogen peroxide.

6.Extraction of Anthraquinone Pigments from fungi soil sample :

In order to obtain pigments for textile dyeing, the current study aims to separate and enhance the fermentation conditions of three fungi:, *Alternaria alternata, and Curvularia lunata.* In 25 days under static conditions, the highest optical density was attained in potato dextrose broth at 28ºC. Wool and silk have excellent wash and rub fastness due to their unmordanted dyeing The pigments' multi-component nature has been demonstrated via thin layer chromatography and paper. SHARMA et al. Fungal Isolates Five PDA plates were placed in various locations throughout the college and left in the air for five minutes. Additionally, soil samples were randomly selected, and in a test tube, 1 g of the soil was dissolved in 10 mL of distilled water. Then, using a sterile spreader, soil solution (0–1 mL) was applied to the PDA plates. Similarly, a sample from the leaf surface and vermicompost soil were also applied to the PDA plates.

After that, all PDA plates were stored for three to four days at 280 C in a B.O.D. incubator. PDA plates showed several fungal colonies Curvularia lunata and Alternaria alternata were used for further study. SHARMA et.al

6.1. Fungal Cultures for the Production of Pigments:

On potato dextrose broth (PD), cultures of Trichoderma virens, Curvularia lunata, and Alternaria alternata were cultivated. A mycelia disk (5 mm diam.) from PDA cultures of Curvularia lunata, and Alternaria alternata was used to inoculate each flask. The flasks were then incubated for three weeks at three different temperatures—15°, 28°, and 37°C—as stationary cultures in order to produce pigment. SHARMA et.al

6.2 Screening of Dye

After three weeks of incubation, colored fungal culture broths were filtered away. The culture filtrates and fungal mycelia were examined for dyeability and color generation.Each of the chosen fungi's mycelium and filtrate was separated into four sections. Only filtered solution was placed in one flask; Mycelium was crushed using a homogenizer and autoclaved in the secondAlcohol was added to the third flask and autoclaved with the crushed mycelium;In the fourth flask, both the filtered solution and the solid mycelium were autoclaved. To remove any intracellular pigment from the mycelia, this was done.The colored filtrate was used to dye the textile samples. SHARMA et.al

6.3 Dyeing

Wool and silk textiles were subsequently dyed using the colorful filtrates .Ferrous sulphate and copper sulphate, each at 5%(owf), were used to pre-mordant the samples. Lastly, 1 g of unmordanted and mordanted wool and silk were dyed in 50 mL of colored filtrate with a dyeing period of 45 minutes and a temperature range of 70-800C. Following dyeing, the samples were washed with lissapol for five minutes at a boil and then rinsed with cold water SHARMA et.al

6.4 Fabric Properties

Percentage absorption of the dyed fabrics was also calculated on Spectrophotometer using the following equation

$$\%\text{absorption} = \frac{(\text{O.D before dyeing} - \text{O.D after dyeing} \times 100)}{(\text{O.D before dyeing})}$$

7. Textile Dye:

Anthraquinone pigments are widely used in textile dyeing due to their excellent colorfastness and vibrant colors.

7.1Anthraquinone Pigments in Textile Dyeing

- Color Range: Anthraquinone pigments produce a range of colors, including red, orange, yellow, green, blue, and purple.
- Colorfastness: Anthraquinone pigments are known for their excellent colorfastness, resisting fading and color bleeding.

- ❖ Lightfastness: Anthraquinone pigments are highly resistant to light, making them suitable for outdoor textiles.
- ❖ Washfastness: Anthraquinone pigments are resistant to washing and dry cleaning, ensuring the color remains vibrant. J. M. Cardamone and A. M. Rele (2018)

7.2 Textile Dyeing Process with Anthraquinone Pigments

- ❖ Preparation: The textile material is cleaned and prepared for dyeing
- ❖ .Dyeing: The anthraquinone pigment is applied to the textile material using a dyeing machine or by hand.
- ❖ Fixation: The dye is fixed to the textile material using heat, steam, or chemicals
- ❖ Rinsing: The textile material is rinsed to remove excess dye
- ❖ Drying: The textile material is dried to remove excess moisture.

8. Calligraphy Ink:

Calligraphy ink is a special type of ink formulated for use with calligraphy pens and nibs. It is typically thicker than regular ink, allowing for precise control and creating beautiful, consistent lines a traditional art form that involves writing or drawing with a brush or pen to create beautiful, flowing lines and shapes.

9. Thin Layer Chromatography

TLC stands for Thin Layer Chromatography, a laboratory technique used to separate and identify the components of a mixture. TLC is based on the principle of differential partitioning between two phases:A thin layer of adsorbent material, usually silica gel 10: 5 coated on a plate.Mobile Phase: A solvent or mixture of solvents that moves up the plate by capillary action Sample Preparation: A small amount of the sample is dissolved in a solvent.Plate Preparation- The TLC plate is coated with a thin layer of adsorbent material.A small amount of the sample solution is applied to the plate.The plate is placed in a solvent chamber, and the mobile phase moves up the plate. The separated components are visualized using various detection methods.TLC is used to identify the components of a mixture.(RED PIGMENT OR CALLIGRAPHY INK) Ninhydrin spray used. Quantitative Analysis: TLC can be used to quantify the amount of each component(N-Butanol glacial acetic acid (Solvent) 10% Isopropanol add 0.1 Tyrosine , Phenylalanine,Tryptophan (pink-Glutamine Aminoacid.) R. M. Smith (2018)

10. Conclusion

The two selected fungi, namely Curvalaria lunata,and Alternaria alternata produce anthraquinone pigments that can be used to dye textile. The culture conditions for these fungi can be optimized to get maximal pigmentation. These dyes can be applied on white fabric cloth for textile dyeing with a good level of wash and rub fastness. There is no adverse effect of these dyes on the tensile strength of the fabrics. Even these pigments are found to be non- toxic to the human skin.. All the pigments are multi -component in nature. It can be concluded from the study that fungi can be a potential source of cultivating dyes which can be adequately applied on textile. Calligraphy ink were used as an application of anthraquinone pigment.The fermentation conditions for maximization of pigmentation can be standardized and therefore, these natural dyes can be commercially produced on mass scale in an inexpensive and environmentally friendly manner. Sources of these dyes producers are readily available and found abundantly in soil, air and other habitats.The anthraquinone pigment market is a vital component of the global industrial ecosystem, offering immense opportunities for innovation and growth. With its eco-friendly properties, diverse applications, and alignment with sustainability goals, this market is set to thrive in the coming years, presenting promising prospects for businesses.

11. Future Perspective Of Anthraquinone Pigment:

Anthraquinone pigments are a class of organic compounds known for their vibrant colors and excellent colorfastness. The future perspectives of anthraquinone pigments are promising, with potential applications in various fields.

11.1 Future Perspectives S. K. Singh (2019)

- Textile Industry: Anthraquinone pigments will continue to be used in the textile industry for dyeing and printing fabrics.
- Paint and Coatings: Anthraquinone pigments will be used in the paint and coatings industry for producing high-quality colors.
- Plastics and Polymers: Anthraquinone pigments will be used in the plastics and polymers industry for producing colored plastics and polymers.
- Cosmetics: Anthraquinone pigments will be used in the cosmetics industry for producing high-quality makeup and skincare products.
- Biotechnology: Anthraquinone pigments will be used in biotechnology applications, such as bioplastics and biosurfactants.

11.2 Challenges and Opportunities

- Sustainability: Developing sustainable and eco-friendly methods for producing anthraquinone pigments is essential.
- Cost-Effectiveness: Making anthraquinone pigments cost-effective is crucial for commercialization.

11.3 Future Perspectives of Textile Dyeing:

Textile dyeing is an essential process in the textile industry, and its future perspectives are promising, with potential applications in various fields.

11.4 Future Perspectives

- Sustainable Dyeing:J. M. Cardamone and A. M. Rele (2020) Developing sustainable and eco-friendly dyeing methods is essential for reducing the environmental impact of the textile industry.
- Digital Printing:R. M. Smith (2020) Digital printing technology will continue to evolve, enabling the production of high-quality, customized textiles with reduced waste.
- Smart Textiles: The integration of smart textiles, which can change color or pattern in response to environmental stimuli, will become more prevalent.
- Biotechnology: Biotechnology will play a crucial role in the development of new dyeing methods, such as bio-based dyes and enzymes.
- Recycling and Upcycling: The textile industry will focus on recycling and upcycling, reducing waste and promoting sustainability.

11.5 Challenges and Opportunities

- Environmental Impact: Reducing the environmental impact of textile dyeing is essential, including minimizing water and energy consumption.
- Cost-Effectiveness: Making sustainable dyeing methods cost-effective is crucial for commercialization.
- Regulatory Framework: Establishing a regulatory framework for sustainable dyeing practices is necessary.
- Public Awareness: Educating the public about the benefits of sustainable dyeing practices is essential.

11.6 Future Research Directions

- Development of New Dyes: Developing new, sustainable dyes with improved colorfastness and reduced environmental impact.
- Optimization of Dyeing Processes: Optimizing dyeing processes to reduce water and energy consumption.
- Biotechnology Applications: Exploring biotechnology applications in textile dyeing, such as bio-based dyes and enzymes.
- Smart Textiles: Developing smart textiles with advanced dyeing capabilities.

11.7 Future Perspectives Of Calligraphy Ink:

Calligraphy ink is a specialized type of ink designed for use in calligraphy, lettering, and other artistic applications. The future perspectives of calligraphy ink are promising, with potential applications in various fields.

- Digital Calligraphy: The rise of digital calligraphy will lead to the development of new, specialized inks for digital pens and tablets.
- Sustainable Inks: The demand for sustainable and eco-friendly inks will drive the development of new, environmentally friendly calligraphy inks.
- Customized Inks: The trend towards customization will lead to the development of bespoke calligraphy inks tailored to specific artistic needs.
- Advanced Formulations: Advances in materials science and chemistry will lead to the development of new, high-performance calligraphy inks with improved flow, colorfastness, and durability.

11.8 Challenges and Opportunities

- Sustainability: Developing sustainable and eco-friendly calligraphy inks is essential for reducing the environmental impact of the art industry.
- Cost-Effectiveness: Making sustainable calligraphy inks cost-effective is crucial for commercialization.
- Regulatory Framework: Establishing a regulatory framework for sustainable ink practices is necessary.
- Public Awareness: Educating the public about the benefits of sustainable calligraphy inks is essential.

11.9 Future Research Directions

- Development of New Ink Formulations: Developing new, sustainable ink formulations with improved performance and reduced environmental impact.
- Advanced Materials: Exploring the use of advanced materials, such as nanoparticles and graphene, in calligraphy ink formulations.

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