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Optimization and Characterization of Herbal Natural Dyes for Silk Fabric: Extraction, Application, and Functional Evaluation

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Abstract
In the research paper "Optimization and Characterization of Herbal Natural Dyes for Silk Fabric: Extraction, Application, and Functional Evaluation," we investigate the extraction, optimization, and application of natural dyes derived from Brassica oleracea var. capitata f. rubra (purple cabbage), Alkannatinctoria roots (Ratanjot), Picrorhiza Kurroa (Kutki), and Curcuma longa roots (Turmeric) on silk fabric. The study focuses on varying pH, time, and temperature to optimize extraction conditions, followed by a thorough characterization of the dyes using color spectra, FTIR, and UV-Vis spectroscopy. Application techniques on silk fabric are optimized, and the effects of mordanting on the dyed fabric are examined. The research further evaluates the dyed silk for color value, color fastness, and functional properties, including antibacterial activity and Ultraviolet Protection Factor (UPF). This comprehensive study aims to contribute to sustainable practices in the textile industry by enhancing the understanding and utilization of herbal natural dyes.

Keywords: Natural Dyes**,** Herbal Dye Extraction**,** Silk Fabric Dyeing**,** Brassica oleracea

Introduction

In the research paper titled "Optimization and Characterization of Herbal Natural Dyes for Silk Fabric: Extraction, Application, and Functional Evaluation," we investigate the possibility of utilising natural dyes that are extracted from herbal sources, such as Brassica oleracea var. capitata f. rubra (purple cabbage), Alkannatinctoria roots (Ratanjot), Picrorhiza Kurroa (Kutki), and Curcuma longa roots (Turmeric), for the purpose of applying them in the process of textile dyeing, more specifically on silk fabric. The objective of this research is to determine whether or not it is feasible to attain optimum extraction conditions by increasing or decreasing the amount of time, temperature, and pH that is used in the extraction process. Furthermore, the characteristics of the dyes that are produced may be identified by the use of colour, Fourier transform infrared, and ultraviolet-visible spectroscopy examination. The research also explores the effect that mordanting has on the amount of dye that is absorbed by the fabric as well as the overall quality of the linen. Furthermore, the dyed silk is evaluated in terms of its colour value as well as its fastness in the research. In addition to this, the research explores the increased functional features, which include antibacterial activity and UV protection factor. When doing the study, each and every one of these aspects is taken into consideration (UPF). With the help of this all-encompassing approach, the goal is to make a contribution to the ongoing transformation of the textile industry toward dying procedures that are more sustainable and kinder to the environment. The textile industry is now undergoing this transformation at the moment.

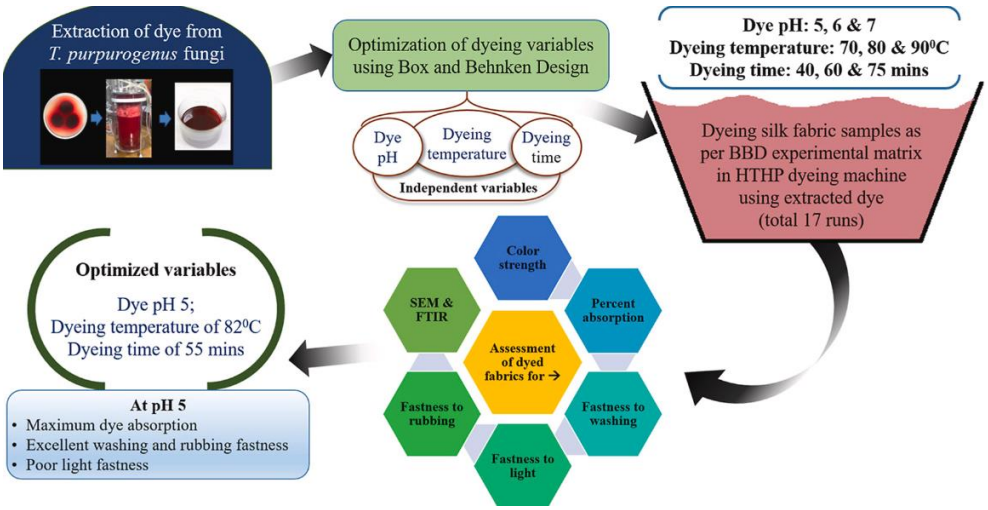
Importance of Study

The textile industry, which has historically been plagued by environmental problems related to synthetic dyes, is the subject of this research. The significance of this research lies in the fact that it contributes to the sustainable transformation of the textile industry, which is the reason for its significance. By focusing on the extraction, optimization, and application of natural colours derived from herbal sources such as purple cabbage, Ratanjot, Kutki, and Turmeric, the study addresses a significant demand for

environmentally responsible dyeing alternatives. This demand has been growing in recent years. The utilisation of these plant-based dyes on silk fabric not only gives a solution that is ecologically benign, but it also brings back traditional dying practises, so blending historical knowledge with current processes. Improving the circumstances under which the dyes are extracted and determining the qualities of the dyes are the primary focuses of the effort. Consequently, this pushes the boundaries of natural dyeing technology, which might potentially result in dyeing procedures that are more effective, scalable, and kind to the environment. In addition, the study provides essential insights into the practical applications and benefits of herbal dyes in the production of high-quality textiles by measuring the functional characteristics of the dyed silk. These characteristics include colour fastness, antibacterial activity, and the Ultraviolet Protection Factor (UPF). This all-encompassing strategy not only encourages the use of renewable resources, but it also satisfies the growing demand from customers for textiles that are produced in an ethical and environmentally responsible manner. This is because the strategy takes into account all aspects of the production process. There is a chance that the findings of the study will have a significant impact on the textile industry, which might result in a shift toward approaches that are less harmful to the environment and a decrease in the environmental imprint that the dyeing process for clothes leaves behind.

Significance of Herbal Dyes in Textile Industry

There is a significant amount of importance placed on herbal dyes within the textile business, mostly due to the fact that they are sustainable and favourable to the environment. The use of herbal colours is an important alternative to the use of synthetic dyes, which are often condemned due to the effects they have on the environment and the health of people. When it comes to the processing of textiles, the employment of herbal dyes is not only a tribute to the traditions of the past; rather, it is a technique that is forward-looking and coincides with the global trends towards natural quality and sustainability. These dyes, which are generated from plants such as Brassica oleracea var. capitata f. rubra, Alkannatinctoria roots, Picrorhiza Kurroa, and Curcuma longa roots, provide a range of brilliant colours, are biodegradable, and reduce the likelihood of allergic responses and other adverse effects. Because of this, they are gaining more and more popularity in a sector that is under pressure to lessen the impact that it has on the environment. In addition, a number of herbal dyes include natural antibacterial properties and provide Ultraviolet Protection Factors (UPF), each of which contributes to the textiles' functional worth in addition to the aesthetic value that they already possess. This movement towards the use of herbal dyes is not only beneficial to the environment, but it also satisfies the growing demand from customers for products that are not only environmentally conscious but also beneficial to their health. It is also possible that the cultivation and processing of these herbal sources might lead to an improvement in the economics of the surrounding areas and the promotion of agricultural practises that are environmentally responsible.



Source: ScienceDirect

Herbal Plants Selected for Study

In order to accomplish the objectives of this inquiry, we have selected a broad range of herbal plants for the purpose of extracting and applying natural colours. Every one of these plants was chosen because of the unique colour characteristics that it contains, in addition to the historical value that it holds in the process of traditional dyeing. Purple cabbage, that is more often known as Brassica oleracea var. capitata f. rubra, is a plant that is known for its vibrant colours and its sensitivity to pH. It comes in a range of colours, from pink to blue, depending on your preference. The roots of the Alkannatinctoria plant, which are also known as Ratanjot to certain people, are responsible for the rich crimson and purple tones that are produced by the plant. Throughout history, this plant has been used in the textile art of South Asian countries. Kutki, which is also referred to as Picrorhiza Kurroa, is a plant that is native to the Himalayas and is highly regarded for its medicinal properties. It moreover creates a wide range of fascinating green to brown colours. Lastly, but certainly not least, the roots of Curcuma longa, which are more popularly referred to as turmeric, are loved not just for their culinary uses but also for the vibrant yellow colour that they generate. Throughout the course of millennia, this dye has been used by a wide range of cultures for the purpose of colouring cloth. The selection of these plants makes it possible to investigate and rekindle the knowledge of ancient dyeing techniques, as well as to assess the usability and performance of these plants in the context of modern textile enterprises. Every single one of these plants has been painstakingly chosen to be representative of a diverse array of colour options that may be achieved via natural dyeing. We want to perform an in-depth examination into the world of natural dyes, and we will do so based on this diverse collection of medicinal plants, which will serve as the foundation for our research.

Literature Review

(B. Zhang et al., 2014) in the study “Natural dye extracted from Chinese gall – the application of color and antibacterial activity to wool fabric” and said that "Mixture strategy for maximising the recovery of coloured phenolics from red pepper (Capsicum annum L.) by-products as prospective source of natural dye and evaluation of its antibacterial activity" (Ksibi et al., 2015) claims that

(Mansour et al., 2017) in the study “The use of response surface method to optimize the extraction of natural dye from winery waste in textile dyeing” and said that the research looks at grape pomace as a potential natural dye for silk and other textiles. Tannic acid is used as a natural mordant in the extraction process, which also includes water-acidified ethanol, temperature, and time.

(Shahid et al., 2017) in the study "Colourful and antioxidant silk with chlorogenic acid: Process development and optimization by central composite design" and said that Using OFT and CCD methods, we refined the silk dyeing process using chlorogenic acid. "We evaluated the colour, fastness, FT-IR spectra, and antioxidant activity". The end result was a light yellowish-brown tint.
(Yin et al., 2017) in the study "Optimization of natural anthocyanin efficient extracting from purple sweet potato for silk fabric dyeing" and said that with the goal of minimising solvent use and environmental impact, this work employs an ultrasonic-assisted ammonium sulfate/ethanol aqueous two-phase system to extract the natural colourant anthocyanin from purple sweet potato powder. Silk fabric dyed using the extracted anthocyanin demonstrated the material's potential as an environmentally friendly substitute for conventional cleaning products.
(Souissi et al., 2018) in the study "Valorisation of natural dye extracted from date palm pits (Phoenix dactylifera) for dyeing of cotton fabric. Part 2: Optimization of dyeing process and improvement of colourfastness with biological mordants" and said that the extraction, optimization, and colour yield of date pits solution dyed cotton fibres are the primary topics of this article. Using a Box-Behnken experimental design, the research shows that biological mordants increase the fastness qualities.
(Aizat et al., 2019) in the study "Valorisation of mangosteen, "The Queen of Fruits," and new advances in postharvest and in food and engineering applications: A review" and said that many scientific disciplines have found uses for mangosteen, a plant rich in bioactive chemicals, such as engineering, food science, and postharvest biology. Industrial items, innovative technology, and biomedical innovation are some of the areas where recent research trends have pointed to its potential.
(Shafiq et al., 2021) in the study "Extraction of Natural Dye from Aerial Parts of Argy Wormwood Based on Optimized Taguchi Approach and Functional Finishing of Cotton Fabric" and said that Argy Worm Wood (AWW) aerial sections were optimally extracted for textile dyeing using the Taguchi technique. The extracts exhibited remarkable antibacterial and UV radiation absorption capabilities, with maximal phytochemical yields reaching 21.96 percent. The textile sector may look forward to this as a potential supply of bio-colorants.
(Diarsa & Gupte, 2022) in the study "The study explores the optimization and extraction of natural dye from Tagetes Erecta and the dyeing of cotton and silk fabric using banana (Musa Sp.) pseudo stem sap." And said that the research aims to enhance the colour strength and fastness attributes of cotton and silk textiles by using natural dye extraction from marigold flowers. Using banana pseudo stem sap as a natural mordant, the ideal dyeing temperature is 80°C for 60 minutes.
(W. Zhang et al., 2022) in the study "Eco-dyeing and functional finishing of wool fabric based on Portulaca oleracea L. as colorant and Musa basjoo as natural mordant" and said that High colour yield and improved anti-ultraviolet and anti-bacterial activity compared to synthetic dyes are achieved in the research by using the Portulaca oleracea L. plant as a natural colourant for wool fabric dyeing.
(Muruganandham et al., 2023) in the study "An eco-friendly ultrasound approach to extracting yellow dye from Cassia alata flower petals: Characterization, dyeing, and antibacterial properties" and said that This research looks at the dyeing industry's use of natural dyes, with a particular emphasis on the process of extracting yellow dye from the petals of the Cassia alata flower. The dye's antimicrobial activity, as well as its washing and rubbing fastness, were examined.
(Talib et al., 2023) in the study "Sustainable Isolation and Application of Plant Extract-Based Natural Dye for Bio-Dyeing of Silk Fabric" and said that the research isolates the black pepper colourant using microwave radiation and then employs bio-mordants to create colorfast hues. It generates dyes, enhances the depth of colour on silk cloth treated with a microwave, and has moderate to excellent colour fastness ratings.

Silk Fabric as a Dyeing Medium

Because of its one-of-a-kind qualities and the historical significance, it has in the textile business, silk fabric is a good medium for dyeing, particularly when it comes to the exploration of natural dyes. Silk cloth is very valuable in the textile industry. Silk, which is composed of protein fibres, naturally has a significant affinity for natural dyes, which allows it to generate colours that are vibrant and deeply saturated. This gives silk the ability to make colours that are a result of its composition. When working with natural dyes, which may provide a varied colour yield compared to their synthetic equivalents, it is of utmost importance to possess this attribute. Silk has a surface that is lustrous and smooth, which enhances the depth and brightness of natural colours. Silk is a naturally occurring material. The dyes are able to reach their full potential as a consequence of this, and the results are visually outstanding, which is something that is not achievable with other kinds of materials. In addition, the delicate structure of silk ensures that the dye is dispersed uniformly and that it is absorbed entirely, which results in a consistent colouring that highlights the subtle tones that are generated from herbal extracts. Silk is a material that is used in the production of silk. Silk is consistent with the sustainability mindset that is driving the use of natural dyes, in addition to the aesthetic and technical advantages it provides. Silk is also ideal for use in the production of silk. Silk, which is a material that is both renewable and biodegradable, offers a holistic approach to the production of textiles that are conscious of their influence on the environment. This is because silk may be combined with colours that are beneficial to the environment. This alignment not only pays homage to the dyeing procedures that have been used for centuries, but it also fits the requirements of today's fashion industry for fashion that is responsible to the environment. Because of this, the selection of silk as a dyeing medium in this inquiry is not only a question of personal taste from a technical standpoint; rather, it is a deliberate step toward bringing together luxury, history, and sustainability in the field of textile art.

Conclusion

In conclusion, this study on the "Optimization and Characterization of Herbal Natural Dyes for Silk Fabric: Extraction, Application, and Functional Evaluation" represents a significant stride in the sustainable use of natural dyes in the textile industry. The successful extraction and application of dyes from herbal sources such as purple cabbage, Ratanjot, Kutki, and Turmeric on silk fabric, achieved through careful optimization of extraction conditions and thorough characterization, demonstrates the viability of eco-friendly alternatives to synthetic dyes. The research highlights not only the environmental benefits of these natural dyes but also their practical efficacy in terms of color vibrancy, fastness, and additional functional properties like antibacterial action and UV protection. By marrying traditional dyeing methods with modern scientific approaches, the study bridges the gap between historical practices and contemporary textile needs. Moreover, the findings underscore the potential for these herbal dyes to invigorate local economies and support sustainable agricultural practices. As the textile industry grapples with the challenges of environmental sustainability, this research provides valuable insights and practical solutions, paving the way for a more responsible and conscious approach to textile dyeing. The implications of this study extend beyond the realm of textile manufacturing, offering a model for integrating sustainable practices into other facets of production and consumption.

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