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Sustainable extraction of natural floral pigment from different flower residues

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Abstract

Concerns about sustainability and environmental issues have grown over the past ten years, and as a result, consumers are pressuring more businesses in the fabric industry to transition from chemical-based synthetic dyes to more environmentally friendly alternatives. It describes some of the environmental impacts of not properly managing floral waste, such as water pollution and methane emissions. This paper discusses how religious flower waste, predominantly comprised of marigold and wax flowers, which are often disposed of in massive quantities via religious practices in India, can serve as a source of eco-friendly natural dyes (including carotenoids and anthocyanins) for sustainable textiles. Methods of dyeing (dry and detergent wash), the role of alum mordanting to enhance colour fastness, and optimizing dyeing conditions (temperature/pH) will be described.

Key Words

Religious flower waste; natural dyes; marigold dye; wax flower anthocyanins; alum mordanting; sustainable textiles

1. Introduction

The global textile industry is in the middle of a paradigm shift towards sustainable practice because people are more aware of environmental concerns and are aware that synthetic colors derived from chemicals are toxic. The conventional use of coal-tar based synthetic colors for a long period resulted in a lot of water pollution. They often contain heavy metals and are carcinogenic; and they do not degrade and are therefore disastrous to marine life. For this reason, research for natural colors that can be derived from botanical sources is on the increase. Of the different natural pigment sources, temple waste flower is an opportunity for value addition. In many countries like India where flowers are intrinsically linked to the cultures and religions, the volume of flowers offered is tremendous. They are usually dumped as waste, causing immense organic load to the water bodies and land. Pigments from these temple wastes are valuable because they are biodegradable dyes, they reduce the problem of managing large quantities of waste, and are an example of "value added waste" thus embodying the concept of the "circular economy".

Extraction of natural pigments from flowers like Marigold and Rose which are abundantly offered as temple waste involves complicated biochemical processes. These flowers contain pigments like carotenoids and anthocyanins, the colors of which can be extracted using both aqueous and solvent methods [1, 2]. But generally natural pigments show a poor fastness because there is poor affinity between the pigment and the fibers. Therefore, mordants are added which provide a bridge between the colorant and fiber [1, 5]. Potassium aluminum sulfate is a frequently used metallic mordant, which is nontoxic, relatively cheap and provides rich and fast colors [1, 5]. By using this process of extraction of pigments by mordanting using alum, high fastness colored eco-fabrics can be obtained. In the following study, we review various approaches used to convert temple waste flowers into textile dyes, environmental aspects and evaluation of the resulting eco-friendly fabrics.

The shift towards a bio-based dyeing system is not just a revival of age-old practices; it is an evolution through technological intervention. Modern scientific studies focus on optimization of extraction process like pH, temperature and concentration to optimize dye yield and reduce energy requirements [2, 4]. Moreover, incorporation of temple flowers as feed stocks for textile coloration is considered as a form of "value addition" to "waste" by producing functional industrial raw materials from dumped biological waste, thus minimizing the carbon footprint by elimination of the energy intensive synthetic petrochemical dyeing industry and leading towards the field of "green" chemistry. Analyzing how cultural and religious significance, as seen in temple waste flowers, can be synergistically applied to industrial sectors illustrates the potential of floral pigments for sustainable textile application.

2. Environmental Impact And Management Of Temple Floral Waste

2.1 Quantities and the ecological implications of religious floral offerings

A phenomenal quantity of floral waste is generated by the numerous religious practices adopted in regions like India where vast amounts of flowers are offered in temples, mosques, etc. Daily. According to a study from the Tata Energy Research Institute (TERI), India is experiencing an annual 1.0%-1.33% increase in waste, where floral waste contributes considerably to the organic solid waste streams of cities. These flowers like Marigold, Rose, Jasmine, etc., being divine in nature are offered in holy rivers (like the Ganges, Yamuna etc.) so as not to be trodden upon or considered waste. This practice has profound negative implications on the aquatic ecosystems. The breakdown of floral waste consuming the dissolved oxygen causes hypoxia and eventually leads to the death of aquatic flora and fauna. Added to this, chemicals used in growing flowers contribute their toxic share to water bodies when leached into them.

Fig.1 marigold flower patels collected from temple (6)

Apart from pollution to water sources, unscientific disposal of temple floral waste causes soil and air pollution. The abundant moisture content in flowers causes it to break down anaerobically in landfills producing methane, which has a GWP 25 times higher than carbon dioxide. These rotten flowers produce an environment for breeding harmful pathogens and public health risks. A management plan based on estimation of the quantity of these flowers is necessary to tackle this great concern. The prevention of waste disposal into water bodies not only poses a solution to pollution but is a resource for obtaining dyes. Thus, the ecological imperative is also an economic opportunity [3]. This seasonal rise in flower waste generated during festival seasons further emphasizes the necessity for a flexible waste disposal system which will aid in reducing these environmental problems as the waste is dumped in sensitive ecosystems, especially since waxes and colors can be extracted from these flowers, making the overall waste disposal process beneficial for human beings and for the environment [3] leading to an adherence of the UN's SDG 12 and 14.

2.2 Current waste management techniques and the CE model

Traditional floral waste management is an area largely overlooked in favor of larger waste streams such as metals and plastics, though in the last few years, several interesting techniques for converting this waste to value added products have come into fruition including composting, vermicomposting and extraction of dyes, ethanol, and biogas [4].
Composting floral waste, often using cow dung or other catalysts, results in a useful nutrient- rich fertilizer though its waste is not completely valuable as most of the high value chemical compounds such as pigments and essential oils from the flowers remain. The CE model focuses on making full use of every aspect of waste in a "closed loop" cycle where a primary step of dye extraction would be performed, and then the remaining floral pulp utilized for a second application such as the adsorption of heavy metals or composting [5].

In the circular economy model, a staged approach would be required for floral waste utilization, starting at the point of source (temples and markets) where the flowers are collected and segregated. Following collection the flowers would be cleaned and dried so that microbial degradation is inhibited. The pigment extraction stage would then follow which would need to be as eco-friendly as possible. The byproduct residue or "herbal pulp" would remain and could then be used for another industrial purpose as shown in an article in which the residual pulp from rose petals was used for heavy metal adsorption (e.g. Pb2+) [5]. This layered approach ensures the maximum yield from waste. Such a scheme contributes to minimizing the negative impacts from waste on the textile sector and environmental impacts while also increasing the opportunities for local income.

Green chemistry principles need to be applied to the extraction process to ensure its compatibility with the CE model. It is necessary to minimize or eliminate the use of harsh chemical reagents and solvents and, instead, utilize eco-friendly water or organic solvents such as ethanol, which can be recovered easily. Using naturally occurring chemicals such as alum as a mordant (which is better for the environment compared to heavy metal mordants such as chrome or copper) ensures the sustainable extraction and application of dyes. The transformation of temple waste to dye represents the practical application of the CE to solve an environmental problem that would also have significant benefits for the Indian economy, the environment and public health.

2.3 Potential of Marigold and Rose species as natural pigment sources

Although there is a myriad of flowers included in temple waste, marigold and rose species represent a potential significant source of natural dyes. Marigold flowers used in religious practices for their vibrant colors representing sanctity have yellow and orange tones as they are composed of carotenoids (such as lutein and zeaxanthin) which have antioxidant qualities and produce warm shades of yellow and orange, that bind well to natural fibers [1]. These carotenes from temple waste are highly effective in dye extraction, and the produced dyes are suitable for natural textiles like cotton and silk [1]. Marigolds are readily available all year round thus proving to be a cheap and steady source for this application.

Rose species used for perfumery and for religious practices have high levels of anthocyanins, a water-soluble compound which produces a wide range of red and purple tones (sensitivity of anthocyanins to pH varies thus can be controlled by pH of the dye bath) [5] and flavonols. These compounds also show potential anti-microbial and UV protective qualities [5]. Industrial scale production of dye from rose waste has also proved cost effective using a simple extraction technique and the dyed materials such as wool have been shown to hold a reasonable amount of dye [5]. This shows that rose petals can compete with artificial reds.

Besides color, there are also other components in rose and marigold flowers which can give a skin friendly and pleasant smelling textile and this is beneficial in the 'wellness textile' sector. Using such naturally derived colors from waste also reduces the dependence of the fashion industry on monocultures that could be detrimental to the biodiversity of regions.

3. Mechanisms of Pigment Extraction and Alum Mordanting Process

3.1 Extraction Techniques for floral anthyocyanins and carotenoids from aqueous and solvent-based means.

To produce dyes from waste, the components needed for color must first be extracted from the flowers. There are two classes of compounds relevant to color: carotenoids which are lipid soluble and create yellow, red and orange colors and anthocyanins, water-soluble and responsible for reds, blues and purples. Aqueous extraction of Anthocyanins, which is most effective for flowers like rose and hibiscus, involves boiling dried, ground flower material in water for a determined amount of time [1, 2]. This is cheap, simple, requires no toxic reagents and is beneficial in preserving water-soluble pigments from thermal damage as it is relatively low cost. However, its efficiency is still low as the pigments can become unstable due to the heat.

To extract carotenes, it is preferable to use an organic solvent as they are lipid-soluble. The most 'green' solvent available to use would be ethanol, as it is biodegradable and easily recoverable [2]. Other such solvents include methanol, however if they are not recovered then it becomes a pollutant. Ultrasound or microwave assisted extraction techniques (UAE or MAE) have become very useful as they are lower temperature alternatives and more efficient in extracting color from pigments as the cell wall structure of the flower is disrupted. [1, 2]. Other variables such as the ratio of solid to liquid and stirring speed can affect the yield from the waste, and needs to be considered when optimizing dye extraction [3]. The dye can then

be used to dye materials, with the color strength being measured against common synthetic dyes.

3.2. Chemical role of potassium aluminum sulfate in fixation and coordination of colors

One of the main drawbacks of natural dyes is its relatively poor substantivity or fixation onto the textile fibers, specifically upon the cellulosic fibers like cotton. Most natural pigments adhere weakly to the fiber via non-covalent bonds such as hydrogen bonding or Van der Waals forces compared to synthetic dyes that form stable ionic or covalent bonds onto the fiber. These naturally dyed textiles possess low wash fastness and light fastness. A mordant is employed to fix the dye onto the fiber. Potassium aluminum sulfate, common known as alum is the most used mordant in natural dyeing industries. It acts as a bridging agent that facilitates the formation of a coordination complex between dye molecule and the fiber. The aluminum ion Al^{3+} has strong affinity towards the hydroxyl group in cellulose and also the carboxyl and amino groups in protein fibers, e.g. Wool, silk, etc., while it complexes with dye molecule via the function groups like hydroxyl in anthocyanin or carbonyl group in carotenoid derivatives [1, 2]. With such complexes formed, the molecule size of pigment inside the fiber matrix increases, thus cannot easily be washed out. This process is called co- ordination or chelating.

Fig.2 silk fabric was dyed with marigold flower dye [6]

Alum is the most desirable mordant because it is known as brightening mordant; compared to iron or copper mordant which results in "saddening" or darkening of colors. The bright yellows of marigold and the light pinks of roses remained vibrant after mordanting with alum [5]. Also, it is safe and non-toxic, therefore acceptable for the application to the "organic" fabrics. It can comply with green chemistry requirements. It is considered one of the highest performance mordant as compare with the heavy metal mordants such as potassium dichromate or tin [2, 5]. Depending on how the mordant is applied to the fabric: pre- mordanting, meta-mordanting or post-mordanting; the performances would be different. The fabrics were mordanted by treating with alum solution prior to dipping into dye bath is called pre-mordanting.

Aluminum ions would fill the fiber binding sites, thus the dye molecules would enter and bind uniformly. In meta-mordanting, alum is added directly into the dye bath to simultaneously dye and mordant; while it would potentially result in precipitation of the dye. Post-mordanting is done after the fabric has been dyed. It is mainly used to shift the hue and improve the fastness. However, pre-mordanting is commonly found to give best colors fastness in dyeing temple waste with alum [1]. Knowledge of co-ordination mechanism of alum helps in fine-tuning the parameter so as to improve the functionality of bio-based dyes on textiles in an industrial perspective.

3.3. Optimization of temperature and concentration parameters for maximum dye yield

To achieve the optimum dye yield and good consistency in colors, a careful optimization of the extraction and dyeing parameters needs to be done. Temperature is one of the most important factors. High temperature leads to increased solubility of pigments and fast diffusion of pigments from plant matrix into the solvent. However, many natural pigments are sensitive to heat. For example, anthocyanins undergo thermal degradation at about 80 C thus result in decreased color intensity and shifted hue. A balance temperature must be obtained between the maximum yield and pigment integrity. Temperatures from 60 to 70 C are known to give a relatively good yield for dyes from marigold and roses [1, 5]. The concentrations of dye and mordant are also important parameters affecting the final shades and fastness. The greater the amount of floral waste in extraction bath, the higher the dye concentration in dye liquor and thus a stronger color can be obtained on fiber. However, there would be a maximum point where solvent becomes saturated. The alum concentration is important to ensure sufficient binding of dye to fiber. If the concentration is too low, it may result in poor dye fixation and low fastness. If it is too high, the fiber might become harsh and brittle or there may occur "bronzing" on the surface of fiber because the dye sits on the surface.

Typical alum concentrations used ranged from 5-20 % on the weight of fabric (owf) depending on the fibers type and desired depth of color [1]. Dyeing time (dwell time) also needs to be sufficiently long so that the pigments can be released and the dye-mordant-fiber complex can be formed effectively. For floral waste dyeing, 60-90 min for extraction and 45- 60 min for dyeing time are normally utilized [1, 5]. Apart from this, pH of the dye bath is another factor which can strongly affect the color of naturally dyed fabrics. For anthocyanins, they act as natural pH indicators from red (acidic) to purple or blue (alkaline). In natural dyeing, one kind of flora might produce a few colors under different pH value. Optimization of parameters: temperature, concentration and time is critical to convert a traditional craft into a process for industrial textile coloration that is both sustainable and reproducible.

4. Application and Performance Evaluation of Biodegradable Dyes on Fabrics

4.1. Dyeing kinetics and affinity of natural pigments for eco-friendly fibers

Natural dyes are applied to fibers according to principles of dyeing kinetics and thermodynamics. The process refers to how dye molecules diffuse from solution onto the fiber surface and get adsorbed and diffused inside the fiber matrix. Affinity of natural dyes obtained from temple waste varies on different types of fibers. Generally, protein-based fibers like wool and silk possess more affinity to natural dyes since they contain abundant polar groups such as amino and carboxyl groups, which can strongly bond with the mordant-dye

complex [5]. Cellulose fibers such as cotton have higher crystallinity and more neutral chemical nature, therefore the large dye molecules diffuse into the fiber interior more difficultly, which is why mordant such as alum plays such a crucial role in enhancing dye fixation on cotton fibers [1]. Dyeing kinetics process involves three main stages: dye molecule diffusion through the dyebath to the fiber surface, adsorption of the dye onto the fiber surface, and diffusion into the inner structure of the fiber. For floral waste dyes, these processes are relatively slow. Higher temperature may facilitate the migration of dyes into fibers and improve dye uptake. Nevertheless, since some natural pigments are not heat stable, one needs to ensure an optimal balance between extraction yield and pigment stability.

Aggregation state and surface charges also contribute to the adsorption of dyes onto fibers. Langmuir or Freundlich isotherm models commonly describes adsorption of natural dyes on fiber surfaces and shows that binding sites would become saturated once filled with dye molecules. The dye migration rates are influenced by various factors such as temperature, time, agitation, and the presence of mordant which may alter surface charge on fibers [2].

Environmental aspect of fibers is one of the key factors while developing bio-based dye system. Natural dyes should be used on bio-based fibers in order to create totally biodegradable product. Rose based dye fixation on wool fibers has been well reported, showing that wastes from rose oil industry are potential sources for natural dye application [5]. The affinity between bio-based dye and natural fiber is not simply chemical, but an integration and symbiosis process. By optimizing dye kinetics and affinity for the substrates, researchers will be able to improve utilization of temple wastes for natural dyes and ensure that dyed textiles are suitable to meet a market demand for their sustainability and effectiveness.

4.2. Assessment of color strength and fastness properties against light and washing

Color strength and fastness are the most critical attributes determining the suitability of a dye system for commercial purpose. Color strength of a dyed substrate is normally quantified by the K/S ratio value measured using a spectrophotometer which reflects a light-reflectance of dyed fabric and its color pigment concentration. A study on marigold and rose wastes dyed fabrics with alum mordanting reveals that K/S values of the natural dyes are comparable with those available from synthetic dyes in market [1, 5]. The color depth can be further intensified by using higher dye concentration and multiple dippings. Colors achieved were often called living colors due to their richness and complexity in comparison with flat monochromatic shades from synthetic dyes. Fastness properties indicate how the color remains under certain condition. Washing fastness describes whether the dyes wash out or fade after washing. Since alum forms a stable bond with the dye molecule and the fiber surface, a dyed sample with temple waste may attain high washing fastness of 3-4 or 4-5 on a 5 point scale [1, 5]. Light fastness, however, is another problematic aspect of many natural dyes. Anthocyanins for instance, are easily degraded by ultraviolet radiation from sunlight.

Alum can help to stabilize pigment molecule, but still the light fastness score may lower than that of synthetic dyes. Despite that, the light fastness from natural floral dyes may still be suitable for application on many textile goods. Color fading may also be considered as development of garments character. Rubbing fastness (crocking) is another test which describes tendency for dye transfer during rubbing. The good quality dyes from rose waste showed good rubbing fastness which means that the dyes were effectively fixed to the fiber, not only on surface [5]. It is essential to assure customers the quality of the bio-based textile

goods. With reliable data from scientific studies, the utilization of textile wastes to natural dye application may be promoted as a common practice in textile industry.

Determination of Color Fastness					
	Fastness to Rubbing				
Samples	Dry	Wet	Fastness to washing	Fastness to Sunlight	Fastness to Pressing
CO	4.6	3	4	3	3
CY	4.3	2.3	3	4	4
LO	4	3.3	4	3	4
LY	4	3.3	3	4	5

Table.1 examination of color fastness in different samples of fabrics [7].

4.3. Comparative analysis of synthetic versus bio-based dyeing system

Comparison of textile coloration via synthetic and bio-based systems is critical in deciding upon future technology development. Synthetic dyes are favored due to their low cost, wide range of colors, and good fastness. However, synthetic dyeing processes are energy-intensive and depend on petro-based non-renewable resources. The textile effluent from the processes could contain harmful chemicals and are often difficult to be treated [2]. Bio-based dyes produced from temple wastes are inherently biodegradable and safe to the environment [4, 5]. The materials are abundantly available as byproducts from existing industries. It conforms to the concept of circular economy, as the waste floral pulp could be utilized for other purposes [5]. Although synthetic dyes have superior light fastness and shade consistency, bio-based dyes often exhibit functional properties lacking in synthetic dyes, e.g. Antimicrobial or UV protection [5]. Market is now strongly driven by customer preference to eco-friendly, ethical, and natural products. Bio-based textile dyeing system has proved a strong candidate and potential substitute for traditional synthetic processes. The coexistence of two types of dye systems in the near future would be an ideal situation where bio-based dyes are prioritized whenever applicable so as to reduce industrial waste and carbon footprint of the global textile consumption.

5. Conclusion and Future Work

The valorization of floral waste from temples for textile dyeing marks an important step towards building a sustainable and circular textile sector. Throughout this review, we have examined the various stages involved, from addressing the ecological impact of the mismanagement of religious offerings to detailing the advanced chemistry of pigment extraction and alum-assisted fixation. It is clear that floral sources such as Marigold and Rose, readily available and currently wasted in large volumes, possess high-quality, biodegradable pigments [1, 5]. Using green methods for extraction and non-toxic mordants such as alum, a strong and durable dye can be produced for textile applications, which also significantly reduces the environmental impact of textile dyeing. The system addresses the problem from two perspectives: it reduces pollution caused by the breakdown of the organic matter in landfills and water bodies and simultaneously presents an alternative to harmful, petroleum-based synthetic dyes [3, 4]. The implementation of the system within a closed-loop economy, such as utilization of the residual plant material as an adsorbent or compost, further improves the system's sustainability [5]. However, several limitations need to be addressed before it can be successfully commercialized. There is a great deal of further research required in the field of "green" finishing agents for improving the light fastness of the natural dyes to widen its application. Another area of further research is focused on identifying additional flora such as hibiscus, jasmine and chrysanthemum that occur in the floral waste generated from temples to increase the spectrum of color range and on establishing small- scale, community-based processing units adjacent to major temples, which will serve as an example of localized sustainable development, employment generation, and reduced transportation costs. Also, the functional properties such as antimicrobial and UV-protective aspects of natural dyes needs to be quantified for promoting "wellness textiles". With the increasing need for environmental friendly production and consumption patterns across the globe, transformation of waste to value using plant pigments represents a potent example of how age-old practice can blend with scientific advancement for a greener future and it is upon us to continue developing the technology at industrial scales and give due recognition to the ritual's intrinsic aesthetic value, by extending its vibrancy into our very attire.

References

1) Treasa, S., 2018. A study on dyeing of eco-friendly fabrics with temple waste flower - Tagetes erecta. http://117.239.78.102:8080/jspui/bitstream/123456789/1690/1/SHERIN%20TREASA%20%28%20SM16MFD004%29.pdf
2) Dey, P., Dey, P., Hoque, M.B., Barla, B. et al., 2025. Sustainable and eco-friendly natural dyes: a holistic review on sources, extraction, and application prospects. Textile Research Journal. https://doi.org/10.1177/00405175251321139
3) Srivastava, N., 2022. Temple floral waste management in India. In: Floral Waste Management (or relevant book chapter). https://doi.org/10.1007/978-981-16-4230-2_37
4) Bennurmath, P., Bhatt, D.S. and Gurung, A., 2021. Novel green approaches towards utilization of flower waste: A review. Environment Conservation Journal. https://doi.org/10.36953/ECJ.2021.22327
5) Karaboyaci, M., 2014. Recycling of rose wastes for use in natural plant dye and industrial applications. The Journal of The Textile Institute, 105(11), 1160-1166. https://doi.org/10.1080/00405000.2013.876153
6) Mishra, V., Verma, M., Singh, A., Singh, K.J., Tewari, S.K. and Pal, M., 2025. Green Textile Innovation: Silk Dyeing with Temple Floral Waste. International Journal of Biochemistry Research & Review, 34(2), 35-41. https://doi.org/10.9734/ijbcrr/2025/v34i2962
7) Treasa, S., & Paulose, V., 2023. A study on dyeing of eco-friendly fabrics with temple waste flower – Tagetes erecta. International Journal of Emerging Technologies and Innovative Research, 10(6), d813-d819. https://www.jetir.org/papers/JETIR2306406.pdf