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Utilization of temple floral waste for extraction of valuable products: A close loop approach towards environmental sustainability and waste management

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ABSTRACT: This study presents the natural dye recovery from various biodegradable temple and household wastes. The raw material for colour extraction consisted residual flowers and garlands from various temples as well as onion and vegetables peels from vegetable markets, university hostels, and households, which were washed, dried, crushed, and sieved. The extracted natural colours were produced by means of ultra-sonication, and were dried in the spray drier, being characterized by FT-IR and UV-Vis Spectrophotometers. They were used to dye various fabrics such as cotton, silk, and wool, not to mention different mordents. It was found out that the remaining residue, left after dye extraction, was rich in nutrients, hence, it could be further used as the resource material, itself. As a result, we explored these residual wastes for vermicomposting and biochar production, which can be further employed as an organic fertilizer for agriculture. Overall, the present waste management approach will lead to a closed-loop environmental management through waste reduction and reutilization. It will also provide value-added materials for economic gains from waste. Thus, it can be promoted as a potential mechanism to maintain the environmental sustainability at wider scales.

Keywords: economic sustainability, natural colour extraction, waste management.

INTRODUCTION

The 21st century has been called the "Century of the Environment" with the current society facing the adverse effects caused by climate change, itself a product of global warming and increased environmental pollution. A healthy and sustainable future is expected to be constructed by proper policies, education, innovation in Green technology, and compatible relationships between the Governmental and Industrial sectors of a country (Sukholthaman and Shirahada, 2015; Shekdar, 2009).

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Waste management is the most debatable issue in the globalized field of research, a trend that seek outcome the most. While examples of domestic, organic, temple, and agricultural wastes such as rotten fruits, peels from vegetable processing, flower trimming, agriculture residue, etc. are biodegradable, if not managed properly, it causes severe nuisance like water and land pollution through its decomposition and nutrient leaching. The appropriate management of such waste could provide as resource materials for a range of processes in industries like biochar from agricultural waste (Singh et al., 2013) color extract from domestic and temple waste. This waste could serve as a source for the extraction of natural dyes for textile-drying operations and biochar based fertilizers (Bernal et al., 1998).

The use of synthetic dyes is consumed more in various textiles, papers, fabric, leather, and cosmetic industries (Sajab et al., 2011; Wang et al., 2014; Singh et al., 2015a) as a result of their faster colouring and efficient ability of binding to natural and synthetic fibbers and diverse colour combinations, not to mention their tolerance against sunlight and other environmental effects (Singh et al., 2016a,b). However, even in their low concentrations, they are regarded as a great menace not only to humans but also to other living organisms, which is due to their toxic, carcinogenic, mutagenic, and teratogenic nature as such or through their intermediates (Singh et al., 2016a). Considering various harmful effects of synthetic dye, there is need for the sustainable variety of natural dyes, which is less harmful and more eco-friendly. Figure 1B shows various applications of natural dye. Managing floral waste from temple is the need of hours. Huge amounts of marigold flowers are offered in temple in India, creating a massive amount of waste. Varanasi, situated in Uttar Pradesh state of India, considered to be the oldest living city of the world, is one of the most religious capitals of India, due to diverse types of temples located in the city. It has been estimated that about 23000 temples are situated in Varanasi only. As the city is located at the bank of River Ganges, mostly flower wastes are dumped in into the river which causes adverse effect on the river ecology, making a foul smell along with a breeding center for variety microbe-related diseases. However, this is not the problem of this city only, but throughout the Indian subcontinent (Padmavathiamma et al., 2008; Wani et al., 2013; Murthy, and Naidu, 2012). Looking into the hazardous impact of improper waste disposal in the environment, our emphasis is to extract the valuable dye, for temple wastes are chiefly rich in marigold flowers and other type of flower (Sajab et al., 2011; Wang et al., 2014; Singh et al., 2015b; Mehanta and Tiwari, 2005).

The waste flowers were collected and used for industrial textile dyeing. Temple wastes mainly consist of marigold flowers, which are a rich source of caroteniod–leutin and flavonid-patulinin, two colorants that have been isolated and utilized for dyeing. Recycling temple wastes after dye extraction mostly consisted of organic matter. This was done through vermitechnology using *Eisenia fetida* and biochar synthesis with pyrolysis. Physicochemical characterization of vermicompost and biochar were carried out and its impact on soil nourishment, seed germination, and plant growth were studied. The present study has shown the complete recycling and utilization of flower waste in diverse sectors, ranging from agriculture to dye industries. It also has dealt with the application of waste water treatment.

MATERIAL AND METHODS

Marigold flower waste was collected from various temples of Varanasi, India. Fibres were procured from carpet waver (Bhadoi India). All other chemical, used in this study, were in analytical grade, purchased from Merck Chemicals India. In order to get dye powder from the extract spray driers were used.

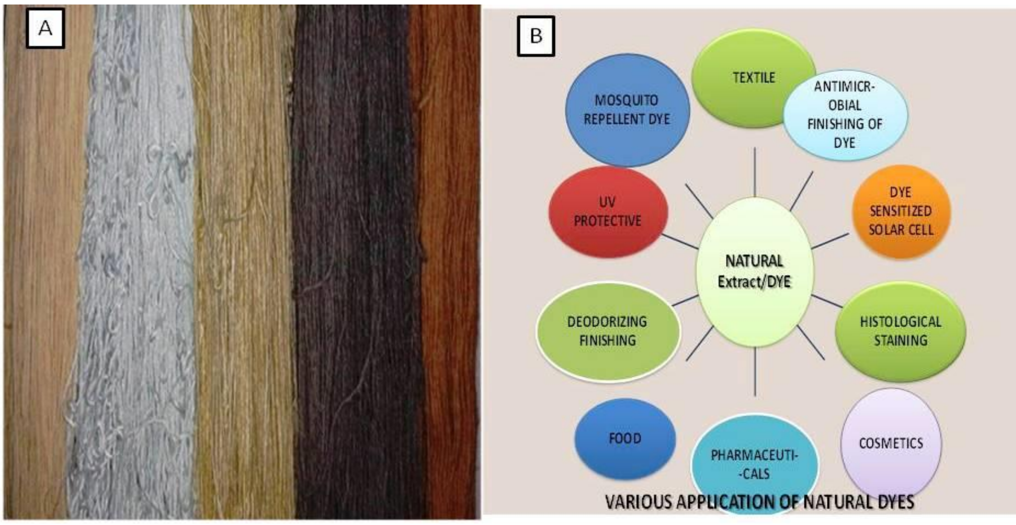

Fig. 1. (A) Coloured fabric from the extracted dye, (B) Various applications of natural dye (adapted and redrawn from Sajab et al., 2011)

Fig. 2. (A) Extract of natural colorant from waste marigold flowers, (B) Floral waste from a temple

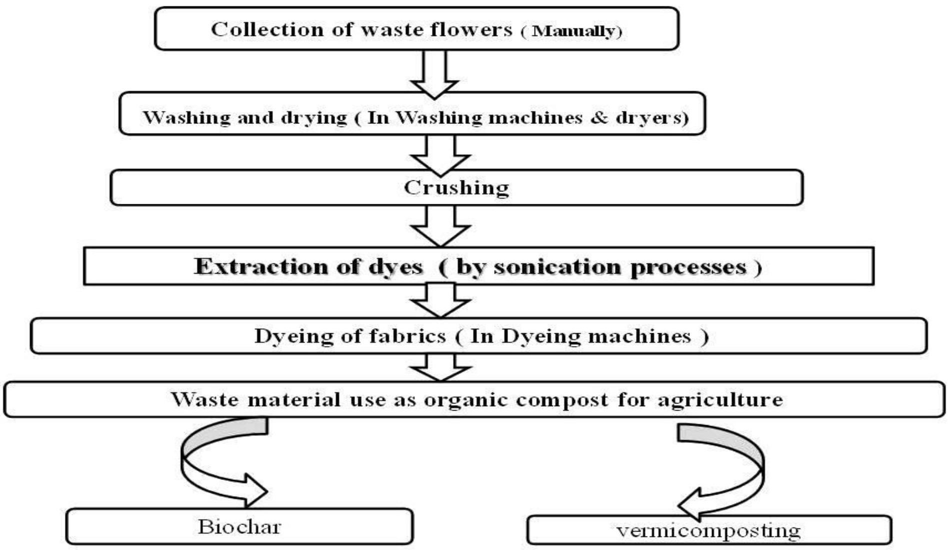

Fig. 3. Illustrative representation of sustainable utilization of floral and vegetable wastes

Collection of waste flowers

Marigold flowers, and other flower types, were collected from various temple waste bins. The collected materials were segregated and the flowers were washed and dried in a hot air dryer at 50°C. Other materials such as plant leaves are typically used to prepare biochar and compost, along with the waste, released from extraction. Figure 3 shows the whole process.

RESULTS AND DISCUSSION

UV-Vis spectrum of natural dye from marigold (segregated from temple waste) flower was obtained and analysed at the wavelength of 370 nm by AU-2701 double beam UV-VIS Spectrophotometer (Fig. 4).

Colorant extraction

Ultrasonic assisted extraction: Solvent extraction

In colour extraction process, various techniques have been used such as soxlet extraction as stated in earlier reported literatures. However, we used ultrasonic assisted extraction: The flowers were crushed in the crusher. Methonol (10 ml/g of crushed materials) was added in the crushed flower petals and then the pH was adjusted at 2.0 by using diluted NaOH and/or HCL to attain maximum colour extraction (Mishra et al., 2012). The beaker was then placed in the ultrasonic bath to be sonicated for 40 min. After sonication, the beaker's content got filtered through various sieves so that the solid materials would be removed. The filtrate colour liquid was vacuum-evaporated in a rotary vacuum, maintaining only half of its original volume. The concentrated liquid was spray dried. The inlet and outlet temperature were kept at 110 and 70°C, respectively at an aspiration speed of 1200 rpm (Mishra et al., 2012; Phillips and Mondal, 2014; Ghouila et al., 2012; Bhuyan and Saikia, 2004).

Gravimetric analysis

After spray drying process, the samples were taken and dried in hot air oven for 10–15 min to remove the moisture, then to be cooled in desiccator and weighted so that the extract's weight could be determined. The weight of the colorant extract obtained per gram of the plant materials was calculated. As for the yield, it was calculated by means of the equation below (Mehanta and Tiwari, 2005).

$$\%\ \text{Yield of natural colorant} = \frac{\text{Natural dye exrtacted}\,(g)}{\%\ \text{Amount of plant materials used}\,(g)}$$

Characterization and Analysis of colour

The colours, extracted via ultra-sonication processes, were further characterized by UV–Visible adsorption spectra, recorded on double beam spectrophotometer (SYSTRONICS AU-2701 double beam UV-VIS Spectrophotometer) ranging between 220-800 nm (Fig. 4). The FT-IR spectra (Thermo NICOLET 5700, USA) of the dye were obtained by means of KBr pellet method in a spectral range of 4000-500 cm^{-1} (Fig. 5). The fastness property of the dyed fibres was measured with the test method ISO 105-X for colour fastness to rubbing: ISO 105 CO_2 for colour fastness to washing and ISO 104-B02 for colour fastness to light (Mishra et al., 2012; Tiwari et al., 2010; Gurav and Pathade, 2010).

FT-IR analysis gives important characterizations of the samples in order to identify the functional group on the marigold extract's dye surface. In the dye analysis, the distinct peaks were revealed at 3355, 2926, 1655, 1379, 1076, and 514 cm^{-1} (Fig. 5). The broad and strong peak, located at 3355 cm^{-1}, indicates the presence of aliphatic C-H stretching from CH_2- group. The O-H stretching vibration can be assigned to the band that appears at 2926 cm^{-1} (Mishra et al., 2012).

Dyeing processes

The wool yarns were washed with 1% non-ionic soap at 50°C for 20 minutes and then the fibre was washed with water and dried at normal temperature. For moderating purposes, alum and sodium-potassium were used, as described by Mishra et al. (2011). The dye solution got prepared with M:L ratio, being equal to 1:15, and pH=6.0, the latter adjusted by diluted acetic acid. A sum of 5 g of the prepared fibre was used with mordant and the temperature was raised to 90°C and continued for 30 min. After the dyeing process, the fibre was washed with cold water and non-ionic soap (Venkatasubramanian et al., 2011; Mehanta and Tiwari, 2005). Figure 1A shows the dyeing fabric.

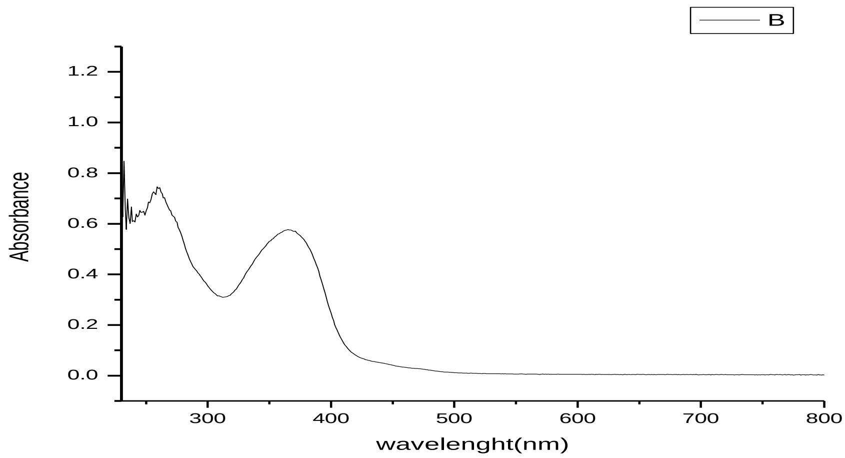

Fig. 4. UV-Vis spectra of Marigold dye at 370 nm

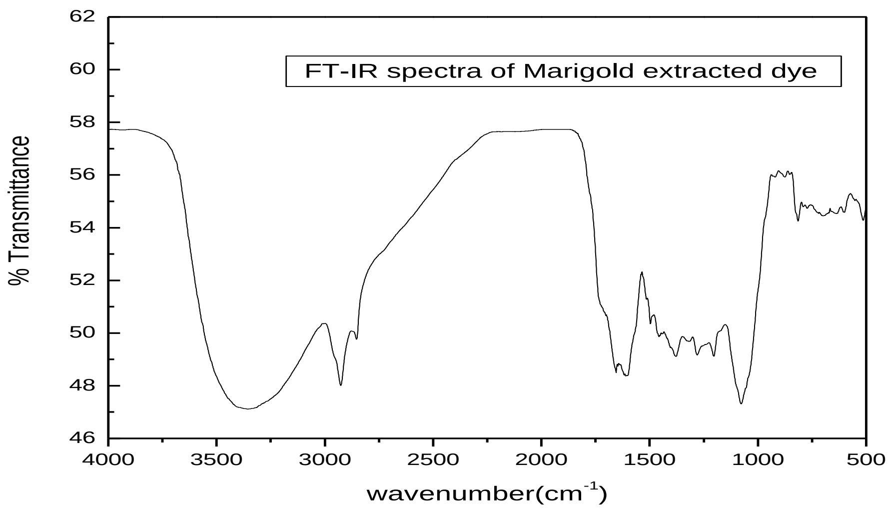

Fig. 5. FT-IR spectra of marigold extracted dye

CONCLUSION

The present study has shown the potentiality of temple floral waste for extracting various valuable products. Natural colour, extracted from floral waste, can be used to dye fabric at an industrial scale. The waste, generated after colour extraction, is also a potential source for vermicomposting and can be further used as a fertilizer in crop fields. We have also proposed bio-char synthesis via pyrolysis process of floral waste, which can be used for various applications such as soil amelioration (Singh et al., 2015b), being an adsorbent for the removal of pollutants from waste water (i.e. dye, heavy metals, and other organic compound). Due to their high organic content, temple wastes mixed with kitchen one can be used to generate biogas. This study also presented the complete recycling and total utilization of floral waste in diverse sectors, ranging from agriculture to dye industries and finally in waste water treatment application. Considering the hazardous impact of improper waste disposal on the environment, the present study aimed to extract valuable natural dye at industrial scale, thus properly managing the wastes, regarding it as a source of wealth which by means of total recycling leads to environmental sustainability.

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