Industrial Crops and Products 50 (2013) 618–624

Contents lists available at ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

Role of cationic and anionic surfactants in textile dyeing with natural dyes extracted from waste plant materials and their potential antimicrobial properties

Sasmita Baliarsingh, Jyotsnarani Jena, Trupti Das, Nalin B. Das*

Institute of Minerals & Materials Technology, Council for Scientific and Industrial Research (CSIR), Bhubaneswar 751013, India

ARTICLE INFO

Article history:
Received 20 February 2013
Received in revised form 13 August 2013
Accepted 15 August 2013

Keywords:
Natural dyestuff
Anionic surfactant
Cationic surfactant
Dyeing
Textiles
Bacterial strains

ABSTRACT

In the last few years, an increasing interest has been developed to the potential use of plant waste as raw material to produce natural dye for dyeing textiles due to environmental aspects. The current study deals with the solvent extraction of natural dyes from three native plant species such as *Mangifera indica*, *Glochidion lanceolarium* and *Litsea sebifera*, statistical analyses, and dyeing techniques on silk and cotton yarn using cationic and anionic surfactant. The dyed yarns displayed excellent antimicrobial activity against the bacterial strains for the development of antimicrobial textiles. The interaction of natural dyes with a cationic surfactant, cetyltrimethyl ammonium bromide, and an anionic surfactant, sodium dodecyl benzene sulphonate, found to be significant. The colour strength of the dyed yarn using cationic surfactant was found to be better and higher than the anionic surfactant. From the dye absorption, it was observed that the dye intensity was enhanced with the increase in dye absorption by the yarns. The reports foresee developing a sustainable technology for utilization of waste bio-resources for the economic growth of the rural weaver's societies in India.

1. Introduction

The use of non-allergic, non-toxic and eco-friendly natural dyes on textiles has become a matter of significant importance due to increased environmental awareness in order to avoid use of some hazardous synthetic dyes (Sewekow, 1988; Bechtold et al., 2003; Samanta and Agarwal, 2009). The market impact of natural dyes is expected to increase in coming years in both large and small-scale segments. There are at present many leading natural dye textile companies in India where these dyes are used on textiles (Vankar, 2007). India has rich natural plant diversity and a large proportion remains unexplored. It is critical to explore the extraction of natural dyes and the standardized dyeing techniques need to be adopted from abundantly occurring plant resources. Low exhaustion colours and the poor fastness properties of dyed fabrics are some of the problems in traditional dyeing with natural colourants. These problems has been dealt with the help of solvent extraction of colourants for dyeing textiles using appropriate dyeing methods to improve fastness properties (Hwang et al., 1998; Lee and Kim, 2004; Burkinshaw and Kumar, 2009).

Surfactants play an important role in the textile industry and dyeing of textile is an obvious application. The added surfactants serve to support the uniform dispersion of the dyes in the dyeing media and proper penetration of the dyeing solution into the fibre matrix. Proper fixing of the dye on the surface enables uniform depth colouration of the textiles (Myers, 2006). Our previous study reports (Baliarsingh et al., 2012) the solvent extraction of dyes from dye yielding plant species and evaluation of their dyeing characteristics on the textiles using metal salts as mordant. In order to obtain acceptable property of colour shade development and fastness, complete penetration of natural dye into the yarn is essential. Surfactants containing both hydrophilic and hydrophobic moieties play a useful role in textile processing, ideally in water medium by wetting the fibre surface quickly and uniformly. Further, these are used as levelling, dispersing, and wetting agents in the dyeing process. The surfactants can form a complex with ionic dyes or they can facilitate absorption of nonionic dyes. The interactions of the dyes with surfactants are of great importance for improving dyeing processes (Simoncie and Kert, 2002; Gokturk and Tuncay, 2003). However, not much attention has been paid to the interaction between natural dyes and surfactants. There are very few reports (Acharya and Rebery, 2009; Chandravanshi and Upadhyay, 2011) on natural dye–surfactant interaction. Therefore, it is worthwhile to make further studies involving natural dyes obtained from plant resources.

In the current study, the interaction of extracted natural dyes from the plant species, *Litsea sebifera* (bark), *Glochidion lanceolarium* (leaf), *Mangifera indica* (eaf) with a cationic surfactant, cetyltrimethyl ammonium bromide (CTAB), and an anionic surfactant, sodium dodecyl benzene sulphonate (SDBS), have been

* Corresponding author. Tel.: +91 674 2379330; fax: +91 674 2581637.
E-mail addresses: nbdas@immt.res.in, nalinbihareedas@gmail.com (N.B. Das).

0926-6690/$ – see front matter
http://dx.doi.org/10.1016/j.indcrop.2013.08.037

investigated for dyeing silk and cotton yarns. Their potential antimicrobial efficacy against common human pathogens has also been carried out. The colourimetric parameters of dyed samples and the dye absorption percentage have been evaluated. A comparative study of the colour strength of two surfactants with respect to metal salt used as mordant is also reported.

The pigments from the plant resources are flavonoids, quinonoids, indigoids, tannins, carotenoids, etc., which are responsible for dyeing textiles. They represent (Gulrajani and Gupta, 1999; Bechtold, 2009; Siva, 2007) potential alternative to synthetic dyes having higher value and comparable quality. Natural dyes from *Punica granatum* and many others are reported (Gerson, 1975; Hussein et al., 1997; Han and Yang, 2005; Prusty et al., 2010; Khan et al., 2011) as potent antimicrobial agents owing to the presence of a large amount of anthraquinones, flavonoids, tannins, naphthoquinones, etc. There is a dearth of systematic studies on bioactive retention of natural dyes into textile materials that find extensive use in different sectors related to health and active life style. The plants under study *L. sebifera* (Pullaiah, 2002; Rahman et al., 2007), *G lanceolarium* (Sandhya et al., 2010; Pullaiah, 2006) and *M indica* (Islam et al., 2010; Wauthoz et al., 2007; Masibo and He, 2008) have been reported to exhibit brilliant medicinal properties against diseases like urinary problems, rheumatism, haemorrhoids, ant-diabetic, eczema, jaundice, anti-inflammatory, analgesic, anti-tumour, antiviral, leucorrhoea, anti-oxidants, CNS depressant, hypoglycemic, anti-cancer and stomach ailments.

Healthy and active lifestyle has led to a rapidly increasing market for a wide range of antimicrobial textiles, which in turn, has stimulated intensive research and development efforts. The dyed yarns with the extracted natural dyes have explored for their potential antimicrobial properties against common human pathogens, such as *Klebsiella pneumoniae*, *Escherichia coli*, *Streptococcus pyogenes*, and *Staphylococcus aureus*. The study envisages the possible use of these naturally dyed yarns in developing protective clothing against common infections.

2. Materials and methods

2.1. Materials

The plant materials such as waste leaves and bark (without causing any harm to the plant) of the plant species *L sebifera* (family: *Lauraceae*), *G. lanceolarium* (family: *Euphorbiaceae*) and *M indica* (family: *Anacardiaceae*) were selected for the present study. The different parts of plants were collected from Mohendragiri forest zone (latitude – 18°58′ N and longitude – 84°20′60″ E), Paralakhemundi, Odisha, India. The collected plant parts (5000 g each) washed under flowing water to remove dust particles and shade dried at room temperature (24–25 °C). The processed plant parts were grinded to powder form in an electrically operated grinder. Heating mantle, soxhlet extractor, condenser, and round bottom flasks were used for the extraction of the natural colourants. Water bath with automatic temperature control was used for dyeing yarns. Degumming of raw silk yarn was carried out using 15–20% alkaline soap solution (150–200 g of soap bar in 1 L water at pH 8–9) at near boiling temperature, washing with running water and drying at room temperature. Bleaching of natural colouring materials present in cotton yarn was done by chlorine bleaching, washing with running water and drying at room temperature. Textile materials, de-gummy mulberry silk yarn 20/22 denier (9000 m weighs 21 g) and cotton yarn 2×100^S (38404.8 m weighs 453.4 g) used for dyeing. Count is the relation between length and weight of the yarn and generally, it refers to diameter of the yarn. The materials were supplied by Weavers Service Center, Bhubaneswar, India for this study (Recipe).

2.1.1. Chemicals used

The chemicals such as alum [$K_2SO_4Al_2\ (SO_4)_3 \cdot 24H_2O$], copper sulphate ($CuSO_4 \cdot 5H_2O$), stannous chloride ($SnCl_2 \cdot 2H_2O$), ferrous sulphate ($FeSO_4 \cdot 7H_2O$) and solvents such as petroleum ether, ethyl acetate, acetone and methanol were procured from E. Merck, India. The chemicals, cetyltrimethyl ammonium bromide (CTAB) and sodium dodecyl benzene sulphonate (SDBS) were procured from HIMEDIA, India.

2.1.2. Test organism used

Lyophilized cultures of *K pneumoniae* (ATCC 35657), *E. coli* (ATCC 14948), *S. pyogenes* (ATCC 19615), and *S aureus* (ATCC 25923) were purchased from Microbiologics, USA through HIMEDIA BioSciences. MicroBioLogics, Inc, is licensed to use the ATCC trademarks and to sell products derived from ATCC® cultures.

2.2. Methods

2.2.1. Extraction of colourants

500–5000 g of the processed powder materials were extracted separately with 2–16 L 10% aqueous methanol at 70–80 °C for 16–30 h as per the reported experimental procedure (Baliarsingh et al., 2012). All the experiments were replicated three times using similar parameters. The average yield obtained for 5 kg plant materials was 749.00 g; 14.98% (w/w) for *L. sebifera* (bark), 547.09 g; 10.94% (w/w) for *G. lanceolarium* (leaf) and 548.75 g; 10.98% (w/w) for *M. indica* (leaf). From several sets of experiments, it was observed that the yield of resulting extracts varied with different plants depending on the pigment contents of the plant materials used.

2.2.2. Statistical analyses

The yield of the leaf and bark of the three plant species was statistically analyzed by analysis of variance and each treatment was replicated three times. The percentage of average yield from three plants along with standard deviation (SD) has been derived. Two-way Analysis Variance (ANOVA) studies were carried out to find out whether the extraction (%) depends on the plant as well as the weight of extracted materials from the leaf and bark. The test was carried out (Gupta, 2005) using null hypothesis. Similarly, analysis of variance was done to study the inhibitory effects of different dyed yarns on the various microorganisms.

2.2.3. Dyeing method using surfactants

The dyeing experiments were carried out with silk and cotton yarns by adopting pre-mordanting technique (Prusty et al., 2010), i.e. the samples were treated with surfactants (CTAB and SDBS) solution before dyeing with dye solution. The aqueous solution of surfactant (0.02 g/dm^3) was prepared 1:30 MLR (material to liquor ratio) and silk yarn (0.5 g) was dipped in 25 mL of surfactant solution and heated on a water bath at 60–70 °C for 30–45 min. In case of cotton yarn (0.5 g) the water bath was heated at 80–90 °C for 30–45 min. The dyed yarn was left for 15 min for aerial oxidation. The dyed silk and cotton yarn was then dipped in 25 mL of prepared 5% dye solution using 0.5% aqueous sodium hydroxide separately at 1:30 MLR and heated on a water bath at 60–70 °C for silk yarn and at 80–90 °C for cotton yarn for 30–45 min. Then the dyed yarn was air dried for 15 min. The dyed yarn washed with cold water followed by soap washing using 2 g/L detergent powder solution (aqueous soap bar solution) and then washed thoroughly with running water. The wet samples dried at room temperature.

2.2.4. Absorbance measurements

The absorption spectra were recorded for the determination of absorbance (%) on Perkins Elmer, Lambda 35 UV/Vis spectrophotometer in the wavelength range 200–800 nm. The absorbance of