Dyes and Pigments 103 (2014) 50–54

Contents lists available at ScienceDirect

Dyes and Pigments

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

Extraction of natural dye from red calico leaves: Gamma ray assisted improvements in colour strength and fastness properties

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ARTICLE INFO

Article history:
Received 2 August 2013
Received in revised form
9 October 2013
Accepted 22 November 2013
Available online 1 December 2013

Keywords:
Natural colourant
Alternanthera bittzickiana
Colour fastness
Irradiation
Mordanting
Spectraflash

ABSTRACT

The present study was conducted to explore the colouring potential of red calico {*Alternanthera bittzickiana* (Regel) G. Nicholson} leaves and to improve colour strength of dye using gamma radiations followed by mordanting process. The results showed that red calico plant leaves could be an excellent source of natural dyes for textile sector. Copper sulphate (1%) and tannic acid (1%) were the best pre- and post-mordants, respectively to improve the colour strength and colourfastness properties. The results from dyeing indicated that gamma ray treatment of 15 kGy was the effective absorbed dose for extraction of dye and surface modification of cotton fabric. Dyeing of cotton fabric with red calico leaf extract at 60 °C for 50 min using dye bath of pH 7.0 and salt concentration of 6 g/L produced good colour strength. Gamma ray treatment of cotton reduced the amount of mordants and improved the colourfastness properties.

1. Introduction

Synthetic dyes are known to be a major source of environmental pollution and their excessive use has led serious health hazards and disturbances in eco-balance of nature [1,2]. In the current scenario, the use of non-allergic, antimicrobial and eco-friendly dyes in textiles has attracted the attention of people throughout the world [3]. Natural dyes extracted from plants, animals or minerals without chemical processing show better compatibility with environment [4,5] due to their non-toxic nature and having renewability potential [6,7]. These are particularly suitable for people with dermatological disorders and allergies to chemicals in synthetic components used for textile finishing. Despite so many benefits associated with the use of natural colourants, textile industries, particularly in developing or underdeveloped countries hesitate to use natural dyes due to their low colour strength, limited availability and high cost in these regions.

Most of the natural colourants are commonly obtained from floral parts of plants [8,9]. However, there are some problems encountered in the use of flower as a source of natural dyes as well. For example, all the perennials begin to flower several years after their germination and the flowers of most of annuals and biennials are available only once in a year. Therefore, due to non-availability/scarcity of flowers, dyes extracted from these plants are highly expensive. In addition, dyes obtained from leaves and barks of commercially important plants are also expensive. Thus, there is need to explore the colourant potential of non-flowering parts of commonly grown, evergreen and less expensive plants. Sedge, red calico {*Alternanthera bettzikana* (Regel) G. Nicholson}, is ubiquitous in presence, fast growing, can withstand harsh environmental conditions particularly, soil salinity [8] and its leaves are regularly subjected to cutting and trimming when used as ornamental.

Scientists working in the field of natural colourant technology are now focusing to improve extraction of colourant from plant material and its application onto surface modified fabric. Different techniques like UV, microwave or ultrasonic treatment; bio polishing, cationization and mercerization are being implied for surface modification of fabric [10,11]. The utilization of gamma radiations in surface modification of fabric has been the subject of many recent studies [12–14]. Gamma radiations treatment can improve the shrinking and wrinkling resistance of the fabric and enhance the shades of dyed fabric. It also increases the ability to

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http://dx.doi.org/10.1016/j.dyepig.2013.11.024

uptake dye onto fabrics at low temperature without affecting the morphology of colourant as well as the physical structure of fabrics [15,16].

Exploration of natural colourant sources has been the subject of many studies from last few decades. Despite all the efforts, scientist can have to explore about 500 plants out of hundred of thousand species found on the earth [17,18]. Keeping in view above mentioned facts; we have selected gamma radiations for the improvements in extraction of colourant from leaves of red calico plant and surface modification of cotton fabric. The objective of study is to get a cheap and easily available natural colourant for textile industry as well as to improve colour strength and colour fastness of fabric.

2. Experimental

2.1. Sample preparation, irradiation and extraction process

Leaves of red calico plant were collected from Government College University Faisalabad, Pakistan. The leaves were washed with distilled water and dried at room temperature. Dry leaves were ground into fine powder. Raw grey cotton was purchased from the local market. The cotton was bleached and mercerized. Cotton fabrics and red calico leaves powder were exposed to different absorbed doses of gamma radiations, such as 5, 10, 15, 20 and 25 kGy using Cs-137 gamma irradiator at Nuclear Institute of Agriculture and Biology (NIAB) Faisalabad, Pakistan [13,19]. After the gamma ray treatment, three different types of media (aqueous, alcoholic and alkaline) were used for the extraction of natural colourant from the leaves of red calico plant. Dyeing process was carried out using NRP/NRC (non radiated powder/non radiated cotton), RP/RC (radiated powder/radiated cotton) & NRP/RC (non radiated powder/radiated cotton). Extraction of colourant was carried out by boiling irradiated (RP) and un-irradiated (NRP) dye powder using the aqueous, alcoholic and alkaline media with material liquor ratio of 1:30 for 1 h [20,21]. After boiling, the liquor mixture was filtered and filtrate was used in further studies.

2.2. Optimization of dyeing and mordanting conditions

To optimize dyeing conditions, irradiated cotton (RC) was treated with extract of red calico leaves using varying values of time interval, temperature, pH, salt concentration and material liquor ratio. Dyeing time was optimized by dyeing irradiated cotton (RC) fabric to dye for different time intervals of 30, 40, 50, 60, 70 and 80 min. To study the effect of salt concentration, different concentrations of NaCl were added in the dyeing medium (2, 4, 6, 8 and 10 g/L). The red calico leaf extract was used to dye irradiated cotton at 60 °C keeping the ratio of M:L 1:30 for 60 min. Varying concentration of NaCl salt (2, 4, 6, 8 or 10 g/100 ml) were added in the dye solution and cotton fabric was treated separately with each dye solution. The pH was optimized at 5, 6, 7, 8, 9 and 10. For the improvement of colourfastness and colour strength properties pre- and post-mordanting was performed. Alum, iron sulphate, copper sulphate and tannic acid were used as pre- or post-mordanting agents. The cotton fabrics were treated separately with various concentrations (1, 3, 5, 7 or 9%) of each of above mentioned chemicals [22]. The fabric was dried and then dyed at optimum conditions. On completing dyeing process, the fabric was washed with water and dried.

2.3. Evaluation of quality characteristics of dyed fabrics

The colour strength values of un-irradiated and irradiated dyed fabrics were investigated by CIE lab system using the Spectraflash (SF 650) at quality control laboratory of Noor Fatima Textile, Faisalabad, Pakistan. Colour fastness properties were investigated following ISO standard methods such as ISO-105 CO3 for washing, ISO 105 X 12 for rubbing and ISO 105 BO2 for perspiration [23].

3. Results and discussion

Exposure of red calico leaf powder and cotton fabrics to different doses of gamma radiations (5, 10, 15, 20 and 25 kGy) had varying effects on colour strength of cotton fabrics (Fig. 1). Gamma ray treatment of 15 kGy proved to be most effective in improving colour strength of cotton fabrics dyed with red calico leaf extract compared with other doses. Gamma ray treatment of 15 kGy produced significant modifications on surface of fabric where hydroxyl group of cellulose units were converted into carboxylic group that upon dyeing showed firm interaction with dye molecules. This interaction was confirmed by investigation of fabric in CIE Lab system [24]. It seemed that below 15 kGy, the surface of fabric cellulose units were not properly activated for dyeing, while at higher doses of gamma radiations, fabric might be either degraded or its fibres might face dislocation [25]. Due to this degradation of actual colourant, molecules might showed less absorbance on fabric and upon investigation showed low colour depth. During extraction process gamma ray caused more interaction with colourant in alkaline media as compared to aqueous or alcoholic [26,27]. Previously, it was found that gamma ray treatment of dye powder improved colour extraction without harming its physiological characteristics [28,29]. The same effects of gamma radiations were observed in our studies. The values given in Figs. 1–3 showed that an absorbed dose of 15 kGy produced darker shades. At this dose, the fabric surface might be evenly modified and sorbed dye molecules. Hence, 15 kGy was the optimum absorbed dose for extraction of the colourant and surface modification of fabrics.

Dyeing of irradiated fabric (RC, 15 kGy) using alkali extracts of irradiated red calico leaves powder (RP) was found to be temperature dependant (Fig. 4). The data revealed that colour strength values were different at temperatures like, 30, 40, 50, 60, 70 and 80 °C, respectively. The dyeing uptake ability evaluation of irradiated fabric (Rc, 15 kGy) using alkali solubilized extract showed that at 60 °C, the dye molecules rapidly rushed onto modified fabric, while, at low temperature, dye molecule might sorbed slowly, which upon investigation by spectra flash showed dull shades [30]. Above 60 °C, the colourant might face hydrolytic

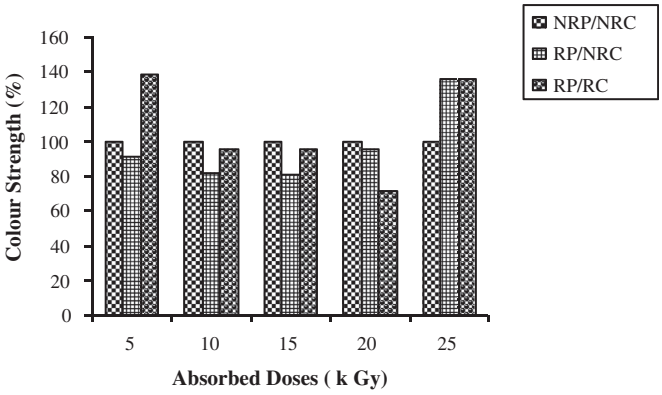

Fig. 1. Effect of gamma radiations on colour strength of cotton fabric dyed with aqueous extract of red calico leaves (NRP/NRC = Non-radiated powder/Non-radiated cotton; RP/NRC = Radiated powder/Non-radiated cotton; RP/RC = Radiated powder/Radiated cotton).