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Colorimetric Analysis and Fastness Properties of Jute Fabric Dyed with Eucalyptus Leaves

Kolorimetrična analiza in obstojnost jutne tkanine, barvane z listi evkaliptusa

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Abstract

Natural dyestuff has reverted its position in the colouration of textile substrates due to rising concerns of consumers and buyers, particularly about environmental impacts and health issues. Eucalyptus leaves were selected in this study as a source of natural dye along with some of the most generally used mordants to observe the impact of dyeing on jute fabric while trying to keep the dyeing parameters at a minimum level. Dyes were extracted from eucalyptus leaves by boiling in water. Then, the fabric was pre-mordanted using different synthetic mordanting agents, such as alum, potassium dichromate, copper sulphate and ferrous sulphate, which are generally used to substantively enhance the dyestuff on textile fabrics and to improve the fastness properties. Synthetic mordant was used here instead of natural mordant due to the better dyeing compatibility of jute fabric with eucalyptus leaves, since natural mordant has little effect on jute fabric during the process of dyeing. Another aim of this research is to curb the time and energy consumption of the jute dyeing process and so the dyeing is carried out at 75 °C for about 30 minutes. Various types of evaluations were conducted through visual assessment, checking the colour-coordinate values and colour strength values. While colour fastness properties were evaluated by different fastness testing, such as colour fastness to water, washing, rubbing and perspiration. This dyeing process yields a colour range from yellowish to brown with the variation of mordants applied on the fabric. In addition to that, colour co-ordinate and colour strength values ensure better results of dyed fabrics pretreated with ferrous sulphate. Jute fabric dyed with only extracted eucalyptus solution provided satisfactory results in all colour fastness tests, while fabric treated with different mordants showed variations in fastness ratings, and fabric treated with ferrous sulphate and copper sulphate had slightly better fastness ratings.
Keywords: Colour-coordinate, colour fastness, eucalyptus leaves, jute fabric, mordant

Izvleček

Odnos do naravnih barvil za barvanje tekstilij se je spremenil ob skrbi potrošnikov in kupcev za okolje in zdravje. V tej študiji so bili izbrani listi evkaliptusa kot vir naravnega barvila skupaj z nekaterimi najpogosteje uporabljenimi čimžami, da bi ugotovili vpliv barvanja na jutno tkanino ob ohranitvi parametrov barvanja na minimalni ravni. Barvila so bila ekstrahirana iz listov evkaliptusa pri vrenju v vodi. Nato je bila tkanina najprej čimžana v prisotnosti različnih sintetičnih čimž, kot so galun, kalijev dikromat, bakrov sulfat in železov sulfat, ki se po navadi uporabljajo za izboljšanje substantiv-

nosti in obstojnosti barvila na tekstiliji. Namesto naravne čimže so bile zaradi boljše združljivosti barvanja jutne tkanine z listi evkaliptusa uporabljene sintetične čimže, ker naravne čimže med barvanjem v manjši meri vplivajo na jutno tkanino. Drugi cilj te raziskave je bil omejiti čas in porabo energije pri barvanju jute, tako da je barvanje potekalo približno 30 minut pri 75 °C. Opravljeni so bili različni načini ocenjevanja in sicer vizualno, preverjanje vrednosti barvnih koordinat in barvne jakosti. Barvna obstojnost je bila ocenjena z različnimi testiranji obstojnosti, kot je barvna obstojnost proti vodi, pranju, drgnjenju in znojenju. Ta postopek barvanja daje barvni razpon od rumenkaste do rjave barve glede na variiranje čimž, nanesenih na tkanino. Poleg tega barvne koordinate in jakost barve zagotavljajo boljše rezultate obarvanja tkanine kot pri predhodno obdelanih z železovim sulfatom. Jutna tkanina, barvana samo z raztopino evkaliptusovega ekstrakta, daje zadovoljive rezultate barvne obstojnosti za vse barvne tone, medtem ko tkanine, obdelane z različnimi čimžami, kažejo razlike v ocenah obstojnosti in nekoliko boljšo oceno le za tkanine, obdelane z železovim sulfatom in bakrovim sulfatom.
Ključne besede: barvna koordinata, barvna obstojnost, listi evkaliptusa, jutna tkanina, čimža

1 Introduction

From ancient times onwards, colour from natural sources has been used enormously in various areas on a daily basis; for food, hair, medicine, furniture and even fabrics. Colour from different parts of plants or insects, in particularly bark, roots, leaves, stems, flowers and fruits [1], has been used extravagantly to dye natural fibres (i.e. wool, silk, cotton and jute). But to cope with the ever increasing demands for clothing, people have decreased the application of natural dye and switched to synthetic dyestuff as it is available and easy to apply, it exhibits moderate to good colour fastness, is economical. Environmental awareness raised questions on the use of huge amounts of salts and alkalis, which has detrimental effects on human life, and in return the usage of natural dyes as well as environment-friendly fabrics was revived [2–4]. Since such dyestuff is non-toxic, biodegradable and some types of dye also have special antimicrobial, UV protective and anti-flammable properties, it will be the buyers' and consumers' first requirement in the near future. Natural dyes, however, have low substantivity for textile substrates, and for this reason various mordanting agents are used before, during and after the dyeing process, what is known as pre-mordanting/simultaneously mordanting or post-mordanting process. Alum, potassium dichromate, copper sulphate, ferrous sulphate, vinegar, tin, etc. were used as mordant to intensify the colouring properties and colour fastness [5–9]. Natural mordants, such as aloe vera, mango bark, oak bark, chestnut wood, etc. are environmentally friendly and act as an effective mordanting agent for protein fabrics (e.g. silk and wool), but not for the jute fabric [10]. On the other hand, compatibility of mordanting agent with natural dyes depends on the chromophores in the dyestuff and the fabric, which the dye has to be applied on. Considering the aforementioned disadvantage of natural mordants, synthetic mordants were applied here to establish, which synthetic mordant is best suited for the dyeing of jute fabric with eucalyptus leaves.

Eucalyptus leaves and bark are a substantial source of natural dyestuff that provides pale yellow to brownish colour [11]. About 10 to 12% of natural tannin and polyphenol in eucalyptus is responsible for the colouring of materials [12]. Quercetin is a major colouring component of eucalyptus bark and also an antioxidant, which is the reason for its utilisation in food colouring [13]. It is also used for colouration purposes of cotton fabrics [11, 14, 15].

Eucalyptus leaves contain up to 11% of tannin, gallic acid and ellagic acid – a pivotal part of phenolic acids and flavonoids, which enable the dyeing of natural fabrics, including wool and silk [16]. These two components are very useful in the dyeing process as they fix up the colour to the fabric.

On the other hand, jute is a nearly 100% biodegradable fibre and is used for various purposes in textile sectors, including technical textiles. However, natural colouration of jute substrate is scarce and it is therefore mostly dyed with basic dyes.

A study conducted by Rattanaphol Mongkholrattanasit1, Jiri Krystufek, Jakub Wiener and Rattanaphol Mongkholrattanasit showed what happens when natural dye was extracted from eucalyptus leaves and applied to wool fabric. They extended their research on the impact of natural dye extracted from eucalyptus leaves on silk and wool fabrics using two padding techniques under different conditions, i.e. the pad-batch and pad-dry techniques [17]. In another study, Nattadon Rungruangkitkrai1, Rattanaphol Mongkholrattanasit, Wirat Wongphakdee and Jarmila Studnickova examined a dye extracted from eucalyptus leaves and its application to wool

fabric using pad-batch and pad-dry techniques under various conditions. The fastness properties of dyed fabrics ranged from good to excellent, while light fastness fair to good. The fabric had an excellent value of ultraviolet protection factor (UPF). In addition, a darker colour was a result of $FeSO_4$, which provided better protection due to its higher UV absorption [18, 19].

It is known that dyes from eucalyptus leaves are mostly applied on protein or cotton fabrics, but its application on jute fabrics is very limited. In this study, a eucalyptus leaves extract is used to dye the jute fabric at an optimum temperature and time. Besides, it assesses which mordanting agent is more compatible for the dyeing of jute fabric with extracted eucalyptus leaves in respect of colour coordinates and colour fastness.

2 Materials and methods

2.1 Materials

Substrate

A plain woven grey jute fabric with mass per unit area 249 gm/m^2 was used for dyeing. The fabric specifications were warp density 1.225 ends per meter, weft density 0.81 picks per meter and thickness 1.02 mm.

Natural dyes

Dye solutions were extracted from 20 g of eucalyptus leaves (i.e. Eucalyptus camaldulensis) that were collected in the Gazipur District. The leaves for extraction were gathered in November because during that time juvenile and adult leaves provide the most intense colour.

Firstly, green eucalyptus leaves were chopped into small pieces and soaked in soft water (20 g of green leaves in 2000 ml of water) and thereafter boiled for one hour. Then, all the colouring matter was mixed with water with the help of heat and the dye solution was reduced to approximately 1000 ml. The maximum absorbency of this extracted dyestuff was obtained in the wavelength of 420 nm.

Mordant

Four types of mordant: alum, ferrous sulphate ($FeSO_4$), potassium dichromate ($K_2Cr_2O_7$) and copper sulphate ($CuSO_4$) were used. All the mordants were 100% anhydrous, produced in the Northern University Textile lab, which was purchased from Mithila Chemicals Ltd.

2.2 Sample preparation

The preparation of jute fabric for dyeing with eucalyptus leaves includes a pre-treatment process and a pre-mordanting process so that it can absorb natural dyestuff easily. As a result, four mordanting agents were used to pre-mordant the bleached jute fabric (Table 1).

Bleaching of grey jute fabric

Bleaching of the raw jute fabric was carried out in a closed vessel for one hour at 50–52 °C keeping the material at a liquor ratio 1:20 with hydrogen peroxide, trisodium phosphate (5 g/l), sodium hydroxide (1 g/l), sodium silicate (10 g/l) and non-ionic detergent (5 g/l). The pH of the bath was 11. After the fabric was washed thoroughly in cold water, it was neutralised with acetic acid (2 ml/l), washed in water again and then air dried.

Mordanting of bleached jute fabric

Bleached jute fabrics were pre-mordanted separately with alum, $FeSO_4$, $CuSO_4$, $K_2Cr_2O_7$ at a similar concentration, i.e. 10% per weight of the fabric, at room temperature for about 24 hours, keeping the material at a liquor ratio 1:10. Then they were dyed without any washing.

Dyeing of mordanted jute fabric with natural dye

Jute fabrics that were pre-mordanted or not were dyed with the extracted dye solution from eucalyptus leaves at 75 °C for 30 minutes following the M:L = 1:20, which means that each of the 10 g jute fabric was dyed with 200 ml extracted dye solution at the above-mentioned dyeing parameters.

Table 1: Designation of the dyed sample

Sample designation	Sample description
S1	Bleached fabric without dyeing
S2	Fabric dyed without mordant
S3	Dyed fabric mordanted with alum
S4	Dyed fabric mordanted with potassium dichromate
S5	Dyed fabric mordanted with copper sulphate
S6	Dyed fabric mordanted with ferrous sulphate

2.3 Testing processes after dyeing

Measurement of colour coordinate
Using Datacolor® 850 Spectrophotometer the colour coordinate value of all dyed samples was measured by the CIE *L*a*b** or the CIELCH method. CIE *L*a*b** and CIELCH mean the following: *L* stands for lightness/darkness value, *a** is red/green axis where +*a* represents redder and -*a* represents greener, *b** is yellow/blue axis where +*b* represents yellower and -*b* bluer, *C* stands for chroma, +*ve* represents brighter and -*ve* represents duller, and *H* stands for hue.

Measurement of colour strength
The *K/S* value was assessed using the spectrophotometer to observe the colour strength of different reactive dyes, which works on the Kubelka-Munk equation 1:

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \quad (1)$$

where, *R* is the reflectance of dyed fibre.

Evaluation of colour fastness to wash
The ISO 105 C06 B2S method was applied to measure wash colour fastness properties of the dyed sample. In this method, a dyed fabric (10 cm × 4 cm) is attached to a TV multi fibre fabric and an undyed fabric like a sandwich and the sample was treated with an ECE reference detergent, sodium perborate tetra hydrate, acetic acid at 40 °C for 30 minutes in a washing machine where M:L was 1:50. Then, colour fastness to wash was assessed in respect to colour change (ISO 105 A02) and colour staining (ISO 105 A03) by matching with standard grey scales.

Evaluation of colour fastness to water (ISO 105 E01)
This test method evaluates the effect of water on fastness properties of a dyed fabric. First, each sample was cut to a size of 10 cm × 4 cm along the length or width. Then, the sample was paired with a TV multifibre fabric and soaked into water for a half an hour. All wet samples were then placed in a perspirometer in an oven to simulate exposure for three hours. Lastly, the colour change of the sample and the staining of the multifibre strip were evaluated.

Assessment of wet and dry rubbing colour fastness (ISO 105-X12)
Dyed samples of 14 cm × 5 cm were mounted on a crock meter and the finger of the crock meter covered with a 5 cm × 5 cm crocking cloth at the pressure of 9 ± 2 N. The samples were rubbed with the finger at 10 turns within 10 seconds. But for the wet rubbing test this process is followed after soaking the crocking cloth in water at a 100% pickup.

Determination of perspiration fastness (ISO 105 E04)
Colour fastness to perspiration of all dyed samples was measured in media like acid and alkali following the ISO 105 E04 testing method. Like the samples (10 cm × 4 cm) for the wash and water fastness, a multifibre fabric and undyed fabric were further soaked in an alkali and acid solution. Alkali and acid solutions were prepared by using 0.5 g/l l-histidine monohydrochloride monohydrate, 5 g/l sodium chloride, disodium hydrogen orthophosphate dehydrate/ sodium dihydrogen orthophosphate dehydrate and definite pH for acid and alkali. Testing samples had been dipped in this solution for about 30 minutes, then put in perspirometer at 37 °C for 4 hours in the oven. Then the samples were assessed.

3 Results and discussion

3.1 Visual appearance

It was observed from the pictorial view of all dyed samples (Figure 1) that jute fabric, which was dyed with only extracted eucalyptus leaves, provides prominent colour, whereas jute fabric, which was pretreated with different mordanting agents (e.g. alum, potassium dichromate and copper sulphate) does not. However, fabric dyed with ferrous sulphate yielded a dark ash colour. The probable reason of S2 yielding a brighter shade than S3 is the content of tannin and gallic acid in eucalyptus leaves, which has the capacity to colour the fabric without using mordanting agents. If alum was used as a mordanting agent, it reacted with dye molecules rather than enabling the fabric to absorb colour. On the other hand, ferrous sulphate intensifies the ability of tannin, gallic acid and quercetin to colour the fabric.

3.2 Colour coordinate value

All of the dyed jute fabrics were assessed under two light sources, i.e. D65 – artificial day light and TL84 – store light, using two methods: CIE *L*a*b** and CIELCH. It is shown in Table 2 that lightness of only bleached fabric is high, whereas it is decreased in fabrics dyed with eucalyptus leaves, pre-mordanted with ferrous sulphate for both light sources. The value of redness/blueness is highest (9.64) for dyed fabrics,

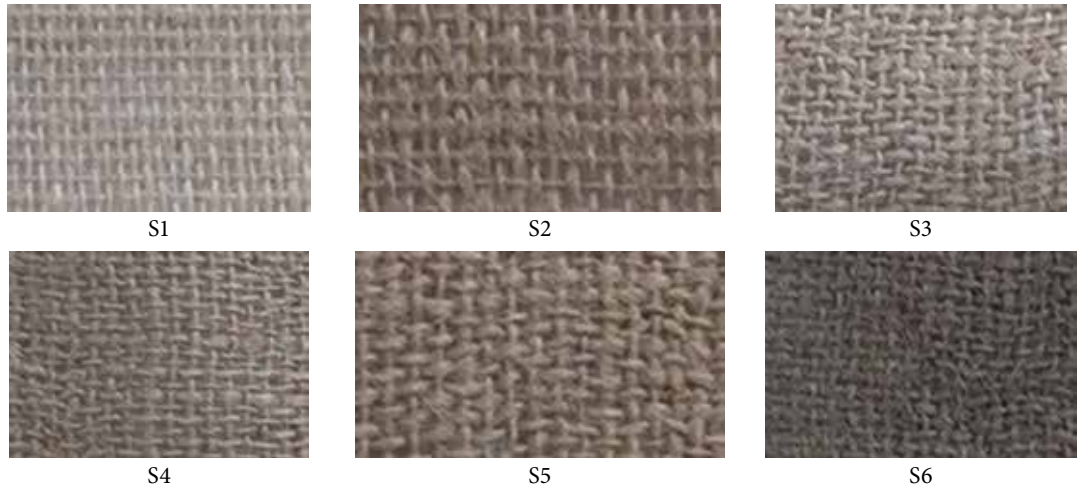

Figure 1: Pictorial view of dyed jute with eucalyptus leaves extract with and without mordant

Table 2: Colour coordinate value of all samples dyed with eucalyptus (average values and their standard deviations are given in brackets)

Sample	D65					LT84					ΔE
	L	*a*	*b*	*C*	*H*	*L*	*a*	*b*	*C*	*H*	
S1	60.71 (0.07)	4.92 (0.03)	16.89 (0.06)	17.59 (0.04)	73.77 (0.06)	61.72 (0.07)	4.97 (0.05)	19.17 (0.06)	19.80 (0.05)	75.48 (0.04)	2.49
S2	53.31 (0.03)	5.65 (0.02)	20.98 (0.05)	21.73 (0.03)	74.92 (0.06)	54.41 (0.04)	5.76 (0.05)	20.98 (0.05)	21.73 (0.03)	74.92 (0.07)	1.11
S3	57.26 (0.03)	5.94 (0.02)	20.44 (0.03)	21.29 (0.04)	73.80 (0.06)	58.41 (0.05)	6.00 (0.09)	23.17 (0.04)	23.93 (0.01)	75.48 (0.02)	2.96
S4	53.87 (0.04)	9.64 (0.02)	20.24 (0.02)	21.39 (0.07)	71.08 (0.05)	55.05 (0.09)	6.89 (0.06)	22.86 (0.06)	23.88 (0.06)	73.24 (0.03)	3.98
S5	51.12 (0.02)	6.71 (0.02)	24.04 (0.03)	24.96 (0.05)	74.41 (0.05)	52.45 (0.07)	6.56 (0.03)	27.24 (0.10)	28.02 (0.07)	76.45 (0.01)	3.47
S6	38.15 (0.02)	3.36 (0.02)	7.20 (0.02)	7.94 (0.03)	65.01 (0.04)	38.02 (0.04)	3.46 (0.03)	8.04 (0.04)	8.76 (0.03)	66.72 (0.03)	0.86

pre-mordanted with potassium dichromate. On the other hand, numerical value of *b*, *C* and *H* is higher for dyed fabric, pre-mordanted with ferrous sulphate. Moreover, it is clearly observed that the colour difference (0.86) of fabrics dyed with eucalyptus leaves and pre-mordanted with ferrous sulphate is lower than in all other dyed samples.

3.3 Evaluation of colour strength value

A colour strength depends on reflectance. Higher value of reflectance is, greater is the value of colour strength. As a result, a dark sample has a high colour strength, and a light shade fabric has lower K/S value. In this regard, fabric dyed with ferrous sulphate gives colour strength in the range of 9 to 21, since it yields dark colour rather than other mordants.

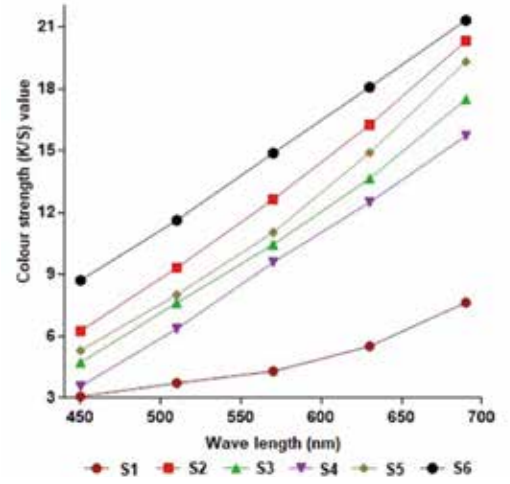

Figure 2: Colour strength value of each sample

3.4 Colour fastness to water

Fabric dyed with eucalyptus leaves yields outstanding water fastness. This was seen in all samples treated with or without mordants. The rating of colour fastness to water is 4 to 5 for both colour change and colour staining.

3.5 Colour fastness to wash

Although there is no variation of colour, change in wash fastness is similar for all samples (4–5), however, in terms of colour staining, wash fastness is better (4–5) for samples dyed with extracted dye solution before they were treated with alum, as the colour is lighter than in other samples. Fabric pre-mordanted with potassium dichromate exhibits comparatively lower fastness rate after dyeing with eucalyptus leaves extraction. Figure 3 also shows that the error bar of samples due to wash fastness in respect of colour change is zero, while colour staining fastness provided a standard error of 0.187.

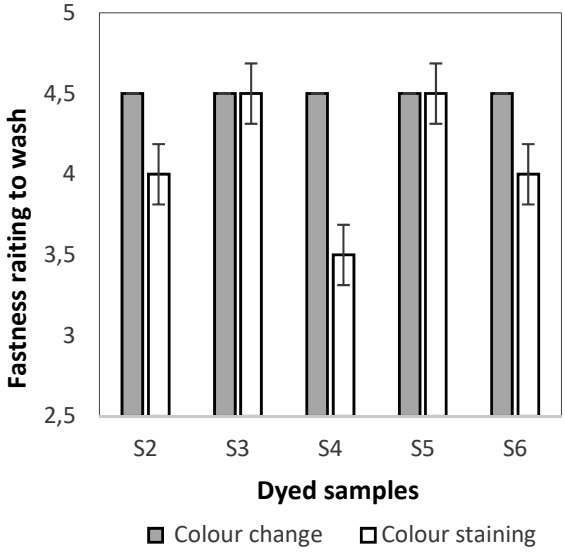

Figure 3: Colour fastness to wash of all dyed samples

3.6 Colour fastness to rubbing

All of the dyed fabric samples provide good (4) dry rubbing fastness, except fabrics pre-mordanted with $CuSO_4$, whereas wet rubbing fastness is fair to moderate (2–3) for every sample, except for the afore mentioned one. Figure 4 shows that there is only a slight error bar for both dry and wet rubbing fastness, as it has a standard error of 0.1, which means that there is no significant difference between the samples.

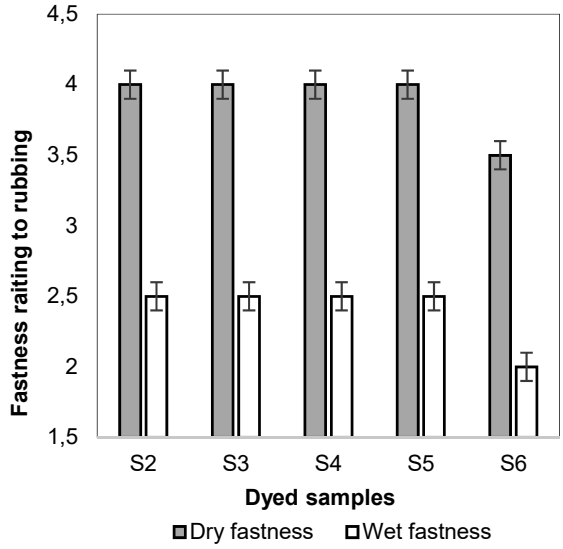

Figure 4: Colour fastness to rubbing of all dyed samples

3.7 Colour fastness to perspiration

Acid perspiration

Colour change of the acid perspiration rating is good (4–5) and similar for all samples, although colour staining of acid perspiration reveals moderate to good results for both samples pre- mordanted with $CuSO_4$ and $FeSO_4$. However, acid perspiration is not good for fabrics mordanted with alum. In addition to that, all the samples show an error bar of 0.187 standard error in respect of colour staining acid perspiration fastness.

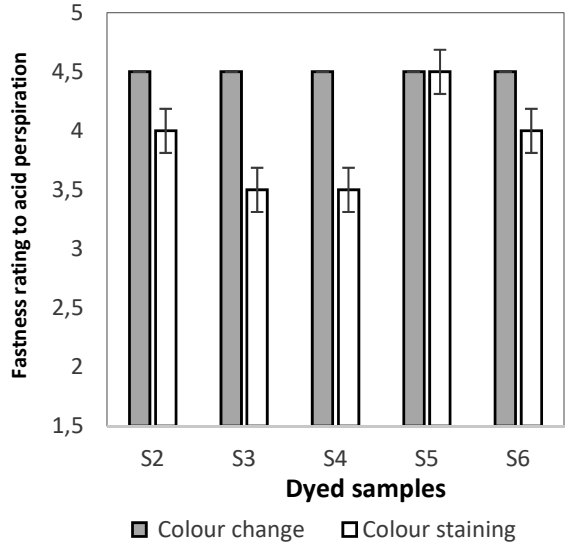

Figure 5: Colour fastness to acid perspiration of all dyed samples

Alkali perspiration

The colour fastness rating of alkali perspiration is identical (i.e. 4–5) for each dyed sample in respect to colour change. However, colour staining of alkali perspiration is better for fabrics pre-mordanted with $CuSO_4$. Like for acid perspiration, there is no standard error for samples of alkali perspiration due to colour change, but fastness rating of colour staining shows an error bar of 0.158 standard error.

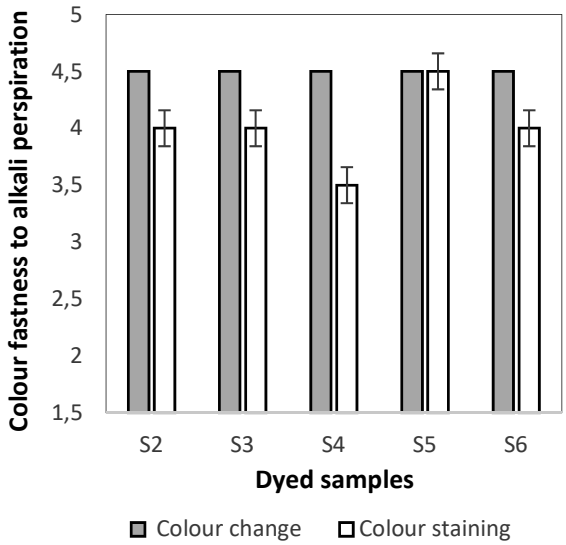

Figure 6: Colour fastness to alkali perspiration of all dyed samples

4 Conclusion

This empirical study shows prominent dyeing effects and their dyeing properties. Both, the visual and spectrophotometric results reveal that fabric dyed with extracted eucalyptus leaves gives bright shade when it is pre-mordanted with ferrous sulphate, as it has yielded higher colour strength. The colour difference value is also lower than in other dyed samples, which had better dyeing results. Dyed fabrics with eucalyptus leaves (without using any mordant) had good results that were very close to pre-mordanted fabric using ferrous sulphate. Although colour fastness properties of different dyed fabrics show fluctuating results, ranging from moderate to good grading. Overall, in terms of all colour fastness properties and dyeing properties, fabrics dyed without mordant and fabrics pre-mordanted with ferrous sulphate yielded better dyeing properties and higher quality.

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