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RESEARCH PAPER

Effect of material to liquor ratio on colour, strength and colour co-ordinates of cotton and excel fabrics dyed with *Wrightia tinctoria* dye liquid

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Abstract: The increasing demand for eco-friendly and sustainable dyeing alternatives has brought natural dyes into the spotlight for both environmental and socio-economic benefits. The present study was carried out with the objective to evaluate the effect of material to liquor ratio (MLR) on the colour strength and colour coordinates of cotton and excel fabrics dyed with *W. tinctoria* dye liquid. In the study, *W. tinctoria* leaves were collected from western ghat forests of Karnataka, and subjected to various extraction methods to extract dye from fresh and dried leaves. Scoured and bleached, cotton and excel fabrics were dyed with *W. tinctoria* dye liquid (extracted from grinded leaves paste form) using exhaust dyeing method at three different MLRs: 1:20, 1:30 and 1:40 at 60°C for 20 minutes with continuous stirring to maintain uniform dye uptake. The dyed samples were evaluated for colour strength (K/S values) and colour coordinates (L, a, b*, dE) using spectrophotometer (SS 5100A). The results of the study revealed that, extraction methods significantly influenced the colour strength and colour coordinates of *W. tinctoria* dye liquids. Among the dye liquids extracted using various methods, dye extracted from grinded fresh leaf paste exhibited higher colour strength(K/S=62.62) and with darker shade (L*value=0.01). In terms of fabric dyeing, irrespective of fabric type, samples dyed with *W. tinctoria* dye liquid at a 1:20 material to liquor ratio exhibited higher colour strength (K/S = 17.20 for cotton and 16.35 for excel) and darker shades with lower lightness values (L* = 61.72 for cotton and 61.79 for excel), compared to fabrics dyed at 1:30 and 1:40 MLRs. Furthermore, fabrics dyed at 1:20 MLR exhibited more greener and bluer hues as reflected by their a* and b* values (a* = -1.88, b* = -7.13 for cotton; a* = -1.86, b* = -6.20 for excel). These findings confirmed that optimization of dye extraction technique and dyeing parameters such as MLR enhanced colour strength and colour coordinates in natural dyeing of cotton and excel fabrics dyed with *W. tinctoria* dye liquid. This study supports the promotion of sustainable textile dyeing practices, highlighting the potential of natural dyes like *W. tinctoria* in reducing environmental impact while contributing to eco-conscious textile production.

Key words: Colour strength, Colour coordinates, Excel fabric, Natural dyes, Sustainable textile dyeing, *Wrightia tinctoria*

Introduction

Natural dyes, obtained from plant, animal and mineral sources, have been an integral part of human culture and civilization for millennia. These dyes not only provide vibrant and diverse colors but also carry inherent ecological and health benefits. Natural dyes are renewable, biodegradable, and generally non-toxic unlike synthetic dyes, which often involve hazardous chemicals and discharge of these chemicals from dyeing units contributes to water pollution, harming aquatic life and contaminating drinking water sources (Kant, 2012). Moreover, exposure to certain synthetic dyes has been linked to skin allergies, respiratory issues and long-term health risks (Yusuf *et al*. 2017). Natural dyes are increasingly valued for their sustainable and eco-friendly properties, aligning with modern priorities of environmental conservation and green chemistry. In addition, many natural dyes possess bioactive compounds such as phenolics, flavonoids and alkaloids, which may exhibit antimicrobial, antioxidant, or medicinal properties, bridging the gap between traditional knowledge and contemporary scientific research.

Wrightia tinctoria (Roxb.) R. Br., commonly referred to as Pala Indigo or Dyers oleander, is a medium-sized deciduous tree belonging to the family Apocynaceae, native to tropical regions of India and Southeast Asia. This species has long been recognized in Ayurvedic, Siddha and Unani medicine for its therapeutic efficacy in treating a variety of ailments, including skin diseases, diarrhea, fever and rheumatism (Khyade *et al*. 2014). Various parts of the plant- including leaves, bark, seeds and roots have been utilized for their therapeutic properties. In Ayurvedic medicine, the leaves and bark are used for treating skin disorders, digestive issues, fevers, and inflammatory conditions. The plant is also noted for its analgesic, antimicrobial, and antioxidant activities, which have been substantiated in recent phytochemical studies.

The leaves of *W. tinctoria* are particularly notable for presence of chemical constituents like Indigotin, indirubin, tryptanthrin, isatin, anthranillate and rutin that are responsible for its vivid colouration (Muruganandam *et al*. 2000) with rich phytochemical profile that adds multi-functional properties like analgesic, anti-inflammatory, antimicrobial, UV-protective and

antioxidant properties. These constituents contribute to both the medicinal potential and natural pigmentation properties of the plant. Consequently, *W. tinctoria* leaves present a valuable resource for multidisciplinary research exploring their chemical composition, bioactivity and applications in traditional and modern contexts. Scientific research on the *W. tinctoria* leaves offers valuable insights into the sustainable use of plant resources in textile dyeing. The main objective of this study was to evaluate the effect of material-to-liquor ratio (MLR) on the colour strength and colour coordinates of cotton and excel fabrics dyed with *W. tinctoria* dye extracts.

Material and methods

Wrightia tinctoria leaves were collected from the Western Ghats forests of Karnataka. The collected leaves were thoroughly washed with water to remove dirt and impurities and subjected to various dye extraction methods to assess colour strength and colour coordinates.

Extraction methods	Form of leaves	Dye quantity	MLR	Extraction time
Aqueous extraction	Paste form	100 g	1:30	45 min.
	Chopped leaves		1:30	45 min.
	Dried leaves powder	10 g	1:30	45 min.
Fermentation	Fresh leaves	100 g	1:30	7 days
Solvent extraction using diluted ethanol	Dried leaves powder	10 g	1:30	45 min.

The dye liquids were extracted using the aqueous method of extraction with a material-to-liquor ratio (MLR) of 1:30 and boiled for 45 minutes and filtered to obtain dye liquid. The obtained dyeliquids were then subjected to colour strength (K/S values) and colour coordinate analysis. Based on the colour strength and colour coordinate analysis, dye liquid extracted fromfresh leaves paste form was used for dyeing purpose in the study. Scoured and bleached, cotton and excel fabrics were dyed with *W. tinctoria* dye liquid using the exhaust dyeing method at three different MLRs: 1:20, 1:30, and 1:40 at 60°C for 20 minutes with constant stirring to maintain uniform dye uptake. After dyeing, the fabrics were rinsed thoroughly in cold water to remove unfixed dye particles and air-dried under shade at room temperature.The dyed samples were then evaluated for colour strength (K/S values) and colour coordinates *(L, a*, b*, dE) using a spectrophotometer (SS 5100A). One-way ANOVA analysis was conducted to determine the influence of extraction methods and material-to-liquor ratio on colour strength and colour coordinates of dye liquids and dyed samples respectively.

Results and discussion

Effect of extraction methods on colour strength and colour coordinates of *W. tinctoria* dye liquids

The effect of extraction methods on colour strength and colour coordinates (L*, a*, b*) of *W. tinctoria* dye liquids obtained from fresh leaves and dried leaves powder was presented in Table 1. It was observed that,among the dye liquids extracted from fresh leaves*, i.e,* through grinded leaf paste, chopped leaves and fermentation, higher colour strength with lower transmittance was recorded with dye extracted from grinded leaf paste (K/S = 62.62, TRN = 0.01) followed by chopped leaves (K/S = 47.91, TRN = 1.37) and fermented dye extract (K/S = 25.63, TRN = 2.41). This may be due to, fresh leaves of *W. tinctoria* reported to contain hydrated indigo precursors, flavonoids and phenolics which yields higher dye pigments. Additionally, the grinding process produced finer particles, increasing the surface area and thereby enhancing the release of major pigments into the extraction medium. Thus, the higher pigment concentration led to better light absorption and increased colour strength of the dye liquid.

In terms of lightness, L* value was found to be lower in dye liquid extracted from grinded leaf paste (0.43), indicated darker shade (due to the presence of indirubin (red) and indigoid (blue) compounds) compared to fermented extract (32.82) and chopped leaves extract,which showed significantly lower L* value (0.53). With respect to a* values, dye extracted from grinded leaf paste (a* = 0.47) and chopped leaves (a* = 0.10) exhibited redder hues, whereas fermented dye extract (a* = –5.68) exhibited greener hue. A mixed trend was observed in b* values, dye extracted form grinded leaf paste (b* = –0.27) and chopped leaves (b* = –0.28) showed bluer hues, while fermented dye extract (b* = 24.31) exhibited a strong yellower hue. Fermented extract (4.16) exhibited significantly greater colour difference (dE) than chopped leaves extract (2.05).

Table 1. Effect of extraction methods on colour strength and colour coordinates of W. *tinctoria* dye extracts [MLR-1:30, extraction time-45 min.]

Form of leaves	Extraction methods	Colour coordinates					
		K/S	TRN	L*	a*	b*	d E
Fresh leaves	Paste form	62.62	0.01	0.43	0.47	-0.27	-
	Chopped leaves	47.91	1.37	0.53	0.1	-0.28	2.05
	Fermentation	25.63	2.41	32.82	-5.68	24.31	4.16
Dried leaves powder	Aqueous extraction	50.65	0.08	0.76	0.51	-0.33	1.23
	Solvent extraction	57.85	0.04	0.51	1.33	-1.00	1.01
		Statistical information					
	S.Em±	0.32	0.005	0.05	0.011	0.008	0.009
	C. D@1%	1.25**	0.02**	1.2**	0.04**	0.03**	0.04**
	C. D@5%	0.93*	0.01*	1.15*	0.03*	0.02*	0.03*
	C.V (%)	4.52	0.54	1.90	0.86	0.33	0.70

**Significant at 1% level *Significant at 5% level

K/S- Colour strength TRN- Transmittance L-The lightness/darkness co-ordinate

a*- The red/green co-ordinate with +a* indicating red -a* indicating green b*- The yellow/blue co-ordinate with +b* indicating yellow and -b* indicating blue

Table 2. Effect of MLR on colour strength and colour co-ordinates of cotton fabrics dyed with *W. tinctoria* dye liquids [Temp. 60°C, Time- 20mins]

Colour coordinates	1:20	1:30	1:40	S.Em±	C.D@5%	CV (%)
K/S	17.20	16.15	14.40	0.01	0.042*	0.42
Rfl(%)	15.42	15.68	16.12	0.004	0.012*	4.89
L*	61.72	61.83	61.95	0.02	0.069*	3.04
a*	-1.88	-1.85	-1.82	0.01	0.031*	1.48
b*	-7.13	6.20	5.97	0.01	0.04*	1.48
d E	–	0.28	0.36	0.03	0.032*	3.19

*Significant @ 5% level

K/S- Colour strength TRN- Transmittance L-The lightness/darkness co-ordinate. a*- The red/green co-ordinate with +a* indicating red – a* indicating green b*- The yellow/blue co-ordinate with +b* indicating yellow and –b* indicating blue

Table 3. Effect of MLR on colour strength and colour co-ordinates of excel fabrics dyed with *W. tinctoria* dye liquids

Colour coordinates	1:20	1:30	1:40	S.Em±	C.D@5%	CV(%)
K/S	16.35	15.08	14.89	0.12	0.37*	3.45
Rfl(%)	15.46	15.93	16.75	0.004	0.011	4.27
L*	61.79	61.85	61.92	0.005	0.015*	1.96
a*	-1.86	-1.84	-1.81	0.006	0.019*	4.23
b*	-6.20	5.18	6.15	0.04	0.017*	4.97
d E	-	0.23	0.31	0.02	0.069*	3.04

*Significant @ 5% level

K/S- Colour strength, TRN- Transmittance L-The lightness/darkness co-ordinate, a*- The red/green co-ordinate with +a* indicating red – a* indicating green, b*- The yellow/blue co-ordinate with +b* indicating yellow and –b* indicating blue

In case of dye liquids extracted from dried *W. tinctoria* leaves powder, through aqueous and solvent (ethanol) media methods, higher colour strength with lower transmittance was recorded with dye extracted from solvent extraction (K/S = 57.85, TRN=0.04) compared to aqueous extraction (K/S = 50.65, TRN = 0.08). It was also noticed that the L* value was lower in solvent dye extract (0.51), indicated darker shade compared to aqueous dye extract (0.76). With respect to a* and b* values, dye liquids extracted with both aqueous (a*= 0.51, b*=-0.33) and solvent media (a* = 1.33, b*= -1.00) exhibited redder and bluer hues, with solvent extracted media exhibited more redder and bluer hue. The dye extract obtained from dried leaves possessed reduced colour pigments compared to dye extract obtained from fresh leaves was due to oxidation and degradation of the chromophore compounds post drying, as reported by Prasath *et al.* (2019).

Dye liquid extracted from grinded leaf paste exhibited significantly greater colour strength, hence used for dyeing of cotton and excel fabrics. The results in Table 2 revealed the effect of liquor ratio on the dyeing performance of cotton fabrics using the *W. tinctoria* dye liquid. It was observed that, among the cotton fabrics dyed with different material-to-liquor ratios (1:20, 1:30 and 1:40), higher colour strength and lower reflectance was recorded with 1:20 (K/S = 17.20, Rfl=15.42) followed by 1:30 (K/S = 16.15, Rfl=15.68) and 1:40 (K/S = 14.40, Rfl=16.12) respectively. Irrespective of material to liquor ratios, it was noticed that, all dyed cotton fabrics exhibited higher L* values indicated lighter shades, where the L* value was lower in the sample dyed at 1:20 (L* = 61.72), indicating darker shade compared to 1:30 (L* = 61.83) and 1:40 (L* = 61.95). With respect to a* values, all the samples exhibited greener hues with negative values, *i.e.*, a*= –1.88 at 1:20, a*= –1.85 at 1:30 and a*= –1.82 at 1:40. A mixed trend was observed in b* values, where the sample dyed at 1:20 (b* = –7.13) exhibited bluish hue, while 1:30 (b* = 6.20) and 1:40 (b* = 5.97) shifted towards yellower hues. With respect to colour difference, cotton dyed fabric with 1:40 MLR (dE=0.36) exhibited higher colour difference than 1:30 (dE=0.28).

The results in Table 3 revealed the effect of liquor ratio on the dyeing performance of excel fabrics using the *W. tinctoria* dye liquid.

In case of excel fabrics dyed with different material-to-liquor ratios (1:20, 1:30 and 1:40), higher colour strength and lower reflectance was recorded with 1:20 (K/S = 16.35, Rfl= 15.46) followed by 1:30 (K/S = 15.08, Rfl= 15.93) and 1:40 (K/S = 14.89, Rfl= 16.75), respectively. Irrespective of material-to-liquor ratios, it was observed that, all dyed excel fabrics exhibited higher L* values indicating lighter shades, where the L* value was lower in the sample dyed at 1:20 (L* = 61.79), indicating a darker shade compared to 1:30 (L* = 61.85) and 1:40 (L* = 61.92). With respect to a* values, all the samples exhibited greener hues confirmed with negative values, *i.e.*, a* = –1.86 at 1:20, a* = –1.84 at 1:30 and a* = –1.81 at 1:40. A mixed trend was observed in b* values, where the sample dyed at 1:20 (b* = –6.20) exhibited bluish hue, while 1:30 (b* = 5.18) and 1:40 (b* = 6.15) shifted towards yellower hues. Excel fabric dyed at 1:40 MLR (dE = 0.31) exhibited higher colour difference than 1:30 (dE = 0.23).

The results from Table 2 and 3 revealed that, irrespective of fabric type and material-to-liquor ratio (MLR), the 1:20 MLR at 60°C for 20 mins exhibited higher colour strength in both cotton (K/S=17.20) and excel (K/S=16.35) fabrics dyed with *W. tinctoria* dye liquids. This might be due to an increase in liquor ratio dilutes the bath and spacing between dyes gets increased; any 2 dye particles cannot reach on fabric surface at the same time thus producing darker and levelled shades. However, each drop of water industry cost a lot and a bath of higher liquor ratio also increase waste water load, more use of chemicals and heating of bath causes wastage of energy. Thus, compromise is to be made between possible lower liquor ratio and highest possible dye uptake, hence preferred to apply from a lower liquor bath. However, these results are supported by Chong *et al.* (1995) who stated that increased concentration of indigo in the dye bath, initially enhanced colour strength, however, beyond optimum concentration, no significant improvement was observed due to the lower affinity of the solubilized indigoid compounds into the fiber.

The lower lightness (L) values were observed at an MLR of 1:20, with 61.72 for cotton and 61.79 for excel, indicated darker shades compared to the of 1:30 and 1:40 MLRs. This may be attributed to, the concentrated dye liquor deposit more pigment on the fabric surface, thereby increasing colour strength

(Dilshad *et al.* 2018). The a* values of dyed cotton and excel fabrics at 1:20 were observed to be –1.88 and –1.86 respectively, reflected stronger greener hues. This might be due to higher amount of chlorophyll and related porphyrin pigments in the dye source, which absorb red and blue light reflecting green wavelengths.The b*values of dyed cotton and excel fabrics showed more bluish hue at 1:20, with –7.13 and –6.20 respectively because of flavonoids and phenolic compounds present in *W. tinctoria* that absorb yellow light and reflect blue as stated by Ashis and Adwaita, (2011).

Conclusion

From the study, it can be concluded that both the extraction method and material-to-liquor ratio (MLR) significantly influenced the colour strength and colour coordinates of *W. tinctoria* dye liquids and their application on cotton and excel fabrics. Among the extraction methods, dye obtained from grinded fresh leaf paste exhibited the highest colour strength and with darker shade. In case of fabric dyeing, cotton and excel fabrics dyed *W. tinctoria* dye liquid under 1:20 material to liquor ratio exhibited higher colour strength (K/S) and darker shades (lower L* values) compared to 1:30 and 1:40 ratios. However, fabrics dyed at 1:20 MLR exhibited more greener and bluer hues.The findings confirmed that optimization of extraction technique and dyeing parameters such as MLR enhances dye uptake and shade depth in natural dyeing with *W. tinctoria* dye liquids. These optimized conditions contribute to producing eco-friendly and visually appealing dyed textiles, further supporting the sustainable application of natural dyes in the textile industry.

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