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Colour Properties of Infrared Bandicoot Berry (Leea Indica) Dyed Silk

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ABSTRACT

Global interest in dyeing fabrics using natural dyes has increased due to recent trends toward sustainable textiles. As opposed to synthetic dyes, colourants from natural dyes contribute to environmental preservation and reduce human dependency on hazardous resources. This study extracted colourants from Bandicoot berry (Leea Indica) or Memali (Malay), using the aqueous water extraction methods. Infrared (IR) and exhaustion (EX) dyeing were performed on 100% plain silk fabrics at 90°C for 60 minutes with a simultaneous mordanting technique. The dyed fabrics were then measured using a spectrophotometer to analyse the L*a*b* values and K/S values of the shades obtained. The ability to withstand washing, perspiration, rubbing/crocking, and light of the dyed fabrics were compared. All fastness testing was done in accordance with MS ISO Standard and AATCC. The K/S values of the dyed fabrics were enhanced using mordants. The fastness properties of the IR-dyed silk fabrics gave ratings from good to excellent compared to EX-dyed fabrics which received mostly fair to good ratings. To conclude, this study provides empirical evidence that the colour properties of dyed silk fabrics with natural colourants extracted from Bandicoot berry (Leea Indica) can be optimized by using IR dyeing.

1. Introduction

Dyes have always been one of the most significant uses in textile colouration. Synthetic dyes are readily accessible on the market, come in a variety of colours, and have good colourfastness. Despite the prevalence of synthetic dyes used in the textile industry, they are made of inorganic compounds and some carcinogenic chemicals, poisonous, non-biodegradable, that may cause skin irritation and skin cancer [1,2]. Recent studies have highlighted that azo-based synthetic dyes are detrimental to the environment and human health because they emit toxic compounds [3-7]. These limitations have led to a massive exploration of natural resources as natural colourants which is more ecologically beneficial compared to synthetic dyes.

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Natural colours can be derived from fungi, minerals, animals, insects, and some plant components such as leaves, flowers, bark, roots, plant shells, fruits, and skins [8]. Apparently, they provide unusual, delicate colours that are pleasing to the eyes and radiate a sense of tranquillity and harmony with nature [9]. Natural dyes have several noteworthy characteristics that offer them more advantages over synthetic dyes. This is supported by Adeel *et al.,* [10], who reported that natural dyes have gained wide acceptance because they exhibit better biodegradability and more compatibility with the environment, which promotes sustainability in textiles. Additionally, Ragab *et al.,* [11] also mentioned that natural dyes offer numerous medical benefits to the wearer as they are skin-friendly and generally non-hazardous to human health. However, Kumar [12], pointed out that natural dyes have drawbacks and inconsistencies in shades when applied alone without mordants. As a result, nearly all-natural dyes need the application of mordants to adhere to the textile substrate [11]. Mordants are used to obtain various shades of colours and achieve spectacular performance parameters on textile materials [13].

This study investigated the potential of Bandicoot Berry (Leea Indica) plants as a new natural colourant for textile dyeing. To date, studies on the extraction of Bandicoot Berry (Leea Indica) plants as natural sources in textile dyeing are found limited in the literature. Leea Indica which belongs to the family of Vitaceae (grape) is a large shrub that can be found easily throughout Malaysia, China, Bangladesh, India, Indonesia, and Thailand [14]. It is also known as Bandicoot Berry (English); Hastipalash (India), huo tong shu (Chinese); Memali (Malay); and katangbai (Thai). Normally, it may grow up to 2–3 metres in height with stout, woody stems with lots of stilt roots; flowers are greenish white in colour with large trichotomous, and tripinnate leaves, followed by the fruit clusters that are small and edible, dark purple in colour and very decorative [15]. The fruit is a kind of berry, which is usually 8 mm across, spherical, often 2–6 lobed, to 0.5 cm in diameter, and purplish-black when ripe. Flowering takes place throughout the year. The leaves consist of hydrocarbons, b-sitosterol, phthalic acid esters, and ursolic acid [16]. It is not simply ornamental but an essential medicinal plant. The leaves, roots, and other parts of the tree are commonly used for medicinal purposes in a traditional way. Leea Indica is commonly used as a cure for pregnancy, birth control, body pain, skin problems, and dizziness recovery [15]. Leea Indica also includes some pharmacological actions, such as anti-inflammatory, analgesic, antioxidant, anti-microbial, anti-hypertensive, anti-diabetic, anti-diarrheal, anti-cancer, cooling, and anxiolytic [15]. The plant contains different classes of compounds including amyrin, esters, palmitic acid, farnesol, vitamin E, squalene, hydrocarbons, gallic acid, phthalic acid derivatives, lupeol, beta-sitosterol and ursolic acid [17].

This study focuses on using infrared (IR) dyeing rather than the traditional exhaust dyeing technique due to the rise in dyeing efficiency when the infrared is applied to the dyeing bath. IR dyeing is a technique that utilizes thermal energy that is transferred as electromagnetic waves in infrared heating to dye textile substrates [18]. The infrared process reduces pollution by decreasing the waste dyes and electrolytes in the effluent from reactive dyeing because of the high fixation that happens using the infrared heating method compared to other traditional dyeing procedures [19]. It was reported recently that the use of IR radiation energy to dye pineapple leaf fibres resulted in brilliant colour shade and higher colour strength value in comparison to conventional exhaustion dyeing [18]. Even though IR technology provides an alternative to traditional dyeing, the application of infrared dyeing of dyed fabrics with natural dyes is still lacking in major publications. In relation to the research gaps, this study will extend the knowledge of natural dyes, focusing on Bandicoot berry (Leea Indica) as a source of dyes, with the aid of IR technology to optimize the dyeing process. Significantly, this study indicates that there is a potential for Bandicoot berry (Leea Indica) to be extracted as natural dyes that could benefit the environment for a long period of time and most importantly in the textile industry's future. Therefore, this study aims to analyse the colour properties of dyed silk fabrics with natural colourants extracted from Bandicoot berry (Leea Indica) using IR dyeing.

2. Methodology

2.1 Material and Chemicals

The petals of the Bandicoot Berry (Leea Indica) were collected from Melor, Kelantan. It was left to dry at room temperature before being crushed into small units. Scoured 100% silk fabric was purchased from a local fabric supplier in Shah Alam. This study utilized both synthetic and natural mordants; iron (II) sulphate (synthetic mordant), lime (natural mordant), sodium carbonate solution, and non-ionic detergent.

2.2 Dye Extraction

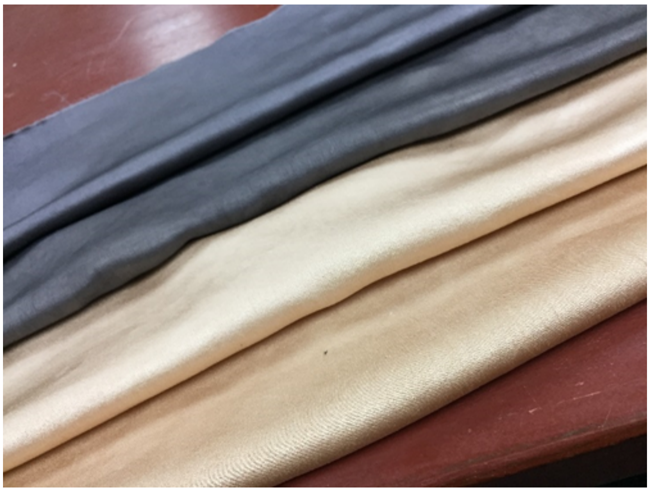
To extract the dye from the petals of the Bandicoot berry as Figure 1 (a), aqueous water extraction was used where the petals were washed and cut from their stem, followed by crushing them into small units by using the dry blender as shown in Figure 1 (b). Bandicoot berries were then extracted by boiling the crushed flowers with a liquor ratio of 1:20 for two hours as Figure 1 (c). Then, the mixture was left to cool down and filtered afterwards, which was applied for the dyeing experiment.

(a) (b) (c)

Fig. 1. Extraction of Bandicoot Berry (Leea Indica) (a) Bandicoot Berry (Leea Indica) (b) Crushed Bandicoot Berry (Leea Indica) in a powder form (c) Dye Solution of Bandicoot Berry (Leea Indica) using boiling water extraction

2.3 Dyeing and Mordanting of Silk Fabrics

The extract of Bandicoot berry was utilized to dye silk fabrics by using infrared (IR) and exhaustion (EX) dyeing techniques. The dyeing process took one hour at 90°C with a liquor ratio of 1:20. Meta-chrome mordanting technique was used where dyeing and mordanting using lime and iron (II) sulphate, were done simultaneously. The use of mordant was about 2% of the weight of the fabric. The dyed silk fabrics were washed, rinsed with tap water, and left to dry when the dyeing cycle was completed. Figure 2 shows the dyeing profile works for both dyeing methods during the dyeing process.



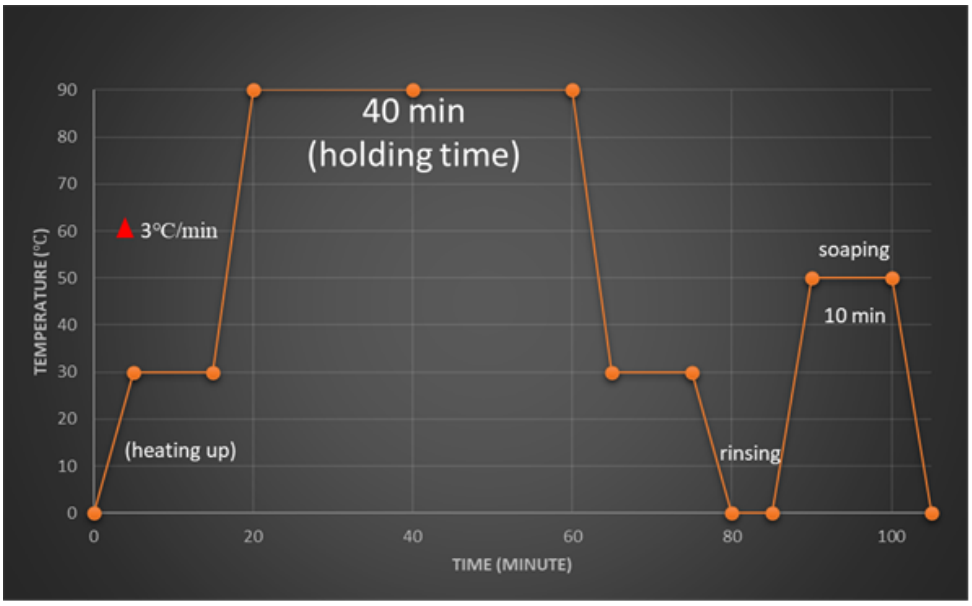


Fig. 2. Dyed Silk with Bandicoot Berry (Leea Indica) colourant and Dyeing Profile for Infrared and Exhaustion Dyeing Technique

2.4 Colourfastness Properties

The colourfastness of dyed silk fabrics to washing, perspiration, rubbing and light was evaluated. The visual assessment was assessed, compared, and rated in accordance with the MS ISO Standard and AATCC. The rating system for colour change and staining ranges from 1 to 5, with 1 representing the lowest rating and 5 the highest.

2.5 Colour Assessments

A HunterLab Labscan XE spectrophotometer was used to measure the shades of the dyed fabrics, and EasyMatch QC Software was used to analyse the results. The results are provided as the colour coordinates as L*, a* and b*. The L* values represent the degree of brightness or darkness; L* value of 0 denotes black and L* value of 100 indicates white. When it comes to the a* values, (+a) values denote redness and (-a) values denote greenness. In terms of b* values, (+b) indicates yellowness and (-b) indicates blueness. The spectrophotometer also provided reflectance and colour strength

(K/S) readings. The Kubelka-Munk Eq. (1) was used to compute the K/S values to assess how much dye was absorbed by dyed fabrics while it was at its maximum absorption wavelength.

$$\frac{K}{S} = \frac{1 - 0.01R^2}{2(0.01)R} \tag{1}$$

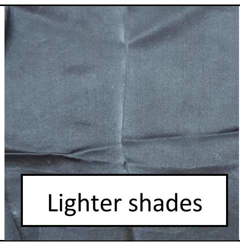
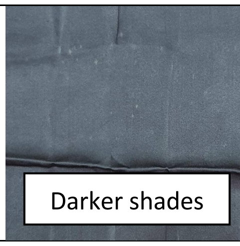
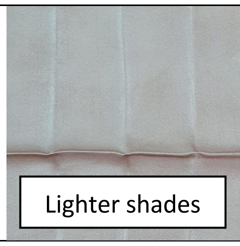
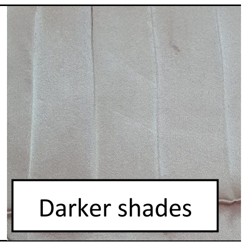
Where K is the amount of dye absorbed; S is how naturally occurring dyes scatter light, which depends on the nature of fabrics employed; and R is the amount of spectral reflectance of the dyed fabrics at its highest wavelength.

3. Results

3.1 Colour Shade of Dyed Fabrics

Table 1 shows the different shades obtained from Bandicoot berry flower extracted using the aqueous water extraction method on silk fabric with lime (natural) and iron (synthetic) mordants using different dyeing techniques. The dyed silk fabrics using IR dyeing with lime and iron mordant produced lighter shade while fabric dyed with EX dyeing method produced darker shade.

Table 1
Colour Shades of Dyed Fabrics

Dyes	Colour Shades			
	Iron (II) Sulphate		Lime	
	Infrared Dyeing (IR)	Exhaustion Dyeing (EX)	Infrared Dyeing (IR)	Exhaustion Dyeing (EX)
Bandicoot Berry (*Leea Indica*)				

3.2 Colour Coordinates of Dyed Fabric

Table 2 provides an overview of the results of the depth of dyed silk fabrics from Bandicoot berry using different dyeing techniques. It shows the CIELAB colour coordinates (L*a*b*) and K/S values for the dyed fabrics obtained by the HunterLab Labscan XE spectrophotometer, a colour prediction computer. The data in Table 2 shows that the L* value for IR dyed with lime is 73.37 while the L* value for EX dyed is 71.52. The measurement difference of L* is +1.85, which shows that bandicoot berry IR dyed silk with a lime produced shade slightly lighter than EX dyed silk with lime. While IR dyed silk with iron mordant has higher value of L* which is 42.49 than EX dyed silk with iron with differences of +2.9, indicating that EX dyed silk has a deeper shade than IR dyed silk. However, the a* and b* values of non-mordant and lime IR-dyed silk fabrics show unexpected results where their a* and b* values are much lower than the a* and b* values of EX-dyed silk on lime and non-mordant. From the results, a* values of non-mordant and lime of IR dyed silk are 9.03 and 8.03, while EX dyed silk are 9.68 and 9.03.

Table 2
L*a*b* and K/S Values of Bandicoot berry *(Leea Indica)*

Dyed fabrics	L*	a*	b*	K/S
Non-mordant IR	69.21	9.03	15.05	1.32
Non-mordant EX	69.08	9.68	15.34	1.31
Iron IR	42.49	5.07	2.64	3.77
Lime IR	73.37	8.03	13.17	0.86
Iron EX	39.59	4.71	2.37	4.59
Lime EX	71.52	9.03	13.74	0.98

The values of a* and b* determine the plotted shades of dyed silk on a 2D colour plot as shown in Figure 3. Therefore, the plotted shades for dyed silk fabrics of non-mordant and lime are more likely to appear in areas between redness and yellowness, suggesting that their shades are presented in a significantly deeper red and yellow colour due to the dye absorption on fabrics during the dyeing process. All the dyed silk fabrics mordanted by iron showed redness shade in their hue. Both coordinates were confirmed by their lower positive values of a* and b*.

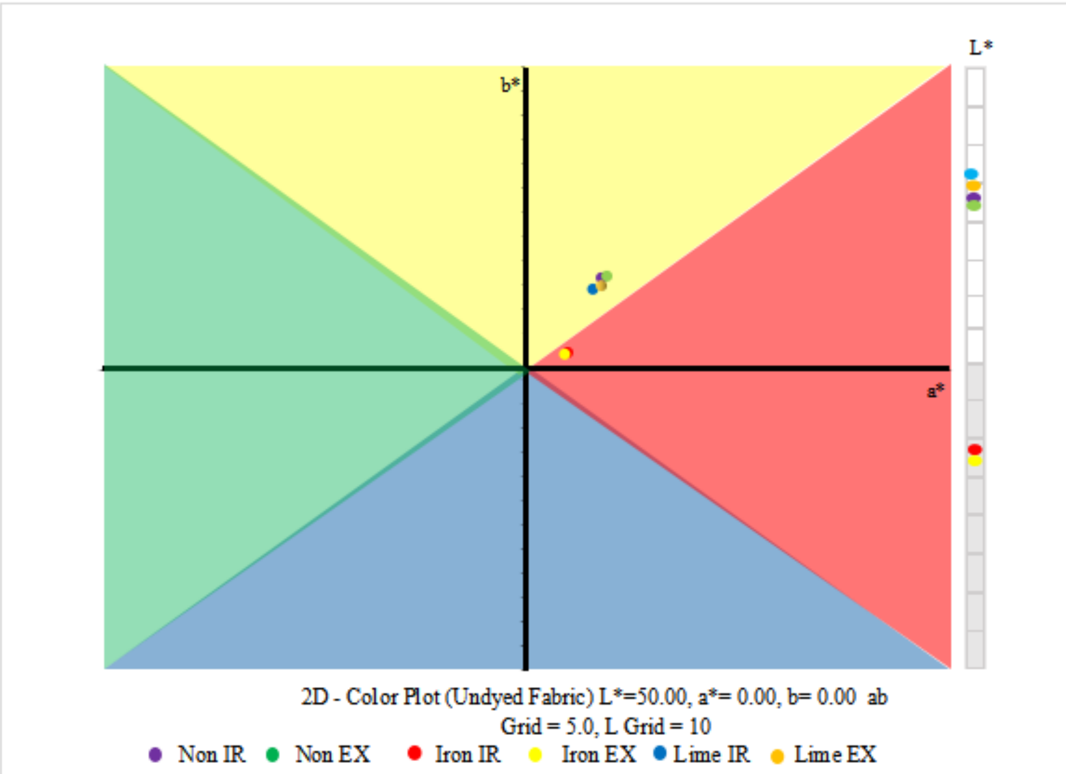


Fig. 3. 2D Colour Plot of Dyed Silk Fabrics

3.3 Colour Reflectance of Dyed Fabrics

Reflectance is defined as the amount of light reflected by an object at different wavelengths. Figure 4 shows that the reflectance curves of the dyed silk fabrics with Bandicoot berry using aqueous water extraction with different dyeing techniques and mordants attained a similar shape where the reflectance (%R) was increased from 400nm to 700nm steadily. The reflectance spectra of mordanted fabrics with iron were much lower than those of other dyed fabrics, indicating that the strength of colour of mordanted fabrics was higher. Mordants are essential for adding and fixing colour to fabrics.

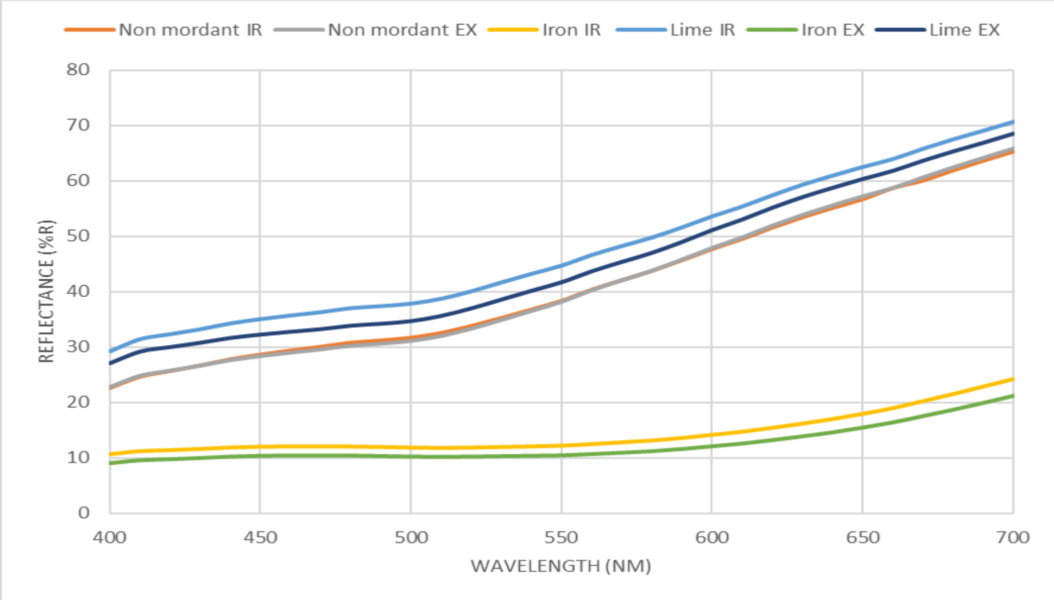


Fig. 4. Reflectance Curves of Dyed Silk Fabrics

3.4 Colour Strength (K/S) of Dyed Fabrics

The different mordants not only resulted in the difference in shades of colour and changes in L* values but also changes to their K/S values as well. The K/S values of the dyed silk fabrics from Bandicoot berry (Leea Indica) can be seen in Figure 5. Although the K/S values for all dyed silk fabrics appear low, they are nonetheless acceptable. It appears that adding mordants at the same time as the dye solution on the dye bath altered the colour strength of dyed silk fabrics. Metallic mordant (iron) aid in the bonding of dye molecules to fibres.

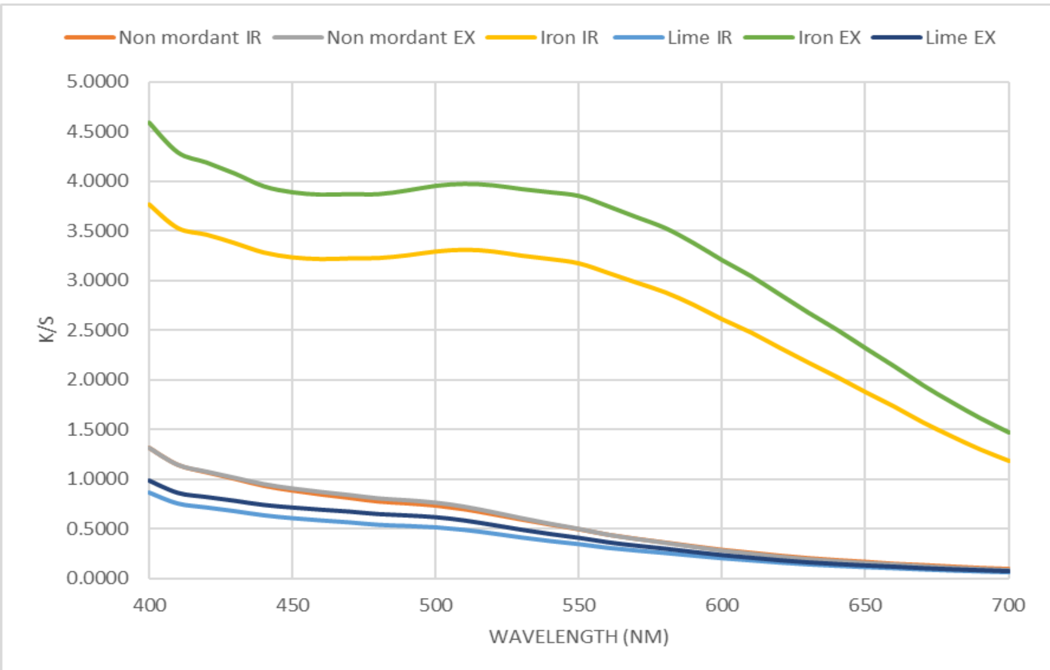


Fig. 1. Colour Strength (K/S) Values of Dyed Silk Fabrics

The K/S value of dyed silk fabric with lime and iron mordants is greater than that of dyed fabrics without mordants. The K/S values non-mordanted for both dyed fabrics are 1.32 and 1.31, respectively, whereas the K/S values for mordanted dyed silk fabrics with iron and lime are 3.77, 4.59, 0.86, and 0.98. This clearly demonstrates that mordanted dyed fabrics have a greater reflectivity and are less absorbent. Non-mordanted dyed fabrics, on the other hand, have a lower K/S value due to higher absorbance and lower reflectance values. In general, mordanted fabrics provided a higher K/S value. It is well known that when the reflectance is low, the absorption is high. Colour strength (K/S) is one of the most essential factors for testing the quality of dyed fabrics in terms of colour depth. Figure 6 depicts the K/S value at the minimum wavelength.

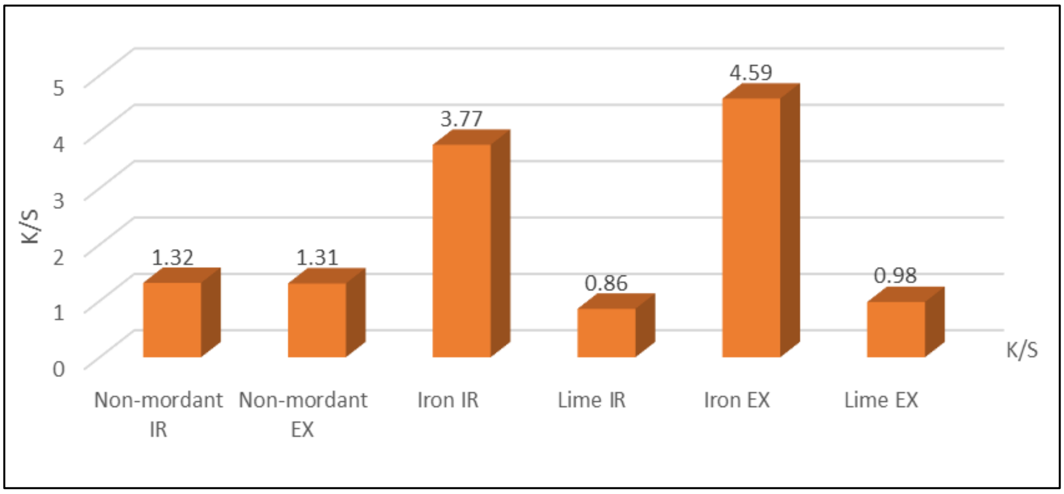


Fig. 2. K/S Chart at the Minimum Wavelength

3.5 Colourfastness Properties of Dyed Fabrics

The dyeing fastness properties of the dyed silk fabrics are presented in Tables 3 and 4. As for washing fastness, the colour change rating was fair to excellent for all dyed fabrics since the colour appreciable loss (3/4 to 5) on silk fabrics. However, the colour staining rating was fair to good (3/4 and 4). The fastness to perspiration showed a very good to excellent rating (4/5 and 5) for both colour change and staining of the adjacent fabric of cotton and silk on all dyed fabrics. Meanwhile, the light fastness for all dyed silk fabrics showed a fair to good rating (3/4 to 4) on colour change and the blue wool rating indicated a very good rating (6) of all dyed silk fabrics due to little fading, and good rating (5) on dyed silk fabric with iron due to moderate fading.

Table 3
Colourfastness Properties of silk fabric dyed with Bandicoot Berry

Dyed Silk	Washing			Perspiration			Light	
	Change in Colour	Staining		Change in Colour	Staining		Change in Colour	Blue Wool Standard
		Cotton	Silk		Cotton	Silk		
Non-mordant IR	4 (good)	4 (good)	3/4 (fair/good)	5 (excellent)	4/5 (very good)	4/5 (very good)	4 (good)	6 (very good)
Non-mordant EX	3/4 (fair/good)	3/4 (fair/good)	4 (good)	4/5 (very good)	4/5 (very good)	4/5 (very good)	4 (good)	6 (very good)
Iron IR	5 (excellent)	4 (good)	4 (good)	5 (excellent)	4/5 (very good)	4/5 (very good)	3/4 (fair/good)	5 (good)
Iron EX	4 (good)	3/4 (fair/good)	3/4 (fair/good)	4/5 (very good)	4/5 (very good)	4/5 (very good)	3/4 (fair/good)	5 (good)
Lime IR	4/5 (very good)	4 (good)	4 (good)	5 (excellent)	4/5 (very good)	5 (excellent)	4 (good)	6 (very good)
Lime EX	4 (good)	3/4 (fair/good)	3/4 (fair/good)	4/5 (very good)	5 (excellent)	5 (excellent)	4 (good)	6 (very good)

For rubbing/crocking fastness results as Table 4, both dyed silk fabrics were rated at 3 to 5 which shows fair to excellent colourfastness to rubbing in dry and wet conditions. However, IR-dyed fabrics were rated from 4 to 5 while EX-dyed fabrics were rated from 3/4 to 4 only.

Table 4
Colourfastness properties to rubbing/crocking

Dyed Silk	Staining							
	Silk				Cotton			
	Warp		Weft		Warp		Weft	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Non-mordant IR	4 (good)	4 (good)	4 (good)	4 (good)	4 (good)	4 (good)	4 (good)	4 (good)
Non-mordant EX	3/4 (fair/good)	4 (good)	3/4 (fair/good)	4 (good)	3/4 (fair/good)	3/4 (fair/good)	3/4 (fair/good)	3/4 (fair/good)
Iron IR	4 (good)	4/5 (very good)	4 (good)	4 (good)	4 (good)	4/5 (very good)	4 (good)	4/5 (very good)
Iron EX	3/4 (fair/good)	4 (good)	4 (good)	4 (good)	3/4 (fair/good)	4 (good)	3/4 (fair/good)	4 (good)
Lime IR	4 (good)	5 (excellent)	4 (good)	5 (excellent)	4 (good)	5 (excellent)	4 (good)	5 (excellent)
Lime EX	4 (good)	4 (good)	4 (good)	4 (good)	3/4 (fair/good)	3/4 (fair/good)	3/4 (fair/good)	3/4 (fair/good)

4. Conclusions

Natural colourants extracted from Bandicoot berry (Leea Indica) have a great potential as a source of dye for textile colouration, instead of its major application for medicinal purposes. It produces exciting and unique brownish to greyish shades on silk fabrics with acceptable fastness properties even without adding a mordant. However, the addition of mordants of iron and lime significantly enhances the dyeability of silk fabrics as the L*, and K/S values were obviously improved in comparison with non-mordanted dyed fabrics. The fastness properties of the IR-dyed silk fabrics showed good to excellent ratings except for EX-dyed fabrics which received ratings as fair to good only. Thus, this study provides evidence that the colour properties of dyed silk fabrics extracted from Bandicoot berry (Leea Indica) can be optimized by using IR dyeing.

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