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Attaining Optimum Values of Colourfastness Properties of Sustainable Dyes on Cotton Fabrics

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Abstract
The aim of this research was to identify optimum values of the colorfastness properties of sustainable dyes on cotton fabrics. Sustainable dyes are ecofriendly, biodegradable, economical and easily attainable from natural sources. The findings of this research established that good colourfastness properties of cellulosic fibres could be obtained using sustainable natural dyes. Experiments were carried out on 100% cotton voile fabrics of plain weave using four types of natural dyes: strawberry dye, beetroot dye, rose dye and China rose dye. Strawberry dye reacted with the cellulose of the cotton in an alkaline condition to form a stable covalent bond amid the dye and cellulose and showed outstanding colour fastness properties. The required experiments were conducted using the standard specified by ASTM and AATCC as stated in this paper. The colour strength properties, colour intensity properties, colour absorbency properties and colorfastness properties were investigated using a reflectance spectrophotometer and "Agilent Cary 630 FTIR Instrument" as stated in this paper. A sample dyeing machine – "Pad Dye Pad Steam" was used in this research to dye the cotton fabrics with sustainable natural dyes. The colorfastness properties were investigated using grey scale test results, and the colour strength and absorbency properties were tested using the spectrophotometer and FTIR instruments. The peak values of the FTIR instrument guaranteed the existence of the colourant or chromophore present in the dyestuffs, and exposed the best colourfastness properties. The findings of this research could be beneficial to personnel involved in textile industries who are in charge of dyeing cotton fabrics with natural dyes as well as controlling their colourfastness properties and colour intensity properties.

Key words: *colourfastness properties, transmittance, absorbency, cellulosic fibres, chromophore, FTIR.*

Introduction

The great importance of this research is for the textile wet processing zone since the task of controlling the colourfastness properties of natural dyes has always been challenging. Natural dyes have been selected for dyeing textile materials since they are cheap and easily available in nature. The dyeing process is carried out both in textile mills and in dyeing laboratories to get the desired result [1].

Different scholars have worked on this and conducted experiments at different times, with varying results. Some of them were similar and some were widely dissimilar. Due to the range of variables involved, if one criterion was changed during experiments, then the other properties of the fabrics were also changed [2].

Natural dyes are colouring materials obtained from natural sources such as plants, minerals, vegetables etc [3]. Natural dyes are sustainable and easily attained from nature. Harmless dyeing can be possible using natural dyes [4]. These dye particles are ecofriendly and do no harm to nature [5].

People from different parts of the world dye textile materials applying easy resources, but rare dyestuffs create brilliant and enduring shades like natural invertebrate colours, such as purple and pink, becaming extremely valued substances in the antique and primitive world [6].

An important technique of dyeing is wringing the substance comprising the dyestuffs in water, adding the textile materials to be coloured to the resultant dye bath, and transporting the solution to a rumble for an extended time. This process is habitually assessed over many days, until the shade has been equally transmitted to the materials [7].

The shades of dyestuffs are reliant on the capability of the ingredient to absorb light in the observable area of the electromagnetic spectrum, that is from 400 nm to 700 nm [8]. Another concept named Witt theory explained that colorants had two modules, one is a chromophore that instructs the colours by absorbing light in the observable area and another is an auxo-chrome that assists in expanding the colour. This model has become outmoded due to a recent electronic construction by which, dyestuffs are visible in the observable light range [9].

Dyes are categorised as consistent with their solubility and chemical properties [10]. Acid dyes are soluble in water and are used to dye fibres like silk, wool etc. Acid dyes are not applicable to dye cellulosic fibres [11].

Basic dyes are soluble in water [12] and are used to dye acrylic fibres. Generally, acetic dyes are used in the dye bath to support the absorption of dye particles into the fibre. Basic dyes can also be applied in colouring papers [13]. Direct dyes are applied in a somewhat alkaline dye bath [14] and can be applied to dye cotton fibres, leather, silk etc [15]. Direct dyes can also be applied to indicate pH and as organic tints [16].

Mordants increase the colourfastness properties of dye particles against water, light and fluid [17]. The selection of mordants is critical since various mordants may change the absolute colour incorrectly [18]. Maximum natural dyes are like mordants, their activity being shown in [19]. Synthetic mordant dyes can be applied on fibres like wool [20]. Mordants like potassium dichromate can be used as a finishing treatment [21]. Mordants containing heavy metal are injurious to health, and precautions should be taken while using them [22].

Vat dyes are not soluble in water [23] and are not capable of dyeing fibres directly [24]. The oxidation process makes the dye insoluble [25]. The blue indigo colour used in the denim industry is mainly a type of vat dye [26]. Reactive dyes are capable of reacting with fibres directly [27]. Covalent bonds help to make bonds between reactive dyes and natural fibres [28]. Cold reactive dyes are easy to use since they can create a dyeing reaction at room temperature [29]. Actually, reactive dyes are the best to dye cellulosic fibres because of their excellent colourfastness properties due to having covalent bonding [30].

Disperse dyes are insoluble in water and are mainly used to dye polyester fibres [31]. But they can also be used to dye manmade fibres like nylon and acrylic [32]. These dyes are mainly used with a dispersing agent [33], at high temperature, like 130 °C and more. The dyeing rate can be changed depending om the choice of dispersing agent [34].

In Azo dye the final colour is measured with the selection of di azoic and connecting substances [36]. Azo dye is not ecofriendly as it creates harmful substances that pollute nature [37]. Sulfur dyes are cheap and used to dye cotton fabrics in dark shades. Sulfur dyes are used mainly in the denim industry to dye black colours [38].

Materials and methods

Fabric used

Light to medium weight pure cotton fabric was used in this research. The fabric was woven and the weave structure plain. Full details of the woven fabric are given below in ***Table 1***.

It is seen from ***Table 1*** that the fabric used for the experiment was 100% cotton voile of plain weave. The weight of the fabric was 151 g/m^2 and the width 57″. The yarn count for both the warp and weft yarn is 40 Ne (14.76 tex), the ends per cm measurement – 55, and the picks per cm measurement is 47. The commercial name of the fabric is voile.

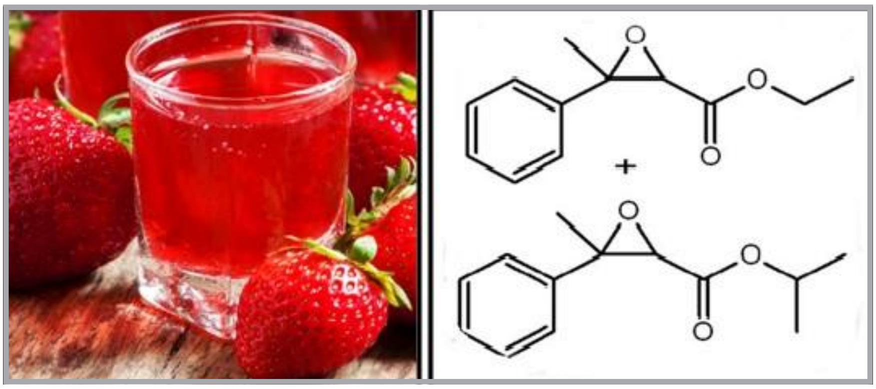

Figure 1. *Strawberry fruit, its liquid dye and chemical structure (ethyl methyl phenyl glycidate aldehyde or ethyl 3-methyl-3-phenyloxirane-2-carboxylate).*

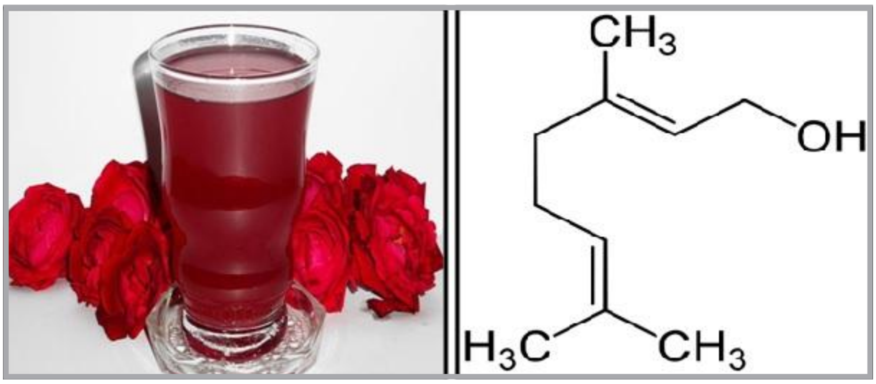

Figure 2. *Rose flowers, liquid rose dye and its chemical structure, Geraniol (C10H18O).*

Table 1. *100% cotton voile fabric.*

S.N.	Composition	Construction	Weave	Weight, g/m^2	Width, ″
1	100% cotton voile	40×40/140×120	Plain	151	57

Dye stuff used

Strawberry dye

Strawberry is a delicious fruit with a good smell that can also be used to dye cotton fabric a pinkish colour. It imparts a mild shade of pink colour to textile material like fibres, yarns and fabrics. ***Figure 1*** shows strawberry fruit, as well as liquid dye and the chemical structure thereof [39].

Rose dye

The rose is a symbol of beauty with a very good smell, and it can be used to dye cotton fabric naturally. Rose dye is obtained from rose extract in a liquid form and can be used to dye with a light shade. It can be used to dye textile material like fibres, yarns and fabrics. ***Figure 2*** shows rose flowers, as well as liquid rose dye and its chemical structure [40].

China Rose dye

The China rose is a flower type plant that is available in nature. This flower is cheap and can be used for dyeing cotton fabric with a light coloured shade. This flower can give a light pink shade in fabric while maintaining uniformity. ***Figure 3*** shows China rose flowers, as well as liquid dye and the chemical structure thereof [41].

Beetroot dye

Beetroot is a fruit type plant that is easily obtainable in nature and has many health benifits. This plant can be used to dye textile materials like fibres, yarns and fabircs. The colour bearing compound for the beetroot plant is "Betanin", which can impart a red or pinkish red colour to textile materials. ***Figure 4*** shows the beetroot vegetable, as well as liquid dye and the chemical structure thereof [42].

Chemical used

Various chemicals, liquids and auxiliaries were mixed with these natural dyes to dye cotton fabric mentioned in ***Table 2***. The chemical names, chemical formula, acidic or alkaline medium as well as their functions are given in this ***Table 2***.

Figure 3. China rose flower (Hibiscus Rosa Sinensis), its liquid dye and chemical structure (Anthocyanins).

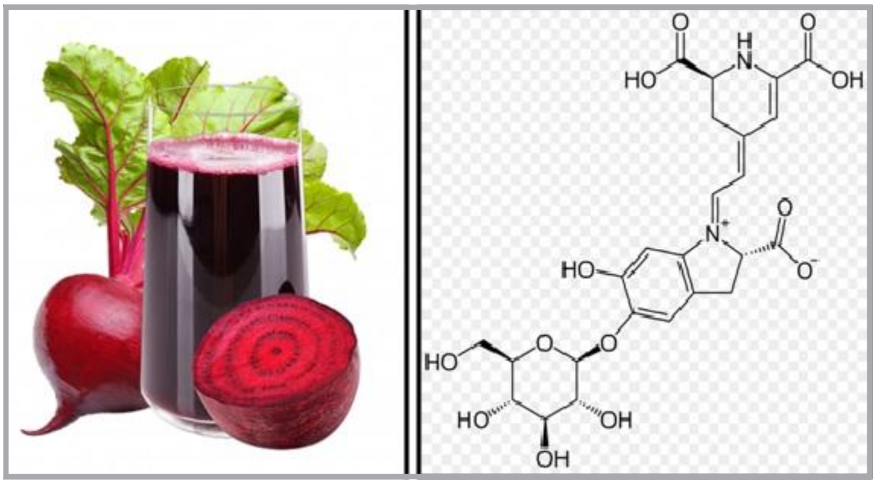

***Figure 4.** Beetroot vegetable, its liquid dye and chemical structure, Betanin ($C_{24}H_{26}N_2O_{13}$).*

Method used

Dyeing and fabric testing method

Light fastness properties of the cotton fabrics were measured in accordance with the test method provided by the AATCC TM16.1 standard. Wash fastness properties of the cotton fabrics were measured in accordance with the test method provided by the ASTM D435-42 standard. Perspiration fastness properties of the cotton fabrics were measured in accordance with the test method provided by the AATCC TM15 standard. The crocking fastness properties of the cotton fabrics were measured in accordance with the test method provided by the AATCC TM8 standard.

Colour intensity and colour strength testing method

Colour strength and colour intensity were measured with the Kubelka monk equation (K/S) and the reflectance and absorption characteristics of the cotton fabrics with ***Equation (1)*** and ***(2)***. In this equation the total colour difference was measured with ΔE* other terms such as ΔL*, Δa*, Δb*, Δc* and Δh*.

Equation (1) of the total colour difference with lightness values:

$$\Delta E * ab = [(\Delta L *)2 + (\Delta a *)2 + + (\Delta b *)2]½ \quad (1)$$

***Table 2.** Auxiliaries and chemicals used in this research.*

S.N .	Chemical formula	Commercial name	Medium	Function
1	$C_{20}H_{37}NaO_7S$	Wetting Agent	Alkaline	to diminish surface tension
2	$C_{15}H_{10}Cl_2O_3$	Sequestering Agent	Alkaline	to reduce water hardness
3	$C_{17}H_{25}OSO_3Na$	Leveling Agent	Alkaline	to level the dyes
4	$(NH_4)_2S_2O_3$	Fixing Agent	Alkaline	to fix the dye chemicals

Equation (2) of colour measurement with colour hue and colour saturation:

$$\Delta H * ab = [(\Delta E * ab)2 - (\Delta L *)2 - + (\Delta C * ab)2]½ \quad (2)$$

Instruments used

The property of colorfastness to light of the cotton fabrics dyed with natural compounds was tested with a Light Fastness Tester TF421. Wash fastness properties of the cotton fabrics were measured with Launder Meter TF418. The properties of colour fastness to perspiration were assessed with a Perspirometer TF416A. Colour fastness to crocking of the cotton fabrics was tested with a crock meter – TF410. An FTIR instrument: "Agilent Cary 630 FTIR Instrument" was applied in this experiment to obtain the colour fastness properties and colour intensity properties of the cotton fabrics dyed with natural dyes. Infrared radiation was transmitted through the fabrics and the colour strength and intensity properties obtained. A reflectance spectrophotometer was used in this research to attain colour strength and colour intensity values. A Pad dye pad steam machine by Benninger was used in this research to dye the cotton fabrics with natural dyes.

Dye extraction and dyeing process

Strawberry dye extraction and fabric dyeing process

Strawberries were first collected, then cut into small pieces and put into a blending machine. 500 grams of strawberries were blended with 500 ml of water with Na_2CO_3 solution and kept for 12 hours to neutralise the pH to 7-8. This solution created a pink colour dye, and the colour was slowly developed due to the application of Na_2CO_3 solution. 10 ml of chloroform was mixed in this solution and kept until evaporation occurred. Mercerised cotton fabrics were used to dye with strawberry dyes since mercerised cotton fabrics have very good dye absorbency properties [43]. A mordant like copper sulphate was used during the dyeing. First the fabrics were neutralised by washing in acetic acid solution to neutralise them, and then they were dyed in a continuous process of dyeing with the mixing in of sodium carbonate solution of 5 g/l with a liquor ratio of 1:10 to fix the dyestuff to the fabrics. The dyeing process was carried out at 90 °C at a speed of 20 metres per minute. After dyeing, the fabrics were washed with detergent water and 5 g/l of Na_2CO_3. After that, the fabric was dried at 60 °C and stored in a safe place [44].

Rose dye extraction and fabric dyeing process

Fresh roses were collected from a garden and washed. Petals were removed from the flowers and then washed again in clean water. Using a blender, the rose petals were blended and liquefied. 500 grams of rose petals was liquefied in 500 milliliters of water. Na_2CO_3 solution was admixed to control the pH. Na_2CO_3 solution was also used to develop the colour of the rose dye. Mercerised cotton fabrics were used to dye cotton fabrics with rose dye solution [45]. Prior to dyeing, the cotton fabrics were neutralised properly and a mordant like copper sulphate was used in the solution. The cotton fabrics were dyed with rose dye solution by the continuous dyeing process in a pad dye pad steam machine. Sodium carbonate solution of 5 g/l with a liquor ratio of 1:10 was used while dyeing to fix the dye to the fabrics. The dyeing bath temperature was kept 90 °C, and the speed of the machine was 20 metres per minute. The dyed fabric was washed off in detergent solution to remove unfixed dye particles and then again in clean water. Finally, the fabric was dried in a dryer at 60v and stored [46].

China rose dye extraction and fabric dyeing process

China roses were collected and then washed properly. Petals of the China roses were plucked off and then washed again. Using a blender, the China rose petals were blended and liquefied. 500 grams of China rose petals was liquefied in 500 milliliters of water. Na_2CO_3 solution was admixed to the solution to control the pH. Na_2CO_3 solution was used to develop the colour of the China rose dye. Mercerised cotton fabrics were used to dye the cotton fabrics with China rose dye solution [47]. Prior to dyeing, the cotton fabrics were neutralised properly and treated with mordants like copper sulphate at 60 °C temperature at a speed of 20 metres per minute. The cotton fabrics were dyed with China rose dye solution by the continuous dyeing process in a pad dye pad steam machine. Sodium carbonate solution of 5 g/l with a liquor ratio of 1:10 was used while dyeing to fix the dye to the fabrics. The dyeing bath temperature was kept at 90 °C, and the speed of the machine was 20 metres per minute. The dyed fabric was washed in detergent solution to remove unfixed dye particles and then again in clean water. Finally, the fabric was dried at 60 °C in a dryer and the fabrics stored [48].

Table 3. *Measurement of K/S values with L* a* b* C* & h* of dyed fabrics.*

Dyestuff	K/S	L	a*	b*	C*	h*
Fabrics dyed with strawberry dye	3.88	40.39	0.37	1.19	1.32	84.22
Fabrics syed with beetroot dye	3.71	53.35	2.18	3.71	4.17	79.09
Fabrics dyed with rose	3.52	74.22	4.54	22.41	25.24	78.33
Fabrics dyed with China rose	3.43	82.62	4.73	26.84	28.33	76.22

Beetroot dye extraction and fabric dyeing process

Beetroots were collected from plants and then washed properly. They were then cut into pieces and then blended and liquefied into water using a blender. 500 grams of beetroot was liquefied in 500 milliliters of water. Na_2CO_3 solution was admixed to the solution to control the pH. Na_2CO_3 solution was used to develop the colour of the beetroots dye. Mercerised cotton fabrics were dyed with beetroot dye solution. Prior to dyeing, the cotton fabrics were neutralised properly and treated with mordants like copper sulphate at 60 °C temperature at a speed of 20 metres per minute [49]. The cotton fabrics were dyed with beetroots dye solution by the continuous dyeing process in a pad dye pad steam machine. Sodium carbonate solution of 5 g/l with the liquor ratio of 1:10 was used while dyeing to fix the dye to the fabrics. The dyeing bath temperature was kept at 90 °C, and the speed of the machine was 20 metres per minute. The dyed fabric was washed in detergent solution to remove unfixed dye particles and then again in clean water. Finally, the fabric was dried at 60 °C in a dryer and the fabrics stored in a safe place [50].

Experiment

Colour strength and colour intensity test

Using a reflectance spectrophotometer, values of the colour strength and colour intensity properties were tested in this research. A sample of 4″×2″ size was cut and prepared for testing on the instrument. The spectrophotometer had a clamp where the samples were set for experimentation. The clamp was opened and samples positioned to register colour strength and colour intensity values. After placing the samples in the right places underneath the clamp, the spectrophotometer created a light with tungsten emissions by reflection of the light source throughout the samples, and the colour strength and color intensity values were obtained. Colour strength (K/S) and colour intensity values or colour saturation values were obtained using a wave number of between 330nm to 900nm within the visible range. Other colour values of the samples like L*, a*, b*, C* and h* were obtained and are placed in ***Table 3***.

Colour fastness test

Colour fastness properties of the samples were tested using the standard specified by ASTM and AATCC. Light fastness properties of the cotton fabrics were measured in accordance with the test method provided by AATCC TM16.1 using an instrument named Light Fastness Tester TF421. Wash fastness properties of the cotton fabrics were measured in accordance with the test method provided by the ASTM D435-42 standard using an instrument named Launder Meter TF418. Perspiration fastness properties of the cotton fabrics were measured in accordance with the test method provided by the AATCC TM15 standard using a perspiration tester named Perspirometer TF416A. Crocking fastness properties of the cotton fabrics were measured in accordance with the test method provided by the AATCC TM8 standard using an instrument named Crock Meter TF410.

FTIR test

Using an FTIR instrument named Agilent Cary 630 FTIR Instrument, experiments were conducted on various dyed cotton samples. These experiments were carried out to identify the colour absorbency properties, colour strength properties and colour intensity properties of the cotton fabrics dyed with natural sustainable dyes. Infrared radiation was transmitted throughout the cotton fabrics, and the colour fastness properties required were found. The FTIR instrument had a clamp under which samples were placed, and their reflectance values were measured from the passage of infrared radiation. IR radiation generated some peaks on the basis of the wavelength it covers. Colour fastness properties and colour intensity

Table 4. Colour fastness properties of cotton fabrics dyed with natural dyes.

Fabric dyed with	Light fastness	Wash fastness	Rubbing fastness		Perspiration fastness	
			Dry	Wet	Acidic	Alkaline
Strawberry dye	3-4	3	3	3	3	3-4
Beetroot dye	3	2-3	2-3	2-3	2-3	3
Rose dye	3	2-3	2-3	2-3	2	2
China rose dye	2-3	2	2-3	2	2	2

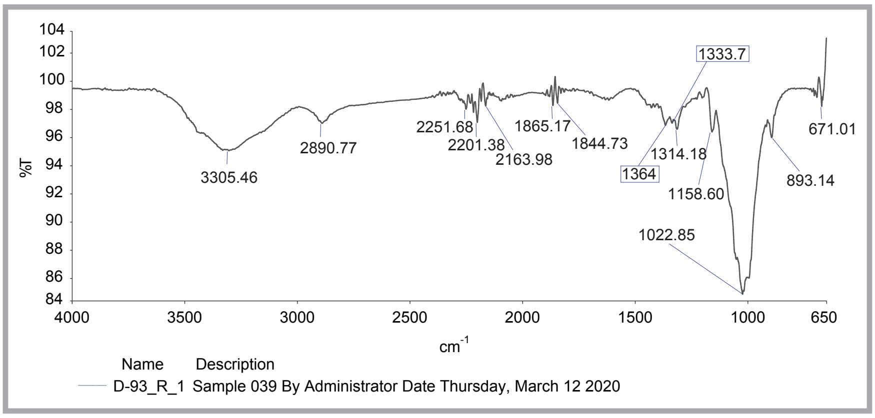

***Figure 5.** FTIR observation of strawberry dyed fabrics, showing the maximum peak value of 3305.46 cm^{-1}.*

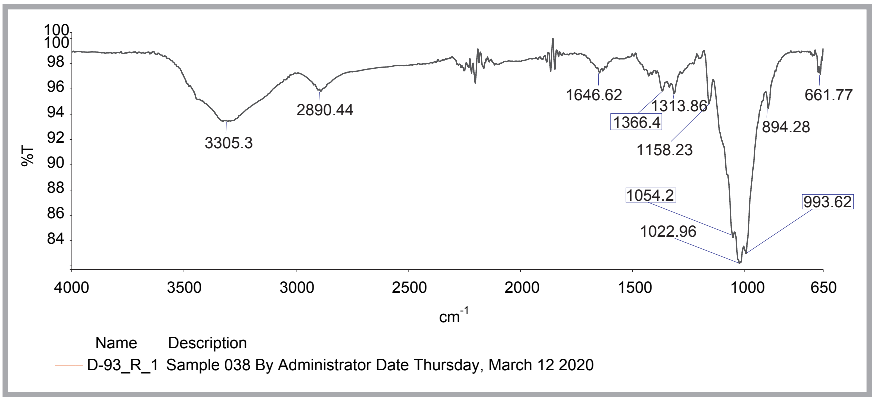

***Figure 6.** FTIR observation of beetroot dyed fabrics, showing the maximum peak value of 3305.33 cm^{-1}.*

properties were obtained from the IR spectral reflectance values. Higher peak values were obtained for the more intense colours. Where the colour saturation was less, IR showed lower peak values.

Results and discussion

Colour strength and colour intensity values

Color strength and colour intensity values were obtained by the Kubelka monk equation using K/S values. A reflectance spectrophotometer was used to acquire the colour strength and colour intensity values using the reflectance of the light source through the sample fabrics. It is seen from ***Table 3*** that colour strength values (K/S) and color intensity values were obtained for the cotton fabrics dyed with natural dye stuffs. The highest values of K/S indicate the most intense colour with the lowest values of lightness (L). Alternately, the lowest values of K/S indicate the least intense colour with the highest values of lightness (L).

Strawberry dyestuffs had the highest K/S values of 3.88 with the lowest lightness values of 40.39. On the other hand, China rose dyestuffs had the lowest K/S values of 3.43 with the highest lightness values of 82.62. Fabrics dyed with China rose showed the lightest shade amongst the selected dyes and the least colour intensity properties. Fabrics dyed with strawberry colour showed the best colour strength and colour intensity properties. ***Table 3*** also shows the values of L*, a*, b*, C* & h*, in which it should be noted that a* and b* have both positive and negative values, where negative values of a* and b* are displayed by green and blue shades. Contrariwise, positive values of a* and b* are exhibited by red and yellow shades.

Colour fastness values

Colorfastness properties were measured using the grey scale. Values of the colourfastness properties are given in ***Table 4***. Light fastness values, wash fastness values, rubbing fastness values and perspiration fastness values were obtained and are displayed in ***Table 4***.

Light fastness values

It is seen from ***Table 4*** that the highest light fastness value of 3.5 is obtained for cotton fabrics dyed with strawberry dyes. It is also seen that the lowest light fastness value of 2.5 is obtained for cotton fabrics dyed with China rose dyes. The other two natural dyes – beetroot and rose show light fastness values of 3.5 and 3.

Wash fastness values

It is seen from ***Table 4*** that the highest wash fastness value of 3 is obtained for cotton fabrics dyed with strawberry dyes. It is also seen that the lowest light fastness value of 2 is obtained for cotton fabrics dyed with China rose dyes. The other two natural dyes – beetroot and rose show wash fastness values of 3 and 2.5.

Rubbing fastness values

It is seen from ***Table 4*** that the highest rubbing fastness value of 3 (dry)/3 (wet) is obtained for cotton fabrics dyed with strawberry dyes. It is also seen that the lowest light fastness value of 2.5 (dry)/2 (wet) is obtained for cotton fabrics dyed with China rose dyes. The other two natural dyes – beetroot and rose show rubbing fastness values of 3.5 (dry)/2.5 (wet) and 3 (dry)/2.5 (wet).

Perspiration fastness values

It is seen from the ***Table 4*** that the highest perspiration fastness values of 3 (acidic)/3.5 (alkaline) is obtained for cotton fabrics dyed with strawberry dyes. It is also seen that the lowest light fastness value of 2 (acidic)/2 (alkaline) is obtained for cotton fabrics dyed with China rose dyes. The other two natural dyes – beetroot and rose showed perspiration fastness values of 2.5 (acidic)/3 (alkaline) and 2 (acidic)/2 (alkaline).

FTIR observation

Colour strength properties, colour intensity or saturation properties and colour absorbency properties of the cotton fabrics dyed with natural dyes were evaluated applying Fourier Transform Infrared spectroscopy. Using a FTIR instrument named Agilent Cary 630 FTIR Instrument, colour intensity properties and colour fastness properties were identified within the spectral range. Infrared radiation could pass a few microns through the sample fabrics, and the peak values were detected.

The area of infrared spectroscopy was from a wave number of 650 to 4000 cm^{-1} in the Fourier Transform Infrared (FTIR) range. FTIR measurement of the dyed cotton fabrics was cunducted using infrared emission within the observable spectral region with the highest IR peak values. It is seen from the Fourier Transform Infrared (FTIR) Spectroscopy that the highest peak value was obtained for cotton fabrics dyed with strawberry dyes.

The highest peak value for the cotton fabrics dyed with strawberry dyes was 3305.46 cm^{-1}, which is shown in ***Figure 5***. The peak values explain the presence of the colourant in the observable spectral region, and the peaks were distinctive enough to detect the existence of chromophore in the dyestuff, which is responsible for the sense of colour on fabrics. The highest peak value for the best saturated colour – strawberry was at 3305.46 cm^{-1}, which signifies the presence of chromophore in fabric with improved colour fastness properties. The lowest peak value for the cotton fabrics dyed with China rose was 3304.83 cm^{-1} which is shown in ***Figure 8***. China rose was the least saturated colour and with the lowest colour fastness properties. The peak values of beetroot and rose dyes are shown in ***Figures 6*** and ***7***. Hence, the best colour fastness properties were achieved by strawberry dyestuffs (3305.46 cm^{-1}), beetroot dyestuffs (3305.33 cm^{-1}), rose dyestuffs (3305.16 cm^{-1}) and lastly by china rose dyestuffs (3304.83 cm^{-1}), respectively, as presented in ***Table 5***.

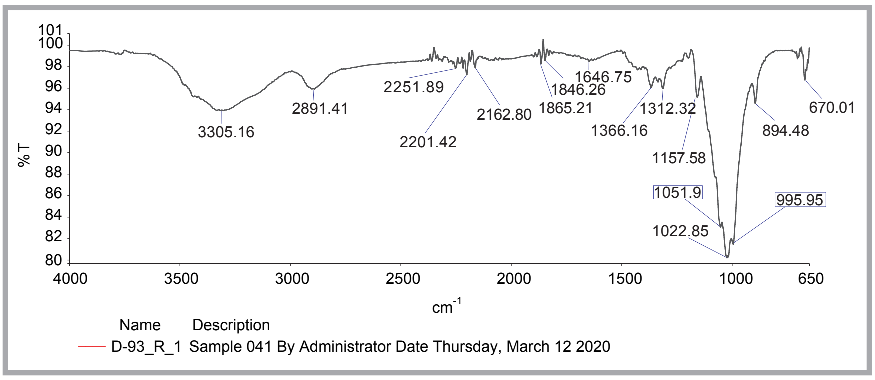

Figure 7. *FTIR observation of rose dyed fabrics, showing the maximum peak value of 3305.16 cm-1.*

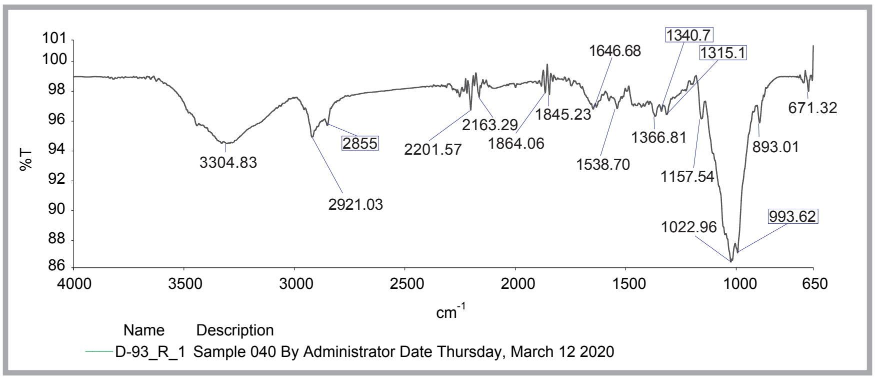

Figure 8. *FTIR observation of China rose dyed fabrics, showing the maximum peak value of 3304.83 cm-1.*

Table 5. *FTIR observation of the highest peak points.*

S.N.	Fabric dyed with	Highest peak points (wave numbers), cm^{-1}
01	Strawberry dye	3305.46
02	Beetroot dye	3305.33
03	Rose dye	3305.16
04	China rose dye	3304.83

Conclusions

It is seen from the research that colour strength properties, colour intensity properties, colour absorbency properties and colourfastness properties were achieved using sustainable natural dyes, which are ecological, economical and easily obtainable from natural sources. Natural dyes can be used in place of synthetic dyes on a commercial basis to dye cellulosic fabrics to reduce environmental contamination. It is seen from the research that natural dyes have a reactive group that reacted with the cellulose of cotton fabrics in an alkaline condition to establish a stable covalent bond between the dye and cellulose, showing outstanding colour fastness properties. Natural dyes have reactive groups as a central part and a covalent bond formed between the dye molecules and terminal reactive groups. Hence, the natural dyes showed very good colour properties. The colour strength properties and color intensity properties were assessed using the Kubelka monk equation (K/S) with reflectance and absorption features of the cotton fabrics. The outcomes of this research can be advantageous to dyeing cotton fabrics with natural dyes instead of using man-made ones as well as to adjusting their color fastness properties. This research opens possible ways for further study to scholars in this field.

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