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Colouration and Performance Evaluation of Ethiopian Kusha Fibres

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Abstract

Bast fibre dyeing process was common practice as the value addition of most bast fibres was demanded for various commercial and household applications. In this research work, kusha fibre (which was extracted in our previous work) subjected to dyeing using direct, reactive, vat and cationic dyes for the first time. The dyeing process was performed using concentrations 0.5%, 1%& 3% (W/W) dye to fibre with MLR 1:20. After dyeing process; performance of dyed fibre (dye absorbency measurement, colourfastness to washing, colourfastness to rubbing, colourfastness to light) and tensile tests were conducted. The results revealed that; K/S value of all dyed kusha fibre samples increases as the concentration of dyes applied increases, the colourfastness to washing of dyed fibres except the of direct dyes were found good, in both dry and wet rubbing fastness, reactive dyed samples have overall good rubbing fatness performance over the others, light fastness result shows it is good performance for all samples according to blue wool light fastness standard that exceeds 6. The tensile strength and elongation of dyed samples showed slight decrement in both vat and direct dyed samples; whereas, the considerable decrement was observed both in samples dyed with reactive and basic dyes as there is formation of covalent bond between fibre and dye and acid medium of processing affected the tensile property respectively.

Keywords

Ethiopian kusha fibre• Dyeing• Performance of dyed fibre• Tensile property

Introduction

The fashion industry saw the emergence of environment-friendly and natural fabric materials recently. The naturalism trend has established sectors in the textile and fashion industry also. In this regards, Cotton is the most abundant of all naturally occurring organic substrates and is widely used. It is used either alone or in conjunction with synthetic fibres in various ranges of apparel. This material characteristically exhibits excellent physical and chemical properties in terms of water absorbency, dyeability, and stability [1]. As stated above, because of global awareness over environment and health, there is an increasing trend of market share towards other natural fibre products including jute to produce decorative and diversified home textile products. The dyeing of textile fibres involves the application of a colorant which is of comparative permanence or fastness. Thus, in dyeing it is required that the dye be associated strongly with the fibre to make it resistant to such agents as water, detergents, perspiration, weather, solvents. The performance and response of different bast fibres after dyeing is more or less different according to their nature [2].

For example, the inherent factors of the difficulties of dyeing of flax fibre are that the flax fibres have a high degree of crystallinity and a high degree of orientation, with more closely structure, the inclination is small, and non-fibre ingredient is high. Flax fibres in the microstructure, the crystalline region is larger than the area of the amorphous region, the smaller the space occupied by the dyeing of the dye molecules can. Meanwhile, the high degree of orientation also hinders the penetration of dye molecule. In case of Jute, it is mostly dyed with basic dye because it has material affinity to this dye and as a cellulosic fibre, jute may have to well respond to reactive dye [3]. The reactive dyes offer a wide range of dyes with varying shades, fastness, and costs with high brilliancy, easy applicability and reproducibility. Because of the presence of non-cellulosic substances in raw hemp bast, the fabric handle, colour yield, and colour fastness of hemp fibers are not satisfactory after dyeing. In our previous study; we have extracted, optimized and characterized kusha bast fibre from kusha plant. In this work, kusha fibre colouration using different dyes was made followed by tensile properties and performance evaluation of dyed fibre [4].

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Materials and Methods

The raw material used for colouration was kusha fibres which were extracted in our earlier work. 100% caustic soda flakes, hydrogen peroxide (50% w/w), sodium silicate, sodium hydrosulphite, glauber's salt were bought from SD fine chem Ltd and sodium carbonate was bought from TATA Chem Ltd. Direct dyes (Sirius blue S-BRR, Sirius red F-3B), Reactive dyes (Remazole blue FCB CY 60724, Remazole red FCB HC-10578), vat dye (Indanthron brown Ay-14050), Cationic dye (Astrazon blue FGRL-300%) were kindly supplied by Dyestar India Pvt Ltd. & Cationic dye (Coracryl red CGST supra 240%) was sourced from Colourtex Ind. Ltd [5].

Methods

Before colouration of kusha fibre, raw fibres were bleached using 5 g/L hydrogen peroxide, 1.8 g/L sodium carbonate, 0.5 g/L caustic soda and 7 g/L sodium silicate at 95°C temperature running for an hour. The resulting bleached fibres were used for dyeing process using dye concentrations 0.5%, 1% and 3% (W/W) of fibre for direct, reactive, vat dyes and cationic dyes using MLR 1:20. Direct dyeing was done raising room temperature to 50°C & holding it for 10 min before adding the required electrolyte; and again its temperature raised to boil within 30 min and kept running for 60 min. Reactive dyeing was done at 60°C raising from room temperature within 20 min by adding glauber's in between; hold the dyeing temperature at 60°C and run for 30 min followed by addition of soda ash and further run the process for 60 min time. Vat dyes also applied on kusha fibres after the vatting process, dyeing of fibres with vat dyes was done at 50°C for 60 min with addition of glauber's salt followed by oxidation with 3 mL/L hydrogen peroxide running for 15 min. Finally, cationic dyes dissolved with acetone were applied to kusha fibres at 90°C rising from room temperature at 1.5 °C/min gradient [6].

Performance and Tensile Tests

Colourfastness of dyed kusha fibres to washing, light and rubbing were evaluated using ISO standards. Tensile properties of the same fibres were measured using ISO test method [7].

Dye absorbency measurement

Shade depth dyed fibre samples was determined from K/S values with D65/10° observer using spectrascan 5100+, spectrophotometer, India. K/S value calculated using the following equation, Eq. (1): K/S=(1-R) 2 / 2R (1) Where R is the reflectance, K is absorbance and S is the scattering [8].

Colourfastness to washing

The dyed kusha fibre samples were washed by sandwiching the dyed fibre specimens in between the white fabrics using laundro-meter-rossari lab tech, India applying ISO 105 C06 A25 test method. Evaluation of specimens after washing had been checked its colour change using grey scale 1-5 grades (grade 1 represents huge colour change or poor performance and grade 5 implies negligible colour change or excellent performance) and the staining effect on white adjacent fabrics using grey scale 1-5 grades (where grade 1 implies more stains on adjacent fabric and grade 5 represents no or negligible colour transfer) [9].

Colourfastness to rubbing

Colourfastness to rubbing tests was conducted using crockmeter FD-11, Hungary applying ISO 105-X12 method. Dyed fibre samples laid horizontally on crockmeter where the edges of the fibres fastened tightly with tape to avoid slippages before the start of rubbing.

The rubbing tests were done on both dry and wet white test fabrics and colour fastness to rubbing test results were evaluated using grey scales on both wet and dry test fabrics after conditioning the specimen specified on ASTM D 1776. The test results were evaluated with grey scale 1-5 grades, where grade 1 represent more colour transferred to white test fabric and grade 5 implies negligible colour transfer to white test fabric.

Colourfastness to light

Dyed kusha fibres colourfastness to light was done using ISO 105 B02 method such that, dyed samples exposed to artificial xenon arch light source where half parts were covered with black mask and the remaining half part exposed to light that styed for 24 hours.

Once the given timing finished, samples removed from light fastness testing set-up and uncovered the mask followed by evaluating of its fastness using blue wool light fastness standard 1-8; where 1 stands for poor while 8 is for outstanding performance respectively.

Tensile strength and elongation of dyed fibres

Tensile strength and elongation of fibres were determined applying ISO-5079; single fibre method, where tests were done for each specimen after dyeing and compared with standard reference sample strength and elongation result that was done before dyeing. Standard test conditions fulfilled for both dyed samples and reference sample using ISO 139 standard before measuring tensile strength and elongation.

Result and Discussions

Colour yield (K/S) measurement: Colour yield is a ratio of absorption and scattering coefficients related to qualitative measurement of dyed textile material. Figure 1 shows the K/S values of dyed kusha fibres with different dyes varying their concentration.

As shown on Figure 1, K/S value of dyed kusha fibre samples increases as the concentration of dyes applied increases. This could be more justified looking on dyed sample images on table 1. This shows the higher concentration of dyes absorbed by the fibre, the more K/S value will be found, but still K/S values could be different for the same quantity of dyes being absorbed with different penetration.

As a result, higher K/S couldn't be the guarantee for amount of dye absorbed to be higher. Here in this condition since different penetration couldn't be occurred with dyeing having similar dyeing condition and raw materials, whatever higher K/S value found could be translated as either more dyes were accumulated on the surface of the fibres or penetrated inside the fibres under same dyeing circumstances.

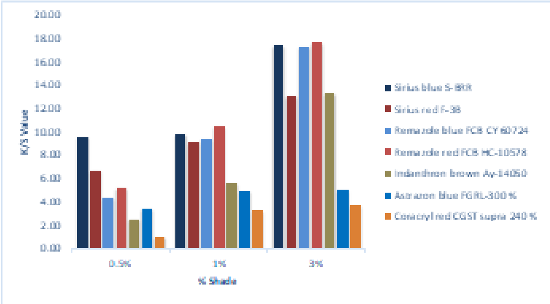
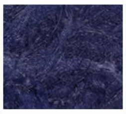
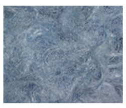
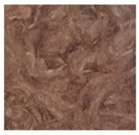
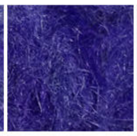
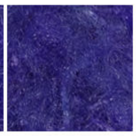
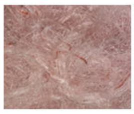
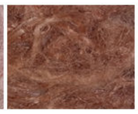


Figure 1. K/S Values of dyed kusha fibres.

On the same Figure 1, kusha fibres were found dyeable with direct, reactive and vat dyes as the fibre is cellulosic in nature; besides to this, cationic dyes were able to colourize the same fibre due to the presence of hemicellulose and lignin. lignin and hemicellulose which are available in the fibre possess -COOH group which enables to have good affinity for cationic dyes. As observed on the same figure, cationic dyes able to dye kusha fibres though uniformity of dyeing and K/S values were lower as compared to other class of dyes; this is probably due to the lower amount of lignin and hemicellulose inside the fibre.

Table 1: Dyed fibres shades with different dyestuffs and concentration.

Dye class	Dye stuff	Dyed fibres pictures with different dye concentration		
		0.5%	1%	3%
Direct dyes	Sirius blue S-BRR			
	Sirius red F-3B			
Reactive dyes	Remazole blue FCB CY 60724			
	Remazole red FCB HC-10578			
Vat Dye	Indanthron brown Ay-14050			
Cationic (basic) dyes	Astrazon blue FGRL-300 %			
	Coracryl red CGST supra 240 %			

Colourfastness to washing

Table 2: Colour fastness values of different dye classes with variable concentration.

Dye class	Dyestuf	Washing fastness						Rubbing fastness						Light fastness	
		Colour change			Staining			Dry			Wet				
% Shade		0.5	1	3	0.5	1	3	0.5	1	3	0.5	1	3	1	3
Direct dyes	Sirius blue S-BRR	44622	44622	2	3	44622	2	5	44685	44685	44685	3	3	6	6
	Sirius red F-3B	44622	3	3	3	44622	2	5	44685	44685	44685	3	3	7	7
Reactive dyes	Remazole blue FCB CY 60724	4	4	44685	5	5	44685	5	44685	44685	44685	4	44654	6	6
	Remazole re	44685	44685	44685	5	44685	44685	5	44685	4	44685	44654	44654	7	7

	dFCBHC-10578														
Vat Dye	Indanthron brown Ay-1 4050	5	5	5	5	5	5	44685	44685	4	3	3	44622	7	7

Dyed kusha fibres were tested using standard procedure for its colourfastness to washing. Washing condition test evaluation considered dyed fibre colour change and staining effect using standard grey scale. As shown on Table 2, the colourfastness of direct dyes were found lower as compared to reactive and vat dyes due to its weaker interaction (bond) between fibres and direct dye molecules; in case of reactive dyes of vinylsulphone (remazole) group shows good washing fastness as strong covalent bond is formed between fibre and dyes. In the other hand excellent washing fastness is observed from vat dyed samples; as the vat dyes forms bigger insoluble aggregates just after smaller dye molecules trapped inside cellulosic fibres.

In the same table, it shows staining effect of dyed kusha fibres washed together with white cotton fabric; staining results of direct dyes generally shows poor result even the worst as the concentration of dyes applied increases; it directly confirms the above phenomenon; the more colour removed from the dyed fibre samples stains highly the white cotton fabric. Staining of reactive and vat dyes are almost negligible as the probability of hydrolized reactive dyes react with white cotton fabric is low and in case of vat dyes since no colour change (no removal of dyes) from the dyed sample at the beginning, it is unlikely staining will be formed that is observed from the graph. Then it is recommended to use either vat or reactive dyes for its best washing fastness of the this fibre according to end use of product.

Colourfastness to rubbing

Dyed kusha fibres rubbed with both dry and wet test cotton fabrics aligning long fibre samples on surface of crockmeter to evaluate its dry and wet rubbing fastness. The test was conducted applying ISO 105x12 method with 10 complete rubbing cycles (turns). Table 2 shows dry rubbing fastness of direct, reactive and vat dyed samples where it shows slight decrement of their fastness as dye concentration applied to the fibres increases that might be due to inadequate washing of direct and reactive dyes. Whereas the vat dyed sample shows less performance starting from low dye concentration applied to the fibre; that could be due to superficial dyes agglomerations present on fibres samples. Wet rubbing fastness results were found low for all direct, reactive and vat dyed samples. As shown on same Table 2, wet rubbing fastness decreases as the dye concentration applied to the fibre increases; thus unfixed dyes remain on surface of the fibre after dyeing could be solubilized and transferred to white test sample as the dyed samples exposed to wet rubbing condition. Generally, as this test result shows direct and vat dyed kusha fibre samples have poor wet rubbing fatness performance as compared to reactive dyed samples. Therefore, comparing both dry and wet rubbing fastness, reactive dyed samples have overall good rubbing fatness performance.

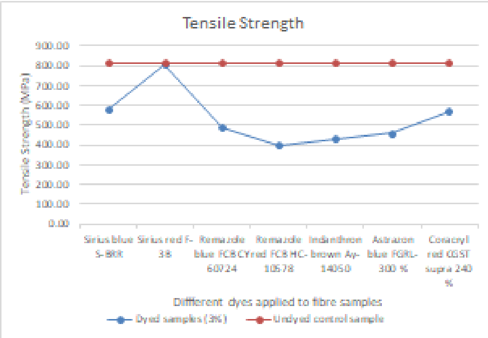
Colourfastness to light

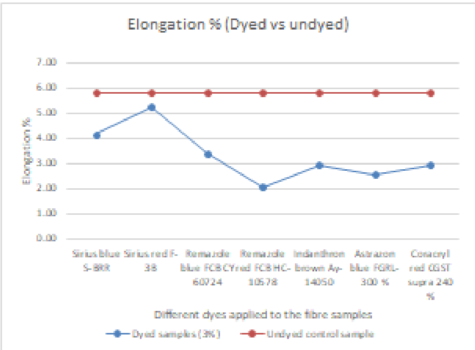
Sample test results shown on Table 2, were found after exposing all the dyed samples to artificial xenon arch light source for 24 hr. It could be enough for 18 hr exposure time for apparel textiles though 24 hr expose time is needed since the fibre could be used for other furnishing and home textiles besides to apparel purpose. As this result shows it is good performance for all samples according to blue wool light fastness standard as all fastness results are above 6. Over all light fastness is best for vat dyed samples since vat dyes has the compacted dye structure, which is not possible with other classes of dyes; that enables or blocking of passage of oxygen or moisture inside, thereby suppressing fading.

Tensile strength and elongation of dyed fibres

Tensile strength of fibre samples was measured by tensile strength tester, Tinius Olsen-H5KS, UK using ISO-5079, single fibre test method with 20mm gauge length. Optimum amount of fibres were taken from each sample and measured their tensile strength and elongation independently and average values calculated for more precise result for both undyed control sample and each of dyed samples. Figure 2 (a), shows the comparison of tensile strength of undyed control and dyed samples. Tensile strengths of dyed fibres are lower as compared to tensile strength of undyed control sample; the tensile strengths of samples dyed with direct dyes shows relatively lesser deviation from control undyed sample, whereas the minimum tensile strength observed for samples dyed with reactive dyes. The tendency of tensile strength for vat and basic dyed samples is in between tensile strength of reactive dyed and direct dyed samples. As it is expected, dye-fibre bonds which were formed could be different as the dyes applied to the fibre are different, therefore these bonds are directly responsible for the variation of tensile strengths among dyed samples with different dyes.

The reason for decrement of tensile strength of reactive dyed samples might be due to its strong covalent bond formation between cellulosic kusha fibres and reactive dyes, as suggested on, it has been proved that dye-fibre interactions are accompanied by changes in the mechanical properties of the fibre; strong covalent bond formation between reactive dye-fibre has decreased the tensile strength and percentage extension. Similarly, reduction of tensile strength of the dyed fibre dyed with basic dye is observed on the same figure, the reason for this is expected the effect of acidic media of dyeing liquor that might damage the cellulosic fibres, this clearly stated on the cellulosic fibres degraded as it exposed to acidic condition since dyeing is taking place in acidic media. Similarly, Figure 2(b) shows derived characteristics from Figure 2(a), because tensile strength and percentage extension are synchronized each other; as tensile strength increases, percentage extension also increases. During dyeing crosslinking of fibres is occurred as of finishing that decreases the percentage extension of fibres.





b.

Figure 2. Tensile Strength (a) and Elongation % (b) of dyed vs undyed fibres samples.

Conclusion

Extracted kusha fibres were taken and dyed with four categories of dyestuffs; direct, reactive, cationic and vat dyes. The dyed samples evaluated their performances and tensile properties of dyed samples were evaluated and examined. Hence, the fibre was found dyeable with all four types of dyestuffs. Colourfastness to washing of dyed fibres except the of direct dyes and rubbing fastness of reactive dyed samples were found good. Light fastness result revealed better performance for all samples. The tensile strength and elongation of dyed samples showed good results except considerable decrement both in samples dyed with reactive and basic dyes dyest.

Acknowledgments

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