Cationization of Cotton Using Extracted Keratin from Human Cut Hair Waste for Salt Free Dyeing With Reactive Dye

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ABSTRACT

Cotton fabric is the most widely used natural fiber in the world textile industry due to its comfortable and hydrophilic properties. Reactive dye is commonly used to dye cotton fabric because of its high wash fastness property. However, the main drawback of reactive dye is low equilibrium exhaustion, due to similarity of negative charge of dye and cellulose fiber tends to repeal each other requiring high amounts of salt in the dyeing bath to overcome repulsive charge between cotton and reactive dyes. The electrolyte and hydrolyzed dye will be disposed to the environment after dyeing and this effluent will cause many environmental and aquatic life problems. This paper was mainly focused on cationization of cotton fabric using extracted keratin hydrolyzat from human cut hair waste to eliminate salt consumption during dyeing with reactive dye. Keratin was extracted from human cut hair using different combinations of NaOH Concentration, Temperature, pH and Time. An experiment/trial which attains maximum absorption obtained at λ_{max} under UV/Vis Spectrophotometer was selected as Optimum extraction condition. The extracted keratin was applied on cotton fabric by pad-dry and pad-dry-cur methods and then dyed with reactive dye without salt. The dye bath exhaustion percentage for cationized by pad-dry, pad –dry-cure and untreated cotton fabric was evaluated using UV/Vis spectrophotometer and recorded as 75% ,68.7% and 66.2 % respectively. The chemical composition (functional groups) of the cationized fabric was investigated under FTIR. The color strength (K/S), CIE L a*b* was examined under Color eye -300 spectrophotometer and the cationized fabric shows better K/S value as compared with untreated fabric. The color fastness for both cationized and untreated dyed fabrics also evaluated and investigated using international standers. The cationized cotton fabric shows very good-excellent color fastness property which is better than that of untreated fabric.*

Key words: *Cationization , keratin extraction, Cotton fabric, Waste of human cut hair, salt free dyeing, Reactive dyes, Dye Exhaustion*

1. Introduction

In industrial process, reactive dye was widely used for cotton fabric dyeing, it has wide color gamut, producing brilliant and high wet fastness (Burkinshaw and Kabambe 2011) and (Petrinić, Čurlin et al. 2009). Reactive dyes stand out from other dyes by their ability to make covalent bonds between carbon atoms of dye reactive group and oxygen atoms of cotton hydroxyl groups under alkaline conditions.

Cellulosic fibers when come in contact with water produce slightly negative charge due to the ionization of hydroxyl groups, whereas most of the dye classes suitable for cotton are anionic in solution. The slightly negative charge on the fiber results in repulsion of anionic dyestuffs and the exhaustion of the bath is limited (Xu, Gao et al. 2011). However by adding an electrolyte like sodium chloride or sodium sulphate, the charge repulsion factor can be offset and those increased dye exhaustion is achieved(Zhang, Chen et al. 2008) and (Tutak and Oktay Özdemir 2011).
The reactive dyes, in particular, required large quantities of electrolyte for its exhaust application, leading to environmental problems. In addition inadequate dye bath exhaustion and dye fixation pose the problem of color effluents (Cook 1994),(Chattopadhyay, Chavan et al. 2007) and (Montazer, Malek et al. 2007). After dyeing, these electrolytes are neither exhausted nor destroyed and only 60–65% dye utilization is attainable (Mughal, Naeem et al. 2008). The residual dyes and electrolyte was discharged as effluents have caused severe environmental problem and disorders in living organisms(Abdou, Hakeim et al. 2011).

Higher electrolyte concentration in the effluent causes worst effect such as; impairing the delicate biochemistry of aquatic organism, destructive attack on pipes if sodium sulphate is used as electrolyte due to the formation of alumino-sulphate complexes which swell and crack concretes with considerable alumina content. This may lead to emission of hydrogen sulphide gas under anaerobic conditions, dissolution of such sulfides and subsequent bacterial oxidation, which may form the corrosive sulphuric acid. The aforementioned process will lead to higher Biological Oxygen Demand (BOD) , Chemical Oxygen Demand (COD) and Total dissolved Solid (TDS) (Kannan, Gobalakrishnan et al. 2006). Finally, if the effluent must be treated, i.e. desalinated, the additional cost of the process renders desalination unattractive just from an economical point of view.

Therefore, an alternative approach to eliminate or reduce on salt consumption and improve dye utilization and minimize environmental problems is important.

Having this in mind, The aim of this paper is to study the use of human cut hair waste extracted keratin hydrolysat as a sustainable material, which can be used in the cationization of cotton during the dyeing of cotton using reactive dyes.

Keratins are difficult to degrade by the common proteolytic enzymes and their disposal leads to environmental problems (Omole and Ogbiye 2013).

The main component of human hair is keratin protein, which is 65–95% of the total mass (Manheim, Doty et al. 2016). It is considered as a useless waste material in most parts of the world and its accumulation in waste streams causes many environmental problems (Kumar, Bhattacharyya et al. 2009). Due to slow degradation, it stays in the dumps/waste streams for long occupying large volumes of space. Over time, the accumulated hair increases the nitrogen concentration in the water bodies, causing problems of on aquatic life. Open dumps of hair generate hair dust which causes discomfort to people near them and, if inhaled in large amounts, can result in several respiratory problems. The best way to address such problems is to develop systems which utilize the waste material as a resource. Therefore, from both an economic and environmental point of view, it is quite desirable to develop an effective and profitable process to use these kinds of resources. As a potential material resource, human hair has the advantage that it is completely biodegradable, renewable, and available in every locality.

If the waste could be used as a valuable resource, it could not only turn waste to treasure, but also reduce environmental pollution. This has been reported in many studies in relation to the application of other waste. However, no one has conducted a study on the use waste of human cut hair keratin as a cationizing agent for cotton. From theoretical considerations human hair keratin will have good reactive properties due to the presence of a large number of reactive amino hydrophilic polar groups (nucleophilic groups) within its molecular structures. If it is possible to synthesize a kind of protein derivative agent, the agent can be applied to cotton, and hence enable salt-free dyeing of cotton using reactive dyes. Such an attempt will lead to use of locally available bio product (human cut hair) as source of keratin hydrolysat to cationize cotton for salt free dyeing. Three advantages will overcome behind this research. One, the environment will be protected from accumulation of the human cut hair wastes disposed from local hair salon. Secondly, the dyeing process will be able to reduce electrolytes in the dyeing water effluents.

Third, there will be a probability of building strong covalent and ionic bond in between the cationic functional groups of treated cotton fabric and the anionic reactive dye molecules leads to enhance the color fastness properties of the dyed fabric. Those three advantages will be a welcomed by the advocates of greener production.

2. Experimental

2.1 Materials

Waste of human cut hair was collected from Dire Dawa City Barbary (local hair salon). Full bleached 100% cotton fabric with count 20 Ne warp and weft count with 65 ends per inch and 54 picks per inch was obtained from Ethiopian Institute of Textile and Fashion Technology (EiTEX) Laboratory.

2.1.1 Chemicals and Auxiliaries

Sodium hydroxide (NaOH), Sodium carbonate ($NaCO_3$), Sodium chloride (NaCl), Acetic acid (CH_3COOH), Blue DCT reactive dye, detergent and water were used throughout this research work to carry out keratin extraction, cationization and dyeing processes. All those listed chemicals auxiliaries were obtained from Ethiopian Institute of Textile and Fashion Technology (EiTEX) Laboratory.

2.1.2 Equipment and Apparatus

Digital electronic balance, The pH meter, Perkin Elmer UV/VIS Spectrometer, COLOR-EYE 3100, FT-IR Spectroscopy Perkin Elmer, wash fastness tester, light fastness tester, rubbing fastness tester, auto dryer, Infrared dyeing machine, padder, Electrophoresis and Scanning Electron Microscope (SEM) were mainly used throughout this research work and found from Bahir Dar University, Ethiopian Institute of Textile and Fashion Technology (EiTEX) and Ethiopian leather Industry Development Institute (LIDI).

2.2 Methods

2.2.1 Extraction of Keratin Hydrolysate

Human cut hair was collected manually from local hair salon and washed thoroughly with hot and detergent to remove impurities and dirt on the surface of human hair. The cleaned hair was exposed to sunlight for drying and then converted into small particles manually using scissors

Keratin was extracted from human hair by hydrothermal process in the presence of NaOH at different combinations of Temperature (60, 80 and 100 ^{o}C), Time (2, 3 and 4 Hrs), pH (12, 13 and 14), NaOH concentrations (20, 40 and 60 g/l). 50 gram of human hair was subjected for extraction in nine different combinations of the above listed extraction parameters and the combination was scientifically done by using Minitab software.

The resultant solution was filtered and its absorption was determined by UV-Visible spectroscopy. The temperature, concentration, pH and time combination yielding the maximum absorption were taken as optimum condition for extraction of keratin from human hair.

2.2.2 Cationization

The extracted keratin haydrolysate was purified using electrophoresis method and then applied on full bleached cotton fabric by pad-dry and pad-dry-cure techniques. The cationized and control (untreated) cotton fabrics were dyed by exhaust method.

2.2.3 Evaluation of FTIR spectrum

The chemical composition (type of bond formation and functional groups available) on the cationized and untreated cotton fabrics were evaluated using FTIR.

2.2.4 Dyeing procedure for cationized and untreated cotton fabrics

Exhaust dyeing method was followed using Infrared (IR) dyeing machine for both treated and untreated cotton fabrics. The dyeing parameters were followed as per the conventional dyeing of cotton fabric with DCT reactive dye except the cationized fabric was dyed without salt where as dyeing of untreated cotton fabric was done in the presence of salt as shown in figures 1 and 2.

The cationized cotton fabric with human hair extracted keratin was immersed in 1% (o.w.f, weight percent of dye relative to fiber) of blue DCT reactive dye solution with a liquor ratio of

1:20. The dyeing temperature was kept at 30ºC constantly for 60 min and the pH of the dye solution maintained at 11. Later, 5 g/L Na_2CO_3 was added to the dye solution after 45 min and continue dyeing at 30ºC for 15 min. Dyed fabric was rinsed with cold water and finally washed with hot water using detergent at room temperature and allowed to air dry.

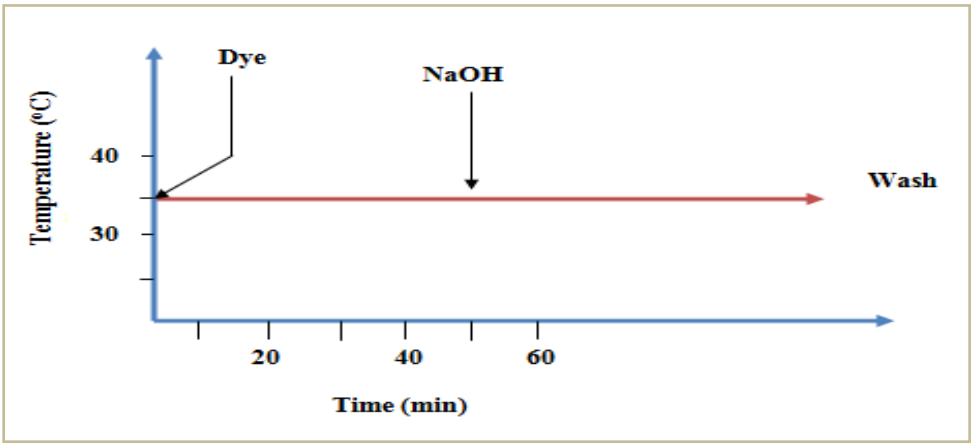

Figure.1 Typical dyeing cycle with Dichlorotriazinyl (DCT) reactive dye for cationized cotton fabric

The untreated cotton fabric was immersed in 1% (o.w.f) of DCT reactive dye solution with a liquor ratio of 1:20 and total dyeing time of 60 min. The dyeing temperature was kept at 30 ºC for 15 min before salt addition (initial exhaustion) and then 30 g/L of NaCl was gradually added to the dye bath with basis of 15 min intervals. Then 5 g/L Na_2CO_3 was added to the dye bath after 45 min at 30 ^oC and then continue dyeing for 15 min after Na_2CO_3 was added.

After dyeing, the dyed fabrics was rinsed with cold water and finally washed with hot water using detergent.

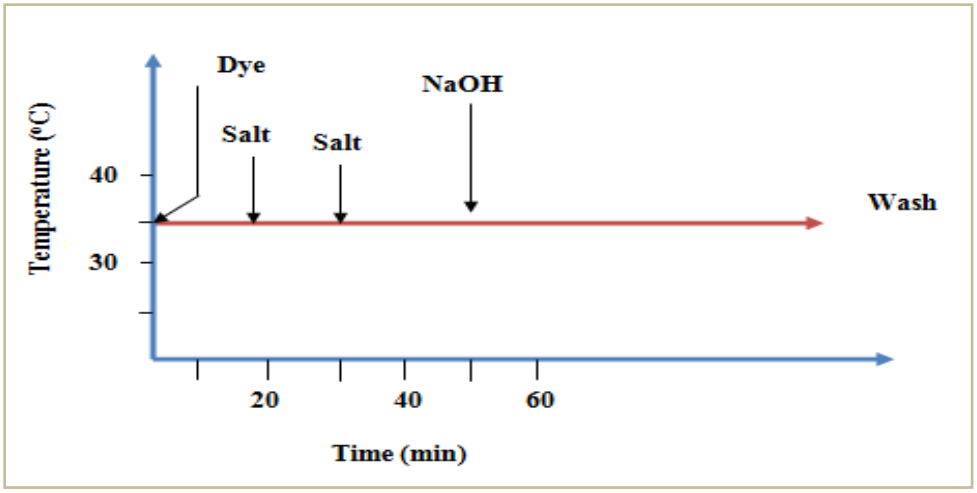

Figure.2 Typical dyeing cycle for untreated cotton fabric with Dichlorotriazinyl (DCT) reactive dye

2.3 Evaluation of dye uptake

2.3.1 Dye exhaustion.

The percentage dye exhaustion for DCT blue reactive dye was determined by comparing concentration of dye in dye bath before and after dyeing. This was done with the help of a UV/Vis spectrophotometer at the maximum wavelength of absorbency and a calibration curve. The exhaustion is calculated using equation:

Determination of dye exhaustion (E%)

$$\%E = \frac{(A_0 - A_1)}{A_0} X100$$

Where, Ao and A1 indicate the absorbencies at maximum wavelength (λ max) of the dye originally in the dye bath and of residual dye after dyeing respectively.

2.3.2 Determination of color measurement

The color strength (K/S), Reflectance percentage (R%) and CIEL*a*b* values of dyed fabrics were evaluated using color eye-300 software based on D65 illuminant and 10^o observer. The reflectance (R) value of dyed cloth at maximum wavelength of absorbency (λ_{max}) is found and the K/S was calculated by using the formula stated below.

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

Where, K/S and R stands to color strength and reflectance at maximum wave length (λ max) respectively.

2.4 Determination of color fastness

Color fastness such as wash fastness, light fastness and rubbing fatness properties of the dyed cotton both treated and untreated fabrics were determined as per the international testing standards.

3. Result and discussion

3.1 Keratin extraction optimization

Human Cut Hair was collected from local Hair salons and then washed using detergent and hot water to remove the dirty and oil substances. After washing it was dried at room temperature and chopped in to small particles to facilitate dissolution. 50g of chopped Hair was used for each trials in different combinations of NaOH concentrations (20g/l, 40g/l and 60g/l), Temperature (60^oC, 80^oC and 100^oC), Time (2Hr, 3Hr and 4Hr) and pH (12, 13 and 14) using different combination of nine trials as shown in Table 1. The extraction was done in a closed Infrared Dyeing Machine with computer aided parameter controlling mechanism. The absorption of extracted keratin Hydrolysate of each trails were evaluated using UV-Visible spectroscopy (Lambda 25). The maximum Absorption and maximum yield % was obtained from trial 2 with absorption of (3.2) at λ_{max} 275 nm and extraction efficiency of 95% as shown in Table 1. The UV absorption of each extracted keratin haydrolysate at λ_{max} 275 nm was graphically represent in Figure 3.Therefore, Concentration of 60g/l of NaOH, Temperature of 100 ^oC, and Time of 4 Hours and pH of 12 was selected as optimum condition for extraction of keratin from Human Cut Hair.

Table 1: Absorption of extracted keratin from Human Cut Hair

MLR: 1:20					Results	
No of Trials	pH	Temperature (^oC)	Concentration of NaOH (g/l)	Time (hr.)	Yield %	UV Absorption (A) At λ_{max} 275 nm
1	13	80	40	3	82	2.5
2	12	100	60	4	92	3.2
3	13	60	40	4	86	2.8
4	12	80	60	2	78	2.3
5	12	60	20	3	72	1.8
6	14	60	20	4	75	2.1
7	13	60	60	2	84	2.7
8	14	80	20	3	66	1.5
9	12	100	20	2	84	2.7

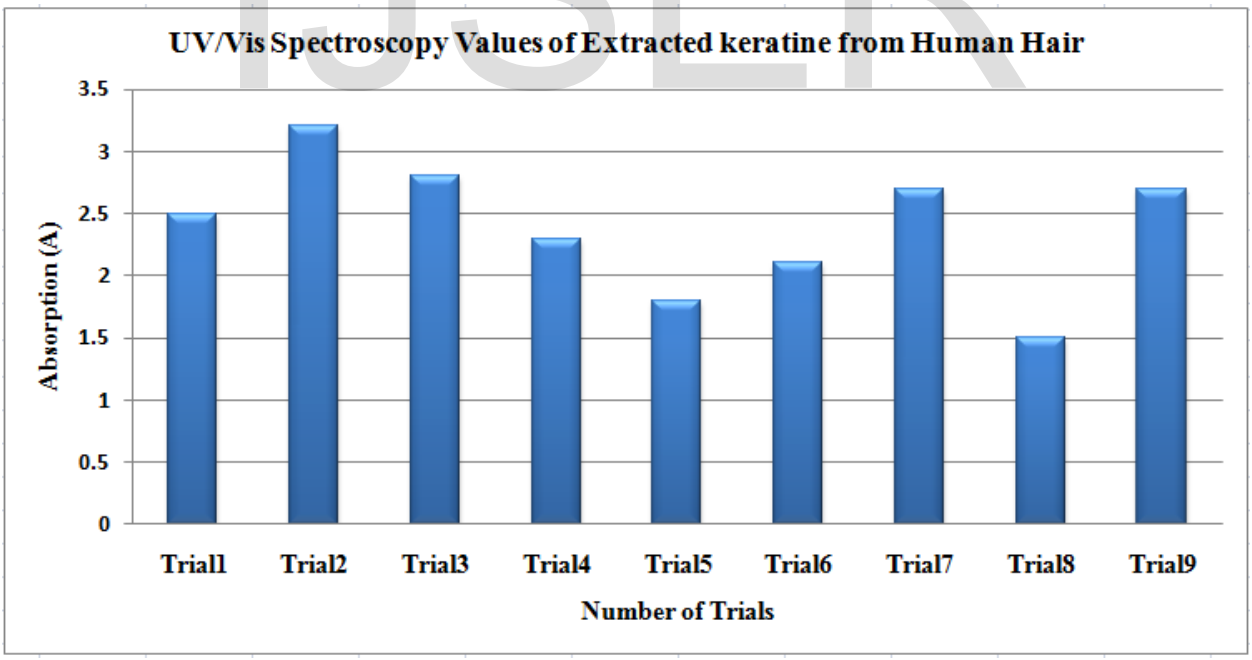

Figure 3: Maximum absorption value for different trials of extracted Keratin from Human Hair at λ_{max} (275 nm)

3.1.1. Effect of Temperature, Time, Ph and NaOH Concentration on Yield % and UV Absorption of Extracted Keratin hydrolysate

In general as extraction Temperature increase and other parameters kept constant, the UV absorption /concentration and yield % of extracted keratin hydrolysate also increase as showed on Figure 4. This was due to increasing in temperature cause to easily breaks the sulfide bond of the protein makes ready to dissolve. Similarly, as extraction Time, concentration of NaOH and pH separately increase and other parameters kept constant, the yield % and absorption of extracted keratin hydrolysate also increase as showed on figure 6.5 and 7.

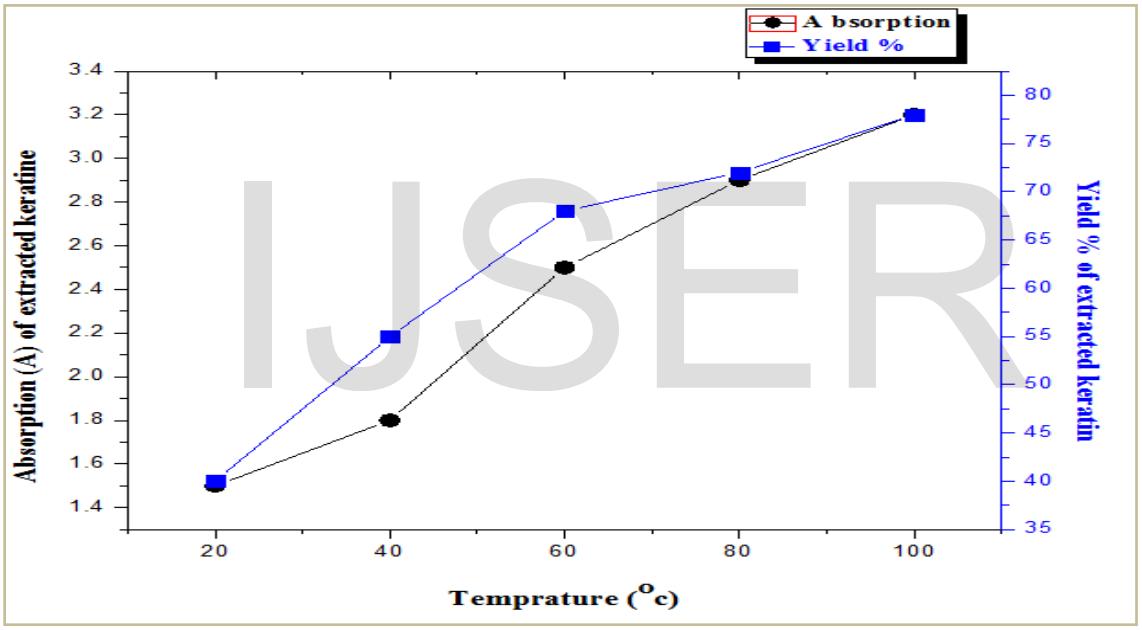

Figure 4: Effect of Temperature on absorption and yield % of keratin extraction from human hair

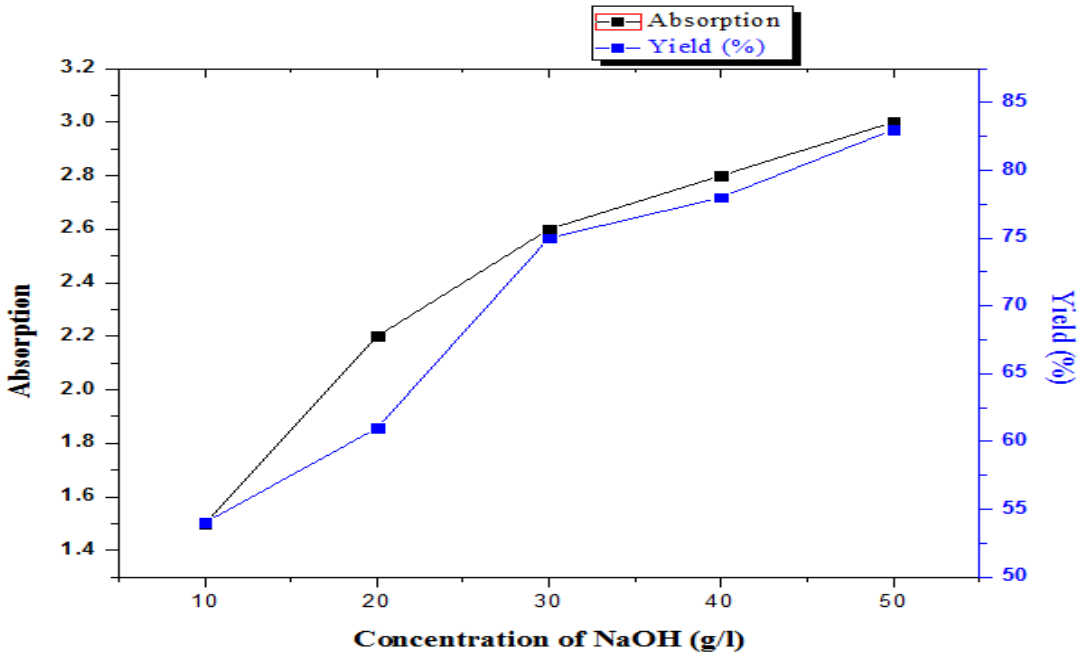

Figure 5: Effect of NaOH concentration on absorption and yield % of keratin extraction from human hair

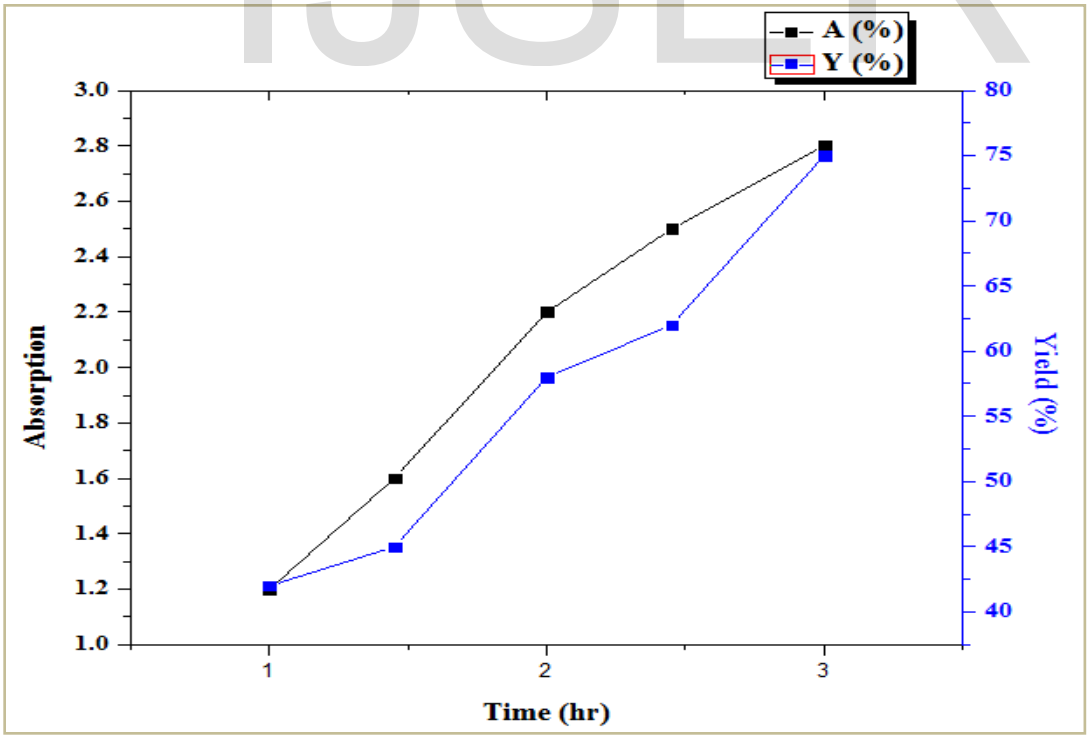

Figure 6: Effect of Time on absorption and yield % of keratin extraction from human hair

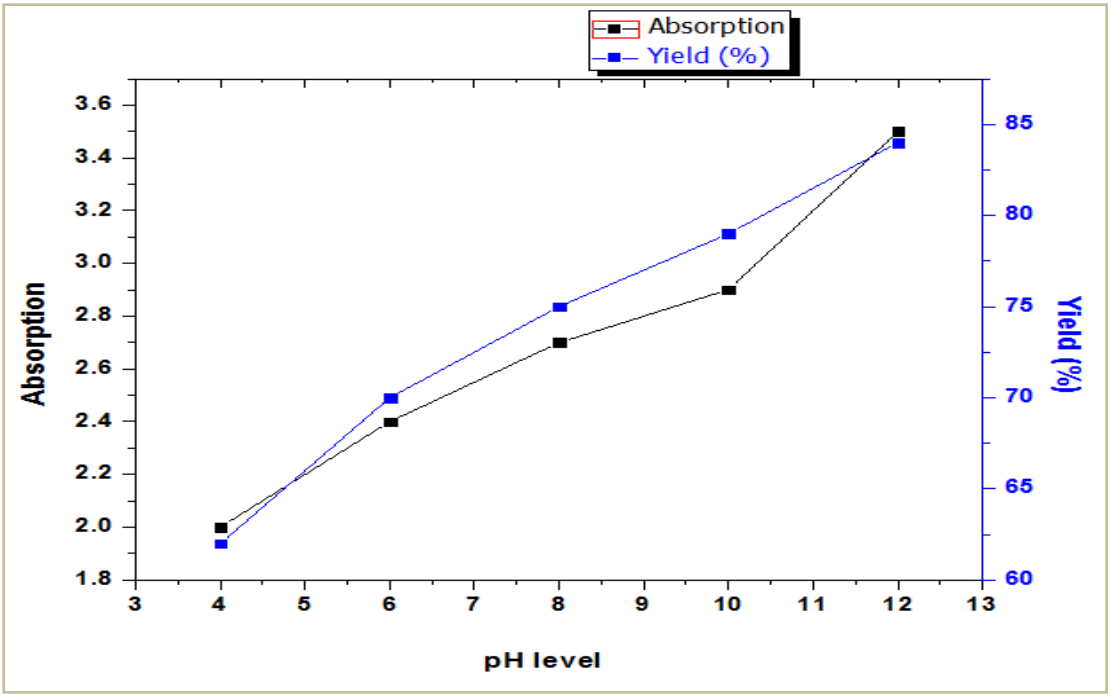

Figure 7: Effect of pH level on absorption and yield % of keratin extraction from human hair

3.2 Cationization of Cotton with Extracted Keratin from Human Hair

full bleached cotton fabric was immersed in 50g/l of keratin haydrolysate extracted from human hair and was subjected to drying and curing temperature at 60 ^{o}C and 130 ^{o}C for 5 and 2 minutes respectively. The peak of FTIR spectrum curve of fabric treated and untreated with human hair extracted hydrolysate was showed in Figure 8. The peaks on the FTIR curve showed that there is a change in chemical composition after being cationized. This indicates the keratin hydrolysate was fixed to the fabric.

The microstructure and chemical composition characterization of micro particles were examined by using FTIR spectroscopy (Perkin Elemer) in the absorption mode with the 4000 cm^{-1} and 500 cm^{-1} wave number range. It will help to detect the changes in chemical composition of peptides (Chen, Tou et al. 2009).

The FTIR spectrum of cationized and untreated cotton fabrics were illustrated in Figure 8.

Compared with untreated cotton, the absorption peak at about Peaks at 1644 and 1625 cm^{-1} were appeared which was assigned to bending vibration of N-H primary amines. This observation

clearly indicated the presence of primary amines which fully demonstrated that the amino group was chemically absorbed on the treated cotton fabrics. It indicated that the reaction between cotton fabrics and cationic keratin polymer occurred. The content of amino groups present on the fabric treated by pad-dry-cure method was higher than that of treated by pad-dry method.

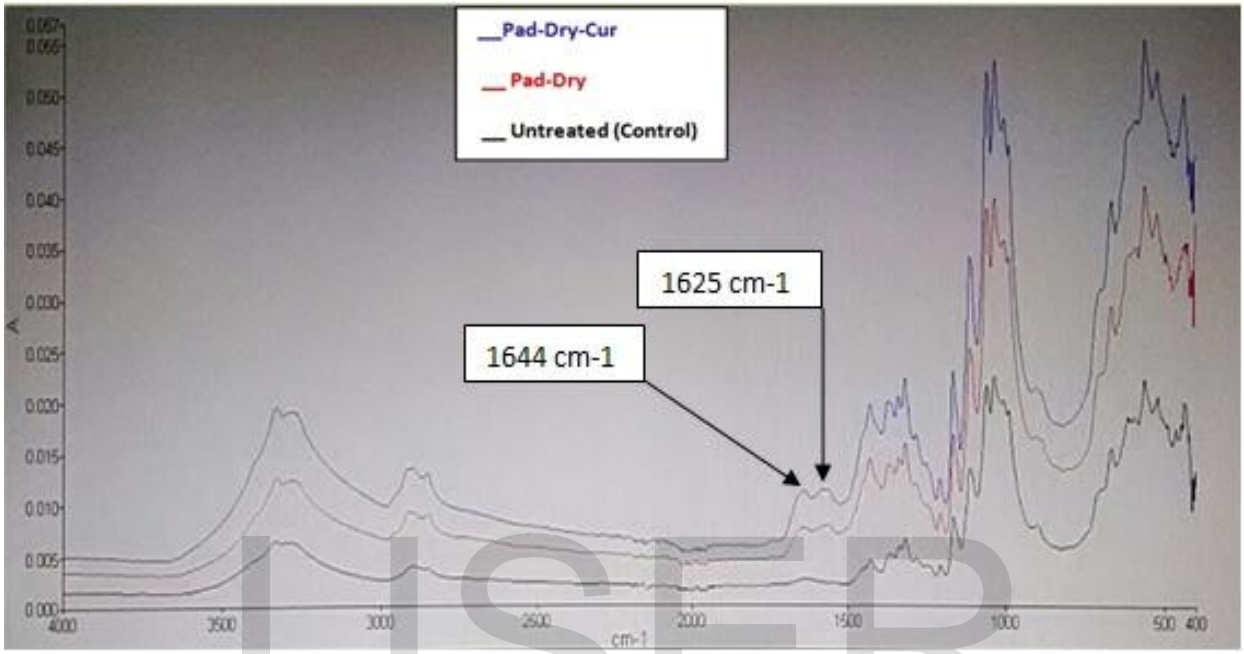

Figure 8: FTIR Curve for untreated and Cationized cotton fabric with Human Hair keratin

3.3 Surface Morphology of treated and untreated Cotton Fabrics

Surface morphology of the untreated and treated samples with extracted keratin from human hair is investigated by scanning electron microscopy (SEM. The SEM micrographs are shown in Fig.9 A1 and B1 .The images demonstrated that a rough surface is formed in the keratin treated cotton fiber due to deposition of cationic agent on cotton fabric. The cationization process was a little bit changed the morphology and structure of the cotton fibers. The morphologic changes of cotton samples after the cationization process and treatment with human hair extracted keratin can be clearly observed from the SEM images. Figure Fig. 9 (A1 and B1) shows the morphology of normal and cationized cotton samples. Significant differences are clear between these cotton fibers; the untreated cotton has a smooth surface and is uniform, whereas the treated cotton is rough, which can be related to the deposition amino groups onto the surface of the fibers.

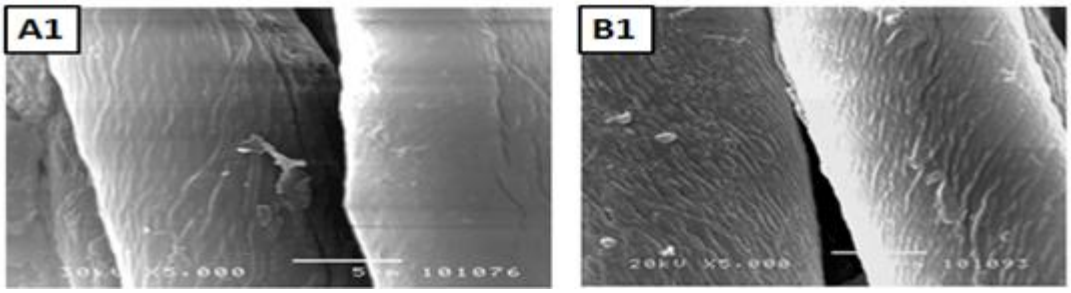

Figure 9: SMS micrographs of untreated and Human Hair keratin treated cotton A1 and B1) respectively

3.4 Dyeing of treated and untreated cotton fabric with Dichloro Trazline Blue Reactive Dye

Dyeing was carried out as per the conventional dyeing procedure at room temperature for 60 min. washing and soaping was done for both treated and untreated cotton fabrics. The visual actual color yield of treated fabric by pad-dry-cur was higher than treated by pad-dry method and untreated fabric samples clearly as shown in Figure 10.

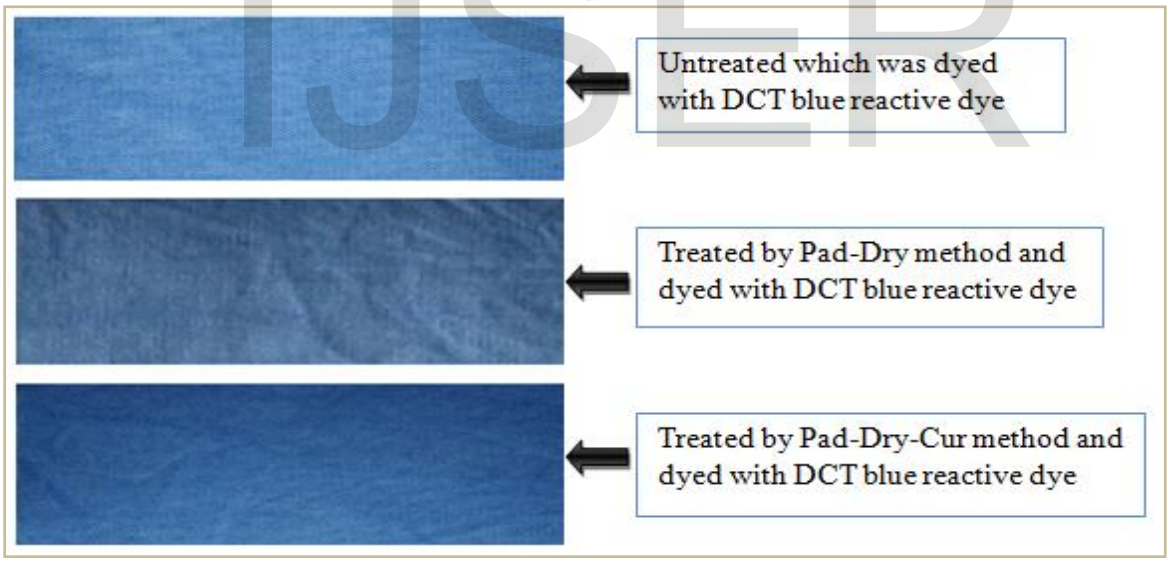

Figure 10: Dyed cotton fabric both treated and untreated

3.5 Dye exhaustion and color measurement

The percent exhaustion of DCT blue reactive dye before and after dyeing of the cationized and untreated fabrics were evaluated and recorded in Figure 11. The dye shows high percent of

exhaustion on cationized cotton than untreated cotton sample due to the presence of cationic functional groups (NH^{3+}) which improves dye exhaustion by simple attraction between cationized cotton and anionic functional groups of reactive dye. Even the dye exhaustion on treated cotton by pad-dry-cur method with (E%=75) was higher than that of cotton treated by pad-dry method with (E%=68.7) and untreated cotton sample (E%=66.3).

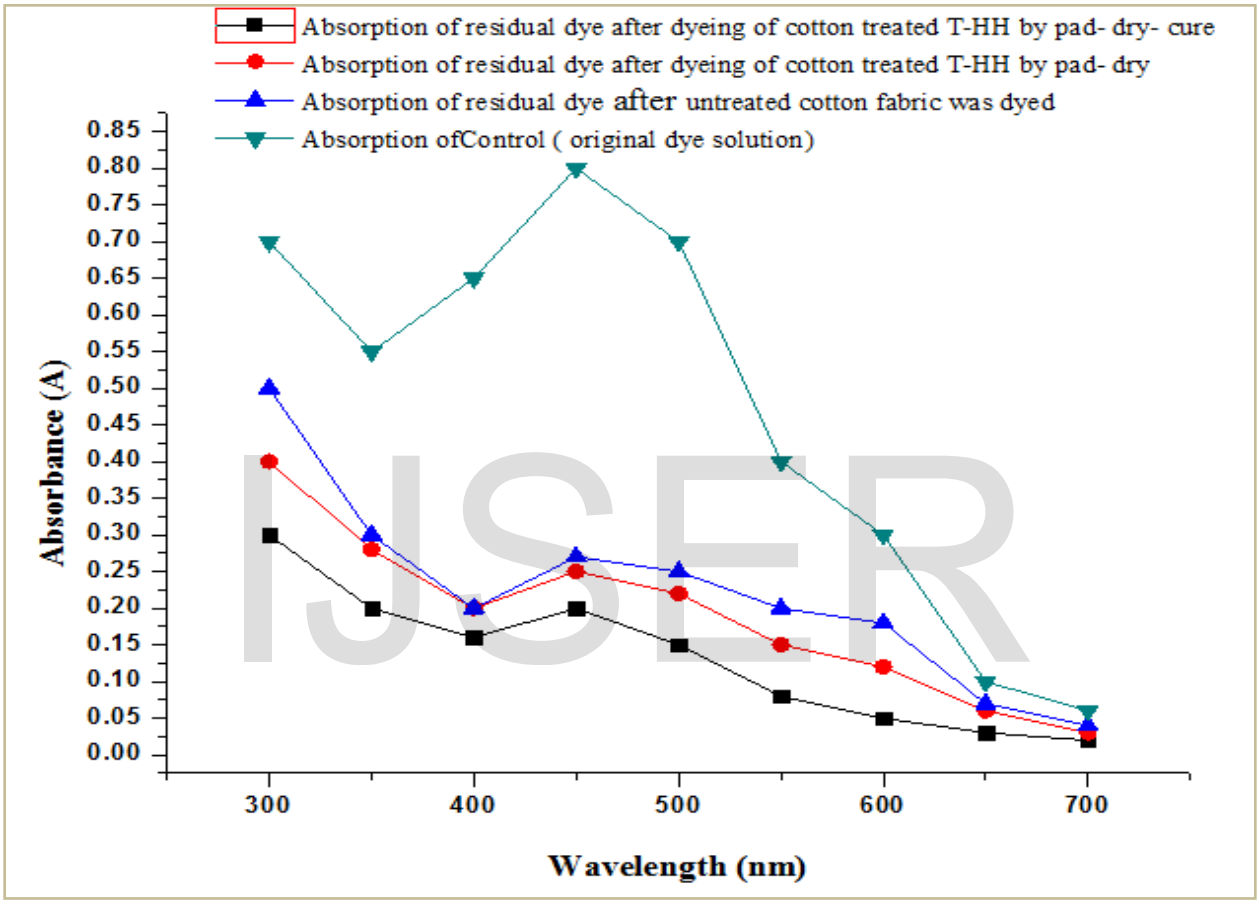

Figure 11: UV/Vis absorbance values of blue DCT reactive dye solution after and before dyeing

Key: T-HH indicates =Fabric treated with human hair extracted keratin

3.6 Determination of Color Strength (K/S) and CIE L*a*b* Value

The color strength, reflectance value and CIE L*a*b* Value of dyed cotton samples which are untreated and treated with human hair extracted keratin were measured in the range of 400-700

nm using Color Eye 300 and recorded in Table 2**.** Color strength (K/S) indicates how much concentration of dye solution was fixed or attached to the cotton fabric after dyeing.

The values used by CIE are called L*, a* and b* indicates, L* (lightness (L=100)/ darkens (L=0)), a* (redness (+a)/greenness (-a)), b* (yellowness (+b)/blueness (-b)) value of dyed cotton samples. The lightness (L*) value of untreated fabric was comparatively higher than cationized cotton fabric samples. All dyed samples shows (–b) means all are in the blue direction. But the blueness of treated sample was higher than untreated cotton fabric sample. Value of a* in all dyed samples of treated and untreated cotton was in –ve a* direction. But the yellowness of treated sample was lower than untreated cotton samples.

In the exhaust dyeing process, most of reactive dye molecules were easily absorbed and diffused into modified cotton by opposite charges attraction. The absorption could greatly increase the concentration of reactive dyes inside treated cotton, which enhance dye exhaustion and dye -fiber fixation reaction in the dye-fixation process. To some degree, the positive charge of modified cotton could also temporarily restrict the movement of anions, especially the hydroxyl anion. It accordingly decreased the hydrolysis of reactive dyes. So the total utilization of reactive dyes was improved greatly.

Color strength (K/S) value at different wavelengths in the range of 400-700 nm for white fabric, untreated and dyed fabric, treated by pad-dry method and dyed fabric, treated by pad-dry-cur method and dyed with DCT reactive dye were evaluated and Maximum K/S was obtained at λ_{max} (620 nm) as shown in Figure 12. Cotton fabric which was cationized by pad-dry-cure method and dyed using DCT reactive dye shows better color strength (K/S) value as compared with cotton treated by pad-dry method and untreated cotton fabric as shown in Figure 13. This indicates the curing temperature during cationization plays grate role on the fixation of more cationic amino functional groups on the fabric leads to take more dye molecules and enhance the color strength of dyed fabric.

In general, Cationized fabrics contain positive functional groups which increase reactive dye exhaustion due to ionic attraction between anionic reactive and cationic ($NH^{3+)}$ of treated cotton fabric. As a result the Exhaustion percentage and K/S value of the cationized fabrics were higher than that of conventional (untreated) fabric.

Table 2: Color strength (K/S), Reflectance (%) and CIEL*a*b* values at 10^{o} observer for untreated and cationized cotton with human Hair keratin and dyed with blue DCT reactive dye

Method	Sample code	Reflectance (%) at 620 nm	K/S at 620 nm	CIE L* a* b * system		
				L*	a*	b *
Cationized with Human Hair extracted keratin and dyed using reactive (DCT) blue dye	White	79.61	0.026	92.15	2.23	-8.68
	Untreated	23.22	1.26	62.36	-3.25	-18.39
	HH-p-d	19.25	1.69	59.84	-2.27	-24.99
	HH-p-d-c	17.96	1.87	58.4	-2.26	-24.99

Key: HH-P-d (Treated cotton with human hair extracted keratin by pad-dry method),

HH-p-d-c (Treated cotton with human hair extracted keratin by pad-dry-cure method)

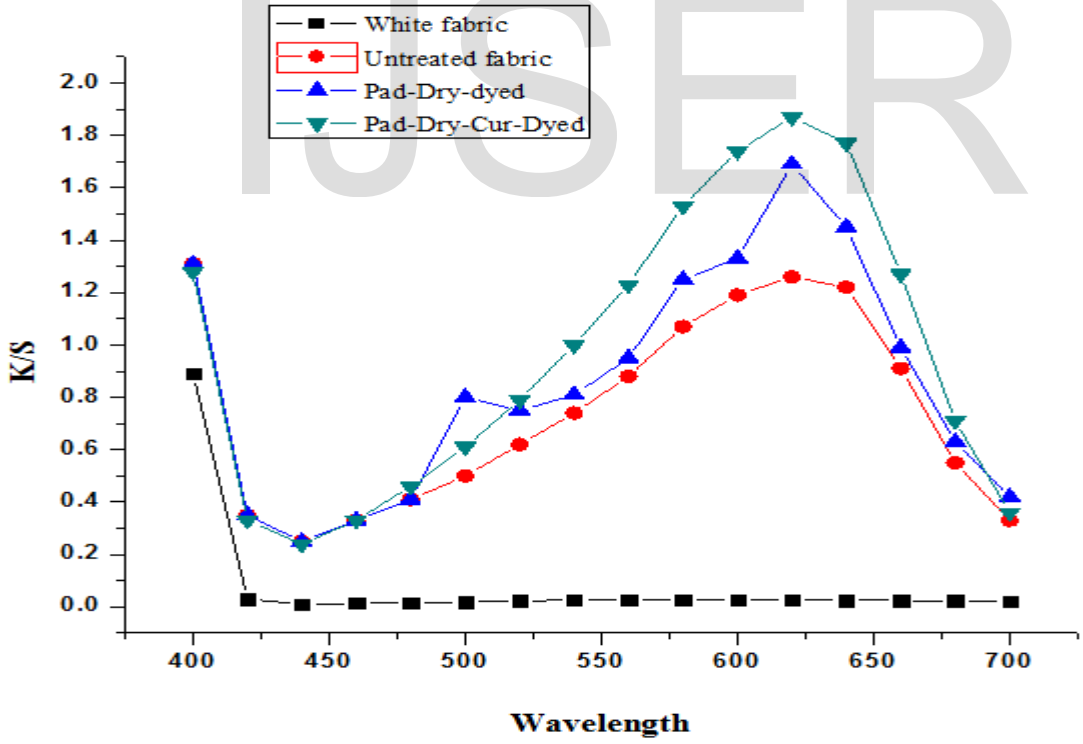

Figure 12: K/S results of treated and untreated cotton fabric at different wavelengths

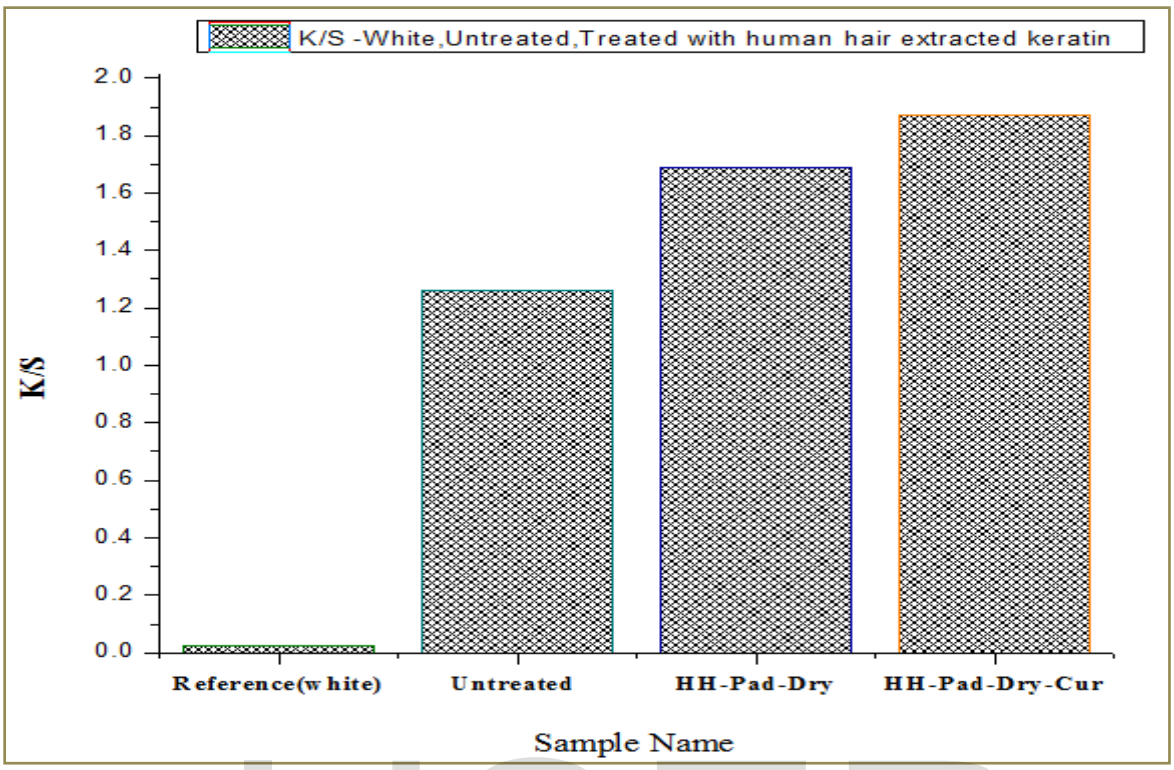

Figure 13: K/S value at λ_{max} (620 nm) for untreated and treated with human hair extracted keratin and dyed with DCT reactive blue dye

3.7 Color Fastness test results of dyed samples

The color fastness such as light fastness, rubbing fastness and washing fastness properties of the dyed fabrics were evaluated based on the international standards of ISO105B02 , AATCC 116 - 1995, ISO 105-A03 respectively.

Color fastness to washing was assessed in respect of color change and staining on multifiber fabric (acetate, cotton, nylon, polyester, acrylic, wool). Wash fatness of the dye would depend on the bonding between the keratin ($NH3^{+}$) and cellulose. To study this effect the washing fastness of the dyed samples of treated and untreated cotton fabrics were evaluated. The cationized cotton fabric samplers showed lower color reduction after repeatedly washing (5 wash cycles) compared with untreated cotton.

Rubbing fastness was evaluated in dry and wet conditions. Fastness ratings of different types of dyed samples are presented in the Table 3.

The table showed that the light and washing fastness ratings of keratin treated fabric shows better performance as compared to untreated fabrics. Due to presence of additional cationic functional groups on the treated fabric, there was a probability to form strong covalent and ionic bonds in between the treated fabric and reactive dye molecules which leads to enhance the washing and light fastness properties as compared to the untreated fabric. However, in case of rubbing fastness both wet and dry conditions, the keratin treated fabrics showed lower rubbing fatness compared with untreated fabrics due to the probability of significant change surface condition occurred after cationization. In general, the performance of color fastness for cationized cotton fabric shows better performance as compared to the untreated fabric. Specially prior to dyeing, fabric which was treated by pad –dry-cure method shows very good to excellent color fastness property as compared to the untreated and even treated by pad –dry method.

Table 3: Color fastness properties of untreated and treated cotton fabric with human hair extracted keratin and dyed with DCT reactive dye

Sample Name	Sample Code	Rubbing fastness		Light fastness	Wash fastness	
		Dry	Wet	24 hr	Acidic	Basic
Cationized with human hair extracted keratin and dyed using reactive(DCT) red dye	Untreated	4	4	3/4	3	3
	HH-p-d	2/3	3	4/5	4	3/4
	HH-p-d-c	3	3	5	5	5

Key: HH-p-d (pad-dry with human hair), HH-p-d-c (pad-dry-cure with human hair keratin)

Conclusion

The present study revealed that application of extracted keratin from human cut hair waste on full bleached cotton fabric for salt free dyeing with reactive dye. The extracted keratin was applied on full bleached cotton fabric by pad-dry and pad-dry-cure methods and the fabric was tested its color fastness, color strength and CIE L*a*b*, dye exhaustion, FTIR spectrum. Dye exhaustion as well as color fastness of the dyed samples was improved after the cationization. Since human cut hair was daily and widely disposed to the environment and accumulated in mass, there was an opportunity and possibility of converting this waste in to valuable purpose such as used as natural biodegradable cationic agent for cotton fabric to improve the dye ability and dye exhaustion of cotton with reactive dye without addition of any electrolyte (salt). The result of this research gives three main advantages:- one, by converting to usable product the waste of human hair will be minimized and the environment keep clean. Secondly, the dye ability, percentage of exhaustion and wash fatness of the reactive dye will be improved after treatment which leads to reduce the effluent of untreated dye disposed to the environment. Thirdly, addition of salt in the dye bath during dyeing of cotton with reactive dye was eliminated and protect environment from this effluent. Therefore, finally it is possible to propose that extracted keratin from human cut hair can be used as bio -degradable eco-friendly cationic agent applied on cotton fabric for salt free reactive dyeing.

Data Availability Statement

The authors confirm that the data supporting the findings of this study are available within the article and/or its supplementary materials.

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References

Abdou, L., O. Hakeim, et al. (2011). "Comparative study between the efficiency of electron beam and gamma irradiation for treatment of dye solutions." Chemical engineering journal 168(2): 752-758.

Burkinshaw, S. and O. Kabambe (2011). "Attempts to reduce water and chemical usage in the removal of bifunctional reactive dyes from cotton: Part 2 bis (vinyl sulfone), aminochlorotriazine/vinyl sulfone and bis (aminochlorotriazine/vinyl sulfone) dyes." Dyes and Pigments 88(2): 220-229.

Chattopadhyay, D., R. Chavan, et al. (2007). "Salt-free reactive dyeing of cotton." International Journal of Clothing Science and Technology 19(2): 99-108.

Chen, Y. C., J. Tou, et al. (2009). "Amino acid and mineral composition of protein and other components and their recovery yields from whole Antarctic krill (Euphausia superba) using isoelectric solubilization/precipitation." Journal of food science 74(2).

Cook, L. (1994). "Increase of cotton's apparel market share has caused salinity in textile effluent streams to become a major issue." Textile World 66(9): 1530-1534.

Kannan, M. S. S., M. Gobalakrishnan, et al. (2006). "Influence of cationization of cotton on reactive dyeing." Textile and Apparel Technology and Management 5: 23-30.

Kumar, S., J. Bhattacharyya, et al. (2009). "Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: An insight." Waste management 29(2): 883-895.

Manheim, J., K. C. Doty, et al. (2016). "Forensic hair differentiation using attenuated total reflection fourier transform infrared (ATR FT-IR) spectroscopy." Applied spectroscopy 70(7): 1109-1117.

Montazer, M., R. Malek, et al. (2007). "Salt free reactive dyeing of cationized cotton." Fibers and Polymers 8(6): 608-612.

Mughal, M. J., M. Naeem, et al. (2008). "Effect of a cationising agent on the conventional reactive dyeing of cotton." Coloration Technology 124(1): 62-65.

Omole, D. and S. Ogbiye (2013). "An evaluation of slaughterhouse wastes in south-west Nigeria." American Journal of Environmental Protection 2(3): 85-89.

Petrinić, I., M. Čurlin, et al. (2009). "Textile wastewater treatment with membrane bioreactor and water re-use." Tekstil: Journal of Textile & Clothing Technology 58.

Tutak, M. and A. Oktay Özdemir (2011). "Reactive dyeing of cationized cotton: effects on the dyeing yield and the fastness properties." Journal of Applied Polymer Science 119(1): 500-504.

Xu, B., P. Gao, et al. (2011). Methods of fabric treatment, Google Patents.

Zhang, F., Y. Chen, et al. (2008). "HBP-NH2 grafted cotton fiber: Preparation and salt-free dyeing properties." Carbohydrate polymers 74(2): 250-256.