J. Text. Color. Polym. Sci., **Vol. 19**, No. 2, pp. 155-178 (2022)

Journal of Textiles, Coloration and Polymer Science

https://jtcps.journals.ekb.eg/

Polycation Natural Materials for Improving Textile Dyeability and Functional Performance

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THE ENVIRONMENTAL aspects of manufacturing are gaining more attention in today's world, especially in the textile industry. However, converting industry to green technology is a critical necessity in the present day to protect our environment from the poisonous effects of industrial effluents; thus, it will be a significant beneficial contribution to safe and healthy living on the planet. Using natural polymers with a variety of desirable characteristics such as biocompatibility, biodegradability, low toxicity, and high biological activity is gaining popularity year after year. Until now, a variety of synthetic chemical compounds have been used to functionalize textiles, that are harmful to humans and aquatic ecosystems and are difficult to degrade. Natural materials, on the other hand, match the current need for industrial applications due to their never-ending sources and advantages over synthetic products. In this study, natural cationic biopolymers such as chitosan, and amino-cellulose have been used to help in increasing dye absorption while improving fabric performance characteristics such as antimicrobial function. The optimum dyeing conditions were (polymer concentration, 2 %;75°C; 45 min.; L: R 1:50) with pH 6 for wool, 4 for acrylic and 8 for cotton fabric using two different dyes natures (basic and natural (moringa extract).

Keywords: Cationic modification, Chitosan, Amino-cellulose, Natural polymers, Moringa, Natural dyes.

Introduction

Nowadays, as people become more concerned about environmental concerns, new pathways aimed at reducing pollution and promoting sustainable development through synthetic transformations have attracted their attention. [1] So the return to nature and use of bio-products such as natural dyes or bio modification has been increased. [2]

Cationization is the chemical modification process that results in the formation of cationic (positively charged) colouring sites in place of existing anionic sites. Because of the ion-exchange interaction between the positive charge on the fibre and the negative charge on the natural dyes, this treatment improves the substantivity of natural dyes. [3-5]

Chitosan is a polysaccharide with anticancer effects, as well as nontoxicity, biodegradability, and biocompatibility.[6] Originally, Chitosan was utilized as a textile dye deepening agent. It also can be used in salt-free dyeing with the assistance of some additives. [7-9]

The presence of chitosan leads to a uniform coating film on the surface of the fibre that improves the surface properties of the fibre and reduces the repulsion between fabric and dyes, therefore greatly improving the dye uptake rate. [10]

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(Received 05/04/2022, accepted 27/04/2022)
DOI, 10.21608/jtcps.2022.131643.1116

Cationic cellulose is a cellulose derivative often used in papermaking, cosmetics, adsorbents, and antibacterial agents. The excellent process of synthesis amino cellulose is to introduce a cationic group to cellulose by chemical reaction, for instance, attaching quaternary ammonium groups using 2,3-epoxypropyl trimethylammonium chloride (EPTMAC). [11, 12] The cationic reagent consists of a quaternary ammonium salt with cationic properties on one end and an epoxy group on the other. In the manufacture of cationic cellulose, the covalent addition of a quaternary amine to polysaccharide is extensively utilized. [13, 14] The reagent's most essential property is its tiny size, which aids penetration into the fibre surface and results in homogeneous dyeing. [15]

Various cross-linking agents have been utilized as polycarboxylic acids, especially 1,2,3,4-butane tetracarboxylic acid (BTCA) and citric acid, have recently been employed as safer cross-linking agents between chitosan and cellulose fibres in several investigations. [16, 17] The interactions of the hydroxyl functional group with the carboxyl groups of polycarboxylic acids increase antibacterial durability and other fibre characteristics significantly. In an esterification process, citric acid and low toxic oxidising agents like potassium permanganate and sodium hypophosphite have been demonstrated to enhance efficient cross-linking between chitosan and textile substrates like cotton cellulose and woollen fabrics. [18]

Natural dyes are biodegradable and environmentally friendly because they are derived from renewable resources. Recent studies have revealed that, in addition to natural textile materials, they may also be used to colour manufactured fibres. [19-24] They also have been found to have excellent ecological advantages, but their extraction yield is limited, and their fastness qualities are also unsatisfactory. [25-28] Researchers are attempting to overcome these two disadvantages by using some modifications for enhancing the colour strength of naturally dyed fabrics. [22, 27]

Moringa Oleifera is mostly cultivated in tropical and subtropical climates. Moringa is known as the miracle tree, and its leaves are a rich resource of digestible proteins, vitamins, minerals, and carbohydrates that are essential for people of different ages. [29, 30]

Basic dyes are dyes that are salts of coloured bases having an amino or dialkylamino group as auxochrome. Basic dyes, also known as cationic dyes, come in a wide spectrum of colours and have excellent wet fastness on acrylic fibres. [31] Basic dyes are widely utilized in the dyeing of jute, acrylic, and wool fibres, among other substances. In terms of wash and rubbing fastness, it performs excellently. Cotton fabrics are known to be unsuitable for basic dyes. The addition of acidic groups into the polymer molecules through radiation grafting of cotton textiles in acrylic acid solution overcomes this disadvantage. [32] **Fig. 1** refers to the chemical structures of polycation materials used as well as the dyes used in the present work.

This study aims to make cotton, wool, and acrylic materials more dyeable to both basic and natural dyes by cationic modification. In the current study, natural surface modification was carried out on three textiles, including cotton, wool, and acrylic fabrics, using chitosan and amino cellulose as cationic polymer. Colour strength (K/S), dye fixation, relative unlevelness index (RUI), and the accompanying fastness properties were used to evaluate dyeing parameters. Physical and mechanical properties, as well as antimicrobial properties, were investigated. To enhance the dyeing process' performance and antibacterial effect, the dyeing conditions were optimised.

Experimental

Materials

Bleached scoured cotton fabric (150 g/m^2) supplied by Ghazel El-Mahala for Textile Industry Co., Egypt, scoured wool fabric (210 g/m^2) supplied by Ghazel El-Mahala for Textile Industry Co., Egypt and bleached acrylic fabric (180 g/m^2) supplied by GoldenTex for Textile Industry Co., Egypt, were used during this research. Chitosan high molecular weight (>600000 g/mole), cellulose powder, 2,3-(epoxy propyl) trimethylammonium chloride (EPTMAC) were purchased from Sigma Aldrich Co. Fluka provided acetic acid 98%, citric acid (CA), sodium hypophosphite (SHP), sodium hydroxide (NaOH) and sodium carbonate (Na_2CO_3). Carl Roth GmbH Co. provided basic dye 9 (Methylene Blue) ($C_{16}H_{18}ClN_3S$). Moringa leaves trees were provided by Egypt's National Research Centre. Without purification, all chemicals and reagents were utilized as obtained.

Methods

Pre-treatment for various fabrics

Before treatment, cotton, wool, and acrylic textiles were washed to eliminate residues from the outer surface of the fibres. The fabrics were washed in a 2 g/L Na2CO3 solution at 40°C for 15 minutes. Then, they were crosslinked using 10 g/L citric acids (CA) and 5 g/L sodium hypophosphite (SHP). The padding process happened in the solution at 50°C for 15 minutes, then squeezed having wet pickup 100% and dried at 80°C for 5 minutes.

Prepatration of chitosan solution

As chitosan is not water-soluble, it must be dissolved in a carboxylic acid solution, such as acetic acid. Chitosan solutions with different concentrations of (0.5, 1, 2 and 3%) were prepared by dissolving in 1% acetic acid. The mixture was stirred under continuous stirring overnight to obtain a perfectly transparent solution.

Preparation of cationized cellulose

In the etherification process, 2,3-(epoxy propyl)trimethylammonium chloride (EPTMAC) was used to cantonize the cellulose powder. The cationization of cellulose powder was performed in a laboratory as follows: during the process, the cellulose powder was first diluted to 10% (weight %); then a certain amount of sodium hydroxide (30 wt.% of the cellulose powder) was added to the solution and stirred at room temperature for 30 min. finally, the cationized agent was slowly added to the mixing systems and stirred at 30°C for 150 min. After that, the mixture was neutralised with acetic acid and then washed with a large amount of deionized water to remove the unreacted materials (see Fig. 2). Cationic cellulose powder was synthesized with an EPTMAC to cellulose molar ratio of 0.4, and water content of 90 wt.%. [33]

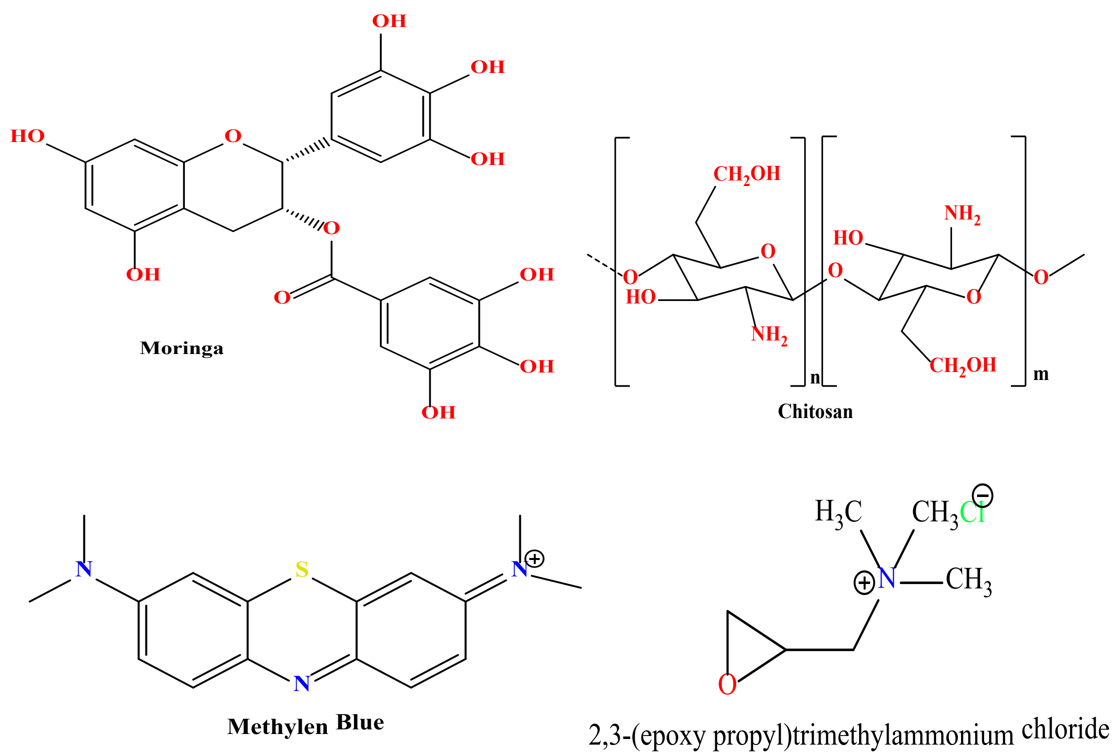


Fig.1. Chemical structure of chitosan, 2,3-(epoxy propyl)trimethylammonium chloride, methylene blue and moringa.

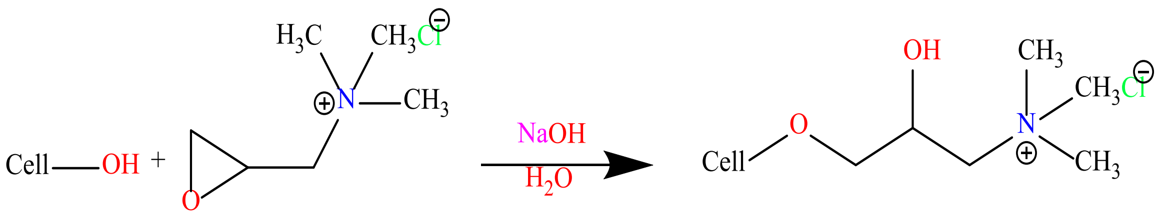


Fig. 2. suggesting reaction mechanism for synthesis of amino cellulose.

Treatment of the fabrics using polycation compounds

In a 250 ml conical flask, chitosan or prepared amino-cellulose solution were prepared at various concentrations (0.5, 1, 2, and 3%). Cotton, wool, and acrylic fabrics were treated with polycation compound using the pad-dry-cure procedure, which required immersing the fabrics in the treated bath at 50°C for 15 minutes, then squeezing with 100% wet pickup, and drying at 100°C for 5 minutes.

Dyeing using basic dye

The fabrics that had been treated were dyed using Methylene Blue (C.I. Basic Dye 9) 2 g/L at various pHs (4, 6 and 8), temperatures (60, 75 and 90°C) and times (30, 45 and 60 minutes), then squeezed and the percent of the wet pickup was 100%, then dried at 100°C for 5 minutes before being cured at 140°C for 3 minutes.

Water extraction of Moringa Oliefera

The leaves of the moringa plant were cleaned and dried. Then they were crushed until they were powdered. The solution was then filtered using filtration paper after taking 30 g of powder for water extract using 1 L of distilled water for 24 hours in the Soxhlet. Then the filtration solution was used in dyeing treated and untreated fabrics.

Dyeing process using Moringa extract

The treated and untreated fabrics were dyed with moringa leaves extract (30 g/L) at various pHs (4, 6 and 8), temperatures (60, 75 and 90°C) and times (30, 45 and 60 minutes), then squeezed with 100 percent wet pickup and dried at 100°C for 5 minutes before being cured at 140°C for 3 minutes. Then all dyed fabrics have been investigated by these measurements.

Measurements

GC-MS chromatography

GC-MS chromatography (Agilent 7890A series, USA) with a polar 5-MS (5% phenyl polymethyl siloxane) capillary column coupled to a Mass Detector was used to characterise Moringa Oleifera leaf extract in water. On a fused silica capillary column, the compounds were separated based on their retention time. Bioactive constituents The extracts were identified by comparing the peak mass spectra to those in the literature and matching the peaks with the Computer Wiley MS library. [34]

Determination of the nitrogen content

Weight 0.25 g (4 number accurate) of sample and put it in Kjeldahl flask with 10 cm^3 of conc. H_2SO_4 and catalyst (¼ teaspoon) mixture of (90 g K_2SO_4 + 10 g $CuSO_4$ + 10 g selenium). Boil in mental heater until the colour change to colourless (about 1 ½ hour) then cooling. Transfer the content with distilled water to the Kjeldahl apparatus using distilled water. Add NaOH to the solution (when the sample is boiled) until brown colour formed [$B(OH)_3$]. Received the result in a beaker containing 25 ml boric acid 4 % with Kjeldahl indicator (mixture of methyl red – methylene blue) blue colour. Titrate all content in a beaker with 0.1 N HCl until the colour is changed from green to blue colour again. The percentage of nitrogen content (%) was estimated using the following equation:

$$\%\,N = \frac{N_{HCl} \times V_{HCl} \times 0.014}{\text{weight of sample}} \times 100$$

which N_{HCl}: normality of HCl (0.1 N) and V_{HCl}: volume consumed from HCl.

Colour Measurements

The colouration and spectrum reflection values of the treated dyed textiles, as well as the colour strength K/S of dyed untreated and treated fabrics, were determined using a computer-based automated spectrometer [Data Colour Model 3890, Marl Co., Germany]. As a result, the Kubelka-Munk equation was used to calculate the K/S values. [35-42]

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

The absorption coefficient is [K], the dispersion coefficient is [S], the colour reflection is [R], and the uncoloured (white) sample reflectance is [R_o]. The basic dye had a wavelength of = 610 nm, whereas the natural dye had a wavelength of = 270 nm.

Colourfastness properties

Using a Launder-Ometer, the AATCC test method 61-2013 was utilised to determine colourfastness to washing. [43] To determine colourfastness to rubbing, the AATCC test method 8-2016 was employed (dry and wet). [44] Colourfastness to perspiration was measured using the AATCC test method 15-2013 (acid and alkaline). [45] The colourfastness to light was determined using the AATCC test method 15-2013. [46] Washing, rubbing, and perspiration fastness properties were evaluated using the grayscale colour change reference, whereas light fastness properties for coloured materials were evaluated using the blue scale colour change reference. [47, 48]

Dye Fixation Measurement

To evaluate dye fixation, coloured materials were washed at 50°C for 30 minutes, and then the colour strength of the coloured fabric was measured after and before washing. Using the equation below, the dye fixation (% F) was calculated. [49]

$$\% F = \frac{(K/S)_a}{(K/S)_b} \times 100$$

where $(K/S)_a$ is the colour strength of the dyed fabric after washing and $(K/S)_b$ is the colour strength of the dyed fabric before washing.

RUI Measurement

The reflectance values of 10 randomly selected spots on the dyed sample were measured using a reflectance spectrophotometer in the visible spectrum area. The standard deviation [equation below], R_m is the mean of reflectance values for n wavelengths, and V is the photopic relative luminous efficiency function was used to produce the relative unlevelness index (RUI). R_i is the reflectance value of the measurement number (i) for each wavelength. [50]

$$S_\lambda = \sqrt{\frac{\sum_{i=1}^{n}(R_i - R_m)^2}{n-1}}$$

$$RUI = \sum_{\lambda=350}^{\lambda=700}\left(\frac{S_\lambda}{R_m} \times V_\lambda\right)$$

If the RUI value was < 0.2 that was used to define excellent levelness, whereas RUI < 0.49 was used to define fair levelness. RUI levels between 0.5 and 1 are considered poor levelness, while RUI values more than 1 are considered bad levelness. [51]

Mechanical properties

The dry crease recovery angle (CRA) was determined using the AATCC Test Method 66–2014. [52] A SE 1700 Surface Roughness Measuring Device and ASTM Test Method D 7127–13 were used to measure fabric roughness. [53] Tensile strength and elongation at break were determined using ASTM Test Method D 5035-2011. [54] The given results were calculated using the average of three measurements.

Antimicrobial Measurement

In this investigation, pathogenic yeast Candida albicans (ATCC 10231), gram-negative bacteria Escherichia coli (ATCC 25922), and gram-positive bacteria Staphylococcus aureus (ATCC 6538) were used. Fresh overnight broth cultures cultured at 37°C were used to introduce all microorganisms. [55]

The fabrics were applied to these tested microorganisms using the shake flask method to calculate antimicrobial activity as a reduction (%) of the growth of these selected pathogenic strains was detected by optical density [OD] at 600 nm, and the antimicrobial activity was measured as a relative [OD%] reduction of these pathogenic strains after being treated with the textile disc samples compared to the control of these pathogenic strains. [56-59] All of the results were explained using the following equation:

$$\text{OD Reduction } (\%) = \frac{A - B}{A} \times 100$$

where A indicates the (OD) of a control flask containing pathogenic strains that have not been treated, and B indicates the (OD) of testing flasks after applying a treated disc sample.

Results and Discussion

Characterization of Moringa Oleifera leaves extract

The GC-MS chromatogram of Moringa Oleifera leaves extract in water revealed many peaks. as shown in Fig. 3. The chromatogram for Moringa Oleifera leaves extract in water shows the presence of many major abundant peaks at various retention durations, indicating distinct

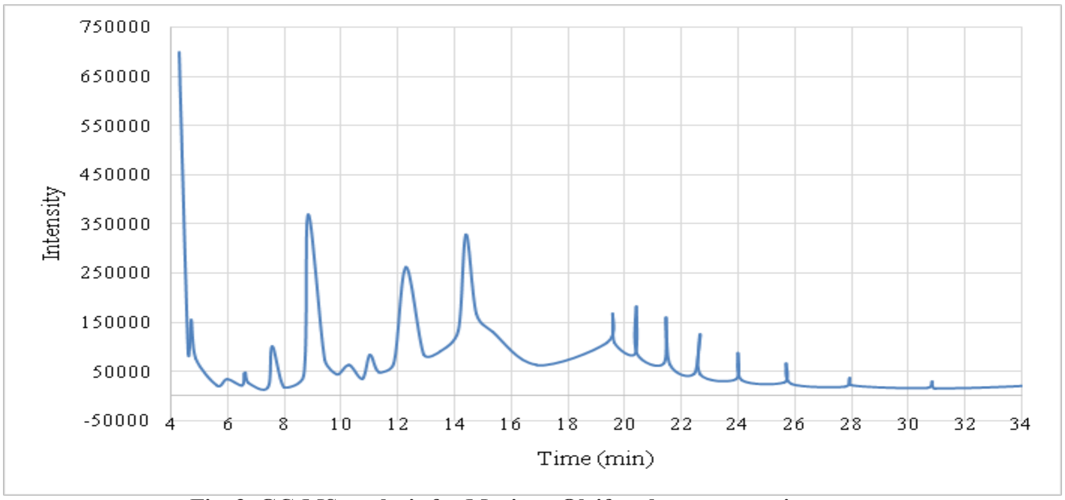


Fig. 3. GC-MS analysis for Moringa Oleifera leave extract in water.

TABLE 1. GC/MS analysis of Moringa Oleifera leaves extract in water.

Rt	Identified compounds	Mol. weight	Molecular Formula
7.56	Pyran-4-one	96	$C_5H_4O_2$
8.75	2-Furancarboxaldehyde	96	$C_5H_4O_2$
13.28	N-Trifluoro acetyl-serine n-butyl ester	257	$C_9H_{14}F_3NO_4$
14.24	3,5-bis(1,1-dimethylethyl)-phenol	206	$C_{14}H_{22}O$
19.35	Docosane	310	$C_{22}H_{46}$
20.25	L(+) Ascorbic acid-2,6-dihexadecanoate	652	$C_{38}H_{68}O_8$
21.22	Tetracosane	338	$C_{24}H_{50}$
22.35	Pentacosane	353	$C_{25}H_{52}$
23.70	3-Methyl-Dodecane	184	$C_{13}H_{28}$
23.73	Heptacosane	381	$C_{27}H_{56}$
25.45	Octacosane	395	$C_{28}H_{58}$
25.60	Methyl 3-ethyl-2-hexenoate	156	$C_9H_{16}O_2$
27.99	1,7-Bis(3,5-bis (bromomethyl)phenyl)heptane	620	$C_{23}H_{28}Br_4$
28.62	N-Allyloxymethylacrylamide	141	$C_7H_{11}NO_2$
28.87	3,5-Dimethyl-4-oxo-4H-pyrazole-1,2-dioxide	142	$C_5H_6N_2O_3$

molecular ions (m/z) for various chemicals, primarily hydrocarbons and phenol, as shown in Table 1. These results are similar to the result illustrated by Shousha *et al,* Tiloke *et al*. and Al-Owaisi *et al*. [60-62]

Optimization of the treatment condition

Effect of polycation concentration

To functionalize the surface of fabrics namely: cotton, wool, and acrylic, four treatment solutions based on polycation compounds (chitosan and amino-cellulose) were prepared with various concentrations (0.5, 1, 2, and 3%). After the fabrics have been treated, the dyeing procedure has been carried out using both basic and natural dyes.

Table 2 and Fig. 4 illustrate that all treated fabrics (cotton, wool, and acrylic) had higher colour strength than untreated fabrics in terms of colour strength, dye fixation, and RUI. Because increasing the polycation concentration increases the colour strength, we may conclude that the best treatment concentration was 2%, as the results improve slightly after this concentration.

In cationic modification for various fabrics, we used chitosan and amino-cellulose whose main functional group is the amino group (NH_2), which means after the surface modification of the treated fabrics, a positive charge [+] is been on the fabrics' surface. Chitosan, a deacetylated derivative of chitin, has been widely used in textile materials in recent years, providing a variety of functions. [63] Chitosan can also be used to improve the dyeability of textiles in the dyeing bath. Maybe this is due to the electrostatic interaction of the protonated amino group in chitosan to the different classes of dyes, resulting in extremely high partiality for certain colours. They have demonstrated a higher interest in textile dyeing as chitosan is more environmentally friendly than synthetic compounds. Cationic modified cellulose is also used for the cationic modification in the dyeing process. Using bio and modified natural polymers is preferred over synthetic polymers, they possess a range of characteristics that are helpful to mankind without posing a threat to the environment or health hazards. [64]

Nitrogen content (N%) for treated fabrics is an indication of the presence of amine groups that have been transferred to the fabrics after the cationic modification.

As shown in Table 2, the more concentration of polycationic material was, the more nitrogen content has been found. That leads to the form of a positive charge [+] on the fabric surface, with the aid of a crosslinker (citric acid [CA] with sodium hypophosphite [SHP]) that leads to improving the colour strength, dye fixation and RUI of treated fabrics. Results indicate that chitosan polymer has higher nitrogen content than amino cellulose, that is due to the deacetylated chitosan polymer contains more free amino groups that can interact with the fabrics. That means higher results of color strength than amino cellulose.

The key result is that increasing the concentration of polycation in the pre-treatment procedure above 2% results in a minor increase in K/S values of dyed textiles, leading to the conclusion that pre-treatment of different fabrics with a 2 % polyamine compound is more appropriate for this study. The increased number of functional groups, such as amino and hydroxyl groups, contribute more efficiently to absorbing dye molecules through ionic interactions and hydrogen bonding, resulting in improved dye absorption on treated fabrics.

The anionic charge of natural dye in water enabled positively charged amino groups of cationic polymers to have substantivity on the modified fabrics treated with chitosan and cationic cellulose.

Effect of pH

The pH level of the dye solution was one of the most important parameters impacting dye adsorption onto fabrics treated with polycation polymers. Table 3 and Fig. 5 present the effect of different pH on treated fabrics.

With both polycations (chitosan and amino-cellulose), the optimum pH for modified cotton fabric is 8, since pH 8 provides greater color strength than pH 4 and pH 6. Treated cotton with chitosan and amino cellulose in pH 8 with basic dye give K/S values (16.82), (15.67) respectively for RUI values (0.162), (0.184) respectively, which means an excellent rate of levelness of dyeing with both two polymers. In treated cotton fabric dyed with moringa natural dye, the K/S value for chitosan with is (17.12) with RUI (0.177), which means an excellent rate of levelness of dyeing and in cationic cellulose modification, the color strength is (16.98) with RUI value (0.195), that means an excellent rate of levelness of dyeing.

In wool fabrics, the absorption of basic and natural dyes to modified fabrics decreased when the pH was raised to 8. Because chitosan has so many ionizable amino side groups, the pH of the dye solution has a significant impact on surface charge. At increasing pH levels, the positively charged amino groups in chitosan decrease, leaving less space for anionic dye absorption, resulting in a reduction in color depth. The optimum pH for modified wool fabric is 6 with both polycations (chitosan and amino-cellulose), as pH 6 gives higher color strength than pH 4 and pH 8.

In the case of chitosan and amino-cellulose treated wool with a basic dye, K/S value is (16.14) and (16.12) and RUI values were (0.192) and (0.362), respectively which means an excellent rate of levelness of dyeing with chitosan and good levelness of amino-cellulose treated fabric. In moringa natural dye the K/S value for chitosan with treated wool fabric is (18.24) with RUI (0.178), which means an excellent rate of levelness of dyeing. In amino cellulose modification, the color strength is (18.19) with an RUI value (0.395), which means a good rate of levelness of dyeing.

The optimum pH for modified acrylic fabric is 4 with both polycations (chitosan and amino cellulose), as pH 4 gives higher color strength than pH 6 and pH 8.

When modified acrylic with chitosan and amino cellulose dyed with a basic dye, K/S values are (5.99) and (5.84) and RUI values were (0.213) and (0.212) respectively, which means good rates of levelness of dyeing with chitosan and good levelness of amino-cellulose treated fabric. For moringa natural dye, the K/S value for acrylic fabric

TABLE 2. Effect of polycation polymers concentration on the amine content andcolour performance.

Fabric	Polycation (%)		N %	Basic dye K/S	Basic dye Dye fixation	Basic dye RUI value	Basic dye RUI rate	Natural dye K/S	Natural dye Dye fixation	Natural dye RUI value	Natural dye RUI rate
Cotton	Chito.	0	0.05	13.18	58.50	0.53	P	9.41	41.77	0.38	G
		0.5	1.495	13.86	89.4	0.412	G	14.04	64.21	0.388	G
		1	2.195	14.13	91.9	0.434	G	14.69	77.37	0.409	G
		2	3.26	14.82	94.34	0.362	G	16.00	82.61	0.341	G
		3	3.96	15.07	96.69	0.29	G	16.20	83.04	0.273	G
	Am. Cell.	0	0.05	13.18	58.50	0.53	P	9.41	41.77	0.38	G
		0.5	1.270	13.35	90.75	0.423	G	11.72	70.6	0.398	G
		1	1.865	13.73	93.15	0.398	G	14.36	79.92	0.375	G
		2	2.771	14.15	89.46	0.45	G	15.34	84.48	0.325	G
		3	3.366	14.79	95.32	0.314	G	16.10	86.33	0.295	G
Wool	Chito.	0	0.89	14.58	79.93	0.68	P	12.41	68.03	0.58	P
		0.5	1.25	15.36	90.57	0.534	P	15.49	73.31	0.519	P
		1	1.74	15.82	97.54	0.455	G	17.44	88.34	0.443	G
		2	2.65	16.14	98.99	0.192	E	17.72	94.31	0.182	E
		3	3.87	16.92	98.86	0.332	G	17.76	94.81	0.323	G
	Am. Cell.	0	0.89	14.58	79.93	0.68	P	12.41	68.03	0.58	P
		0.5	1.062	15.09	94.2	0.495	P	13.95	80.61	0.481	G
		1	1.479	15.68	98.29	0.424	G	16.46	91.24	0.412	G
		2	2.252	16.12	98.92	0.362	G	17.58	99.29	0.352	G
		3	3.289	16.43	99.66	0.221	G	17.74	99.55	0.215	G
Acrylic	Chito.	0	0.47	3.69	78.51	0.49	G	5.17	49.94	0.69	P
		0.5	1.225	4.12	92.94	0.39	G	6.42	58.24	0.379	G
		1	1.799	4.76	95.66	0.318	G	7.73	70.16	0.309	G
		2	2.673	5.48	96.68	0.222	G	8.90	72.96	0.216	G
		3	3.247	5.75	97.62	0.227	G	9.51	74.28	0.221	G
	Am. Cell.	0	0.47	3.69	78.51	0.49	G	5.17	49.94	0.69	P
		0.5	1.042	4.03	94.5	0.354	G	5.79	58.24	0.344	G
		1	1.529	4.62	96.23	0.27	G	7.07	71.54	0.262	G
		2	2.272	5.17	97.15	0.224	G	8.32	73.62	0.218	G
		3	2.760	5.79	98.36	0.211	G	9.21	74.54	0.205	G

Treatment condition: polycations (chitosan (chito) and amino cellulose (Am. cellulose)) (0.5, 1, 2, 3 %), citric acid 10 g/L, sodium hypophosphite (SHP) 5 g/L, drying at 80°C for 5 min

Dyeing condition: dye conc.: 2 g/L (basic dye (l = 610)) and extract of moringa leaves as 30 g leaves /L water (l= 270), pH 4, dyeing time: 45 min, dyeing temperature: 75°C, drying at 100°C for 5 min, curing at 140°C for 3 min

RUI values range can be categorized into If RUI<0.2 that considered as excellent levelness. (E). If 0.2<RUI<0.49 that is considered good levelness. (G), If RUI is between 0.5 and 1 that means poor levelness. (P), If RUI values are greater than 1 that indicates bad levelness. (B)

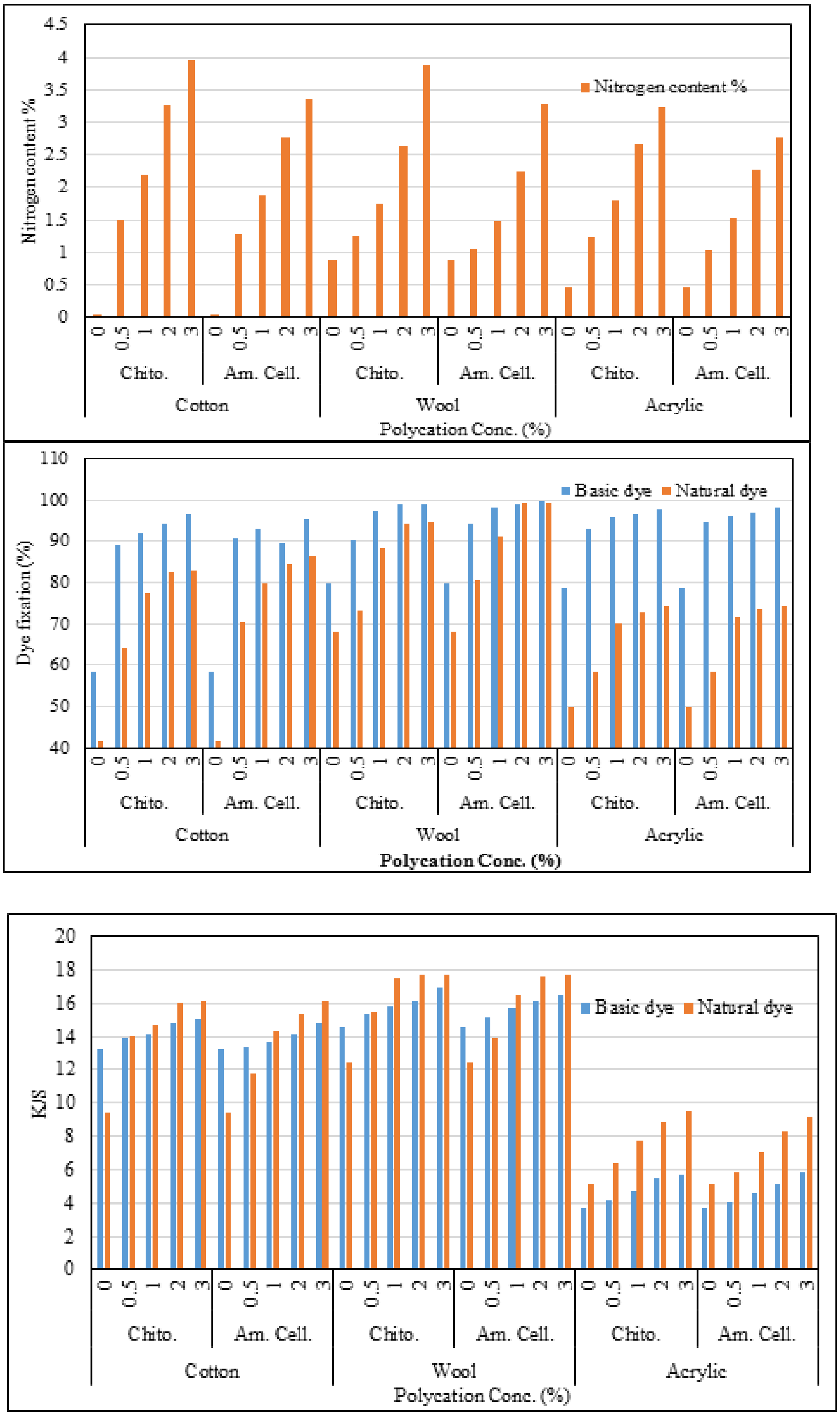
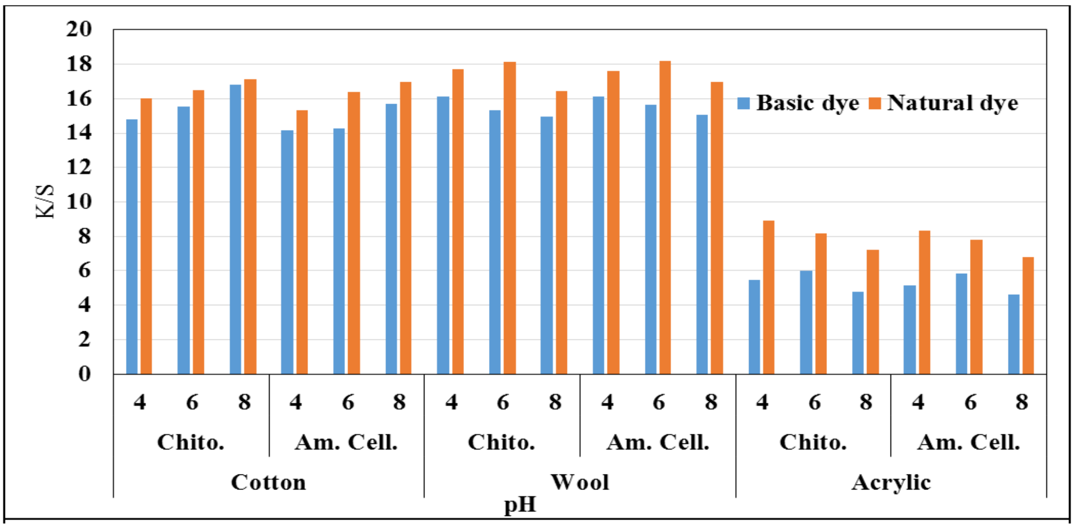


Fig. 4. Effect of polycation polymers concentration on the nitrogen content and colour performance

TABLE 3. Effect of pH on the colour strength.

Fabric	Poly cation 2%	pH	Basic dye				Natural dye			
			K/S	Dye fixation	RUI value	RUI rate	K/S	Dye fixation	RUI value	RUI rate
Cotton	Chito.	4	14.82	94.34	0.362	G	16.00	82.61	0.341	G
		6	15.52	95.78	0.237	G	16.47	95.2	0.2	G
		8	16.82	98.44	0.162	E	17.12	99.53	0.177	E
	Am. cellulose	4	14.15	89.46	0.45	G	15.34	84.48	0.325	G
		6	14.25	94.53	0.326	G	16.41	68.48	0.257	G
		8	15.67	96.35	0.184	E	16.98	96.86	0.195	E
Wool	Chito.	4	15.34	95.39	0.243	G	17.72	94.31	0.182	E
		6	16.14	98.99	0.192	E	18.24	97.41	0.178	E
		8	14.96	96.32	0.313	G	16.43	70.25	0.248	G
	Am. cellulose	4	15.62	97.1	0.388	G	17.58	99.29	0.352	G
		6	16.12	98.92	0.362	G	18.19	99.77	0.395	G
		8	15.05	95.7	0.448	G	16.98	87.69	0.454	G
Acrylic	Chito.	4	5.99	96.68	0.213	G	8.90	72.96	0.216	G
		6	5.48	95.92	0.222	G	8.17	70.16	0.172	E
		8	4.78	87.25	0.319	G	7.21	52.23	0.261	G
	Am. cellulose	4	5.84	99.36	0.212	G	8.32	88.42	0.218	G
		6	5.17	97.15	0.224	G	7.78	73.62	0.188	E
		8	4.61	83.14	0.345	G	6.80	62.71	0.279	G

Treatment condition: polycations (Chitosan or Amino cellulose (Am. cellulose)) (2 %), citric acid 10 g/L, sodium hypophosphite (SHP), drying at 80°C for 5 min
Dyeing condition: dye conc.: 2 g/L (basic dye (l = 610)) and extract of moringa leaves as 30 g leaves /L water (l= 270), pH (4, 6, and 8), dyeing time: 45 min, dyeing temperature: 75°C, drying at 100°C for 5 min, curing at 140°C for 3 min
RUI values range can be categorized into If RUI<0.2 that considered as excellent levelness. (E). If 0.2<RUI<0.49 that is considered good levelness. (G), If RUI is between 0.5 and 1 that means poor levelness. (P), If RUI values are greater than 1 that indicates bad levelness. (B)



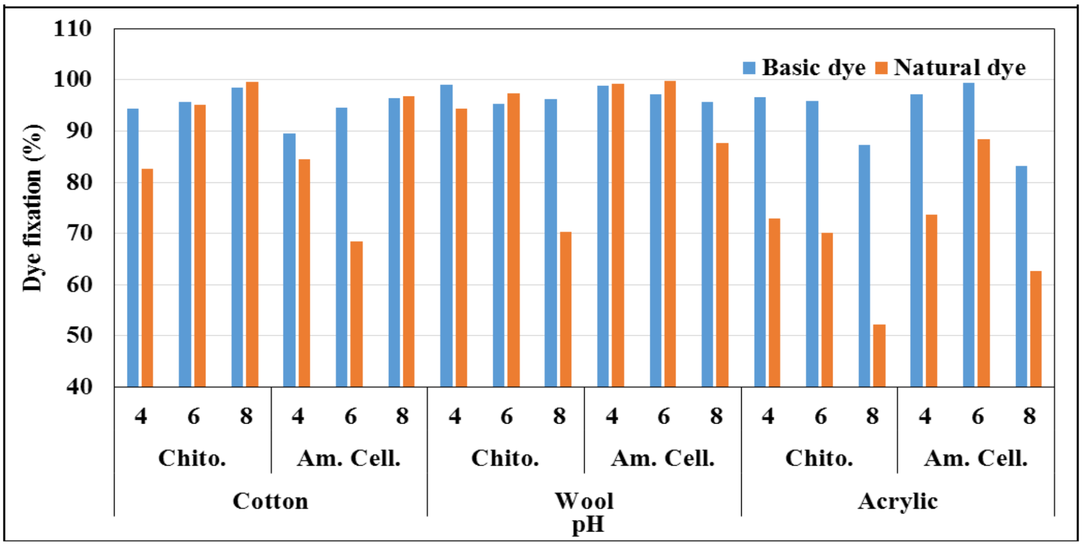


Fig. 5. Effect of pH on the colour strength.

treated with chitosan is (8.90) with RUI (0.216), which means a good rate of levelness of dyeing. In the case of amino cellulose modification, the color strength is (8.32) with an RUI value (0.218), which means a good rate of levelness of dyeing.

Effect of Dyeing Temperature

An overall characteristic of greater dyeability was observed as the dyeing temperature was raised. The colour strengths (K/S) of all fabrics treated with chitosan and amino-cellulose rise when dyeing temperatures are raised from 60 to 90°C as shown in Table 4 and Fig. 6. More dye molecules can be fixed in fabrics and moved from the surface to the non-crystalline portions, resulting in greater dye solution absorption. Based on the previous results, the optimum dyeing temperature is 75 minutes since the percent increase in K/S as a result of increasing dyeing time from 75 to 90 minutes is fairly minor.

K/S values for treated cotton with chitosan and amino cellulose with a basic dye, are respectively (16.82), (15.67) for RUI values (0.162), (0.184), showing an excellent rate of levelness of chitosan and amino-cellulose treated fabric. The K/S value for chitosan in treated cotton fabric colored with moringa natural dye is (17.12) with RUI (0.177), indicating an excellent rate of dyeing levelness, and the color strength in amino cellulose modification is (16.98) with RUI value (0.195), indicating an excellent rate of dyeing levelness. The K/S values for chitosan and amino-cellulose treated wool with basic dye are (16.14) and (16.12), respectively, for RUI values (0.192) and (0.362), indicating an excellent rate of levelness of chitosan and a good rate of dyeing levelness with chitosan and amino-cellulose treated fabric. The K/S value for chitosan with treated wool cloth in moringa natural dye is (18.24) with RUI (0.182), indicating an excellent rate of dyeing levelness. The color strength of amino cellulose modification is (18.19) with an RUI value of (0.395), also indicating a good rate of dyeing levelness.

The K/S values for modified acrylic with chitosan and amino cellulose dyed with basic dye are (5.99), (5.84), respectively, for RUI values (0.213), (0.232), indicating good levels of dyeing levelness with chitosan and amino-cellulose treated fabric. The K/S ratio for moringa natural dye for acrylic fabric treated with chitosan is (8.90) with RUI (0.172), indicating a great rate of dyeing levelness. The color strength of cationic cellulose modification is (8.32) with an RUI value of (0.218), indicating a good rate of dyeing levelness.

Effect of Dyeing Time

The colour strength of samples coloured with both basic and natural dyes increased as the duration extended from 30 to 60 minutes, as illustrated in Table 5 and Fig. 7.

These are predicted results since the dye had more time to enter and distribute throughout the fibres when it reached the dynamic dyeing equilibrium stage, allowing it to attain its maximal dye absorption capacity. Based on the previous results, the optimum dyeing time is 45 minutes since the percent increase in K/S as a result of increasing dyeing time from 45 to 60 minutes is rather small.

For treated cotton with chitosan and amino-cellulose with a basic dye, K/S values (16.82) and (15.67) for RUI values (0.162) and (0.184), respectively, indicate an excellent rate of levelness of dyeing. The color strength for moringa natural dye in chitosan modification is (17.12) with an RUI value (0.177), suggesting an excellent rate of dyeing levelness, while the K/S value for amino cellulose in treated cotton fabric dyed with moringa natural dye is (16.98) with RUI (0.195), indicating an excellent rate of dyeing levelness.

The K/S values for chitosan and amino-cellulose treated wool with basic dye are (16.14), (16.12), and RUI values are (0.192), (0.172), showing that chitosan and the amino-cellulose treated fabric has an excellent rate of dyeing levelness. In moringa natural dye, the K/S ratio for chitosan with treated wool material is (18.24), with RUI (0.182), suggesting an excellent rate of dyeing levelness. The cationic cellulose modification's color strength is (18.19), with an RUI value of (0.182), showing an excellent rate of dyeing levelness.

Modified acrylic with chitosan and amino cellulose dyed with basic dye has K/S values (5.99), (5.84), and the RUI values are (0.213), (0.232) respectively, which means good levels of dyeing with chitosan and amino-cellulose treated fabric. The K/S ratio for moringa natural dye on chitosan-treated acrylic fabric is (8.90), with

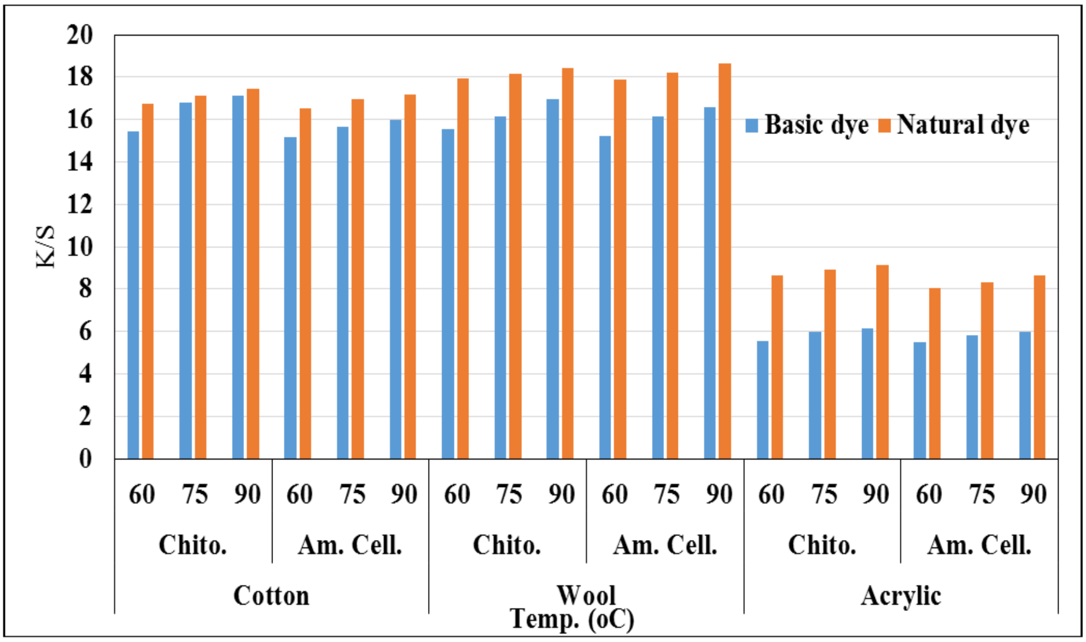
TABLE 4. Effect of dyeing temperature on the colour strength.

Fabric	Poly cation 2%	Dyeing tempera-ture (°C)	Basic dye				Natural dye			
			K/S	Dye fixation	RUI value	RUI rate	K/S	Dye fixation	RUI value	RUI rate
Cotton	Chito.	60	15.46	97.37	0.186	E	16.74	98.51	0.195	E
		75	16.82	98.44	0.162	E	17.12	99.53	0.177	E
		90	17.12	98.99	0.165	E	17.43	99.89	0.195	E
	Am. cellulose	60	15.19	95.41	0.197	E	16.51	96.23	0.198	E
		75	15.67	96.35	0.184	E	16.98	96.86	0.195	E
		90	15.98	96.45	0.151	E	17.19	97.41	0.185	E
Wool	Chito.	60	15.54	98.15	0.192	E	17.92	94.31	0.182	E
		75	16.14	98.99	0.192	E	18.24	97.41	0.182	E
		90	16.98	99.12	0.459	G	18.43	97.81	0.196	E
	Am. cellulose	60	15.22	98.57	0.362	G	17.87	99.29	0.352	G
		75	16.12	98.92	0.362	G	18.19	99.77	0.395	G
		90	16.59	99.01	0.175	E	18.65	95.94	0.195	E
Acrylic	Chito.	60	5.53	95.74	0.231	G	8.62	69.81	0.194	E
		75	5.99	95.92	0.213	G	8.90	70.16	0.172	E
		90	6.16	96.17	0.174	E	9.14	76.31	0.197	E
	Am. cellulose	60	5.51	99.04	0.212	G	8.06	88.42	0.223	G
		75	5.84	99.36	0.232	G	8.32	88.42	0.218	G
		90	5.98	99.74	0.198	E	8.67	91.53	0.234	G

Treatment condition: polycations (Chitosan or Amino cellulose (Am. cellulose)) (2 %), citric acid 10 g/L, sodium hypophosphite (SHP), drying at 80°C for 5 min

Dyeing condition: dye conc.: 2 g/L (basic dye (l = 610)) and extract of moringa leaves as 30 g leaves /L water (l= 270), pH (4), dyeing time: 45 min, dyeing temperature: (60, 75, and 90°C), drying at 100°C for 5 min, curing at 140°C for 3 min

RUI values range can be categorized into If RUI<0.2 that considered as excellent levelness. (E). If 0.2<RUI<0.49 that is considered good levelness. (G), If RUI is between 0.5 and 1 that means poor levelness. (P), If RUI values are greater than 1 that indicates bad levelness. (B)



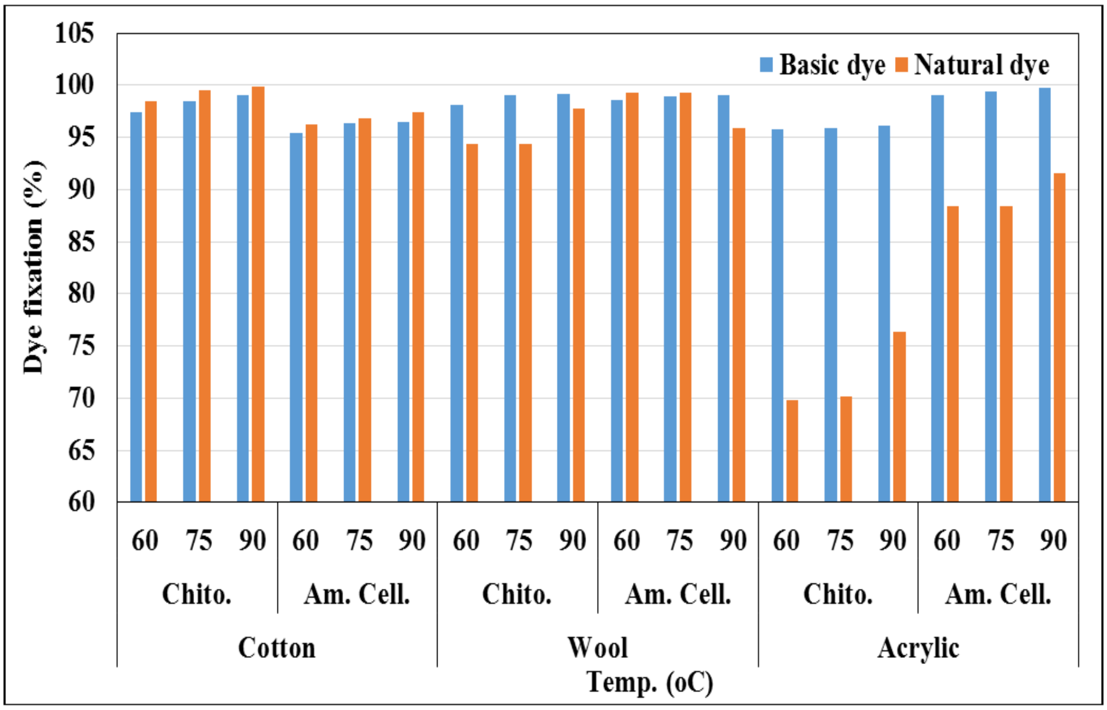


Fig. 6. Effect of dyeing temperature on the colour strength.

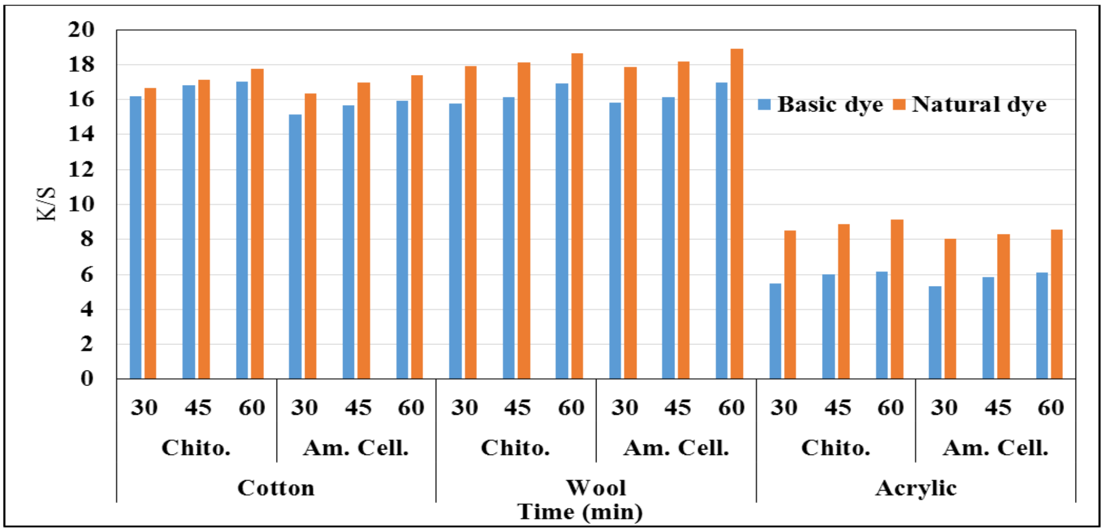
TABLE 5. Effect of dyeing time on the colour strength.

Fabric	Polycation (2%)	Dyeing time (min.)	Basic dye				Natural dye			
			K/S	Dye fixation	RUI		K/S	Dye fixation	RUI	
					value	rate			value	rate
Cotton	Chito	30	16.21	98.26	0.184	E	16.65	99.48	0.198	E
		45	16.82	98.44	0.162	E	17.12	99.53	0.177	E
		60	17.05	99.69	0.141	E	17.78	99.95	0.169	E
	Amino-cellulose	30	15.12	95.92	0.245	G	16.35	96.71	0.264	G
		45	15.67	96.35	0.184	E	16.98	96.86	0.195	E
		60	15.94	96.87	0.206	G	17.37	97.19	0.236	G
Wool	Chito	30	15.78	98.13	0.17	E	17.91	96.42	0.194	E
		45	16.14	98.99	0.192	E	18.24	97.41	0.182	E
		60	16.93	99.23	0.158	E	18.67	99.67	0.178	E
	Amino-cellulose	30	15.84	98.45	0.187	E	17.87	98.86	0.175	E
		45	16.12	98.92	0.172	E	18.19	99.77	0.182	E
		60	16.96	99.59	0.185	E	18.89	99.63	0.187	E
Acrylic	Chito	30	5.48	95.58	0.182	E	8.52	69.64	0.162	E
		45	5.99	95.92	0.213	G	8.90	70.16	0.172	E
		60	6.16	96.18	0.168	E	9.13	70.68	0.137	E
	Amino-cellulose	30	5.31	99.05	0.254	G	8.04	87.71	0.204	G
		45	5.84	99.36	0.232	G	8.32	88.42	0.218	G
		60	6.09	99.89	0.184	E	8.56	89.11	0.234	G

Treatment condition: polycations (Chitosan or Amino cellulose (Am. cellulose)) (2 %), citric acid 10 g/L, sodium hypophosphite (SHP), drying at 80°C for 5 min

Dyeing condition: dye conc.: 2 g/L (basic dye (l = 610)) and extract of moringa leaves as 30 g leaves /L water (l= 270), pH (4), dyeing time: (30, 45, and 60 min), dyeing temperature: (75°C), drying at 100°C for 5 min, curing at 140°C for 3 min

RUI values range can be categorized into If RUI<0.2 that considered as excellent levelness. (E). If 0.2<RUI<0.49 that is considered good levelness. (G), If RUI is between 0.5 and 1 that means poor levelness. (P), If RUI values are greater than 1 that indicates bad levelness. (B)



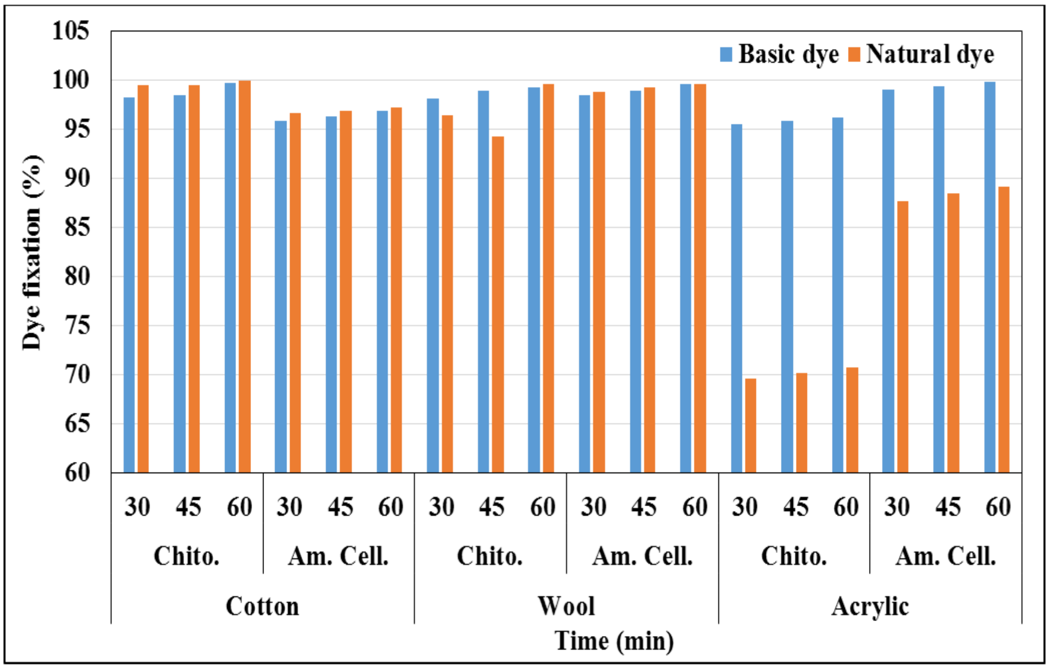


Fig. 7. Effect of dyeing time on the colour strength.

RUI (0.172), showing an excellent rate of dyeing levelness. The cationic cellulose modification has a color strength of (8.32) and an RUI value of (0.218), showing an excellent rate of dyeing levelness foe chitosan modification, and a good rate for amino cellulose for treated dyed fabrics.

Characterization of the dyed textile fabrics

Fastness properties

Table 6 shows the fastness properties of dyed treated fabrics (cotton, wool, and acrylic fabrics) with polycation polymers (chitosan and amino-cellulose; 2%) at optimum dying conditions (45 min.; 75°C; dye conc. 2 g/L; L: R 1:50) with pH 4 for wool, 6 for acrylic and 8 for cotton fabric, using two different dye natures (basic and nature (moringa extract)).

Treated fabrics excelled over untreated materials in terms of washing, perspiration, light, and rubbing properties. Compared to untreated materials, chitosan and amino-cellulose treatment greatly improved the washing and lightfastness qualities of coloured fabrics using both studied dyes. The light-fastness qualities of modified textiles improved as the dye content in the fibre increased. This enhancement is due to the chemical interactions formed between polycation-treated materials, crosslinkers, and dye molecules.

Consequently, improved hydrogen bonding between dye molecules, polycation polymers, the fabric surface, and the crosslinker binds the dye molecules inside and on the textile surface. Furthermore, when the fabric is treated with polycation polymers, dyeing homogeneity is improved because the fibres have a uniform thin coating of polycation polymers on the surface, and dye molecules are absorbed better and more consistently.

Physical and mechanical properties

Tensile strength, elongation at break, crease recovery angle in the warp and weft directions and surface roughness of cotton, wool, and acrylic fabrics were measured before and after they were treated with 2% polycation polymers, and the results are provided in Table 7 and Fig. 8. The inclusion of cationic groups in both polycation polymers has been shown to have a positive effect on textile fibres.

The presence of a cationic group is treated textile materials produces changes in physicomechanical characteristics, as seen in Table 7 and Fig. 8. Fabric roughness, tensile strength, and elongation at the break all increased as well as the crease recovery angle was increased. This suggests that the polycation polymers under examination were deeply buried in the microstructure of the textile textiles, resulting in a thin coating layer on the fabric's surface that caused the observed alterations. [65-68]

The influence of citric acid catalysed by sodium hypophosphite (SHP) in the pre-crosslinking treatment of cotton, wool, and/or acrylic fabrics on the

TABLE 6.Colour strength and fastness properties of dyed fabrics using basic and natural dyes.

Fabric	Dye	Polyanion (2 %)	Fastness properties										
			Washing		Rubbing				Perspiration				Light
					Dry		Wet		Acidic		Alkaline		
			Alt	St	Alt	St	Alt	St	Alt	St	Alt	St	
Cotton	Basic Dye	without	2	2	2	2	2-3	2-3	2	2	2	2	3-4
		Chitosan	4	4	4	4	4	4	4	4	4	4	5
		Am. Cell.	4	4	4	4	4	4	4	4	4	4	5
	Natural dye	without	2	2	2	2	2	2	2	2	2	2	2-3
		Chitosan	4	4	3-4	4	3-4	4	3-4	4	3-4	4	4-5
		Am. Cell.	4	4	3-4	4	3-4	4	3-4	4	3-4	4	5
Wool	Basic Dye	without	3	3	3	3	3	3	3	3	3	3	3-4
		Chitosan	3	4	3	4	3	4	3	4	3	4	4-5
		Am. Cell.	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	5
	Natural dye	without	3	2-3	3	2-3	3	2-3	3	3	2-3	3	4
		Chitosan	4	4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	5
		Am. Cell.	4	3-4	3-4	4	4	4	4	4	4	4	5
Acrylic	Basic Dye	without	4	4	3-4	3-4	3-4	3-4	3-4	4	4	4	4-5
		Chitosan	4	4	3-4	4	4	4	4	4	3	3	5
		Am. Cell.	4	4	3-4	4	4	4	4	4	3	3	5
	Natural dye	without	2-3	2-3	3	3	3	2-3	3	3	3	3	3
		Chitosan	4	4	3-4	4	4	4	4	4	4	4	4-5
		Am. Cell.	4	4	3-4	4	3-4	4	3-4	4	3-4	4	4-5

Treatment condition: polycations (chitosan or amino cellulose (Am.Cell)) (2 %), citric acid 10 g/L, sodium hypophosphite (SHP), drying at 80°C for 5 min
Dyeing condition: dye conc.: 2 g/L (basic dye (l = 610)) and extract of moringa Oleifera leaves as 30 g leaves /L water (l= 270), pH (4), dyeing time: (45 min), dyeing temperature: (75°C), drying at 100°C for 5 min, curing at 140°C for 3 min

TABLE 7.physical and mechanical properties for treated dyed fabrics.

Fabric	Dye	Polycation (2 %)	Physical and Mechanical properties			
			Tensile Strength (N/mm^2)	Elongation at a break (%)	Crease Recovery Angle (warp+weft)(°)	Surface Roughness
Cotton	Basic dye	without	157.08	36.82	231.95	21.32
		Chitosan	164.00	37.41	268.19	24.18
		Am. Cell.	166.90	41.47	244.40	25.74
	Natural dye	without	149.23	34.98	220.35	20.25
		Chitosan	166.45	37.97	272.21	24.54
		Am. Cell.	169.40	42.09	248.07	26.13
Wool	Basic dye	without	161.16	37.74	231.95	21.83
		Chitosan	168.20	38.28	275.21	24.83
		Am. Cell.	171.25	42.49	250.77	26.52
	Natural dye	without	153.10	35.85	220.35	20.74
		Chitosan	170.72	38.85	279.34	25.20
		Am. Cell.	173.90	43.12	254.53	26.92
Acrylic	Basic dye	without	165.34	38.76	237.97	22.44
		Chitosan	172.55	39.30	282.23	21.45
		Am. Cell.	175.74	43.65	257.14	22.99
	Natural dye	without	157.07	36.82	226.07	21.32
		Chitosan	175.14	39.88	286.46	21.77
		Am. Cell.	178.38	44.30	261.00	23.33

R: Roughness, CRA (W+F): average Crease Recovery Angle in warp and weft directions

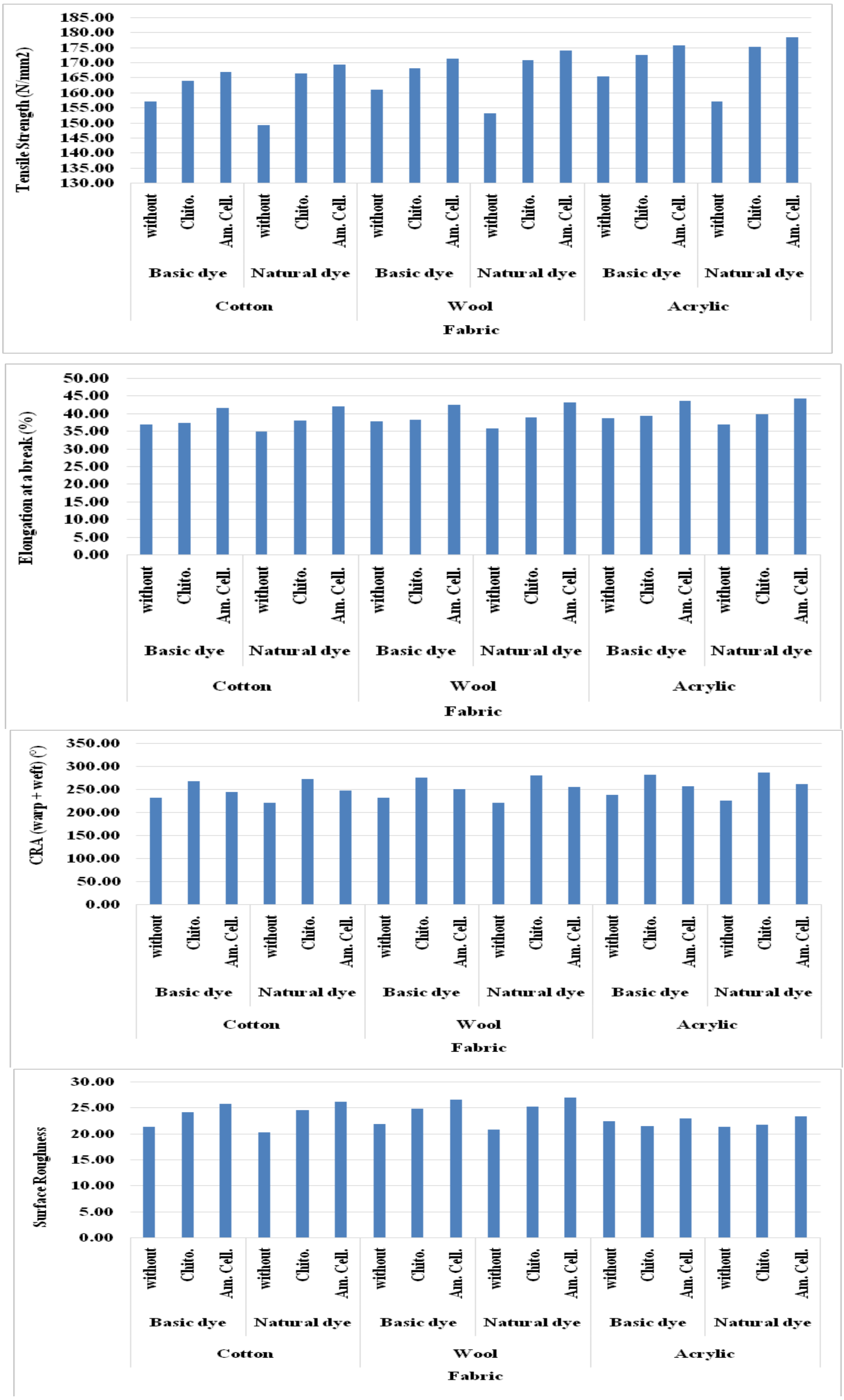


Fig. 8. Physical and mechanical properties of dyed fabrics using different dyes.

performance of the previously evaluated properties was also significant. Covalent crosslinking linkages between adjacent cellulosic or proteinic chains would develop during this pre-treatment, providing the cotton structure stiffness. The enormous rise in the crease recovery angle was most likely caused by the formation of an extensive network with a high degree of crosslinking via covalent chemical bonding.

Antimicrobial properties

Chitosan is a polycationic biopolymer that has a wide range of biological activity, including antimicrobial and antifungal characteristics, that has been thoroughly described. Two major structural characteristics determine its antibacterial capacity: the degree of deacetylation [DD] and the number of ionized groups. It has been demonstrated that when the molecular weight [MW] of chitosan increases, so does the rate of bacteria decrease. The number and placement of amino groups, which are linked to both criteria, are the major drivers for chitosan antibacterial efficacy, in addition to DD and MW. [69]

Table 8 and Fig. 9 illustrate the antimicrobial effects of cotton, wool, and acrylic fabrics treated with 2% polycation polymer (chitosan and amino-cellulose) that dyed with two different dye natures (basic and natural (moringa extract)) on three different microorganisms I gram-positive (Staphylococcus aureus), (ii) gram-negative (Escherichia coli), and (iii) fungal (Candida Albicans). The findings demonstrate that both gram-positive and negative bacteria, as well as a fungus (Candida Albicans), had a greater inhibitory effect on untreated coloured textile materials than on blank material. The presence of cationic groups in the basic dye, as well as phenolic acids and flavonoids in natural dye extract, causes this activity.

The treated textiles are more effective against gram-negative bacteria than gram-positive bacteria because the cell walls of both tested bacterial strains differ in composition. Ergosterol, a crucial component of the fungal cell membrane, is likewise blocked by the polycations used. [17, 24, 41, 70-73]

Amino cellulose-treated textiles have a greater antibacterial effect than chitosan-treated textiles. This is due to the presence of quaternary amino groups in amino-chitosan, which play an important role in destroying microbial cell membranes while simultaneously acting as a powerful antibacterial agent. [65, 74]

Metals, phenolic acids, and flavonoids included in natural colouring extract (moringa extract) have successfully interacted with the bacterium's cells. The polycation polymers in the cover disseminate and stable the extract dyes' components (metals, phenolic acids, and flavonoids) well on the cloth surface, reducing their ability to interact with microorganisms. [75-78]

Moreover, treated and coloured textile materials have better antibacterial properties than untreated textile fabrics before and after washing. The treated fabrics' durability provides strong antibacterial activity against all pathogens tested after washing. [79]

The treated textiles are more effective against gram-positive bacteria than gram-negative bacteria because the cell walls of both tested bacterial strains differ in composition. Ergosterol, a crucial component of the fungal cell membrane, is likewise blocked by the polycations used.

Conclusion

The textile industry has made several attempts to use renewables, such as biopolymers, as a consequence of increased attention to sustainable development and environmental challenges. Natural polymers with a variety of desirable characteristics such as biocompatibility, biodegradability, low toxicity, and high biological activity are increasing in popularity year after year and significantly improves the environmental aspects and sustainability of textile goods. In this work, fabrics namely; cotton, wool and acrylic were treated using different concentrations of cationic biopolymers as chitosan and amino cellulose then dyed with two different dyes type (basic and natural). The optimum dyeing conditions were (polymer conc. 2 g/L; 75°C; 45 min.; L:R 1:50) with pH 8 for cotton fabric, 6 for wool, and 4 for acrylic using two different dye natures (basic and natural (moringa extract)). The colour strength of dyed treated textiles (K/S) has been improved, mechanical and physical properties as well as the antibacterial effect of treated dyed fabrics to different kinds of bacterias and fungi.

This treatment is very useful for dyeing blends like polyacrylic/cotton with basic dyes in one bath, that leads to use less energy, less water, less chemicals and less hazards to the environment. Biopolymers can be utilised as a replacement of a wide range of chemical processes, as the environmental aspects of production are gaining more attention in today's globe.

TABLE 8. CFU reduction(%) of different microbial strains for untreated and treated dyed fabrics before and after washing.

Fabric	Dye	Polycation (2 %)	Microbial Reduction %					
			E. coli (ATCC 25922)		S. Aureus (ATCC 29213)		C. Albicans (ATCC 10231)	
			before washing	after 10 washing cycles	before washing	after 10 washing cycles	before washing	after 10 washing cycles
Cotton	Blank		21.1	16.5	21.3	15.1	20.1	13.3
	Basic dye	without	23.21	18.25	25.14	17.88	24.11	16.23
		Chitosan	33.89	26.65	36.70	27.89	35.20	25.32
		Am. Cell.	49.47	38.90	53.59	40.72	51.39	36.97
	Natural dye	without	74.27	58.40	80.45	57.22	77.15	51.94
		Chitosan	94.88	85.26	91.76	89.26	95.04	81.02
		Am. Cell.	98.95	77.80	96.46	93.66	97.65	88.72
Wool	Blank		31.0	26.3	34.4	25.6	32.6	22.3
	Basic dye	without	36.44	32.30	39.47	31.65	37.85	28.73
		Chitosan	53.20	50.39	57.63	49.37	55.26	44.81
		Am. Cell.	77.67	64.97	84.13	68.01	80.69	61.73
	Natural dye	without	80.17	71.07	86.83	69.62	83.28	63.20
		Chitosan	95.76	90.71	97.96	88.87	99.48	80.67
		Am. Cell.	97.09	90.95	96.75	88.41	96.82	80.25
Acrylic	Blank		27.8	22.3	30.7	25.6	27.1	22.3
	Basic dye	without	31.80	32.30	34.44	31.65	33.03	28.73
		Chitosan	46.42	47.16	50.29	46.21	48.22	41.94
		Am. Cell.	72.89	74.04	78.95	72.54	75.71	65.85
	Natural dye	without	69.95	71.07	75.77	69.62	72.67	63.20
		Chitosan	83.56	84.89	85.48	83.17	86.80	75.49
		Am. Cell.	91.11	92.55	98.68	90.68	94.64	82.31

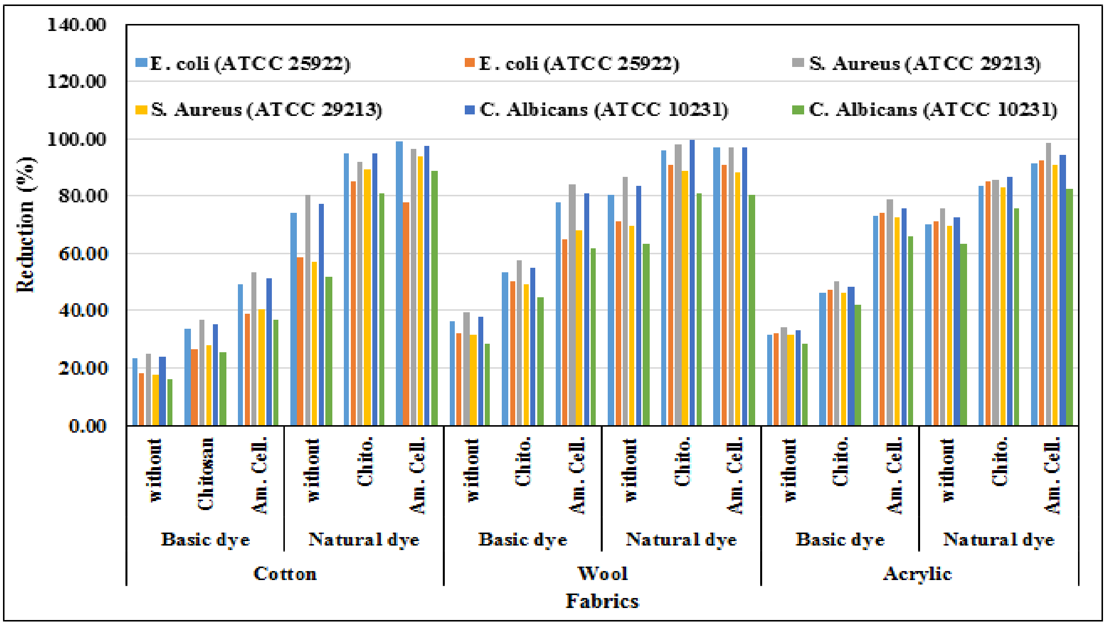


Fig. 9. Reduction (%) of antibacterial properties of dyed fabrics.

Declaration of Interest

The authors declare that there is no conflict of interest

Acknowledgements

The authors are gratefully grateful to acknowledge the faculty of Applied Arts, at Benha University. Furthermore, the authors are gratefully grateful to acknowledge the Textile Research and Technology Institute (TRTI), National Research Centre (NRC).

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بوليمرات كاتيونية متعددة الاستعمالات لتحسين قابلية النسيج للصباغه والأداء الوظيفي

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تكتسب الجوانب البيئية للتصنيع مزيدًا من الاهتمام في عالم اليوم ، لا سيما في صناعة النسيج. ومع ذلك ، فإن تحويل الصناعة إلى التكنولوجيا الخضراء هو ضرورة حاسمة في الوقت الحاضر لحماية بيئتنا من الآثار السامة للنفايات الصناعية السائلة ؛ وبالتالي ، ستكون مساهمة مفيدة كبيرة في حياة آمنة وصحية على هذا الكوكب. يكتسب استخدام البوليمرات الطبيعية مع مجموعة متنوعة من الخصائص المرغوبة مثل التوافق الحيوي وقابلية التحلل البيولوجي والسمية المنخفضة والنشاط البيولوجي العالي شعبية عامًا بعد عام. حتى الآن ، تم استخدام مجموعة متنوعة من المركبات الكيميائية الاصطناعية لتفعيل المنسوجات ، والتي تضر بالبشر والنظم البيئية المائية ويصعب تحللها. من ناحية أخرى ، تتوافق المواد الطبيعية مع الحاجة الحالية للتطبيقات الصناعية نظرًا لمصادرها التي لا تنتهي ومزاياها على المنتجات الاصطناعية. في هذه الدراسة ، تم استخدام البوليمرات الحيوية الموجبة الطبيعية مثل الكيتوزان ، والسليلوز الأميني للمساعدة في زيادة امتصاص الصبغة مع تحسين خصائص أداء النسيج مثل وظيفة مضادات الميكروبات. كانت ظروف الصباغة المثلى (تركيز بوليمر ، ٢٪ ؛ ٧٥ درجة مئوية ؛ ٤٥ دقيقة ؛ L: R 1:50) مع درجة حموضة ٦ للصوف ، و ٤ للأكريليك و ٨ للأقمشة القطنية باستخدام طبيعتين مختلفتين من الصبغات (أساسية وطبيعية. (مستخلص المورينجا).

الكلمات الرئيسية: الكولاجين؛ المعالجات الأولية؛ الصباغة ، التجهيز.