



Research article

Improving the functionality of raw cotton: simultaneous strength increases and additional multi-functional properties

Salma Katun Sela^{a,*}, A.K.M. Nayab-Ul-Hossain^b, Md. Shafikul Islam Rakib^b,
Md. Khalid Hasan Niloy^b^a Department of Textile Engineering, Jashore University of Science and Technology, Jashore, Bangladesh^b Department of Textile Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh

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ABSTRACT

It has, nowadays, become indispensable to get multi-functional properties from a single piece of fabric or garment in the sector of textile and fashion. Cotton fabric is now extremely being utilized in garments all over the world. At the raw stage, cotton fabric has less reflectance, high ignition tendency, moreover the proclivity to be attracted by microorganisms. The strength of the fabric might be deteriorated because of frequent processing. In this study, a single jersey raw (grey) cotton fabric of 150 GSM was processed with a pertinent chemical treatment to convert the reflectance to about 100 % and impart flame resistance property together with the other functional properties. Due to the attainment of high reflectance and flame resistance traits, the heat-absorbing tendency of the fabric became low which improved the comfortability of the fabric. The strength of the processed fabric was increased by 4 %. Crease recovery angle was increased by 57 % in the course way and by 82 % in wales way direction that attributed crease-resistance and more stability to the modified fabric. Moreover, the processed fabric was also able to exhibit antimicrobial properties. Strength improvement, attainment of crease-resistance, and antimicrobial property could enhance the longevity of the fabric. The attainment of multifunctional properties together with the strength improvement simultaneously provided a unique feature to the modified cotton fabric. It was a permanent chemical treatment, and it modified the surface of the fabric, which ultimately enhanced the proclivity of cotton fabric to be more compact or crystalline and more stable. The addition of the new quality of the cotton fabric could endure even after washing. The modified cotton fabric with newly added characteristics could be a good choice to prepare garments with felicitous longevity to protect from heat, fire flame sensitivity. It really could create an opportunity in multi-functional fabric processing as well as modern textiles.

1. Introduction

Cotton fabric is abundantly used among different types of fabrics. The rudimentary component of cotton is cellulose above 90% [1]. Cotton fabric is good with high moisture-wicking breathable quality, medium heat retention, medium stretchability, and greatly susceptible to pilling or bubbling [2]. Washability of cotton fabric can be satisfactory when a greater quantity of heat is applied. It drapes well on the body. The bending tendency of cotton fabric is comparatively high that can shrink during different functional processes whether water is being used or not [3]. Apart from cellulose, cotton fiber also contains natural impurities, and it is a prerequisite to remove the natural coloring matters and make the fiber clean. Pretreatment (scouring and bleaching) plays a vital role in this purpose [4]. Cotton Knitted fabric is manufactured utilizing knitting machines, and the characteristics are actually different from woven

fabric [5]. The pliable quality of knitted fabric is superior to woven fabric. It can mainly be differentiated into weft knitted and warp knitted fabrics while loop formation is regarded as per the position of the threads [6]. Weft knitted fabrics can be classified into four basic structures. Jersey fabrics are widely used among them. Knitted fabric has a distinctive feature of fine elasticity and recovery [7]. It can be distended adequately and retained to its original length and configuration when augmentation is released. It has a curling tendency from the backside to the front. Knitted fabric has good drape ability as well as satisfactory comfort [8]. It allows the skin to breathe without restrictions due to its better porosity and also permits to move freely for its elastic nature.

To ascertain the strength of knitted fabric, bursting strength is mostly utilized [9]. When tension is perpendicularly applied to fabric, it is called bursting. This is the force involved to decompose the fabric considering several requisite parameters. So, bursting strength is an important

* Corresponding author.

E-mail address: shila_te@just.edu.bd (S.K. Sela).

physical property of cotton fabric which is needed to withstand force when the fabric is in tension and other environmental stresses from both vertical and horizontal direction [10]. During using or frequent processing of the cotton fabric, it can get ruptured at the point where the bursting strength is low. So, it is important to increase the bursting strength of the fabric. It can be increased by various chemical treatments of applying cross-linking agents, which increase the crystallinity and compactness of fabric [11]. By increasing elasticity, the bursting strength of the fabric can also be increased.

The reflectance of the surface of cotton fiber refers to its effectiveness in reflecting radiant energy [12]. When cotton is exposed to sunlight, it is subjected to loss of strength gradually. And it is degraded by oxidation when the heat is raised because of absorbing the light intensity [13]. So reflectance property is necessary for cotton fabric [14]. The reflectance of the fabric can be increased using several chemical treatments. Bleaching chemicals like: hydrogen peroxide, zinc dust have been used for this purposes. For increasing the apparent reflectance, optical brightening agent is used. It absorbs the UV light and converts it into visible region [15]. As a result, the brightness or reflectance of the cotton fabric surface is increased. By treating cotton fabric with brightening agents, the reflectance of cotton fabric can be increased [16]. The reflectance of cotton fabric can also be increased by coating the surface of the fabric with Nano-titanium dioxide at a suitable temperature.

Other special features of the finished fabric are flame resistance, antimicrobial property, crease-resistance, etc. [17]. The process by which a combustible substance can be busted into flames, producing fire or combustion, or can be exploded is called flammability. Cotton is highly flammable [18]. It propagates fire easily and burns quickly. Flammability is relevant to the materials which can induce ignle at room temperature. Due to a higher proportion of cellulosic material, cotton fiber burns rapidly. Flame resistance is much essential property for cotton fabric. Cotton fiber is made of cellulosic materials that contain carbon [19]. These carbon substances react with oxygen and it propagates frequently at high temperature or ignition temperature. So, flame resistance is needed in cotton fabric [20]. This specific property of cotton can easily be attained using certain chemicals at a certain proportion [21]. It was practiced to obtain the effect of flame resistance by depositing insoluble material compounds like antimony oxychloride. The used chemical precipitated on the fiber by double decomposition of tartar emetic and stannic oxychloride. In the same manner, metallic salts such as magnesium borate, ammonium sulfate, and magnesium also produce fireproofing.

Natural cotton fiber has the proclivity to be attracted by microorganisms which subsequently deteriorate the quality. The property which prevents the growth of different microorganisms is considered as antimicrobial property. It is an important stuff for cotton fabric. It can also be responsible to hinder the growth of these organisms [22]. When a fabric is exposed to the surroundings, it can be attracted by microorganisms that prone difficulty to the quality [23]. Because of the existence of carbohydrates in natural cotton fiber, the microorganisms can easily attack the fiber. So, antimicrobial property is a much-desired requirement in cotton fabric [24]. Antimicrobial property is needed here for the diminution of transmission of infection. It can also improve the performance of the lifespan of consumer products [25]. For the antimicrobial property, the creation of unpleasant odors is decreased. Presently, antimicrobial textiles have come into focus and practiced widely for bacterial growth control as well as infection, injury healing, hygiene. Natural antibacterial finishes for cotton fabric are also done by herbal textile finishes. For antimicrobial and self-cleaning property, clothes can be treated with titanium dioxide in the presence of platinum.

To counter the fabric from creasing is a typical feature attributed to crease resistance [26]. The resistive characteristic of fabric from creasing means the capability of the fabric to retain its initial position after the removal of the crease. Anti-creasing is important for cotton fabric as it is made of cellulose [27]. When it contacts with water and other environmental stresses, the molecules of cellulose break down and move. So,

crease mark is imparted in the amorphous and intermediate region, bonded together by weak bonds. While natural fiber has not sufficient crease-resistance property, cotton can be greatly treated with chemicals to restrain its crease [28]. To reduce the crease mark, different cross-linking agents or resins are used. Crease resistance is achieved by the cross-linking of cellulose chains to stop the molecules from moving when in contact with water and other stresses [29]. Citric acid is a good cross-linking agent for imparting this feature. High concentrated citric acid and tri sodium citrate also show excellent performance for reducing crease. Formaldehyde based resin and non-formaldehyde based resin are also used for reducing crease. Durable press finish and non-durable press finish are applied for imparting anti creasing property [30]. So, crease resistance of cotton fabric should be ameliorated as it is one of the most important factors of textile fabrics.

Normally the cotton fabric is processed in a way to attain a single functional property. The present paper represented a research-based study aimed at altering the inherent characteristic of raw cotton. The distinct feature of the study was to treat the raw cotton fabric chemically to induce multifunctional properties simultaneously besides the increment of strength, crease resistance. The attainment of multifunctional properties could allow the modified fabric to be used for various functional and aesthetic purposes. The attainment of new capabilities exemplifies the increase of reflectance, anti-microbial property, and flame resistance property, crease-resistance as well as strength improvement which can promote the fabric to be more felicitous for protective clothing with the desired outcome. It is not always easy to improve fabric strength together with the attainment of crease-resistance, reflectance enhancement, and other multifunctional properties. If the fabric is chemically treated to obtain various functional properties, the strength can go down. In this study, the strength was increased together with the attainment of other functional properties of the fabric while the crease resistance was enhanced in both course, wales way direction and the high reflectance of the processed fabric was unchanged or undiminished. With having flame resistance property, increased reflectance altogether, the altered fabric could be the right choice to make a garment where fire flame and heat sensitivity issues are considered. Most importantly, the increase of strength together with crease-resistance and anti-microbial property could influence the longevity as well as the stability of the fabric positively. The processed fabric of newly added characteristics could upgrade the quality of cotton fabric to be used in value addition related multifunctional purposes rather than the traditional use in daily life.

2. Materials and methods

100 % cotton knitted fabric was produced in the knitting section of a fabric manufacturing company named Abir Fashion Limited. Specified chemicals were used at a certain quantity to carry out the study. The selected raw cotton knitted fabric weighted 15 g. The construction of the fabric was single jersey, yarn count was 28^s Ne and its GSM (gram per square meter) was 150. The stitch length of the used fabric was 2.70 mm. Wales per inch (WPI) was 30, and the course per inch (CPI) was 50 of the raw fabric. The Material and liquid ratio (M:L) of the entire process was 1:15. Electrical balance and automatic pipette were used for measurement purposes throughout the procedure. A calculated amount of water (225 ml) was taken into a hollow cylindrical shape nozzle (made of stainless steel) of the lab fabric dyeing machine. All the pretreatment chemicals such as detergent (Ultravon®), sequestering agent (Lufibrol®antoxliq), wetting agent (Ultravon®), soda ash and hydrogen peroxide were added into the nozzle. The initial machine temperature was 40 °C. Uvitex BAM and Uvitex BSB were added into the solution at 70 °C. Then the temperature was raised to 100 °C and the machine temperature was kept fixed for 30 min while the pH of the medium was around 10.9. After the completion of the required time, the sample was taken out of the nozzle and washed properly to make the fabric surface clean. The fabric was further treated with wetting agent (Ultravon®), sequestering agent (Lufibrol®antoxliq), and anti-creasing agent

Table 1. Selected fabric specification and used chemicals.

Used Fabric	Chemicals
100% cotton knitted fabric	<ul style="list-style-type: none"> • Detergent-1 g/l • Wetting agent-0.5 g/l • Sequestering agent-0.8 g/l • Soda Ash-3 g/l • Hydrogen per-oxide-5 g/l • Anti-creasing agent -0.5 g/l • Uvitex BAM-1% • Uvitex BSB-0.5% • Acetic acid (CH_3COOH)-1 g/l • Dimethylol Dihydroxy Ethylene Urea (DMDHEU)-1.5 g/l • Titanium dioxide (TiO_2)-0.8 g/l • Borax-0.7 g/l • Boric Acid Powder -0.6 g/l • Disodium hydrogen phosphate-0.7 g/l
GSM: 150	
Yarn count: 28/1 (single count)Ne	
Stitch length: 2.7 mm	
Wales per inch (WPI):30	
Course per inch (CPI):50	
Color: grey (raw)	

(Albafluid®) at 60 °C for 20 min to control the physical quality of the fabric. Then the fabric was washed properly, including a cold and hot wash (see Table 1).

Neutralization of the fabric was carried out by using acetic acid and the fabric was washed properly and dried in a drying machine. Then the water absorbency of the fabric was checked and found satisfactory.

The fabric was again treated with titanium dioxide at 60 °C for 20 min. After that, a chemical solution of dimethylol dihydroxy ethylene urea and titanium dioxide was prepared, and the fabric was padded to apply the chemical solution with the help of the paddler machine at 80 % wet pick up. Another chemical mixture was also prepared using 60 % borax, 20 % boric acid powder, and 20 % disodium hydrogen phosphate. The fabric was immersed in that last chemical solution for 90 min at 80 °C. Then the treated fabric was washed properly. After that, the fabric was dried in a drying machine at 100 °C temperature. The curing of the fabric was also carried out at 150 °C. Then the fabric was conditioned for relaxation at ambient temperature for 3 h.

3. Results and discussion

Several tests were carried out to ensure the attainment of the multi-functional properties of the processed cotton fabric. The spectrophotometer was used to measure the reflectance which indicated 70 % increase of reflectance of modified fabric. Together with that, flame resistance test result of the processed one indicated that the fabric after chemical treatment was able to withstand its quality due to the exposure

of fire flame and the quality was not diminished. If the longevity of the processed fabric were better than the raw fabric, it would provide an extra advantage to the processed cotton fabric and would also be beneficial to the consumer. Bursting strength was increased to 4 % and with the attainment of antimicrobial activity, the processed fabric was able to hinder the growth of microorganisms which positively influenced the endurance of the processed cotton fabric. The stability of the fabric should be increased, otherwise, there would be the formation of crease mark. Crease-resistant test result ensured the resistance of crease mark formation, which ultimately increased the stability of the processed fabric. Scanning electron microscopy investigation provided an idea about the increased tendency of compactness as well as the crystallinity of the processed fabric. Fourier-Transform Infrared Spectroscopy investigation ensured the physicochemical properties of the cotton fabric. All the used individual chemicals chemically interacted with the cellulose present in cotton. Hydroxyl group of cellulose chemically interacted with the chemicals in such a way that it can become a part of it. Moreover, H_2O was eliminated at the end of the reaction.

At the beginning of all the tests, reflectance measurement was carried out to ensure the light-absorbing tendency of the fabric. The reflectance of the raw fabric was less, which meant the more light absorption. On the other hand, the reflectance of the processed fabric was increased, which meant less light absorption. This newly added characteristic would increase the comfortability of the fabric.

3.1. Reflectance measurement

The reflectance of the modified fabric was measured using a spectrophotometer under 400–700 nm wavelength. It was necessary to ensure the calibration of the spectrophotometer. It was found that the reflectance of the processed fabric was increased to around 100 %. In comparison to that, the grey fabric reflectance was also measured which was near about 30 %. So it was illustrated that the increment percentage of reflectance was 70 %. The processed fabric became into a condition where the incident light could be reflected properly, which ultimately turned into a small quantity of light absorbent condition. The chemical treatment increased the apparent reflectance of the fabric by converting the shorter wavelength into a longer wavelength. Therefore, the modified cotton was able to emit more than the total amount of daylight fallen on it (see Figure 1).

If the flame resistance characteristics were added to the increased reflectance fabric, it would provide an additional feature to the processed fabric to be used for flame resistance-related purposes. If the processed fabric would not burn or ignite, it could be said the fabric flame resistant.

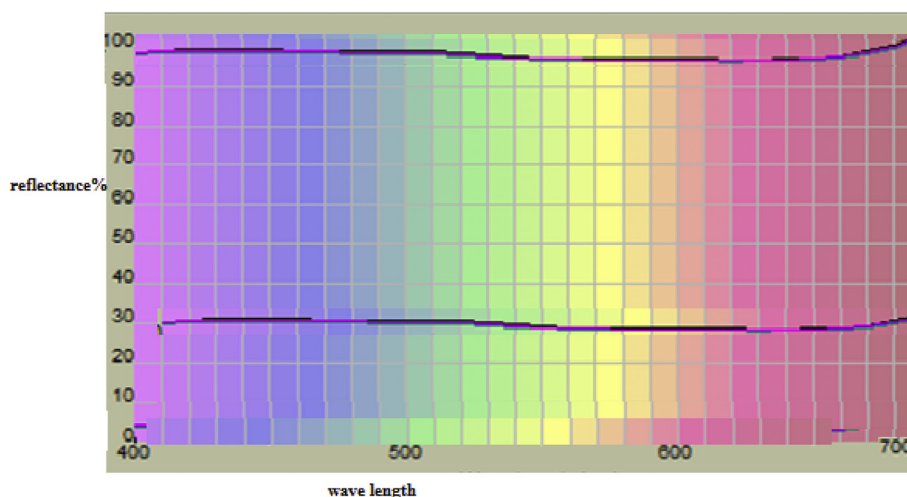


Figure 1. Reflectance measurement of grey and processed fabric in spectrophotometer under visible wave length.

3.2. Flame resistance test

Flame resistance of the treated sample was tested in the multinational testing company SGS Bangladesh Limited. Flame Resistance Test CAN/CGSB 4.2 method was applied. The flame resistance of the fabric was tested 5 times which indicated the result “DNI”, which meant, didn't ignite. Then the average of the test was estimated and concluded with a similar result “DNI”. The final result of the test was declared positive (see Figure 2).

The test result also recommended the modified fabric could be used for general textile products. It was illustrated from the report of the flame resistance test that the flame resistance property was fully attained in the treated fabric. When the cellulose of cotton cross-linked with the hydroxyl-containing polymer of flame-resistant chemicals, dehydrating agent was formed. Catalytic dehydration was carried out, and the modified cotton was converted into a hydrolytically stable form which could subsequently function as flame-resistant during the burning process.

If the processed fabric could attain the quality of antimicrobial activity, it would positively influence the longevity of the processed cotton

fabric of natural fiber class. Antimicrobial activity was checked to get an idea for this purpose.

3.3. Antimicrobial test

The antimicrobial test for treated and untreated samples was checked using the disk diffusion method against *Staphylococcus aureus* and *Salmonella bacillus* bacteria. In this method, the disk of antibiotics was used to identify the scope of the bacteria to be influenced by the antibiotics. Bacteria were sub cultured from stock by keeping bacteria in the incubator overnight. Then bacteria were given into the nutrient broth containing conical flasks and were incubated for 24 h at 37 °C. For serial dilution purposes, distilled water contained test tubes (9 ml/test tube) were taken and serial dilution was done by taking the bacteria from conical flasks. The samples were sterilized at 121 °C for 15 min in autoclave machine. Then the samples given into petri plates by using forceps and petri plates were kept into the laminar airflow overnight (see Figure 3).

While the antibiotics hindered the growth of the bacterium, the formation of the specific area surrounding the wafers depicted that the

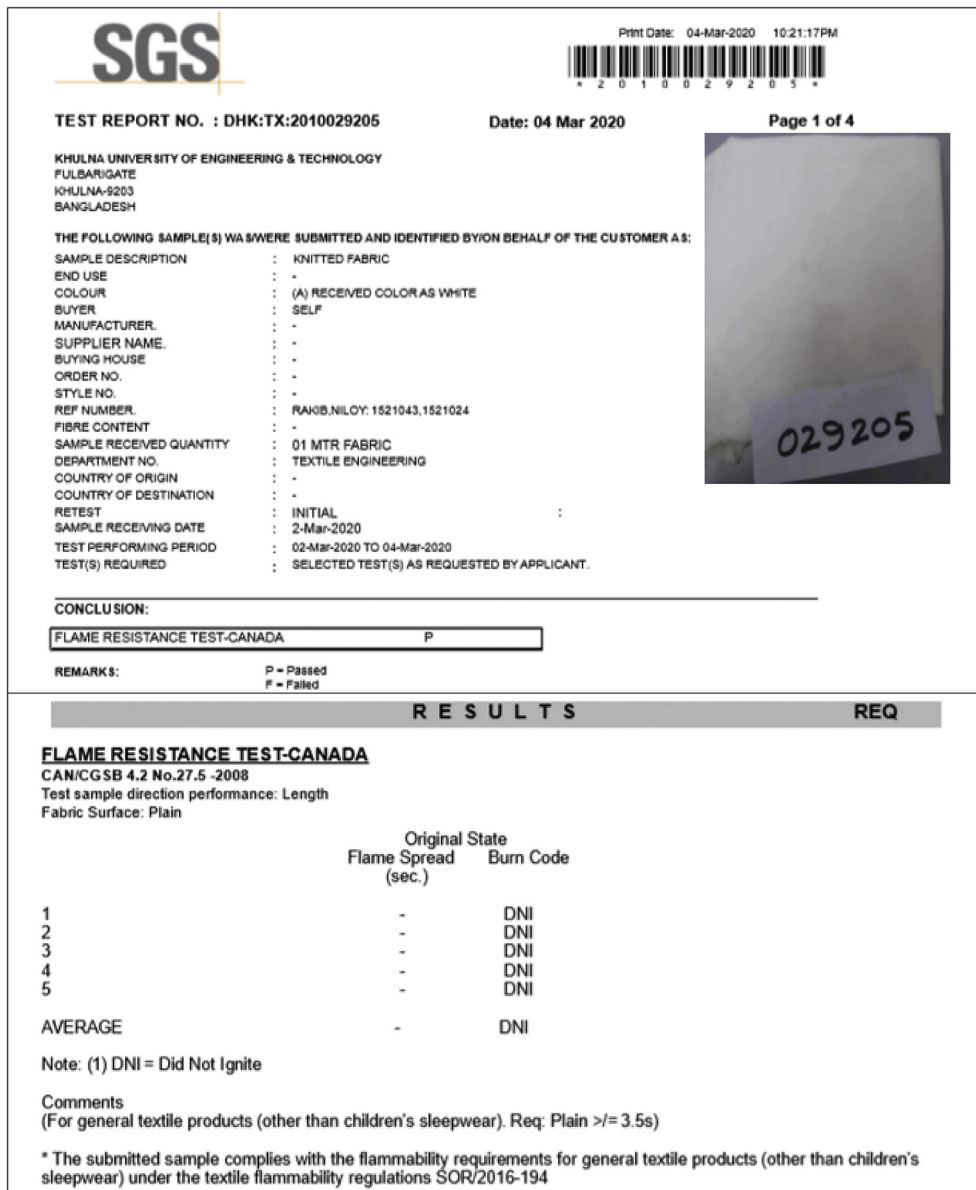


Figure 2. Positive result of flame resistance of treated fabric sample.

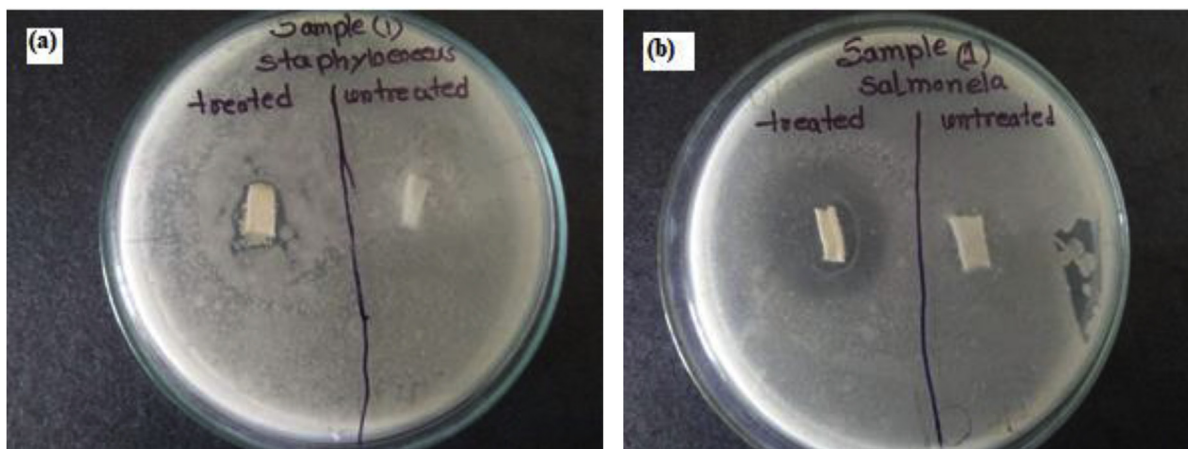


Figure 3. Comparison of antimicrobial activity of both treated and untreated fabric samples against a) *Staphylococcus aureus* and b) *Salmonella bacillus*.

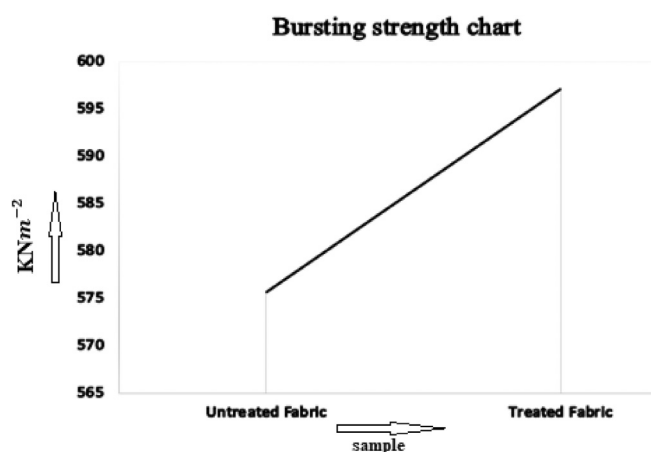


Figure 4. Increase of bursting Strength of the fabric sample after chemical treatment.

growth of bacteria was inhibited. It was observed that the inhibition zone of processed fabric showed antimicrobial activity against both *Staphylococcus aureus* and *Salmonella bacillus* bacteria whereas the raw fabric could not show the similar characteristics. From the assessment, it was clear that the treated sample got the properties of antimicrobial activities against the bacteria used for this purpose. But the untreated sample did not achieve this type of quality. The used antimicrobial agents cross-linked with the cellulose of cotton and hindered the microorganism to diffuse into the fiber. The bacterial cell wall synthesis was also partially inhibited.

If the bursting strength of the processed fabric would be increased, it could be marked as the satisfactory durability increment. For this purpose, bursting strength of both the raw as well as processed fabric was analyzed.

3.4. Strength measurement

Bursting strength of both the treated fabric and untreated fabric was measured and a comparison was also carried out using the obtained values. Diaphragm bursting strength test (British Standard 3424 Method) was followed for this measurement. The average value of bursting strength of both treated and untreated fabric was estimated by recurring the test 5 times (see Figure 4 and Table 2).

It was found that the mean bursting strength of untreated fabric was 575.7 KNm⁻² and the mean bursting strength of treated fabric was 597.1 KNm⁻². The bursting strength of the treated fabric was increased by around 4 % which indicated that the strength of the treated fabric was ameliorated satisfactory.

To check the stability and the ability of the fabric to resist crease mark formation, crease resistance test was carried out in both wales and course direction of the raw, and processed fabric.

3.5. Crease resistance test

Crease resistance test of the untreated and treated fabric sample was carried out by using the Shirley Crease Recovery Test method.

In this method, the crease recovery angle was measured for untreated and treated fabric samples in both course and wales direction and a comparison was prepared using those values. It was tested 5 times in both course and wales way direction and then the average value was estimated (see Figure 5 and Table 3).

From the data of this test, it was found that the increase of crease recovery angle of treated fabric in the course way was 23.8° and in wales way direction was 41.8°. The increased percentage of crease recovery in course way direction was 57 % and in wales way direction was 82 %. Thus, it was confirmed that there was an increase of crease resistance property of the treated fabric in both course and wales direction (see Figure 6 and Table 4).

Table 2. Bursting strength of treated and untreated fabric.

Serial No.	Untreated Bursting strength (KNm ⁻²)	Fabric Mean value	Treated Bursting strength (KNm ⁻²)	Fabric Mean value	Increase percentage of Bursting strength of treated fabric
1	570.8		598.9		
2	573.5		594.8		
3	578.9	575.7	595.5	597.1	3.72 %–4 %
4	579.5		599.4		
5	575.8		597.1		

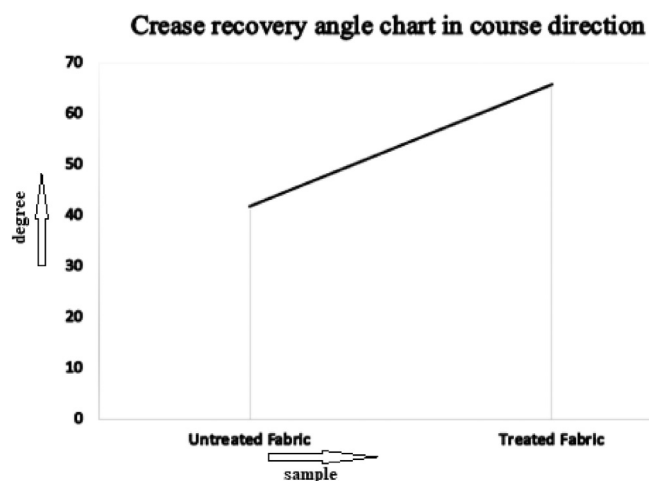


Figure 5. Increase of crease recovery angle of treated fabric sample in course direction.

The attainment of the crease resistance feature ensured the stability of the processed fabric.

Together with the attainment of multifunctional properties, it was also necessary to observe the color quality and physicochemical properties of the modified fabric.

3.6. Color quality and physicochemical properties assessment

The color quality of the processed fabric was checked under the D65 light source in a light box. The modified fabric was free from any foreign color spot and the color levelness of the fabric surface was satisfactory. There was no crease mark formation and no color unevenness on the fabric was found. Incremental reflectance of the modified fabric was also viewed under ultraviolet light source in the light box. Color fastness quality of the processed fabric like the color fastness to dry and wet rubbing was also checked. Both the dry and wet rubbing result was satisfactory, and the rating was 4–5 in gray scale.

The GSM of the processed fabric was checked which was 148 and no noticeable shrinkage of the fabric was found after modification. The stitch length was remained unchanged and the yarn count was the same. The elastic recovery of the modified fabric was satisfactory. The absorbency of the fabric was quite good after modification. Wales per inch (WPI) and course per inch (CPI) of the processed fabric was equal to the raw fabric. So, the physical quality of the modified fabric was not diminished significantly. Moreover, multifunctional properties were attained simultaneously from the modified fabric.

The morphological structure of the processed cotton fabric was changed as it was processed with multiple chemicals. It was needed to check the morphological structure of the raw cotton fabric as well as the processed fabric.

3.7. Scanning electron microscopy investigation

The Scanning Electron Microscope was used to check the morphological structure. Different magnifications were utilized to observe both the untreated and modified cotton sample. The prepared film was cut into small pieces. A small portion of the sample was placed on the conductive carbon tape pasted on the alumina plate. It was sputtered with gold and mounted on the sample chamber for SEM operation. Carl Zeiss Sigma 300- SEM machine was used to investigate the morphology of the sample materials. It was probable to get at least an idea about the compactness as well as the crystallinity of the processed sample from the SEM test (see Figure 7).

When the untreated cotton sample was observed under specific magnification it was noticed that the compactness of the contiguous fiber was less which meant that the amorphous region dominancy was more. In comparison to that, when the modified cotton sample was viewed under similar magnification, it was observed that the compactness between the fibers of the treated sample was increased which subsequently enhanced the tendency of the crystalline portion of the modified sample. The increased tendency of compactness provided the modified cotton sample a more distinct characteristic.

Additionally, Fourier-Transform Infrared Spectroscopy investigation was carried out to understand the physicochemical properties of used cotton fabric.

3.8. Fourier-Transform Infrared Spectroscopy investigation

Fourier-Transform Infrared Spectroscopy investigation test was carried out to ensure the physicochemical properties of the tested sample. At

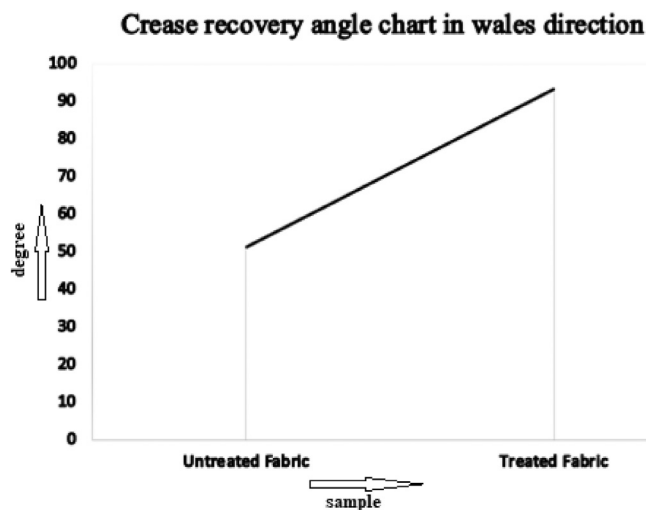


Figure 6. Increase of crease recovery angle of treated fabric sample in wales direction.

Table 3. Crease recovery angle of treated and untreated fabric in course direction.

Serial No.	Untreated Fabric Crease recovery angle in course direction	Fabric Average value	Treated Fabric Crease recovery angle in course direction	Fabric Average value	Increase of crease recovery angle of treated fabric in course direction
1	44°		68°		
2	39°		63°		
3	42°	41.8°	70°	65.6°	23.8°
4	47°		62°		
5	38°		65°		

Table 4. Crease recovery angle of treated and untreated fabric in wales direction.

Serial No.	Untreated Crease recovery angle in wales direction	Fabric Average value	Treated Crease recovery angle in wales direction	Fabric Average value	Increase of crease recovery angle of treated fabric in wales direction
1	50°		95°		
2	53°		93°		
3	51°	51.2°	90°	93°	41.8°
4	50°		92°		
5	52°		95°		

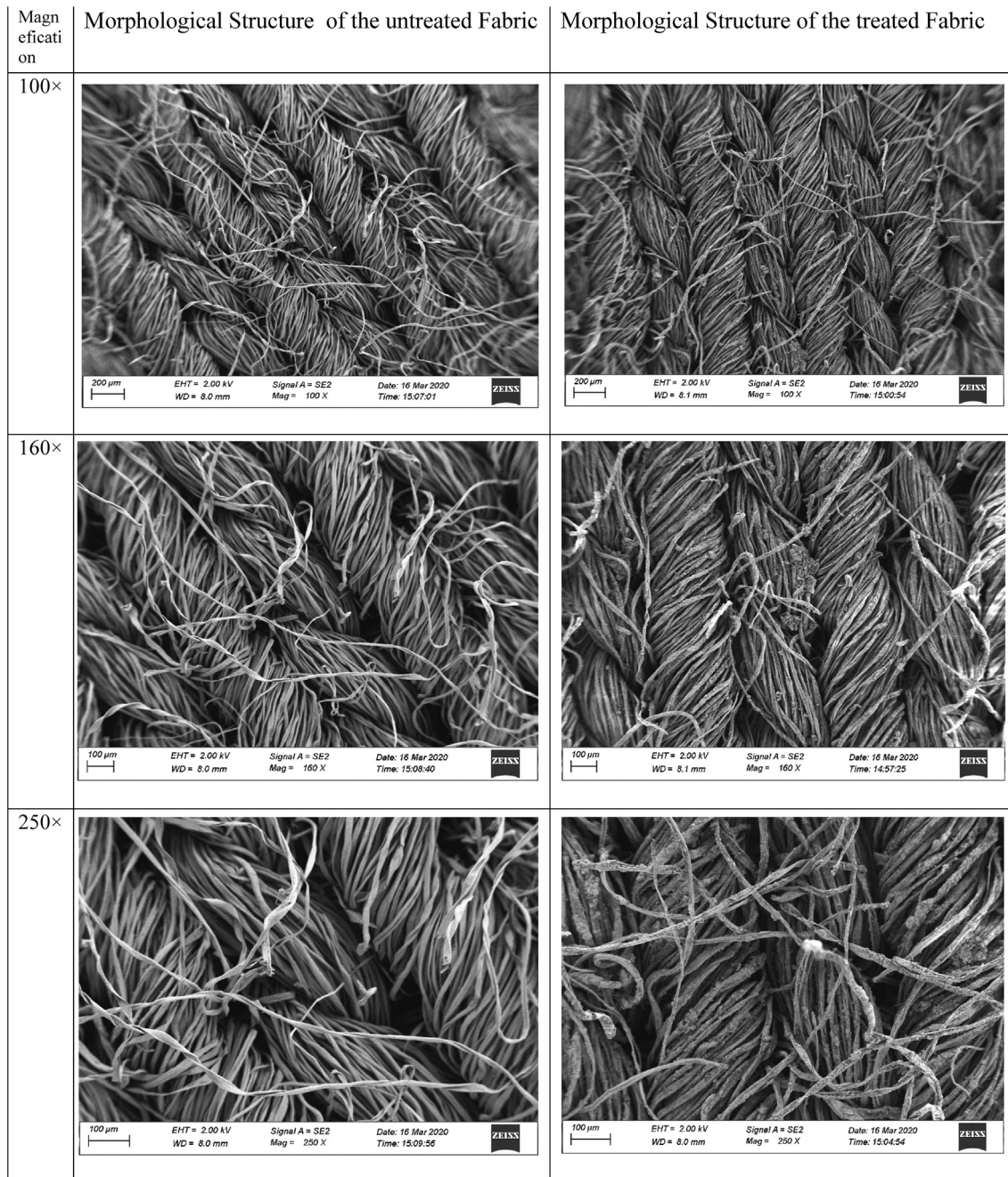


Figure 7. SEM test of the untreated and treated sample under different magnification.

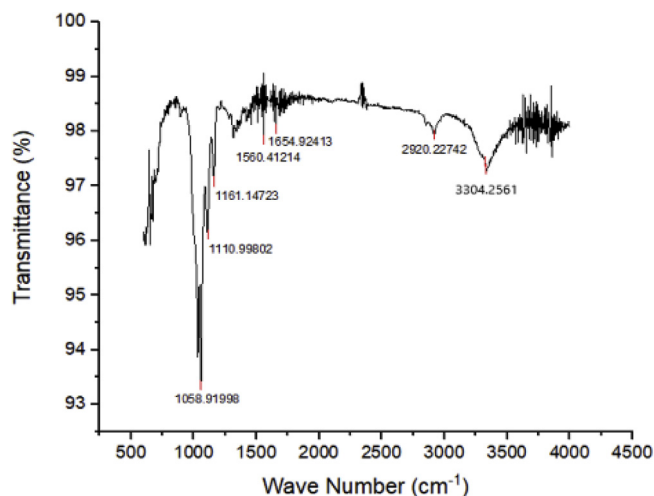


Figure 8. FTIR test result of fabric sample.

first, the machine was opened and reading was taken without sample. The sample to be tested was conditioned and relaxed properly. Then the tested fiber was positioned at the specific place of attenuated total reflectance (ATR). It was a direct contact of the fiber with the ATR. The machine was run, and the reading was shown in the monitor (see Figure 8 and Table 5).

From the table of the characteristics, the FTIR absorption peak (frequency) at $1320\text{--}1000\text{ cm}^{-1}$ indicates C–O stretching vibration and the presence of alcohol. From the FTIR result of the tested sample, peak at $1058.91998\text{ cm}^{-1}$ could support the presence of C–O stretching vibration. Standard FTIR absorption peak (frequency) at $1500\text{--}1400\text{ cm}^{-1}$ represents C–C stretching vibration. The standard FTIR absorption peak (frequency) at $1470\text{--}1450\text{ cm}^{-1}$ represents the C–H bend stretching vibration. The peak at 1465.71 cm^{-1} of tested sample could provide the presence of C–C stretching vibration as well as the C–H bend stretching vibration. The standard frequency at $3500\text{--}3200\text{ cm}^{-1}$ indicates the confirmation of the O–H stretching vibration and the presence of alcohol. From the tested sample of the FTIR spectrum, peak at 3304.2561 cm^{-1} could indicate the presence of O–H stretching vibration. From the analysis of the FTIR spectrum, it was understood that the tested sample was 100 % cotton.

All the test results provided a clear idea about the increase of reflectance and also the attainment of multifunctional properties of the processed fabric. The processed fabric was washed and the quality was not degraded even after that. The quality of the modified fabric was still unchanged and everything was found satisfactory. All the used chemicals were non-hazardous and used in the proper quantity of acceptable range. Most importantly, regarding the safety issue, the materials safety data sheet (MSDS) provided a clear idea about the presence of non-hazardous elements in the used chemicals. Several studies were carried out to improve multifunctional properties of textile fabric [31]. Some studies were conducted to make the fabric UV protective and attain antimicrobial property [32, 33, 34]. To protect the fabric from solar radiation and attain antimicrobial property, some studies were carried out [35]. In some studies, the antimicrobial property was only induced to the fabric [36, 37]. It was an endeavor in the study to attain multifunctional

Table 5. FTIR findings of the tested sample.

FTIR Frequency	Functional Group
$1058.91998\text{ cm}^{-1}$	C–O stretching vibration
1465.71 cm^{-1}	C–C stretching vibration
	C–H bend stretching vibration
3304.2561 cm^{-1}	O–H stretching vibration

properties simultaneously together with the increment of strength, crease resistance to make the fabric more durable, functional, and comfortable.

4. Conclusion

If the light-absorbing tendency of the fabric becomes low, the comfortability of the fabric will be increased especially for those which are used in summer. The reflectance increment of the fabric was a similar to lowering the light-absorbing tendency. Attainment of flame resistance property to the processed cotton fabric provided an additional feature to retain the quality from the fire flame. Together with that, longevity as well as the stability was ameliorated by attaining the strength and crease resistance improvement in addition to the antimicrobial property which ultimately upgraded the quality of the fabric and provided unique multifunctional characteristics. The processed fabric of high strength and crease resistance could be comfortably used in multifunctional purposes while light, heat sensitivity factors are especially considered. It could also be a good choice to select the high strength and crease-resistant modified fabric for flame-resistant garment manufacturing. Further research could promote the quality of the fabric to be more comfortable. At this stage, the processed fabric of high strength with multifunctional properties could be considered for value addition purpose in protective clothing as well as modern fabric processing.

Declarations

Author contribution statement

Salma K. Sela, A.K.M.Nayab-Ul- Hossain, Shafikul I. Rakib, Khalid H. Niloy: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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